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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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3 1 **Socio-demographic and environmental risk factors accounting for the co-existence of**
4 **wasting, stunting, and underweight in children under five: Analysis of cross-sectional**
5 **surveys from 31 sub-Saharan African countries**
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3 45 **ABSTRACT**
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5 46 **Objective:** This study investigated the socio-demographic and environmental risk factors
6 47 of the co-existence of wasting, stunting, and underweight among children under age five
7 48 in sub-Saharan Africa.

9 49 **Methods:** Data from 31 sub-Saharan African countries were pooled from the Demographic
10 50 and Health Surveys (DHS) collected between 2010 and 2019. We examined the risk of co-
11 51 existence of malnutrition using multinomial logistic regression models, with results
12 52 presented as relative risk ratios (RRR) with their respective confidence intervals.

13 53 **Outcome measures:** The outcome variables were three child anthropometrics: stunting
14 54 (height-for-age z-scores); wasting (weight-for-height z-scores); and underweight (weight-
15 55 for-age z-scores).

16 56 **Results:** The prevalence of co-existence of stunting, wasting and underweight varied
17 57 across countries and sub-regions, with the highest and lowest prevalence of co-existence
18 58 of stunting, wasting, and underweight as Benin (12.14%) and Gambia (0.58%) respectively.
19 59 The risk of co-existence of the three malnutrition dimensions was higher among children
20 60 age 1 year compared to those aged 0. Children who were females were less likely to have
21 61 a co-existence of the three dimensions of malnutrition compared to their male
22 62 counterparts. The risk of co-existence of the three dimensions was higher among children
23 63 with small size at birth, those whose mothers had no education, not working, had no
24 64 antenatal visits during pregnancy, children delivered at home, those whose mothers were
25 65 poor, had no access to media, and children whose mothers had unimproved toilet facility.

26 66 **Conclusion:** Findings suggest context nutrition-specific interventions such as
27 67 complimentary feeding, dietary supplementation and increasing dietary diversity to
28 68 promote children feeding practices in the studied countries are warranted. Planned
29 69 interventions should prioritize all the identified factors noted in the current study to help
30 70 reduce the risks of co-existence of stunting, wasting, and underweight among children
31 71 under age 5.

32 72 **Keywords:** co-existence; wasting; stunting; underweight; children under five; sub-Saharan
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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.

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82 BACKGROUND

83 Malnutrition among children under 5 years remains a major public health problem across
84 many developing countries¹⁻³. Factors such as insufficient food intake, diarrhoea, recurring
85 infections, poor sanitation practices, and low parental education have been identified as
86 significant contributors to the high prevalence of malnutrition during childhood^{1,4,5}.
87 Despite the numerous interventions rolled out to address childhood malnutrition
88 especially in sub-Saharan Africa where the phenomenon is quite pervasive, the progress
89 seems to be insignificant^{6,7}. For example, a study reported that child malnutrition
90 accounted for nearly half (45%) of child mortality rate in developing countries⁸. Aside from
91 that, it was reported in 2018 that about 149 million and 49 million children under age 5 were
92 stunted and wasted respectively⁹.

93 Three main indicators that are often used to represent malnutrition are underweight or
94 low weight for age, stunting or low height for age, and wasting or low weight for height^{2,10-}
95 ¹². Among the three indicators of malnutrition, stunting has been identified as the problem
96 with the greatest magnitude among under 5 children in developing countries^{2,3}. Even
97 though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting that
98 it is still above 30%¹³ which is undeniably high. Research also indicates that the country-
99 specific prevalence of wasting, underweight, and stunting is still high^{2,3}. For instance, in
100 Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively¹⁴.
101 Additionally, the prevalence of stunting, underweight and wasting among children in
102 South Africa were 35.8%, 20.5%, and 17.2%³. Likewise, Anin et al.² reported 33.2%, 14.1%, 27%
103 and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants
104 (6-23 months) across Northern Ghana.

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

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

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

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3 125 under 5 years and also suggest pragmatic ways of reducing malnutrition among children
4 126 in the sub-region.

6 127 Malnutrition is one of the pervasive and leading causes of death, especially among
7 128 children. Globally, more than half of child mortality is attributed to malnutrition¹⁹. In
8 129 developing countries, especially, in Africa, the prevalence of nutritional insecurity among
9 130 children is staggering. According to studies^{20,21}, SSA accounts for a disproportionate
10 131 number of children suffering from malnutrition in the world. The situation is more alarming
11 132 as the co-existence of stunting, wasting and underweight and other diet-related (double
12 133 burden) is increasingly becoming prevalent². The World Health Organization (WHO)
13 134 report²² indicates that aggressive actions are needed to address the double burden of
14 135 malnutrition to achieve the 6 global nutrition targets by 2025. This call underscores the
15 136 need for more research that provides useful insights that could inform policy actions and
16 137 intervention programming. Studies have examined the independent prevalence of
17 138 stunting, wasting, and underweight and the risk factors associated with each of them
18 139 among children under the age of 5 years in sub-Saharan African countries²¹. However, the
19 140 “multiple burdens”, that is, the co-existence of the three conditions among children under
20 141 the age of 5 years in SSA has received little attention. Here, we analyze the prevalence of
21 142 the co-existence of stunting, wasting, and underweight among children under the age of
22 143 5 years and the risk factors associated with it in SSA.

28 144

29 145 **METHODS**

30 146 **Data Source**

31 147 Data of 127,487 children under the age of 5 years from 31 sub-Saharan African countries
32 148 were pooled from the most current Demographic and Health Surveys (DHS) conducted
33 149 between 2010 and 2019 (Table 1). Specifically, the data were pooled from the children’s file
34 150 in each of the countries. The DHS Program has conducted over 400 surveys in over 90
35 151 developing countries around the world since 1984 every five years²³. The program
36 152 implements cross-sectional surveys to gather nationally-representative data, analyze and
37 153 disseminate accurate information on important demographic and health indicators
38 154 spanning population, nutrition, and diseases. For all surveys, standardized protocols
39 155 designed for each target group including children, women, and men at the household level
40 156 are employed to allow for cross-national comparisons. Stratified two-stage sampling
41 157 involving first, the listing of enumeration areas and selection of clusters, and then a
42 158 random selection of households in each cluster. The detailed sampling method can be
43 159 found in a previous study²⁴. The dataset is freely available for download at:
44 160 <https://dhsprogram.com/data/available-datasets.cfm>. The Strengthening Reporting of
45 161 Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the
46 162 manuscript²⁵.

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167 Study Variables

168 Outcome Variable

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

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

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

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

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

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210 **Independent Variables**

211 Several risk factors spanning socio-demographic and environmental have been associated
212 with child malnutrition. The relevant biosocial characteristics and sociocultural factors
213 related to the child, mother, household head and the household together form
214 compositional factors^{26,27}. Factors that describe location or “place-based” variables are
215 contextual factors^{26,28,20}. In this study, contextual and composition factors except
216 household-level characteristics related to environment and sanitation are categorized as
217 “Socio-demographic risk factors”. Socio-cultural household characteristics related to
218 environment and sanitation are categorized as “Environmental risk factors”.

219 **Socio-Demographic Risk Factors**

220 The relevant variables under socio-demographic risk factors considered include the age of
221 the child (0, 1, 2 and 4); sex of child (female and male); birth order of child (1, 2 to 4, and 5
222 and above); perceived size at birth (small, average and large (see¹⁵); mother’s age (re-
223 coded into two categories “15-19” years and “20-49” years); educational attainment (no
224 formal, primary, secondary and higher); working status (yes and no); antenatal visits
225 during pregnancy (yes and no); postnatal check within 2 months (yes and not); and place
226 of delivery (home, health facility, other). At the household level, relevant variables
227 included are the wealth status (recoded as “poor”, “middle” and “rich”); the age of
228 household head (recoded as ages below 35 years “young adults”, between 35 and 55 years
229 “middle-aged adults” and those above 55 years “Old-aged adults” (see²⁸); sex of
230 household head (male and female); access to electricity (yes and no); and access to media
231 (yes, no) which was derived from the three variables “access to television”, “radio” and
232 “newspaper”. The contextual factors considered are Urbanicity (rural and urban) and the
233 country of origin of the participant.

234 **Environmental Risk Factors**

235 We considered the following variables: type of toilet facility (re-coded into “improved”
236 and unimproved” (see²⁸); source of drinking water (re-coded as “improved” and
237 “unimproved” (see²⁸); and type of household cooking fuel (re-coded into “clean” and
238 “unclean” (see^{28,30}) under the category “environmental risk factors”

239 **Data Analyses**

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

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

256 **Ethical Approval**

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

267 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

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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
				854.964580	
Yes	113,759.99	89.24	South Africa	7	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		
			Type of toilet facility		
Other	1,481.88	1.16	Improved	54,131.64	42.47
Wealth status			Unimproved	73,331.75	57.53
Poor	54,066.08	42.41	Source of drinking water		
Middle	25,855.00	20.28	Improved	83,659.77	65.63
Rich	47,566.22	37.31	Unimproved	43,815.68	34.37
Age of household head			Type of cooking fuel		
Young-adults	54,920.16	43.08	Clean	114,424.88	89.76
Middle-aged adults	55,787.81	43.76	Unclean	13,049.03	10.24
Old-aged adults	16,778.46	13.16	Geographic region		
Sex of household head			Western	53,262.07	41.78
Male	101,698.36	79.77	Eastern	41,863.95	32.84
Female	25,788.94	20.23	Central	25,602.42	20.08
Access to electricity			South Africa	6,758.86	5.3
No	88,219.82	69.2			
Yes	39,257.69	30.8			

268

269 ***Figure 1***

270 ***Figure 2***

271 **Patient and public involvement**

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

273 **Results**274 **Descriptive Analysis on the Prevalence of Co-existence of Stunting, Wasting and Underweight Varied across Countries and Sub-Regions**

275 The prevalence of co-existence of stunting, wasting and underweight varied across
 276 countries and sub-regions, with the highest and lowest prevalence of co-existence of
 277 stunting, wasting, and underweight as Benin (12.14%) and Gambia (0.58%) respectively
 278

(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

1
2
3 323 significant risk factors. The risk of co-existence of the three malnutrition dimensions
4 324 decreases with the increasing age of children. Thus, children aged 1 year [RRR = 3.714 95%
5 325 CI = 3.319, 4.156], 2 years [RRR = 2.739, 95% CI = 2.480, 3.222], and 3 years [RRR = 1.464, 95%
6 326 CI = 1.227, 1.748] were at greater risk of having co-existence of all the three forms of
7 327 malnutrition. Children who were females were less likely to have a co-existence of the
8 328 three dimensions of malnutrition compared to their counterpart males [RRR = 0.468, 95%
9 329 CI = 0.429, 0.510].

12 330 The risk of co-existence of the three dimensions was higher among children with average
13 331 size at birth [RRR = 1.756, 95% CI = 1.574, 1.958], small size at birth [RRR = 3.818, 95% CI =
14 332 3.383, 4.308], those whose mothers had no education [RRR = 3.291, 95% CI = 1.961, 5.522],
15 333 had primary education [RRR = 2.381, 95% CI = 1.417, 4.001], not working [RRR = 1.195, 95% CI
16 334 = 1.086, 1.314], had no antenatal visits during pregnancy [RRR = 1.364, 95% CI = 1.208, 1.541],
17 335 delivered at home [RRR = 1.372, 95% CI = 1.232, 1.529], those whose mothers were poor
18 336 [RRR = 1.408, 95% CI = 1.235, 1.605], had middle wealth status [RRR = 1.214, 95% CI = 1.054,
19 337 1.397], had no access to media [RRR = 1.255, 95% CI = 1.144, 1.377], and had unimproved
20 338 toilet facility [RRR = 1.158, 95% CI = 1.032, 1.300].

24 339 Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having
25 340 the co-existence of the three dimensions compared to those from Angola. Countries such
26 341 as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Malawi, Senegal,
27 342 Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa had a lower risk
28 343 among their children having co-existence of the three malnutrition dimensions (.
29 344
30 345

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

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

1						
2						
3	20-49	2.71	2.6-2.8	Guinea	2.26	1.7-2.9
4						
5						
6	Educational attainment			p<0.001	Kenya	0.94 0.7-1.2
7	No education	4.19	4.0-4.4		Lesotho	0.86 0.7-1.0
8	Primary	2.09	2.0-2.2		Liberia	2.37 1.7-3.1
9	Secondary	1.22	1.1-1.3		Malawi	1.03 0.7-1.4
10	Higher	0.66	0.4-1.0		Mali	3.62 2.5-4.1
11						
12	Working status			p<0.001	Namibia	1.99 1.2-3.1
13	No	3.13	3.0-3.3		Nigeria	4.1 3.7-4.6
14	Yes	2.48	2.4-2.6		Rwanda	6.17 5.5-6.9
15						
16	Antenatal visits during pregnancy					
17				p<0.001	Senegal	2.43 1.8-3.2
18	No	5.41	5.0-5.8		Sierra Leone	1.94 1.4-2.5
19						0.02-
20	Yes	2.39	2.3-2.5		South Africa	0.18 0.8
21						
22	Postnatal check within 2 months			p<0.001	Tanzania	1.86 2.1-3.5
23	No	2.93	2.8-3.1		Togo	2.72 2.1-3.4
24	Yes	2.42	2.3-2.6		Uganda	1.2 0.8-1.7
25						
26	Place of delivery			p<0.001	Zambia	1.22 1.0-1.5
27	Home	4.36	4.2-4.6		Zimbabwe	0.78 0.5-1.1
28	Health facility	1.96	1.9-2.1			
29						
30	Other	2.45	1.7-3.3			
31						p<0.001
32	Wealth status			p<0.001	Improved	1.76 1.6-1.9
33	Poor	3.46	3.3-3.6		Unimproved	3.43 3.3-3.6
34						
35	Middle	2.74	2.5-2.9		Source of drinking water	p<0.001
36	Rich	1.86	1.7-2.0		Improved	2.54 2.4-2.6
37						
38	Age of household head			p =	Unimproved	3.06 2.9-3.2
39				0.276		
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			Type of cooking fuel		
Young-adults	2.65	2.5-2.8			p<0.001
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 head			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			Central	2.87	2.7-3.1
No	3.21	3.1-3.3	South Africa	0.88	1.1
Yes	1.61	1.5-1.7			

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

Variable	Base outcome (Ref: Normal)				Co-existence of three-dimensions					
	RRR	Robust SE	p-value	95% CI	RRR	Robust SE	p-value	95% CI		
Age of child (Ref:o)										
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

1											
2											
3	5 and above	0.969	0.026	0.238	0.920	1.021	0.995	0.076	0.952	0.858	1.155
4	Perceived size at birth (Ref:										
5	Large)										
6	Average	1.320	0.023	<0.001	1.276	1.365	1.756	0.098	<0.001	1.574	1.958
7	Small	1.931	0.045	<0.001	1.846	2.020	3.818	0.235	<0.001	3.383	4.308
8	Maternal age (Ref: 15-19)			<0.001							
9	20-49	0.834	0.028	<0.001	0.780	0.891	0.881	0.081	0.171	0.735	1.056
10	Educational attainment (Ref:										
11	Higher)										
12	No education	2.624	0.173	<0.001	2.305	2.987	3.291	0.869	<0.001	1.961	5.522
13	Primary	2.189	0.142	<0.001	1.927	2.487	2.381	0.631	<0.001	1.417	4.001
14	Secondary	1.751	0.112	<0.001	1.545	1.985	1.617	0.420	0.065	0.971	2.691
15	Working status (Ref:										
16	Yes)										
17	No	1.018	0.018	0.314	0.984	1.053	1.195	0.058	<0.001	1.086	1.314
18	Antenatal visits during pregnancy (Ref: Yes)										<0.001
19	No	1.139	0.031	<0.001	1.079	1.201	1.364	0.085	<0.001	1.208	1.541
20	Postnatal check within 2 months (Ref: Yes)										
21	No	0.980	0.018	0.258	0.946	1.015	0.977	0.053	0.670	0.879	1.086
22	Place of delivery (Ref: Health										
23	facility)										
24	Home	1.183	0.024	<0.001	1.137	1.230	1.372	0.076	<0.001	1.232	1.529
25	Other	1.046	0.073	0.517	0.912	1.201	1.047	0.207	0.818	0.710	1.543
26	Wealth status (Ref: Rich)										
27	Poor	1.297	0.032	<0.001	1.235	1.361	1.408	0.094	<0.001	1.235	1.605
28	Middle	1.195	0.029	<0.001	1.138	1.254	1.214	0.087	0.007	1.054	1.397
29	Age of household head (Ref: Young-adult)										
30	Middle-aged adults	0.954	0.017	0.008	0.921	0.987	1.010	0.052	0.841	0.913	1.118
31	Old-aged adults	0.974	0.023	0.273	0.930	1.021	1.065	0.070	0.338	0.936	1.213
32	Sex of household head (Ref:										
33	Male)										
34	Female	0.977	0.019	0.223	0.940	1.015	1.035	0.060	0.548	0.925	1.159
35											
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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
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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
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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
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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
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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
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Urbanicity (Ref: Urban)

Rural	1.050	0.023	0.024	1.006	1.095	0.943	0.060	0.359	0.832	1.069
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Country (Ref: Angola)

Benin	0.651	0.028	<0.001	0.598	0.708	0.625	0.078	<0.001	0.489	0.798
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Burkina Faso	0.952	0.046	0.304	0.866	1.046	1.946	0.241	<0.001	1.526	2.481
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Burundi	1.580	0.084	<0.001	1.424	1.753	2.049	0.295	<0.001	1.545	2.718
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Cameroon	0.669	0.041	<0.001	0.593	0.756	0.398	0.086	<0.001	0.261	0.609
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Chad	0.910	0.047	0.067	0.823	1.007	1.505	0.184	0.001	1.184	1.913
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Comoros	0.883	0.076	0.149	0.745	1.046	0.656	0.184	0.133	0.378	1.138
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Congo	0.674	0.052	<0.001	0.580	0.783	0.472	0.127	0.005	0.279	0.800
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Cote d'Ivoire	0.734	0.052	<0.001	0.638	0.844	0.739	0.153	0.144	0.492	1.109
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DR Congo	1.229	0.069	<0.001	1.100	1.373	1.351	0.216	0.059	0.988	1.847
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Ethiopia	0.810	0.045	<0.001	0.726	0.904	0.813	0.123	0.172	0.604	1.095
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Gabon	0.495	0.044	<0.001	0.415	0.590	0.319	0.149	0.014	0.128	0.796
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Gambia	0.732	0.073	0.002	0.603	0.889	1.001	0.246	0.997	0.618	1.620
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Ghana	0.453	0.037	<0.001	0.386	0.531	0.545	0.126	0.009	0.346	0.857
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Guinea	0.798	0.051	<0.001	0.705	0.904	0.726	0.132	0.078	0.509	1.036
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Kenya	0.553	0.030	<0.001	0.498	0.615	0.321	0.055	<0.001	0.230	0.449
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Lesotho	0.777	0.068	0.004	0.654	0.924	0.369	0.139	0.008	0.177	0.772
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Liberia	0.658	0.052	<0.001	0.565	0.768	0.776	0.187	0.291	0.484	1.243
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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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351 DISCUSSION

352 The study investigated the socio-demographic and environmental risk factors of the co-
353 existence of wasting, stunting, and underweight among children under age 5 in sub-
354 Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The
355 study found that the countries with the highest and lowest prevalence of co-existence of
356 stunting, wasting, and underweight were Benin (12.14%) and Gambia (0.58%) respectively.
357 In terms of geographic region, the highest prevalence of co-existence of stunting, wasting,
358 and underweight was observed in Western Africa (41.78%) and the lowest prevalence in
359 Southern Africa (5.3%). Age of the child, sex of the child, the perceived size of birth size,
360 maternal educational attainment, working status, antenatal visits during pregnancy, place
361 of delivery, wealth status, access to media, and type of toilet facility was also found as
362 significant risk factors. The disparities in the prevalence among the countries and
363 geographical regions could be attributed to the nutritional practices and beliefs practised
364 in the countries and geographical regions. Differences in the health policies provided by
365 governments in the various countries could also account for the disparities noted. This
366 finding implies that countries that have high prevalence should take critical lessons from
367 the countries that are doing well regarding the implementation of nutritional policies and
368 interventions (e.g., increasing dietary supplementation, increasing dietary diversity) that
369 target the reduction of the co-existence of wasting, stunting, and underweight among
370 children under age 5 in sub-Saharan Africa².

371 Similar to previous studies^{1,3}, this study found that children aged 1 year, 2 years, and 3 years
372 were at greater risk of having co-existence of all the three forms of malnutrition compared
373 to those aged 0. A plausible reason for this finding could be that as children grow their
374 energy needs also increase¹, increasing their risk of having all three nutritional conditions.
375 Alternatively, since these nutritional conditions may manifest after long durations of
376 improper nutritional practices or undernutrition^{1,3}, older children may be at higher risk of
377 having all three nutritional conditions. The finding suggests that complementary foods
378 given to children as they grow are inadequate. To reduce the risk of co-existence of
379 stunting, wasting and underweight among under 5 children, the health sectors in the
380 various countries should invest heavily in providing adequate complementary feeding to
381 this category of children.

382 Corroborating the findings of other studies^{1,3,31,32}, this study also found that children who
383 were females were less likely to have a co-existence of the three dimensions of
384 malnutrition compared to their male counterparts. An acceptable explanation for this
385 finding could be the biological variations in morbidity between males and females at that
386 young age³. It is also possible that since male children have higher birth weight compared
387 to females, they require more energy^{1,33}, which increases the risk of males having all three
388 nutritional conditions. Moreover, male children are perceived to be hungrier than females,
389 therefore breastfeeding alone could be insufficient or inadequate^{3,34}, increasing their
390 susceptibility to having the three nutritional conditions. The finding suggests that male
391 children should be given critical attention in the development and implementation of
392 nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of
393 stunting, wasting, and underweight among these male children under 5.

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

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3 396 children with large size at birth. It has been proven that malnutrition in children is partly
4 397 influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional
5 398 behaviours during the prenatal and postnatal period is key to improve child growth.
6 399 Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the
7 400 fetus to poor development often associated with small birth size and low birth
8 401 weight^{1,3,21,35}. This finding indicates that mothers of children under 5 should continuously
9 402 be educated on the best nutritional practices such as exclusive breastfeeding,
10 403 complementary feeding, and dietary supplementation. These strategies will help
11 404 ameliorate the risk of acquiring health conditions associated with malnutrition among
12 405 children under 5.

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16 406 The risk of co-existence of the three dimensions was higher among children whose
17 407 mothers had no education and primary education compared to those whose mothers had
18 408 higher education. Mothers who have attained higher education are better informed about
19 409 improved childcare practices³⁶, are more empowered to make health decisions³⁷, practice
20 410 good personal hygiene³⁷, are more likely to use the health facility³⁸, proper feeding
21 411 practices³⁵ and childcare in times of illness^{35,39}. This finding suggests that mothers with
22 412 no formal or little education are neglected in nutritional programs that help to eliminate
23 413 stunting, wasting, and underweight. Hence, they should be given the needed
24 414 consideration to deal with this persistent health issue.

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28 415 This study also found that the risk of co-existence of the three dimensions was higher
29 416 among children whose mothers were not working compared to those whose mothers
30 417 were working. Women's employment status indicate their ability to afford proper
31 418 nutritional products and health care services^{35,39}. Therefore, if mothers are not employed,
32 419 the children become highly susceptible or vulnerable because mothers are unlikely to meet
33 420 their nutritional needs or requirements. Mothers with children under 5 with such
34 421 disadvantaged background should be given subsidies on children's nutritional products
35 422 and perhaps, free access to health care services by governmental and non-governmental
36 423 organizations. This step will be significant in reducing the risks of the co-existence of
37 424 stunting, wasting, and underweight among children under 5.

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41 425 The risk of co-existence of the three dimensions was higher among children whose
42 426 mothers had no antenatal visits during pregnancy compared to those whose mothers had
43 427 antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are
44 428 usually educated on the best practices of nutrition and general healthcare, which hitherto
45 429 would not be known by these mothers³⁷. Therefore, mothers who did not have antenatal
46 430 visits may lack some knowledge about proper nutritional practices, increasing their
47 431 children's risk of having these malnutrition related challenges. Regular antenatal visits
48 432 could reduce children's risk of having stunting, underweight, and wasting, therefore,
49 433 mothers should continuously be encouraged to go for antenatal care services in their
50 434 countries.

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54 435 Children who were delivered at home compared to children who were delivered at a health
55 436 facility were found to have a higher risk of co-existence of the three dimensions. Since
56 437 mothers who deliver at home do not receive any expert nutritional advice from a qualified
57 438 health practitioner³⁶, the children of such mothers are at higher risk of having these
58 439 conditions because poor and/ or inadequate dietary practices. This finding shows that
59 440 facility delivery may help reduce the risk of co-existence of stunting, wasting, and

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3 441 underweight among children under 5. Therefore, mothers should regularly be educated
4 442 on the need to opt for facility delivery because its positive implications on children's
5 443 growth. .

7 444 The risk of co-existence of the three dimensions was higher among children whose
8 445 mothers were poor and had middle wealth status compared to those whose mothers were
9 446 rich. Usually, mothers who have average income may lack the financial capacity to feed
11 447 themselves and their children properly and adequately^{3,17,35} , increasing the children's risk
12 448 of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth
13 449 quintile may not have access to quality nutritional products and health care systems^{35,39} ,
15 450 making their children more susceptible to having all three nutritional conditions. This
16 451 finding implies that women from poor economic backgrounds should be assisted with
17 452 nutritional products and services to facilitate the reduction in the risks of the co-existence
18 453 of stunting, wasting, and underweight among children under 5.

20 454 The risk of co-existence of the three dimensions was higher among children whose
21 455 mothers had no access to media compared to those whose mothers had access to media.
22 456 Since many people are educated about proper nutritional practices through the mass
23 457 media^{10,11} , mothers who have no access to the media may lack certain important nutritional
24 458 information they need. This information gap could increase children's risk of having all
25 459 three nutritional conditions through improper dietary practices from their mothers. For
26 460 instance, mothers' access to appropriate information from the media would help them
27 461 decide on which proper diets or food commodities are readily available on market for their
28 462 children. More pragmatic ways of reaching mothers who have no access to media are
29 463 encouraged. Regular outreach or sensitization programs to target women without access
30 464 to media for example could help in reducing the risks of the co-existence of stunting,
31 465 wasting, and underweight among children under 5.

35 466 Children whose mothers had unimproved toilet facilities were found to have a higher risk
36 467 of co-existence of the three dimensions of child malnutrition compared to those whose
37 468 mothers had improved toilet facility. Insanitary or unhygienic toilet conditions may
38 469 increase mother-child-environment interactions that may result in increased exposure to
39 470 childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever)
40 471 either through consumption of contaminated foods, drinking water or poor
41 472 environmental sanitation²¹ . These conditions have been shown to cause growth
42 473 retardation in children. Governmental and non-governmental organizations should
43 474 support with the provision of improved household toilet facilities for poorer communities
44 475 to help minimize the risks of the co-existence of child malnutrition indicators.

48 476 Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having
49 477 the co-existence of the three dimensions compared to those from Angola. On the other
50 478 hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho,
51 479 Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa
52 480 had a lower risk among their children having co-existence of the three malnutrition
53 481 dimensions. The sub-regional and country-specific variations in socio-economic, agro-
54 482 ecological and geographical characteristics may strongly influence the nutritional status of
55 483 children because inadequate food supplies, limited access to arable land for agriculture,
56 484 unfavorable climatic conditions (e.g., desertification), rapid population growth, and
57 485 increasing cost of living may determine food access, availability and production in studied

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3 486 countries in SSA^{40,41}. Governmental priorities should intensify efforts to minimize the risk
4 487 of co-existence of stunting, wasting, and underweight among children under age 5 with
5 488 sound socio-economic and sustainable human capital development.

7 489 **Conclusions**

9 490 The study investigated the socio-demographic and environmental risk factors of the co-
10 491 existence of wasting, stunting, and underweight among children under age 5 in sub-
11 492 Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The
12 493 study found that the prevalence of co-existence of stunting, wasting, and underweight
13 494 ranged from 0.58 % in the Gambia to 12.14% in Benin. The study also found that the
14 495 prevalence of co-existence of stunting, wasting, and underweight was high in Western
15 496 Africa (41.78%) but low in Southern Africa (5.3%). The significant findings show that the
16 497 disadvantaged have more risks of the co-existence of wasting, stunting and underweight
17 498 among under 5 children in selected SSA countries. Findings require context nutrition-
18 499 specific interventions such as complimentary feeding, dietary supplementation and
19 500 increasing dietary diversity to promote children feeding practices across the studied
20 501 countries. Besides, country-specific sustainable human capital developmental agenda
21 502 (e.g., empowerment initiatives, entrepreneurial training), especially among mothers is
22 503 required to help improve children's dietary intake by governments and partnering
23 504 institutions or agencies.

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28 509 content. All authors read and approved the final manuscript.

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32 513

33 514

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35 516

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37 518 as we did not use any details, images or videos related to individual participants. In
38 519 addition, data used are available in the public domain.

39 520

40 521 **Ethics Approval and consent to participate**

41 522 DHS reports ethical clearance are provided by the Ethics Committee of ORC Macro Inc. as
42 523 well as Ethics Boards of partner institutions (e.g., Ministries of Health) from studied
43 524 countries. The DHS procedures require that principles for the protection of respondents'
44 525 anonymity and confidentiality are adhered. Inner City Fund International also guarantees
45 526 that the survey protocols meet the United States Department of Health and Human
46 527 Services' regulations for the respect of human subjects. The current study used a
47 528 secondary data, hence, no further ethical approval was sought. The datasets are freely
48 529 available for download and usage at <https://dhsprogram.com/data/available-datasets.cfm>.

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7 534 repository. Data for this study were sourced from Demographic and Health surveys

8 535 (DHS) and available here: <http://dhsprogram.com/data/available-datasets.cfm>

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668 **Figure legends**

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

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

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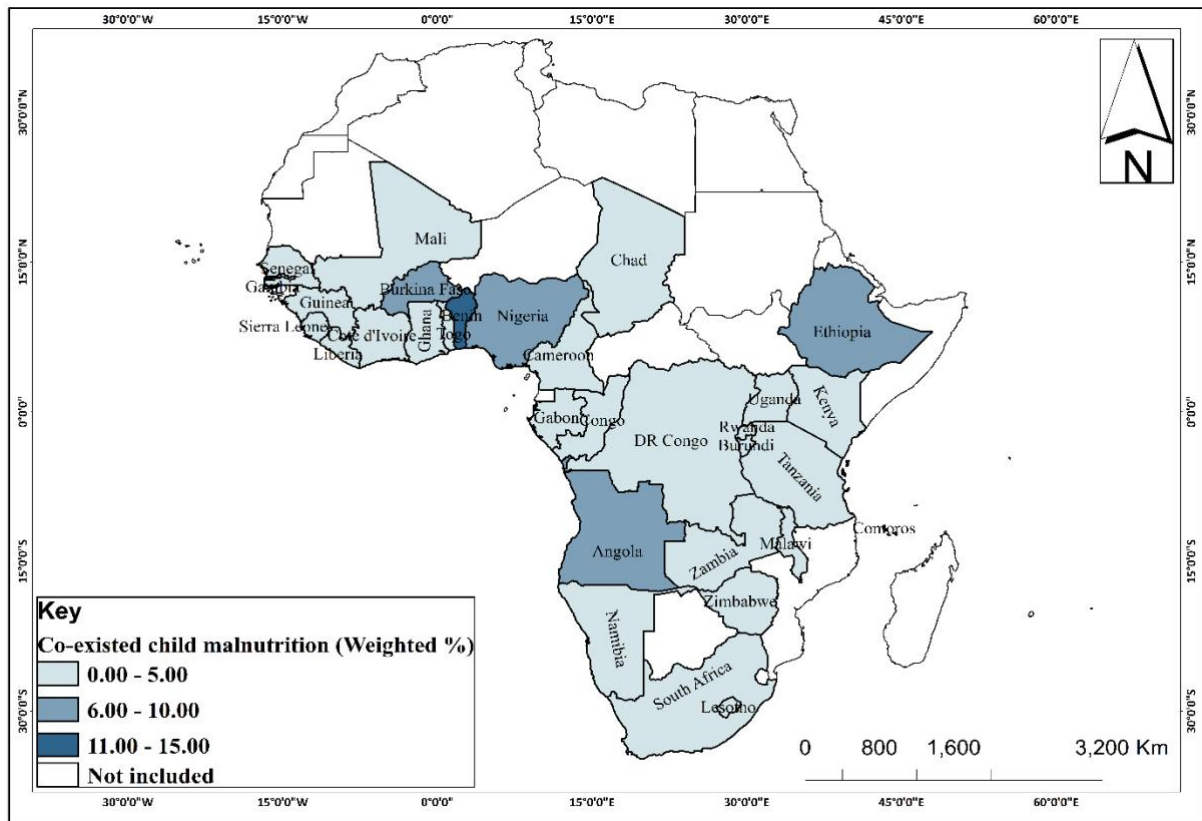


Figure 1: Percentage distribution of co-existed child malnutrition in the 31 study countries in SSA

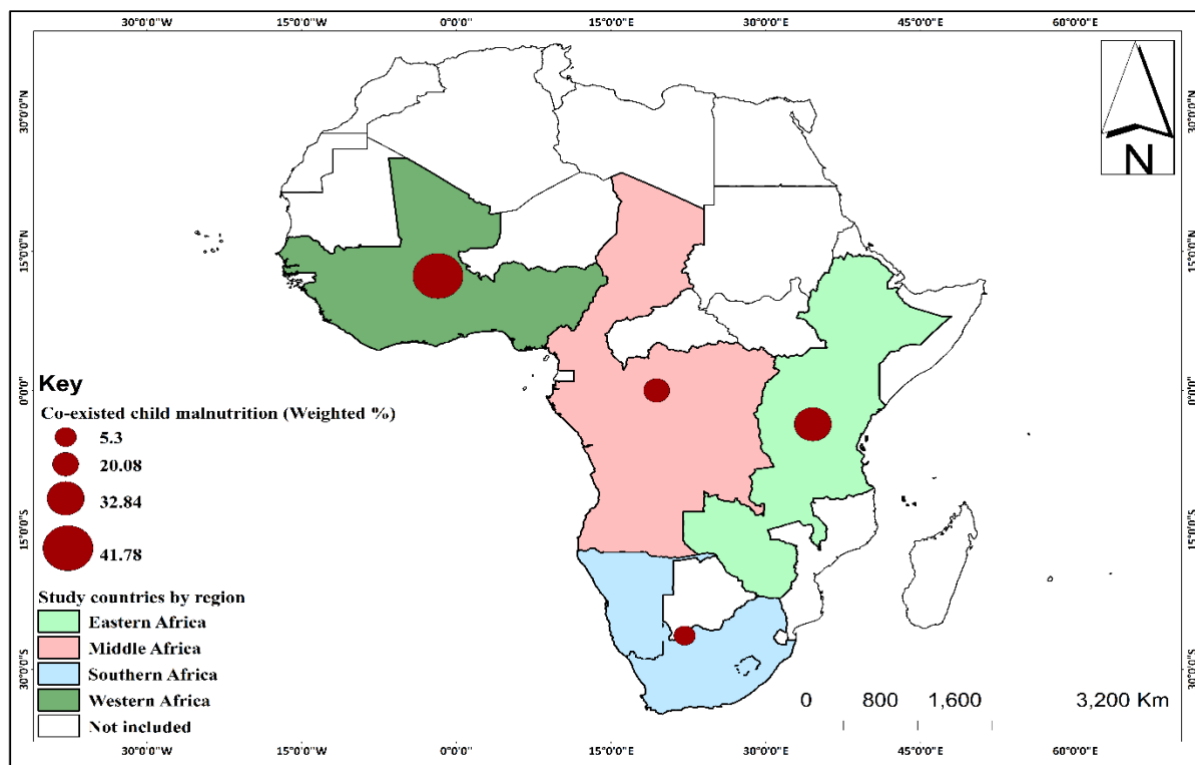


Figure 2: Proportional circle map showing the percentage distribution of co-existed child malnutrition in study countries by regions of SSA

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3 1 **Socio-demographic and environmental risk factors accounting for the co-existence of**
4 **stunting, underweight, and wasting in children under five: Analysis of cross-sectional**
5 **surveys from 31 sub-Saharan African countries**
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3 444 45 **ABSTRACT**

7 46 **Objective:** This study investigated the socio-demographic and environmental risk factors
8 47 of the co-existence of stunting, underweight, and wasting among children under age five
9 48 in sub-Saharan Africa.

11 49 **Methods:** Data from 31 sub-Saharan African countries were pooled from the Demographic
12 50 and Health Surveys (DHS) collected between 2010 and 2019. We examined the risk of co-
13 51 existence of undernutrition using multinomial logistic regression models, with results
14 52 presented as relative risk ratios (RRR) with their respective confidence intervals.

17 53 **Outcome measures:** The outcome variables were three child anthropometrics: stunting
18 54 (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-
19 55 for-height z-scores).

21 56 **Results:** The prevalence of co-existence of stunting, underweight, and wasting varied
22 57 across countries and sub-regions, with the highest and lowest prevalence of co-existence
23 58 of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively.
24 59 The risk of co-existence of the three undernutrition dimensions was higher among children
25 60 age 1 year compared to those aged 0. Children who were females were less likely to have
26 61 a co-existence of the three dimensions of undernutrition compared to their male
27 62 counterparts. The risk of co-existence of the three dimensions was higher among children
28 63 with small size at birth, those whose mothers had no education, not working, had no
29 64 antenatal visits during pregnancy, children delivered at home, those whose mothers were
30 65 poor had no access to media, and children whose mothers had unimproved toilet facility.

34 66 **Conclusion:** Findings suggest context nutrition-specific interventions such as
35 67 complementary feeding, dietary supplementation and increasing dietary diversity to
36 68 promote children feeding practices in the studied countries are warranted. Planned
37 69 interventions should prioritize all the identified factors noted in the current study to help
38 70 reduce the risks of co-existence of stunting, underweight, and wasting among children
39 71 under age 5.

42 72 **Keywords:** co-existence; stunting; underweight; wasting; children under five; sub-Saharan
43 73 Africa

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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.

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82 BACKGROUND

83 Undernutrition among children under 5 years remains a major public health problem
84 across many developing countries^{1,3}. Factors such as insufficient food intake, diarrhoea,
85 recurring infections, poor sanitation practices, and low parental education have been
86 identified as significant contributors to the high prevalence of undernutrition during
87 childhood^{1,4,5}. Despite the numerous interventions rolled out to address childhood
88 undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive,
89 the progress seems to be insignificant^{6,7}. For example, a study reported that child
90 undernutrition accounted for nearly half (45%) of the child mortality rate in developing
91 countries⁸. Aside from that, it was reported in 2018 that about 149 million and 49 million
92 children under age 5 were stunted and wasted respectively⁹.

93 Three main indicators that are often used to represent undernutrition are underweight or
94 low weight for age, stunting or low height for age, and wasting or low weight for height^{2,10-}
95 ¹². Among the three indicators of undernutrition, stunting has been identified as the
96 problem with the greatest magnitude among under 5 children in developing countries^{2,3}.
97 Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting
98 that it is still above 30%¹³ which is undeniably high. Research also indicates that the country-
99 specific prevalence of stunting, underweight and wasting is still high^{2,3}. For instance, in
100 Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively¹⁴.
101 Additionally, the prevalence of stunting, underweight and wasting among children in
102 South Africa were 35.8%, 20.5%, and 17.2%³. Likewise, Anin et al.² reported 33.2%, 14.1%, 27%
103 and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants
104 (6-23 months) across Northern Ghana.

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

113 Apart from studies that have examined the factors associated with either stunting,
114 underweight, and wasting, some scholars have begun looking at predictors of the co-
115 existence of any two or three of the indicators of malnutrition. A study in 84 countries that
116 examined the prevalence and predictors of co-existence of stunting and wasting found
117 sex and age of children as significant predictors¹⁹. Other studies in Ghana²⁰ and India²¹ also
118 examined the co-existence of stunting, underweight, and wasting and found birth interval,
119 birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's
120 educational level, and partners' educational level as associated factors. The need to
121 examine the co-existence of stunting, underweight and wasting is important because not
122 much work has been done on that subject and hence children who concurrently suffer
123 from stunting, underweight, and wasting are less likely to be reached in malnutrition
124 prevention programmes, especially in SSA. For instance, some scholars have indicated that
125 despite evidence that wasting and stunting are global public health problems that
126 frequently co-exist, they are usually separated in terms of policy, guidance, programming

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3 127 and financing²². This creates a gap in literature that needs to be filled. Despite the
4 128 detrimental consequences of undernutrition on the health and wellbeing of children under
5 129 5 in SSA, few studies have utilised current nationally representative data from a larger
6 130 sample to investigate the socio-demographic and environmental risk factors associated
7 131 with the co-existence of stunting, underweight, and wasting among this age group.
8 132 Studies presenting empirical analyses of the co-existence of these three indicators of child
9 133 undernutrition in SSA are absent in extant literature making it difficult for policymakers and
10 134 nutritional experts to provide up-to-date trends with appropriate strategies to curb the
11 135 situation in the sub-region. This research lag presents a void in extant literature which this
12 136 study seeks to bridge. Therefore, the study investigated the socio-demographic and
13 137 environmental risk factors of the co-existence of stunting, underweight, and wasting
14 138 among children under age 5 in sub-Saharan Africa using data from the Demographic Health
15 139 Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study
16 140 could contribute to the formulation of policies and interventions to respond to the
17 141 nutritional needs of children under 5 years and also suggest pragmatic ways of reducing
18 142 undernutrition among children in the sub-region.
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24 144 **METHODS**

25 145 **Data Source**

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29 146 The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African
30 147 countries (Figure 1) were pooled from the most current Demographic and Health Surveys
31 148 (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled
32 149 from the children's files in each of the countries. The DHS Program has conducted over
33 150 400 surveys in over 90 developing countries around the world since 1984 every five years²³.
34 151 The program implements cross-sectional surveys to gather nationally-representative data,
35 152 analyze and disseminate accurate information on important demographic and health
36 153 indicators spanning population, nutrition, and diseases. For all surveys, standardized
37 154 protocols designed for each target group including children, women, and men at the
38 155 household level are employed to allow for cross-national comparisons. Stratified two-
39 156 stage sampling involving first, the listing of enumeration areas and selection of clusters,
40 157 and then a random selection of households in each cluster. The detailed sampling method
41 158 can be found in a previous study²⁴. The dataset is freely available for download at:
42 159 <https://dhsprogram.com/data/available-datasets.cfm>. The Strengthening Reporting of
43 160 Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the
44 161 manuscript²⁵.

45 162 **Study Variables**

46 163 **Outcome Variable**

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51 164 The outcome variable considered in this study is derived from three child anthropometric
52 165 variables including stunting (height-for-age z-scores); underweight (weight-for-age z-
53 166 scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization
54 167 for each of these variables following the WHO child growth standard. Each of the three
55 168 variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and
56 169 "Wasting" respectively.
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3 170 These three variables were then added to generate the outcome variable “Co-existed
4 171 undernutrition” with scores (discrete) ranging from 0 to 4 where 0 implies “Normal”, that
5 172 is, children with none of the three conditions; 1 implies “Single burden”, that is, the child
6 173 suffers from one of the three conditions; 2 indicates that child suffers from “Two burdens”
7 174 out of the three; and 3 shows “Co-existed”, that is, the child suffers from all three
8 175 conditions of undernutrition. For parsimony, children who suffered from “Single burden”
9 176 and those who suffered from “Two burdens” were added resulting in the variable “Co-
10 177 existed undernutrition” with three response categories: 0=Normal; 1=One or two burdens;
11 178 and 3=co-existed.

15 179 **Independent Variables**

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17 180 Several risk factors spanning socio-demographic and environmental factors have been
18 181 associated with child undernutrition. The relevant biosocial characteristics and
19 182 sociocultural factors related to the child, mother, household head and the household
20 183 together form compositional factors^{26,27}. Factors that describe location or “place-based”
21 184 variables are contextual factors^{20,26,28,29}. In this study, contextual and composition factors
22 185 except household-level characteristics related to environment and sanitation are
23 186 categorized as “Socio-demographic risk factors”. Socio-cultural household characteristics
24 187 related to environment and sanitation are categorized as “Environmental risk factors”.

27 188 **Socio-Demographic Risk Factors**

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29 189 The relevant variables under socio-demographic risk factors considered include the age of
30 190 the child; sex of child; birth order of child ; perceived size at birth; mother’s age;
31 191 educational attainment; working status; antenatal visits during pregnancy; postnatal
32 192 check within 2 months; and place of delivery. At the household level, relevant variables
33 193 included are the wealth status; the age of household head ; sex of household head (male
34 194 and female); access to electricity ; and access to media which was derived from the three
35 195 variables “access to television”, “radio” and “newspaper”. The contextual factors
36 196 considered are Urbanicity and the country of origin of the participant.

39 197 **Environmental Risk Factors**

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41 198 We considered the following variables: type of toilet facility (re-coded into “improved”
42 199 and unimproved”²⁸; source of drinking water (re-coded as “improved” and
43 200 “unimproved”²⁸; and type of household cooking fuel (re-coded into “clean” and “unclean”
44 201 ^{28,30}under the category “environmental risk factors”

47 202 **Data Analyses**

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49 203 The statistical analysis of the data was performed using the Stata SE software version 14.2.
50 204 The “svyset” command was first used to declare the data as survey data to prevent the
51 205 potential effects of the complex sampling techniques on the analyses. To understand the
52 206 distributions of the variables, the data were summarized and presented in tables using
53 207 descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals
54 208 (CIs) of percentages). We further integrated the data into a GIS environment and
55 209 presented the distribution of key variables across the study countries and geographic
56 210 regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of
57 211 the data and understanding of the context of the study. The associations between the co-
58 212 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,

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3 255 birth order, educational level, maternal age, ANC attendance, place of delivery, source of
4 256 drinking water, sex of household head, wealth index, access to electricity and place of
5 257 residence were associated with one or two dimensions of undernutrition. See Appendix 3
6 258 for country-level risk of co-existence of stunting, wasting, and underweight.
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260 **Co-existence of Three Dimensions of Undernutrition**

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

266 *****Table 3*****

267 **DISCUSSION**

268 The study investigated the socio-demographic and environmental risk factors of the co-
269 existence of stunting, underweight, and wasting among children under age 5 in sub-
270 Saharan Africa using data from DHS conducted in 31 countries between 2010 and 2019. The
271 study found that the countries with the highest and lowest prevalence of co-existence of
272 stunting, underweight, and wasting were Benin and Gambia respectively. In terms of
273 geographic region, the highest prevalence of co-existence of stunting, underweight, and
274 wasting was observed in Western Africa and the lowest prevalence in Southern Africa.
275 The disparities in the prevalence among the countries and geographical regions could be
276 attributed to the nutritional practices and beliefs practised in the countries and
277 geographical regions. Differences in the health policies provided by governments in the
278 various countries could also account for the disparities noted. This finding implies that
279 countries that have high prevalence should take critical lessons from the countries that are
280 doing well regarding the implementation of nutritional policies and interventions (e.g.,
281 increasing dietary supplementation, increasing dietary diversity) that target the reduction
282 of the co-existence of stunting, underweight, and wasting among children under age 5 in
283 sub-Saharan Africa².

284 Similar to previous studies^{1,3}, this study found that children aged 1 year, 2 years, and 3 years
285 were at greater risk of having co-existence of all the three forms of undernutrition
286 compared to those aged 0. A plausible reason for this finding could be that as children
287 grow their energy needs also increase¹, increasing their risk of having all three nutritional
288 conditions. Alternatively, since these nutritional conditions may manifest after long
289 durations of improper nutritional practices or undernutrition^{1,3}, older children may be at
290 higher risk of having all three nutritional conditions. The finding suggests that
291 complementary foods given to children as they grow are inadequate. To reduce the risk of
292 co-existence of stunting, underweight, and wasting among under 5 children, the health
293 sectors in the various countries should invest heavily in providing adequate
294 complementary feeding to this category of children.

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

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3 298 finding could be the biological variations in morbidity between males and females at that
4 299 young age³. It is also possible that since male children have higher birth weight compared
5 300 to females, they require more energy^{1,33}, which increases the risk of males having all three
6 301 nutritional conditions. Moreover, male children are perceived to be hungrier than females,
7 302 therefore breastfeeding alone could be insufficient or inadequate^{3,34}, increasing their
8 303 susceptibility to having the three nutritional conditions. The finding suggests that male
9 304 children should be given critical attention in the development and implementation of
10 305 nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of
11 306 stunting, underweight, and wasting among these male children under 5.

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15 307 The study found that the risk of co-existence of the three dimensions of undernutrition
16 308 was higher among children with the average size at birth and small size at birth compared
17 309 to children with large size at birth. It has been proven that undernutrition in children is
18 310 partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional
19 311 behaviours during the prenatal and postnatal period is key to improve child growth.
20 312 Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the
21 313 foetus to poor development often associated with a small birth size and low birth
22 314 weight^{1,3,21,35}. This finding indicates that mothers of children under 5 should continuously
23 315 be educated on the best nutritional practices such as exclusive breastfeeding,
24 316 complementary feeding, and dietary supplementation. These strategies will help
25 317 ameliorate the risk of acquiring health conditions associated with undernutrition among
26 318 children under 5.

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30 319 The risk of co-existence of the three dimensions was higher among children whose
31 320 mothers had no education and primary education compared to those whose mothers had
32 321 higher education. Mothers who have attained higher education are better informed about
33 322 improved childcare practices³⁶, are more empowered to make health decisions³⁷, practice
34 323 good personal hygiene³⁷, are more likely to use the health facility³⁸, proper feeding
35 324 practices³⁵ and childcare in times of illness^{35,39}. This finding suggests that mothers with
36 325 no formal or little education are neglected in nutritional programs that help to eliminate
37 326 stunting, underweight, and wasting. Hence, they should be given the needed
38 327 consideration to deal with this persistent health issue.

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42 328 This study also found that the risk of co-existence of the three dimensions was higher
43 329 among children whose mothers were not working compared to those whose mothers
44 330 were working. Women's employment status indicates their ability to afford proper
45 331 nutritional products and health care services^{35,39}. Therefore, if mothers are not employed,
46 332 the children become highly susceptible or vulnerable because mothers are unlikely to meet
47 333 their nutritional needs or requirements. Mothers with children under 5 with such
48 334 disadvantaged backgrounds should be given subsidies on children's nutritional products
49 335 and perhaps, free access to health care services by governmental and non-governmental
50 336 organizations. This step will be significant in reducing the risks of the co-existence of
51 337 stunting, underweight, and wasting among children under 5.

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55 338 The risk of co-existence of the three dimensions was higher among children whose
56 339 mothers had no antenatal visits during pregnancy compared to those whose mothers had
57 340 antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are
58 341 usually educated on the best practices of nutrition and general healthcare, which hitherto
59 342 would not be known by these mothers³⁷. Therefore, mothers who did not have antenatal

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3 343 visits may lack some knowledge about proper nutritional practices, increasing their
4 344 children's risk of having these undernutrition-related challenges. Regular antenatal visits
5 345 could reduce children's risk of stunting, underweight, and wasting, therefore, mothers
6 346 should continuously be encouraged to go for antenatal care services in their countries.

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9 347 Children who were delivered at home compared to children who were delivered at a health
10 348 facility were found to have a higher risk of co-existence of the three dimensions. Since
11 349 mothers who deliver at home do not receive any expert nutritional advice from a qualified
12 350 health practitioner³⁶, the children of such mothers are at higher risk of having these
13 351 conditions because of poor and/ or inadequate dietary practices. This finding shows that
14 352 facility delivery may help reduce the risk of co-existence of stunting, underweight, and
15 353 wasting among children under 5. Therefore, mothers should regularly be educated on the
16 354 need to opt for facility delivery because of its positive implications on children's growth.

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19 355 The risk of co-existence of the three dimensions was higher among children whose
20 356 mothers were poor and had middle wealth status compared to those whose mothers were
21 357 rich. Usually, mothers who have an average income may lack the financial capacity to feed
22 358 themselves and their children properly and adequately^{3,17,35}, increasing the children's risk
23 359 of being stunted, underweight or wasted. Likewise, mothers from poor and middle wealth
24 360 quintiles may not have access to quality nutritional products and health care systems^{35,39},
25 361 making their children more susceptible to having all three nutritional conditions. This
26 362 finding implies that women from poor economic backgrounds should be assisted with
27 363 nutritional products and services to facilitate the reduction in the risks of the co-existence
28 364 of stunting, underweight, and wasting among children under 5.

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32 365 The risk of co-existence of the three dimensions was higher among children whose
33 366 mothers had no access to media compared to those whose mothers had access to media.
34 367 Since many people are educated about proper nutritional practices through the mass
35 368 media^{10,11}, mothers who have no access to the media may lack certain important nutritional
36 369 information they need. This information gap could increase children's risk of having all
37 370 three nutritional conditions through improper dietary practices from their mothers. For
38 371 instance, mothers' access to appropriate information from the media would help them
39 372 decide on which proper diets or food commodities are readily available on market for their
40 373 children. More pragmatic ways of reaching mothers who have no access to media are
41 374 encouraged. Regular outreach or sensitization programs to target women without access
42 375 to media for example could help in reducing the risks of the co-existence of stunting,
43 376 underweight, and wasting among children under 5.

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47 377 Children whose mothers had unimproved toilet facilities were found to have a higher risk
48 378 of co-existence of the three dimensions of child undernutrition compared to those whose
49 379 mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may
50 380 increase mother-child-environment interactions that may result in increased exposure to
51 381 childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever)
52 382 either through consumption of contaminated foods, drinking water or poor
53 383 environmental sanitation²¹. These conditions have been shown to cause growth
54 384 retardation in children. Governmental and non-governmental organizations should
55 385 support the provision of improved household toilet facilities for poorer communities to
56 386 help minimize the risks of the co-existence of child undernutrition indicators.

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3 387 Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having
4 388 the co-existence of the three dimensions compared to those from Angola. On the other
5 389 hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho,
6 390 Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa
7 391 had a lower risk among their children having co-existence of the three undernutrition
8 392 dimensions. The sub-regional and country-specific variations in socio-economic, agro-
9 393 ecological and geographical characteristics may strongly influence the nutritional status of
10 394 children because of inadequate food supplies, limited access to arable land for agriculture,
11 395 unfavourable climatic conditions (e.g., desertification), rapid population growth, and
12 396 increasing cost of living may determine food access, availability and production in studied
13 397 countries in SSA^{40,41}. Governmental priorities should intensify efforts to minimize the risk
14 398 of co-existence of stunting, underweight, and wasting among children under age 5 with
15 399 sound socio-economic and sustainable human capital development.

400 **Conclusions**

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

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419 AS, ED, JBF, JEH, RGA, BA, CA and BOA drafted and revised the manuscript critically for its
420 intellectual content. All authors read and approved the final manuscript. AS had the final
421 responsibility to submit the manuscript.

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427 **Competing interests:** None

428
429 **Patient consent for publication:** No consent to publish was needed for this study
430 as we did not use any details, images or videos related to individual participants. In

431 addition, data used are available in the public domain.

432

433 **Ethics Approval and consent to participate**

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

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443 **Provenance and peer review: Not commissioned; externally peer reviewed.**

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

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15 577 **Figures**

16 578 **Figure 1:** Percentage distribution of co-existence of stunting, underweight, and
17 579 wasting (SUW) in children from the 31 study countries in SSA

18 580 **Figure 2:** Percentage distribution of co-existence of stunting, underweight, and
19 581 wasting (SUW) in children by regions of SSA

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602 Tables

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

604

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	

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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)

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606 Distribution by country is shown in appendix 1

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

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

4		1.33	1.1-1.6				
5	Sex of child				Country		p<0.001
6				p<0.001	Angola	2.46	2.1-2.8
7	Male	3.43	3.3-3.6		Benin	2.04	1.8-2.2
8							4.9-
9	Female	1.99	1.9-2.1		Burkina Faso	5.31	5.8
10							
11	Birth order						
12				p<0.001	Burundi	3.76	3.2-4.4
13	1	2.25	2.1-2.4		Cameroon	1.27	0.9-1.7
14	2 to 4	2.56	2.4-2.7		Chad	5.86	5.2-6.5
15	5 and above	3.23	3.1-3.4		Comoros	1.98	1.3-2.9
16	Perceived size at birth						
17				p<0.001	Congo	0.98	0.7-1.5
18	Large	1.78	1.7-1.9		Cote d'Ivoire	2.28	1.7-3.0
19	Average	2.6	2.5-2.7		DR Congo	2.66	2.2-3.2
20	Small	4.98	4.7-5.3		Ethiopia	3.64	3.2-4.1
21	Mother's characteristics				Gabon	0.63	0.3-1.0
22							
23				P =			
24	Maternal age			0.080	Gambia	3.61	2.4-5.2
25							0.9-
26	15-19	2.78	2.5-3.1		Ghana	1.37	2.0
27	20-49	2.71	2.6-2.8		Guinea	2.26	1.7-2.9
28							
29	Educational attainment						
30				p<0.001	Kenya	0.94	0.7-1.2
31	No education	4.19	4.0-4.4		Lesotho	0.86	0.7-1.0
32	Primary	2.09	2.0-2.2		Liberia	2.37	1.7-3.1
33	Secondary	1.22	1.1-1.3		Malawi	1.03	0.7-1.4
34	Higher	0.66	0.4-1.0		Mali	3.62	2.5-4.1
35	Working status						
36				p<0.001	Namibia	1.99	1.2-3.1
37	No	3.13	3.0-3.3		Nigeria	4.1	3.7-4.6
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3	Yes	2.48	2.4-2.6		Rwanda	6.17	5.5-6.9
4	Antenatal visits during pregnancy			p<0.001	Senegal	2.43	1.8-3.2
5	No	5.41	5.0-5.8		Sierra Leone	1.94	1.4-2.5
6							0.02-
7							
8	Yes	2.39	2.3-2.5		South Africa	0.18	0.8
9	Postnatal check within 2 months			p<0.001	Tanzania	1.86	2.1-3.5
10	No	2.93	2.8-3.1		Togo	2.72	2.1-3.4
11	Yes	2.42	2.3-2.6		Uganda	1.2	0.8-1.7
12	Place of delivery			p<0.001	Zambia	1.22	1.0-1.5
13	Home	4.36	4.2-4.6		Zimbabwe	0.78	0.5-1.1
14	Health facility	1.96	1.9-2.1		Environmental factors		
15					Type of toilet		
16					facility		
17	Other	2.45	1.7-3.3		Improved	1.76	1.6-1.9
18	Wealth status			p<0.001	Unimproved	3.43	3.3-3.6
19	Poor	3.46	3.3-3.6		Source of drinking water		
20					Improved	2.54	2.4-2.6
21	Middle	2.74	2.5-2.9		Unimproved	3.06	2.9-3.2
22	Rich	1.86	1.7-2.0		Type of cooking		
23	Age of household			p =	fuel		
24	head			0.276	Clean	0.98	1.2
25	Young-adults	2.65	2.5-2.8		Unclean	2.92	2.8-3.0
26					Geographic		
27	Middle-aged adults	2.76	2.6-2.9		region		
28	Old-aged adults	2.8	2.6-3.1		Western	3.11	3.0-2.3
29	Sex of household			p<0.001	Eastern	2.43	2.3-2.6
30	head						
31	Male	2.82	2.7-2.9				
32	Female	2.33	2.1-2.5				
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Access to electricity

p<0.001

Central

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Yes3.21 3.1-3.3
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South Africa

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611 **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

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

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

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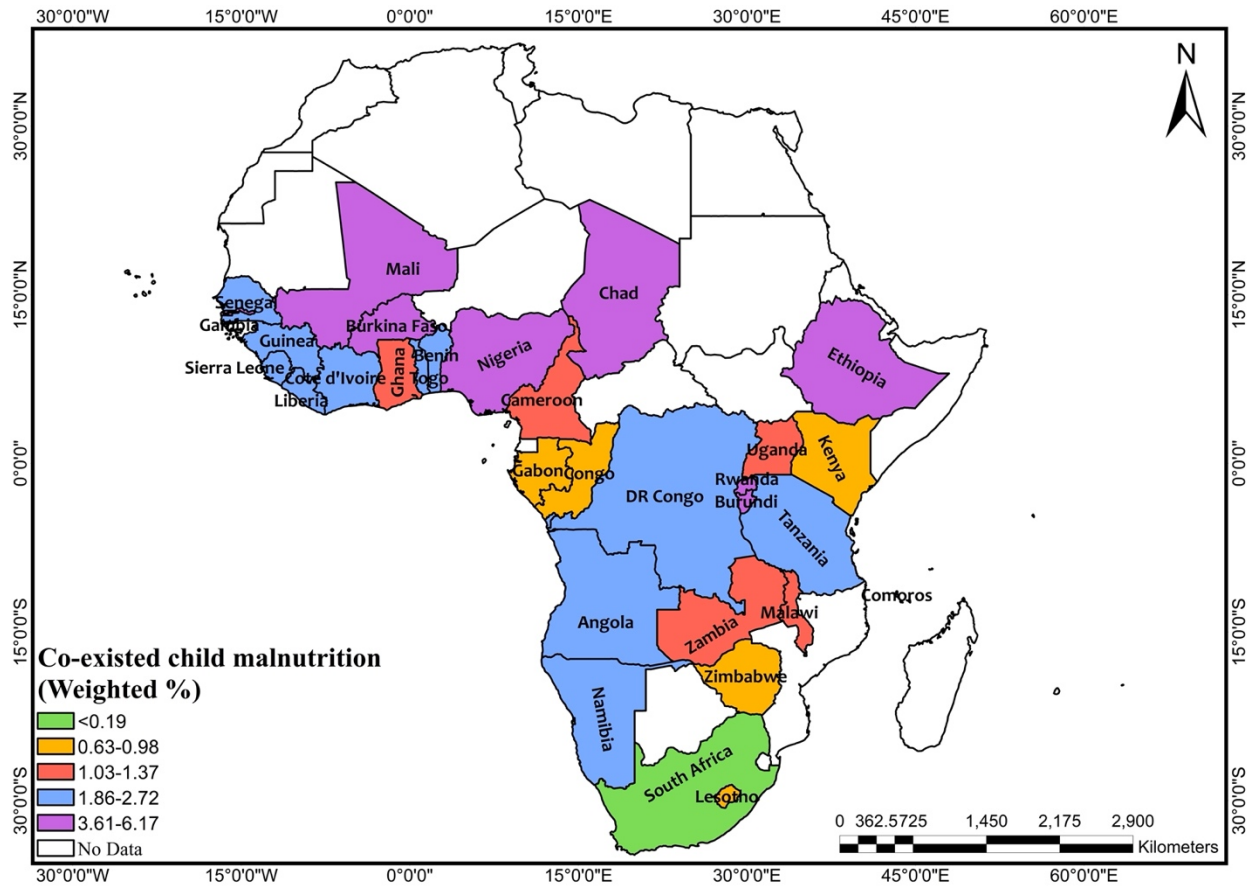


Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

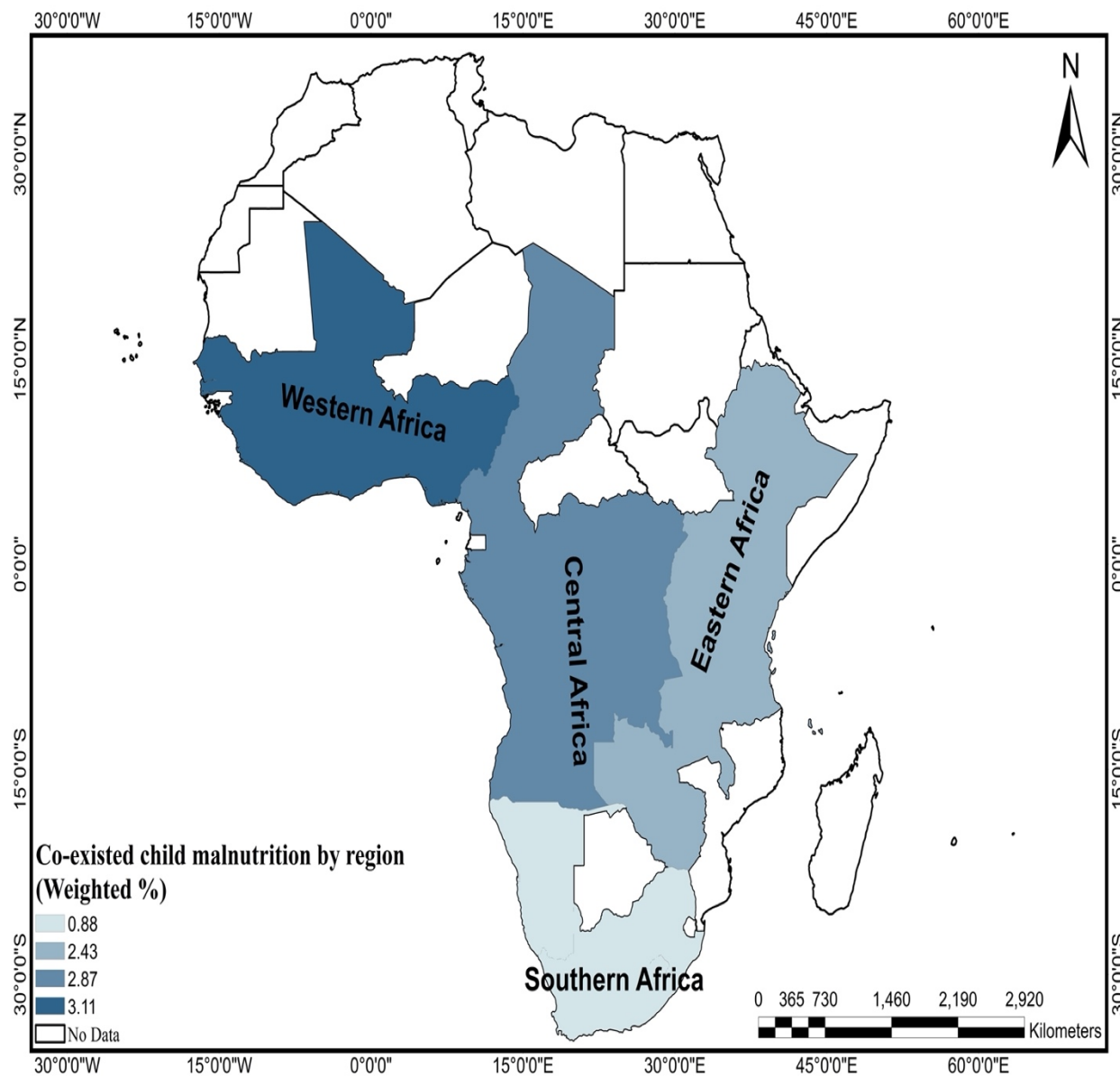


Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

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

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3 44 **ABSTRACT**
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5 45 **Objective:** This study investigated the risk factors associated with the co-existence of
6 46 stunting, underweight, and wasting among children under age five in sub-Saharan
7 47 Africa(SSA).

8
9 48 **Methods:** Data from 31 sub-Saharan African countries were pooled from the Demographic
10 49 and Health Surveys collected between 2010 and 2019. We examined the risk of co-
11 50 existence of undernutrition using multinomial logistic regression models, with results
12 51 presented as relative risk ratios with their respective confidence intervals.

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15 52 **Outcome measures:** The outcome variables were three child anthropometrics: stunting
16 53 (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-
17 54 height z-scores).

18
19 55 **Results:** The prevalence of co-existence of stunting, underweight, and wasting varied
20 56 across countries and sub-regions, with the highest and lowest prevalence of co-existence
21 57 of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively.
22 58 The risk of co-existence of the three undernutrition dimensions was higher among children
23 59 age 1 year compared to those aged 0. The risk of co-existence of the three dimensions was
24 60 higher among female children, those with small size at birth, those whose mothers had no
25 61 education, not working, had no antenatal visits during pregnancy, children delivered at
26 62 home, those whose mothers were poor, had no access to media and children whose
27 63 mothers had unimproved toilet facility.

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31 64 **Conclusion:** Findings suggest the urgent need for consideration of the co-existence of
32 65 stunting, wasting and underweight among under-five children in policy design and
33 66 programming of interventions to eradicate child malnutrition in SSA. In the short-term,
34 67 national-level policies and interventions need to be well-tailored considering the
35 68 compositional characteristics. In the long-term, regional policies and coordinated
36 69 interventions among governments of SSA countries need to be designed to address the
37 70 disparate prevalence of the co-existence of stunting, wasting and underweight in under-
38 71 five children across the four geographic regions.

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41 72 **Keywords:** co-existence; stunting; underweight; wasting; children under five; sub-Saharan
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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.

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82 BACKGROUND

83 Undernutrition among children under 5 years remains a major public health problem
84 across many low-and middle-income countries¹⁻³. Factors such as insufficient food intake,
85 diarrhoea, recurring infections, poor sanitation practices, and low parental education have
86 been identified as significant contributors to the high prevalence of undernutrition during
87 childhood^{4,5}. Despite the numerous interventions rolled out to address childhood
88 undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive,
89 the progress seems to be insignificant^{6,7}. For example, a study reported that child
90 undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-
91 income countries⁸. Aside from that, it was reported in 2018 that about 149 million and 49
92 million children under age 5 were stunted and wasted respectively⁹.

93 Three main indicators that are often used to represent undernutrition are underweight or
94 low weight for age, stunting or low height for age, and wasting or low weight for height^{2,10-}
95 ¹². Among the three indicators of undernutrition, stunting has been identified as the
96 problem with the greatest magnitude among under 5 children in developing countries^{2,3}.
97 Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting
98 that it is still above 30%¹³ which is undeniably high. Research also indicates that the country-
99 specific prevalence of stunting, underweight and wasting is still high^{2,3}. For instance, in
100 Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively¹⁴.
101 Additionally, the prevalence of stunting, underweight and wasting among children in
102 South Africa were 35.8%, 20.5%, and 17.2%³. Likewise, Anin et al.² reported 33.2%, 14.1%, 27%
103 and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants
104 (6-23 months) across Northern Ghana.

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

113 Apart from studies that have examined the factors associated with either stunting,
114 underweight, and wasting, some scholars have begun looking at predictors of the co-
115 existence of any two or three of the indicators of malnutrition. A study in 84 countries that
116 examined the prevalence and predictors of co-existence of stunting and wasting found
117 sex and age of children as significant predictors¹⁹. Other studies in Ghana²⁰ and India²¹ also
118 examined the co-existence of stunting, underweight, and wasting and found birth interval,
119 birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's
120 educational level, and partners' educational level as associated factors. The need to
121 examine the co-existence of stunting, underweight and wasting is important because not
122 much work has been done on that subject and hence children who concurrently suffer
123 from stunting, underweight, and wasting are less likely to be reached in malnutrition
124 prevention programmes, especially in SSA. For instance, some scholars have indicated that
125 despite evidence that wasting and stunting are global public health problems that
126 frequently co-exist, they are usually separated in terms of policy, guidance, programming

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3 127 and financing²². This creates a gap in the literature that needs to be filled. Despite the
4 128 detrimental consequences of undernutrition on the health and wellbeing of children under
5 129 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk
6 130 factors associated with the co-existence of stunting, underweight, and wasting among this
7 131 age group are absent in the literature. Studies presenting empirical analyses of the co-
8 132 existence of these three indicators of child undernutrition in SSA are absent in extant
9 133 literature making it difficult for policymakers and nutritional experts to provide up-to-date
10 134 trends with appropriate strategies to curb the situation in the sub-region. This research lag
11 135 presents a void in extant literature which this study seeks to bridge. Therefore, the study
12 136 investigated the risk factors of the co-existence of stunting, underweight, and wasting
13 137 among children under age 5 in sub-Saharan Africa using data from the Demographic Health
14 138 Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study
15 139 could contribute to the formulation of policies and interventions to respond to the
16 140 nutritional needs of children under 5 years and also suggest pragmatic ways of reducing
17 141 undernutrition among children in the sub-region.
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143 **METHODS**

144 **Data Source**

145 The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African
146 countries (Figure 1) were pooled from the most current Demographic and Health Surveys
147 (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled
148 from the children's files in each of the countries. The DHS Program has conducted over
149 400 surveys in over 90 developing countries around the world since 1984 every five years²³.
150 The program implements cross-sectional surveys to gather nationally-representative data,
151 analyze and disseminate accurate information on important demographic and health
152 indicators spanning population, nutrition, and diseases. For all surveys, standardized
153 protocols designed for each target group including children, women, and men at the
154 household level are employed to allow for cross-national comparisons. Stratified two-
155 stage sampling involving first, the listing of enumeration areas and selection of clusters,
156 and then a random selection of households in each cluster. The detailed sampling method
157 can be found in a previous study²⁴. The dataset is freely available for download at:
158 <https://dhsprogram.com/data/available-datasets.cfm>²⁵. The Strengthening Reporting of
159 Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the
160 manuscript²⁶.

161 **Study Variables**

162 **Outcome Variable**

163 The outcome variable considered in this study is derived from three child anthropometric
164 variables including stunting (height-for-age z-scores); underweight (weight-for-age z-
165 scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization
166 for each of these variables following the WHO child growth standard. Each of the three
167 variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and
168 "Wasting" respectively.
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3 169 These three variables were then added to generate the outcome variable “Co-existed
4 170 undernutrition” with scores (discrete) ranging from 0 to 3 where 0 implies “Normal”, that
5 171 is, children with none of the three conditions; 1 implies “Single burden”, that is, the child
6 172 suffers from one of the three conditions; 2 indicates that child suffers from “Two burdens”
7 173 out of the three; and 3 shows “Co-existed”, that is, the child suffers from all three
8 174 conditions of undernutrition. For parsimony, children who suffered from “Single burden”
9 175 and those who suffered from “Two burdens” were added resulting in the variable “Co-
10 176 existed undernutrition” with three response categories: 0=Normal; 1=One or two burdens;
11 177 and 3=co-existed.

15 178 **Independent Variables**

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17 179 Several risk factors spanning compositional to contextual factors have been associated
18 180 with child undernutrition. The relevant biosocial characteristics and sociocultural factors
19 181 related to the child, mother, household head and the household together form
20 182 compositional factors^{27,28}. Factors that describe location or “place-based” variables are
21 183 contextual factors^{20,27,29,30}. The relevant compositional factors considered include the age
22 184 of the child; sex of the child; birth order of child; perceived size at birth; mother’s age;
23 185 educational attainment; working status; antenatal visits during pregnancy; postnatal
24 186 check within 2 months; and place of delivery. At the household level, relevant variables
25 187 included are the wealth status; the age of household head; sex of household head (male
26 188 and female); access to electricity; and access to media which was derived from the three
27 189 variables “access to television”, “radio” and “newspaper”. Household basic needs
28 190 including the type of toilet facility (re-coded into “improved” and unimproved”²⁹; source
29 191 of drinking water (re-coded as “improved” and “unimproved”²⁹, and type of household
30 192 cooking fuel (re-coded into “clean” and “unclean”^{29,31} are also considered. The contextual
31 193 factors considered are urbanicity and the country of origin of the participant.

36 194 **Data Analyses**

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38 195 The statistical analysis of the data was performed using the Stata SE software version 14.2.
39 196 The “svyset” command was first used to declare the data as survey data to prevent the
40 197 potential effects of the complex sampling techniques on the analyses. The sample weight
41 198 variable in the DHS was used to provide weighted samples in the analyses. To understand
42 199 the distributions of the variables, the data were summarized and presented in tables using
43 200 descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals
44 201 (CIs) of percentages). We further integrated the data into a GIS environment and
45 202 presented the distribution of key variables across the study countries and geographic
46 203 regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of
47 204 the data and understanding of the context of the study. The associations between the co-
48 205 existence of undernutrition and each of the risk factors considered were assessed using
49 206 the chi-square test of independence, with results presented in a contingency table. The
50 207 risk factors as independent variables were then subjected to collinearity diagnosis tests,
51 208 including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was
52 209 done to ascertain whether the independent variables were actually “independent”, that
53 210 is, are not correlated with one another and will not share variance in the outcome variable.
54 211 Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables
55 212 were not correlated (Mean VIF=1.26; Maximum VIF=1.71; Minimum VIF=1.02). To determine

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

215 **Ethical Approval**

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

222 **Patient and public involvement**

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

224 **Results**

225 ***Distribution of sample characteristics***

226 The study included a total of 127,487 under-five children. It is found that most (30.87%) of
227 the children were less than a year (Table 1). With regards to sex, both males and females
228 constituted approximately half of the sample. A majority of the children (92.87%) were
229 born to mothers aged between 20 to 49 years while only 7.13% were born to mothers aged
230 15 to 19 years. In terms of education, most (41.82%) of the children were born to mothers
231 with no formal education. Only 3.10% of the children were born to a mother with a higher
232 level of educational attainment. Further, 42.1% of the children were born in poor
233 households while 37.21% were born in rich households. More than half (57.53%) of the
234 children lived in a household with unimproved toilet facilities. However, most (65.63%) of
235 the children lived in households with access to improved drinking water sources. Similarly,
236 a majority (89.76%) of the children lived in households using clean cooking fuel (Table 1).

237 As shown in Appendix 2, the prevalence of co-existence of stunting, underweight, and
238 underweight varied across countries and sub-regions, with the highest and lowest
239 prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and
240 South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence
241 of co-existence of stunting, underweight, and wasting was observed in Western Africa
242 (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2).

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

246 ***Table 1***

247

248 ***Figure 1***

249 ***Figure 2***

250 ***Table 2***

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

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

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3 254 children under five years in the SSA. Age of child, size of the child at birth, sex of the child,
4 255 birth order, educational level, maternal age, ANC attendance, place of delivery, source of
5 256 drinking water, sex of household head, wealth index, access to electricity and place of
6 257 residence were associated with one or two dimensions of undernutrition. See Appendix 3
7 258 for country-level risk of co-existence of stunting, wasting, and underweight.

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10 259 Regarding the co-existence of the three dimensions of undernutrition (stunting,
11 260 underweight, and wasting), age of the child, sex of the child, perceived birth size, maternal
12 261 educational attainment, working status, antenatal visits during pregnancy, place of
13 262 delivery, wealth status, access to media, and type of toilet facility were found to be
14 263 significant risk factors (Table 3).

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17 264 *****Table 3*****

18 265 **DISCUSSION**

19
20 266 The study investigated the risk factors of the co-existence of stunting, underweight, and
21 267 wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted
22 268 in 31 countries between 2010 and 2019. The study found that the countries with the highest
23 269 and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin
24 270 and Gambia respectively. In terms of geographic region, the highest prevalence of co-
25 271 existence of stunting, underweight, and wasting was observed in Western Africa and the
26 272 lowest prevalence in Southern Africa. The disparities in the prevalence among the
27 273 countries and geographical regions could be attributed to the nutritional practices and
28 274 beliefs practised in the countries and geographical regions. Differences in the health
29 275 policies provided by governments in the various countries could also account for the
30 276 disparities noted. This finding implies that countries that have high prevalence should take
31 277 critical lessons from the countries that are doing well regarding the implementation of
32 278 nutritional policies and interventions (e.g., increasing dietary supplementation, increasing
33 279 dietary diversity) that target the reduction of the co-existence of stunting, underweight,
34 280 and wasting among children under age 5 in sub-Saharan Africa².

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39 281 Similar to previous studies^{1,3}, this study found that children aged 1 year, 2 years, and 3 years
40 282 were at greater risk of having co-existence of all the three forms of undernutrition
41 283 compared to those aged 0. A plausible reason for this finding could be that as children
42 284 grow their energy needs also increase¹, increasing their risk of having all three nutritional
43 285 conditions. Alternatively, since these nutritional conditions may manifest after long
44 286 durations of improper nutritional practices or undernutrition^{1,3}, older children may be at
45 287 higher risk of having all three nutritional conditions. The finding suggests that
46 288 complementary foods given to children as they grow are inadequate. To reduce the risk of
47 289 co-existence of stunting, underweight, and wasting among under 5 children, the health
48 290 sectors in the various countries should invest heavily in providing adequate
49 291 complementary feeding to this category of children.

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53 292 Corroborating the findings of other studies^{1,3,32,33}, this study also found that children who
54 293 were females were less likely to have a co-existence of the three dimensions of
55 294 undernutrition compared to their male counterparts. An acceptable explanation for this
56 295 finding could be the biological variations in morbidity between males and females at that
57 296 young age³. It is also possible that since male children have higher birth weight compared
58 297 to females, they require more energy^{1,34}, which increases the risk of males having all three

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

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

316 The risk of co-existence of the three dimensions was higher among children whose
317 mothers had no education and primary education compared to those whose mothers had
318 higher education. Mothers who have attained higher education are better informed about
319 improved childcare practices³⁷, are more empowered to make health decisions³⁸, practice
320 good personal hygiene³⁸, are more likely to use the health facility³⁹, proper feeding
321 practices³⁶ and childcare in times of illness^{36,40}. This finding suggests that mothers with no
322 formal or little education are neglected in nutritional programs that help to eliminate
323 stunting, underweight, and wasting. Hence, they should be given the needed
324 consideration to deal with this persistent health issue.

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

335 The risk of co-existence of the three dimensions was higher among children whose
336 mothers had no antenatal visits during pregnancy compared to those whose mothers had
337 antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are
338 usually educated on the best practices of nutrition and general healthcare, which hitherto
339 would not be known by these mothers³⁸. Therefore, mothers who did not have antenatal
340 visits may lack some knowledge about proper nutritional practices, increasing their
341 children's risk of having these undernutrition-related challenges. Regular antenatal visits
342 could reduce children's risk of stunting, being underweight, and wasting, therefore,

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

345 Children who were delivered at home compared to children who were delivered at a health
346 facility were found to have a higher risk of co-existence of the three dimensions. Since
347 mothers who deliver at home do not receive any expert nutritional advice from a qualified
348 health practitioner³⁷, the children of such mothers are at higher risk of having these
349 conditions because of poor and/ or inadequate dietary practices. This finding shows that
350 facility delivery may help reduce the risk of co-existence of stunting, underweight, and
351 wasting among children under 5. Therefore, mothers should regularly be educated on the
352 need to opt for facility delivery because of its positive implications on children's growth.

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

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

375 Children whose mothers had unimproved toilet facilities were found to have a higher risk
376 of co-existence of the three dimensions of child undernutrition compared to those whose
377 mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may
378 increase mother-child-environment interactions that may result in increased exposure to
379 childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever)
380 either through consumption of contaminated foods, drinking water or poor
381 environmental sanitation²¹. These conditions have been shown to cause growth
382 retardation in children. Government and non-governmental organizations should support
383 the provision of improved household toilet facilities for poorer communities to help
384 minimize the risks of the co-existence of child undernutrition indicators.

385 Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having
386 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.

398 **Conclusions and implications**

399 The study investigated the risk factors of the co-existence of stunting, underweight, and
400 wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted
401 in 31 countries between 2010 and 2019. The study found that the prevalence of co-
402 existence of stunting, underweight, and wasting ranged from 0.58 % in the Gambia to
403 12.14% in Benin. The study also found that the prevalence of co-existence of stunting,
404 underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa
405 (5.3%). The significant findings show that the disadvantaged have more risks of the co-
406 existence of stunting, underweight, and wasting among under 5 children in selected SSA
407 countries. These findings demonstrate the urgent need for consideration of the co-
408 existence of stunting, wasting and underweight among under-five children in policy design
409 and programming of interventions to eradicate child malnutrition in SSA. In the short-term,
410 national-level policies and interventions needs to be well-tailored considering the
411 compositional characteristics including child's age, sex, birth size; maternal education,
412 working status, place of delivery, antenatal visit; and household's wealth status, access to
413 media and improved toilet facility are required. For instance, such programs could be
414 geared towards improving females' access to education, reducing unemployment,
415 expanding access to the media and using it to promote education on the need for
416 antenatal care. In the long-term, regional policies and coordinated interventions among
417 governments of SSA countries need to be designed to address the disparate prevalence
418 of the co-existence of stunting, wasting and underweight in under-five children across the
419 four geographic regions. The implementation of these at the local-level should consider
420 rural-urban differences in the prevalence of the condition and the risk factors elicited.

421

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428

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431 **Competing interests:** None

432

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434 as we did not use any details, images or videos related to individual participants. In
435 addition, data used are available in the public domain.

436

437 **Ethics Approval and consent to participate**

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

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446 **Data availability statement:** Data are available in a public, open access repository.

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Figures

18 582 **Figure 1:** Percentage distribution of co-existence of stunting, underweight, and
19 583 wasting (SUW) in children from the 31 study countries in SSA

20 584 **Figure 2:** Percentage distribution of co-existence of stunting, underweight, and
21 585 wasting (SUW) in children by regions of SSA

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599 Tables

600 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		Type of toilet facility	
No education	41.82	Improved	42.47
Primary	31.26	Unimproved	57.53
Secondary	23.82	Source of drinking water	
Higher	3.10	Improved	65.63
Working status		Unimproved	34.37
No	35.49	Type of cooking fuel	
Yes	64.51	Clean	89.76
Antenatal visits during pregnancy		Unclean	10.24
No	10.76	Geographic region	
Yes	89.24	Western	41.78
Postnatal check within 2 months		Eastern	32.84
No	58.49	Central	20.08
Yes	41.51	South Africa	5.30
Access to media (tv/radio/newspaper)			
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
	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)		
Primary	2.09 (2.0-2.2)	Improved	1.76 (1.6-1.9)	Nigeria
Secondary	1.22 (1.1-1.3)	Unimproved	3.43 (3.3-3.6)	Rwanda
	Source of drinking water			
	(p<0.001)			
Higher	0.66 (0.4-1.0)		Senegal	2.43 (1.8-3.2)
	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
Yes	2.48 (2.4-2.6)	Type of cooking fuel (p<0.001)		
	Antenatal visits during pregnancy (p<0.001)			
	Clean	0.98 (0.8-1.2)	Togo	2.72 (2.1-3.4)
No	5.41 (5.0-5.8)	Unclean	2.92 (2.8-3.0)	Uganda
Yes	2.39 (2.3-2.5)	Urbanicity (p<0.001)		
	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			
	Central			
	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)						
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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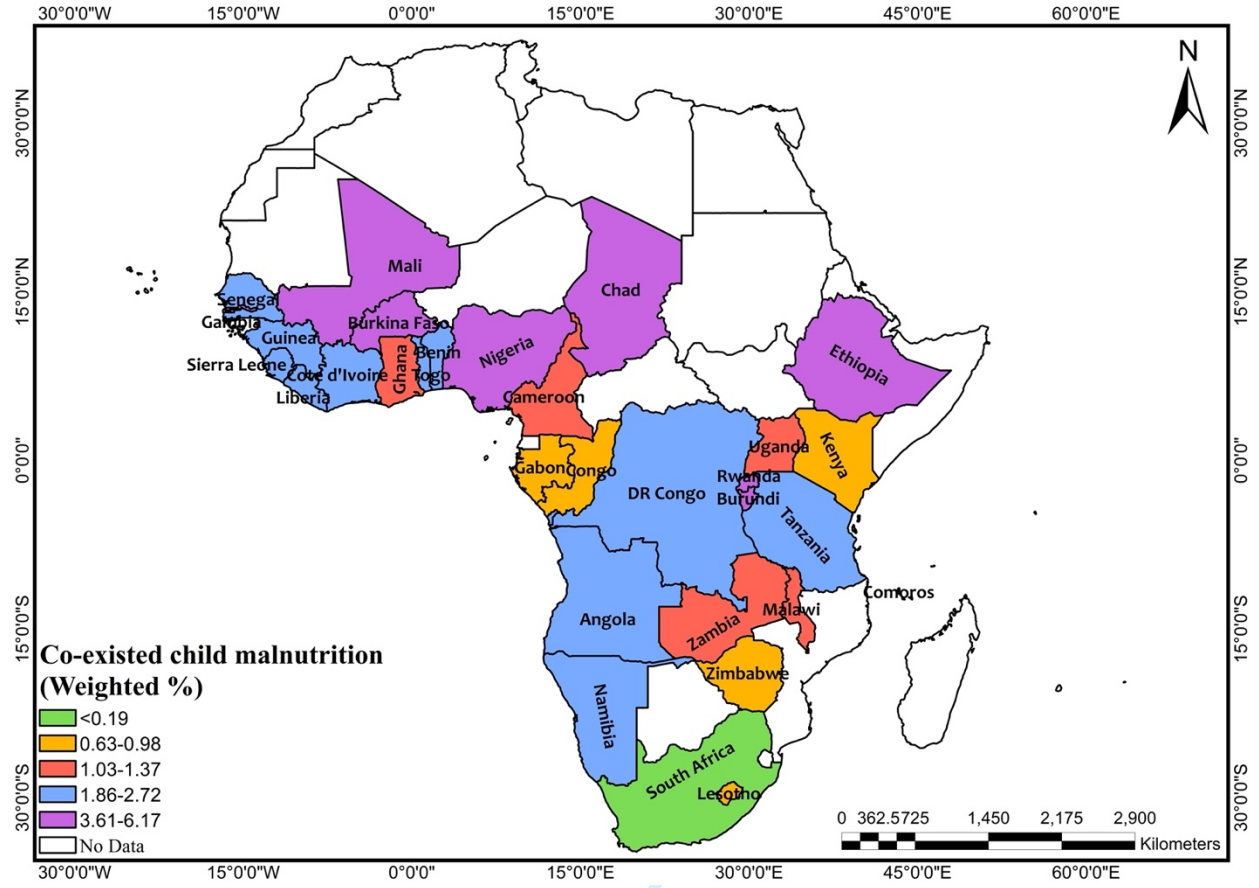


Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

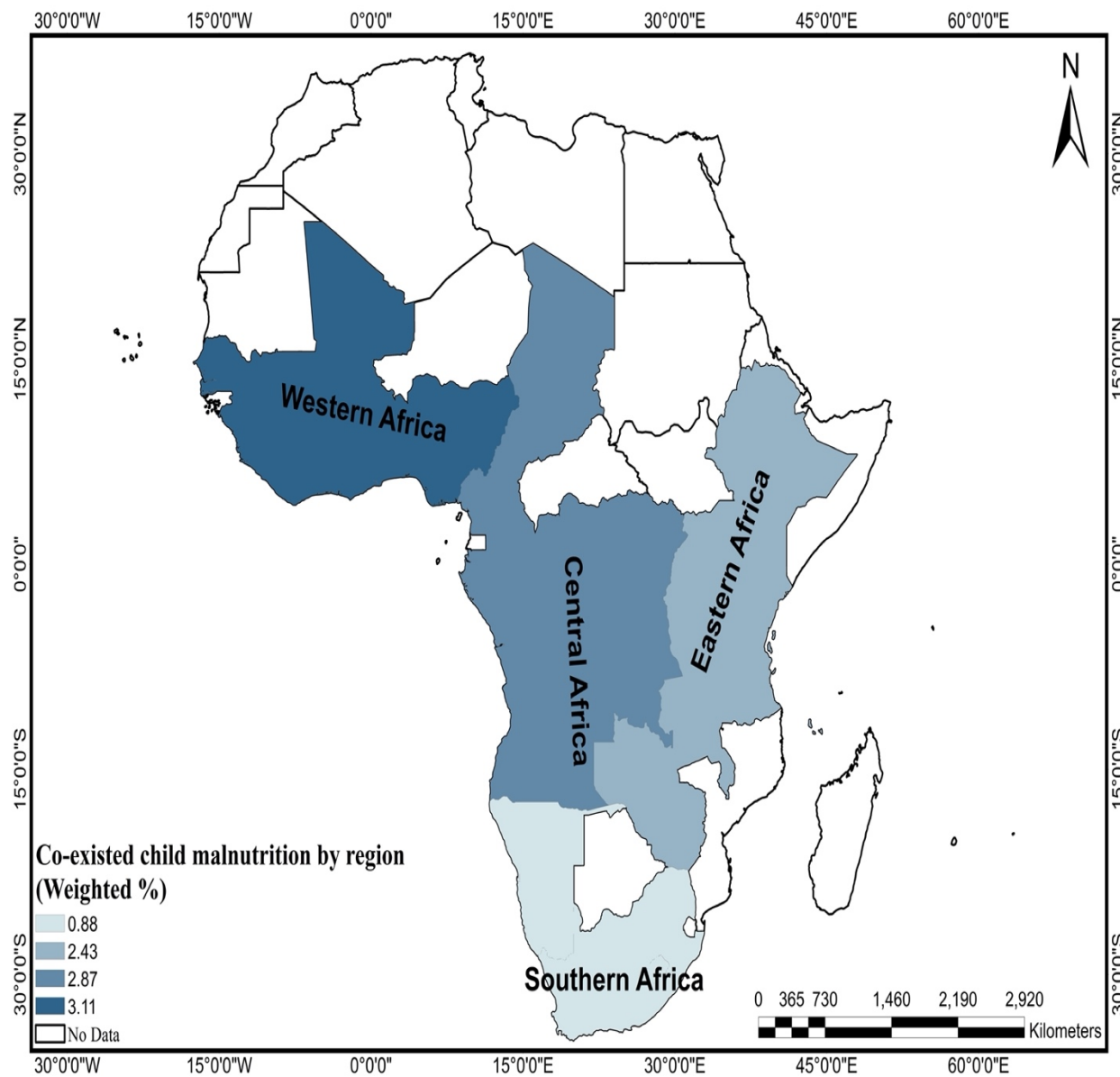


Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

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

Country (Ref: Angola)	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
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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1 **Risk factors associated with the co-existence of stunting, underweight, and wasting in**
2 **children under five: Analysis of cross-sectional surveys from 31 sub-Saharan African**
3 **countries**

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3 44 **ABSTRACT**
4

5 45 **Objective:** This study investigated the risk factors associated with the co-existence of
6 46 stunting, underweight, and wasting among children under age five in sub-Saharan
7 47 Africa(SSA).

8
9 48 **Methods:** Data from 31 sub-Saharan African countries were pooled from the Demographic
10 49 and Health Surveys collected between 2010 and 2019. We examined the risk of co-
11 50 existence of undernutrition using multinomial logistic regression models, with results
12 51 presented as relative risk ratios with their respective confidence intervals.

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15 52 **Outcome measures:** The outcome variables were three child anthropometrics: stunting
16 53 (height-for-age z-scores); underweight (weight-for-age z-scores); and wasting (weight-for-
17 54 height z-scores).

18
19 55 **Results:** The prevalence of co-existence of stunting, underweight, and wasting varied
20 56 across countries and sub-regions, with the highest and lowest prevalence of co-existence
21 57 of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively.
22 58 The risk of co-existence of the three undernutrition dimensions was higher among children
23 59 age 1 year compared to those aged 0. The risk of co-existence of the three dimensions was
24 60 higher among female children, those with small size at birth, those whose mothers had no
25 61 education, not working, had no antenatal visits during pregnancy, children delivered at
26 62 home, those whose mothers were poor, had no access to media and children whose
27 63 mothers had unimproved toilet facility.

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30 64 **Conclusion:** Findings suggest the urgent need for consideration of the co-existence of
31 65 stunting, wasting and underweight among under-five children in policy design and
32 66 programming of interventions to eradicate child malnutrition in SSA. In the short-term,
33 67 national-level policies and interventions need to be well-tailored considering the
34 68 compositional characteristics. In the long-term, regional policies and coordinated
35 69 interventions among governments of SSA countries need to be designed to address the
36 70 disparate prevalence of the co-existence of stunting, wasting and underweight in under-
37 71 five children across the four geographic regions.

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39 72 **Keywords:** co-existence; stunting; underweight; wasting; children under five; sub-Saharan
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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.

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82 BACKGROUND

83 Undernutrition among children under 5 years remains a major public health problem
84 across many low-and middle-income countries¹⁻³. Factors such as insufficient food intake,
85 diarrhoea, recurring infections, poor sanitation practices, and low parental education have
86 been identified as significant contributors to the high prevalence of undernutrition during
87 childhood^{4,5}. Despite the numerous interventions rolled out to address childhood
88 undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive,
89 the progress seems to be insignificant^{6,7}. For example, a study reported that child
90 undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-
91 income countries⁸. Aside from that, it was reported in 2018 that about 149 million and 49
92 million children under age 5 were stunted and wasted respectively⁹.

93 Three main indicators that are often used to represent undernutrition are underweight or
94 low weight for age, stunting or low height for age, and wasting or low weight for height^{2,10-}
95 ¹². Among the three indicators of undernutrition, stunting has been identified as the
96 problem with the greatest magnitude among under 5 children in developing countries^{2,3}.
97 Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting
98 that it is still above 30%¹³ which is undeniably high. Research also indicates that the country-
99 specific prevalence of stunting, underweight and wasting is still high^{2,3}. For instance, in
100 Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively¹⁴.
101 Additionally, the prevalence of stunting, underweight and wasting among children in
102 South Africa were 35.8%, 20.5%, and 17.2%³. Likewise, Anin et al.² reported 33.2%, 14.1%, 27%
103 and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants
104 (6-23 months) across Northern Ghana.

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

113 Apart from studies that have examined the factors associated with either stunting,
114 underweight, and wasting, some scholars have begun looking at predictors of the co-
115 existence of any two or three of the indicators of malnutrition. A study in 84 countries that
116 examined the prevalence and predictors of co-existence of stunting and wasting found
117 sex and age of children as significant predictors¹⁹. Other studies in Ghana²⁰ and India²¹ also
118 examined the co-existence of stunting, underweight, and wasting and found birth interval,
119 birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's
120 educational level, and partners' educational level as associated factors. The need to
121 examine the co-existence of stunting, underweight and wasting is important because not
122 much work has been done on that subject and hence children who concurrently suffer
123 from stunting, underweight, and wasting are less likely to be reached in malnutrition
124 prevention programmes, especially in SSA. For instance, some scholars have indicated that
125 despite evidence that wasting and stunting are global public health problems that
126 frequently co-exist, they are usually separated in terms of policy, guidance, programming

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3 127 and financing²². This creates a gap in the literature that needs to be filled. Despite the
4 128 detrimental consequences of undernutrition on the health and wellbeing of children under
5 129 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk
6 130 factors associated with the co-existence of stunting, underweight, and wasting among this
7 131 age group are absent in the literature. Studies presenting empirical analyses of the co-
8 132 existence of these three indicators of child undernutrition in SSA are absent in extant
9 133 literature making it difficult for policymakers and nutritional experts to provide up-to-date
10 134 trends with appropriate strategies to curb the situation in the sub-region. This research lag
11 135 presents a void in extant literature which this study seeks to bridge. Therefore, the study
12 136 investigated the risk factors of the co-existence of stunting, underweight, and wasting
13 137 among children under age 5 in sub-Saharan Africa using data from the Demographic Health
14 138 Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study
15 139 could contribute to the formulation of policies and interventions to respond to the
16 140 nutritional needs of children under 5 years and also suggest pragmatic ways of reducing
17 141 undernutrition among children in the sub-region.
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24 143 **METHODS**

25 144 **Data Source**

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28 145 The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African
29 146 countries (Figure 1) were pooled from the most current Demographic and Health Surveys
30 147 (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled
31 148 from the children's files in each of the countries. The DHS Program has conducted over
32 149 400 surveys in over 90 developing countries around the world since 1984 every five years²³.
33 150 The program implements cross-sectional surveys to gather nationally-representative data,
34 151 analyze and disseminate accurate information on important demographic and health
35 152 indicators spanning population, nutrition, and diseases. For all surveys, standardized
36 153 protocols designed for each target group including children, women, and men at the
37 154 household level are employed to allow for cross-national comparisons. Stratified two-
38 155 stage sampling involving first, the listing of enumeration areas and selection of clusters,
39 156 and then a random selection of households in each cluster. The detailed sampling method
40 157 can be found in a previous study²⁴. The dataset is freely available for download at:
41 158 <https://dhsprogram.com/data/available-datasets.cfm>²⁵. The Strengthening Reporting of
42 159 Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the
43 160 manuscript²⁶.
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48 161 **Study Variables**

49 162 **Outcome Variable**

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52 163 The outcome variable considered in this study is derived from three child anthropometric
53 164 variables including stunting (height-for-age z-scores); underweight (weight-for-age z-
54 165 scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization
55 166 for each of these variables following the WHO child growth standard. Each of the three
56 167 variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and
57 168 "Wasting" respectively.
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3 169 These three variables were then added to generate the outcome variable “Co-existed
4 170 undernutrition” with scores (discrete) ranging from 0 to 3 where 0 implies “Normal”, that
5 171 is, children with none of the three conditions; 1 implies “Single burden”, that is, the child
6 172 suffers from one of the three conditions; 2 indicates that child suffers from “Two burdens”
7 173 out of the three; and 3 shows “Co-existed”, that is, the child suffers from all three
8 174 conditions of undernutrition. For parsimony, children who suffered from “Single burden”
9 175 and those who suffered from “Two burdens” were added resulting in the variable “Co-
10 176 existed undernutrition” with three response categories: 0=Normal; 1=One or two burdens;
11 177 and 3=co-existed.

15 178 **Independent Variables**

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17 179 Several risk factors spanning compositional to contextual factors have been associated
18 180 with child undernutrition. The relevant biosocial characteristics and sociocultural factors
19 181 related to the child, mother, household head and the household together form
20 182 compositional factors^{27,28}. Factors that describe location or “place-based” variables are
21 183 contextual factors^{20,27,29,30}. The relevant compositional factors considered include the age
22 184 of the child; sex of the child; birth order of child; perceived size at birth; mother’s age;
23 185 educational attainment; working status; antenatal visits during pregnancy; postnatal
24 186 check within 2 months; and place of delivery. At the household level, relevant variables
25 187 included are the wealth status; the age of household head; sex of household head (male
26 188 and female); access to electricity; and access to media which was derived from the three
27 189 variables “access to television”, “radio” and “newspaper”. Household basic needs
28 190 including the type of toilet facility (re-coded into “improved” and unimproved”²⁹; source
29 191 of drinking water (re-coded as “improved” and “unimproved”²⁹, and type of household
30 192 cooking fuel (re-coded into “clean” and “unclean”^{29,31} are also considered. The contextual
31 193 factors considered are urbanicity and the country of origin of the participant.

35 194 **Data Analyses**

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37 195 The statistical analysis of the data was performed using the Stata SE software version 14.2.
38 196 The “svyset” command was first used to declare the data as survey data to prevent the
39 197 potential effects of the complex sampling techniques on the analyses. The sample weight
40 198 variable in the DHS was used to provide weighted samples in the analyses. To understand
41 199 the distributions of the variables, the data were summarized and presented in tables using
42 200 descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals
43 201 (CIs) of percentages). We further integrated the data into a GIS environment and
44 202 presented the distribution of key variables across the study countries and geographic
45 203 regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of
46 204 the data and understanding of the context of the study. The associations between the co-
47 205 existence of undernutrition and each of the risk factors considered were assessed using
48 206 the chi-square test of independence, with results presented in a contingency table. The
49 207 risk factors as independent variables were then subjected to collinearity diagnosis tests,
50 208 including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was
51 209 done to ascertain whether the independent variables were actually “independent”, that
52 210 is, are not correlated with one another and will not share variance in the outcome variable.
53 211 Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables
54 212 were not correlated (Mean VIF=1.26; Maximum VIF=1.71; Minimum VIF=1.02). To determine

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

215 **Ethical Approval**

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

222 **Patient and public involvement**

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

224 **Results**

225 ***Distribution of sample characteristics***

226 The study included a total of 127,487 under-five children. It is found that most (30.87%) of
227 the children were less than a year (Table 1). With regards to sex, both males and females
228 constituted approximately half of the sample. A majority of the children (92.87%) were
229 born to mothers aged between 20 to 49 years while only 7.13% were born to mothers aged
230 15 to 19 years. In terms of education, most (41.82%) of the children were born to mothers
231 with no formal education. Only 3.10% of the children were born to a mother with a higher
232 level of educational attainment. Further, 42.1% of the children were born in poor
233 households while 37.21% were born in rich households. More than half (57.53%) of the
234 children lived in a household with unimproved toilet facilities. However, most (65.63%) of
235 the children lived in households with access to improved drinking water sources. Similarly,
236 a majority (89.76%) of the children lived in households using clean cooking fuel (Table 1).

237 As shown in Appendix 2, the prevalence of co-existence of stunting, underweight, and
238 underweight varied across countries and sub-regions, with the highest and lowest
239 prevalence of co-existence of stunting, underweight, and wasting as Rwanda (6.17%) and
240 South Africa (0.18%) respectively (Figure 1). In terms of sub-region, the highest prevalence
241 of co-existence of stunting, underweight, and wasting was observed in Western Africa
242 (3.11%) and the lowest prevalence in Southern Africa (0.88%) (Figure 2).

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

246 ***Table 1***

247

248 ***Figure 1***

249 ***Figure 2***

250 ***Table 2***

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

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

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3 254 children under five years in the SSA. Age of child, size of the child at birth, sex of the child,
4 255 birth order, educational level, maternal age, ANC attendance, place of delivery, source of
5 256 drinking water, sex of household head, wealth index, access to electricity and place of
6 257 residence were associated with one or two dimensions of undernutrition. See Appendix 3
7 258 for country-level risk of co-existence of stunting, wasting, and underweight.

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10 259 Regarding the co-existence of the three dimensions of undernutrition (stunting,
11 260 underweight, and wasting), age of the child, sex of the child, perceived birth size, maternal
12 261 educational attainment, working status, antenatal visits during pregnancy, place of
13 262 delivery, wealth status, access to media, and type of toilet facility were found to be
14 263 significant risk factors (Table 3).

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17 264 *****Table 3*****

18 265 **DISCUSSION**

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20 266 The study investigated the risk factors of the co-existence of stunting, underweight, and
21 267 wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted
22 268 in 31 countries between 2010 and 2019. The study found that the countries with the highest
23 269 and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin
24 270 and Gambia respectively. In terms of geographic region, the highest prevalence of co-
25 271 existence of stunting, underweight, and wasting was observed in Western Africa and the
26 272 lowest prevalence in Southern Africa. The disparities in the prevalence among the
27 273 countries and geographical regions could be attributed to the nutritional practices and
28 274 beliefs practised in the countries and geographical regions. Differences in the health
29 275 policies provided by governments in the various countries could also account for the
30 276 disparities noted. This finding implies that countries that have high prevalence should take
31 277 critical lessons from the countries that are doing well regarding the implementation of
32 278 nutritional policies and interventions (e.g., increasing dietary supplementation, increasing
33 279 dietary diversity) that target the reduction of the co-existence of stunting, underweight,
34 280 and wasting among children under age 5 in sub-Saharan Africa².

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39 281 Similar to previous studies^{1,3}, this study found that children aged 1 year, 2 years, and 3 years
40 282 were at greater risk of having co-existence of all the three forms of undernutrition
41 283 compared to those aged 0. A plausible reason for this finding could be that as children
42 284 grow their energy needs also increase¹, increasing their risk of having all three nutritional
43 285 conditions. Alternatively, since these nutritional conditions may manifest after long
44 286 durations of improper nutritional practices or undernutrition^{1,3}, older children may be at
45 287 higher risk of having all three nutritional conditions. The finding suggests that
46 288 complementary foods given to children as they grow are inadequate. To reduce the risk of
47 289 co-existence of stunting, underweight, and wasting among under 5 children, the health
48 290 sectors in the various countries should invest heavily in providing adequate
49 291 complementary feeding to this category of children.

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53 292 Corroborating the findings of other studies^{1,3,32,33}, this study also found that children who
54 293 were females were less likely to have a co-existence of the three dimensions of
55 294 undernutrition compared to their male counterparts. An acceptable explanation for this
56 295 finding could be the biological variations in morbidity between males and females at that
57 296 young age³. It is also possible that since male children have higher birth weight compared
58 297 to females, they require more energy^{1,34}, which increases the risk of males having all three

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

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

316 The risk of co-existence of the three dimensions was higher among children whose
317 mothers had no education and primary education compared to those whose mothers had
318 higher education. Mothers who have attained higher education are better informed about
319 improved childcare practices³⁷, are more empowered to make health decisions³⁸, practice
320 good personal hygiene³⁸, are more likely to use the health facility³⁹, proper feeding
321 practices³⁶ and childcare in times of illness^{36,40}. This finding suggests that mothers with no
322 formal or little education are neglected in nutritional programs that help to eliminate
323 stunting, underweight, and wasting. Hence, they should be given the needed
324 consideration to deal with this persistent health issue.

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

335 The risk of co-existence of the three dimensions was higher among children whose
336 mothers had no antenatal visits during pregnancy compared to those whose mothers had
337 antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are
338 usually educated on the best practices of nutrition and general healthcare, which hitherto
339 would not be known by these mothers³⁸. Therefore, mothers who did not have antenatal
340 visits may lack some knowledge about proper nutritional practices, increasing their
341 children's risk of having these undernutrition-related challenges. Regular antenatal visits
342 could reduce children's risk of stunting, being underweight, and wasting, therefore,

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

345 Children who were delivered at home compared to children who were delivered at a health
346 facility were found to have a higher risk of co-existence of the three dimensions. Since
347 mothers who deliver at home do not receive any expert nutritional advice from a qualified
348 health practitioner³⁷, the children of such mothers are at higher risk of having these
349 conditions because of poor and/ or inadequate dietary practices. This finding shows that
350 facility delivery may help reduce the risk of co-existence of stunting, underweight, and
351 wasting among children under 5. Therefore, mothers should regularly be educated on the
352 need to opt for facility delivery because of its positive implications on children's growth.

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

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

375 Children whose mothers had unimproved toilet facilities were found to have a higher risk
376 of co-existence of the three dimensions of child undernutrition compared to those whose
377 mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may
378 increase mother-child-environment interactions that may result in increased exposure to
379 childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever)
380 either through consumption of contaminated foods, drinking water or poor
381 environmental sanitation²¹. These conditions have been shown to cause growth
382 retardation in children. Government and non-governmental organizations should support
383 the provision of improved household toilet facilities for poorer communities to help
384 minimize the risks of the co-existence of child undernutrition indicators.

385 Children from Burkina Faso, Burundi, Chad, Nigeria, and Rwanda had a higher risk of having
386 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.

398 **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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431 **Competing interests:** None

432

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

436

437 **Ethics Approval and consent to participate**

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

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444 **Provenance and peer review:** Not commissioned; externally peer reviewed.

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446 **Data availability statement:** Data are available in a public, open access repository.

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- 16 576

17 18 577 **Figures**

19
20 578 **Figure 1:** Percentage distribution of co-existence of stunting, underweight, and
21 579 wasting (SUW) in children from the 31 study countries in SSA

23 580 **Figure 2:** Percentage distribution of co-existence of stunting, underweight, and
24 581 wasting (SUW) in children by regions of SSA

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595 Tables

596 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		Type of toilet facility	
No education	41.82	Improved	42.47
Primary	31.26	Unimproved	57.53
Secondary	23.82	Source of drinking water	
Higher	3.10	Improved	65.63
Working status		Unimproved	34.37
No	35.49	Type of cooking fuel	
Yes	64.51	Clean	89.76
Antenatal visits during pregnancy		Unclean	10.24
No	10.76	Geographic region	
Yes	89.24	Western	41.78
Postnatal check within 2 months		Eastern	32.84
No	58.49	Central	20.08
Yes	41.51	South Africa	5.30
Access to media (tv/radio/newspaper)			
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
	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
Secondary	1.22 (1.1-1.3)	Unimproved	3.43 (3.3-3.6)	Rwanda
	Source of drinking water			
Higher	0.66 (0.4-1.0)	(p<0.001)	Senegal	2.43 (1.8-3.2)
	Working status (p<0.001)			
	Improved	2.54 (2.4-2.6)	Sierra Leone	1.94 (1.4-2.5)
No	3.13 (3.0-3.3)	Unimproved	3.06 (2.9-3.2)	South Africa
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 (0.8-1.2)	Togo	2.72 (2.1-3.4)
No	5.41 (5.0-5.8)	Unclean	2.92 (2.8-3.0)	Uganda
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<0.001)
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)						
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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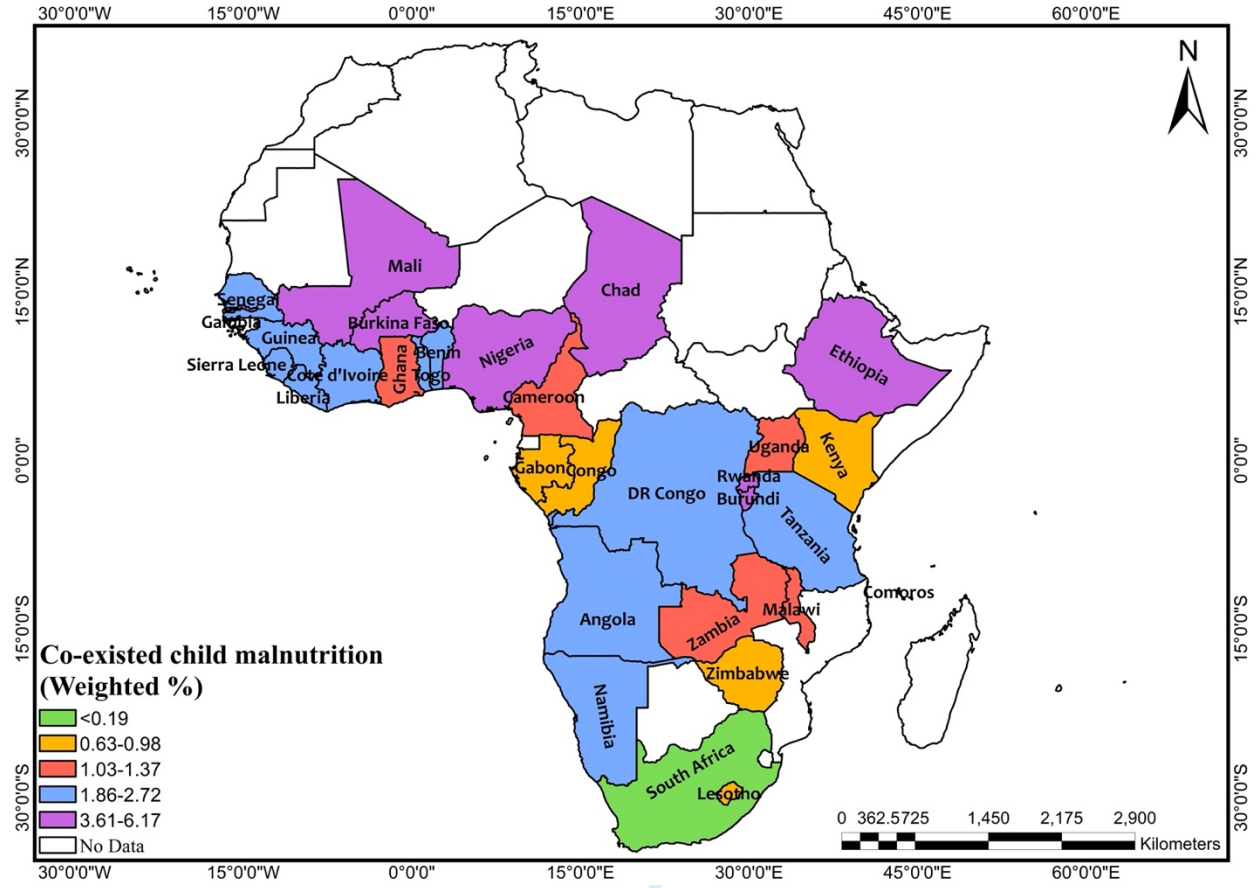


Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

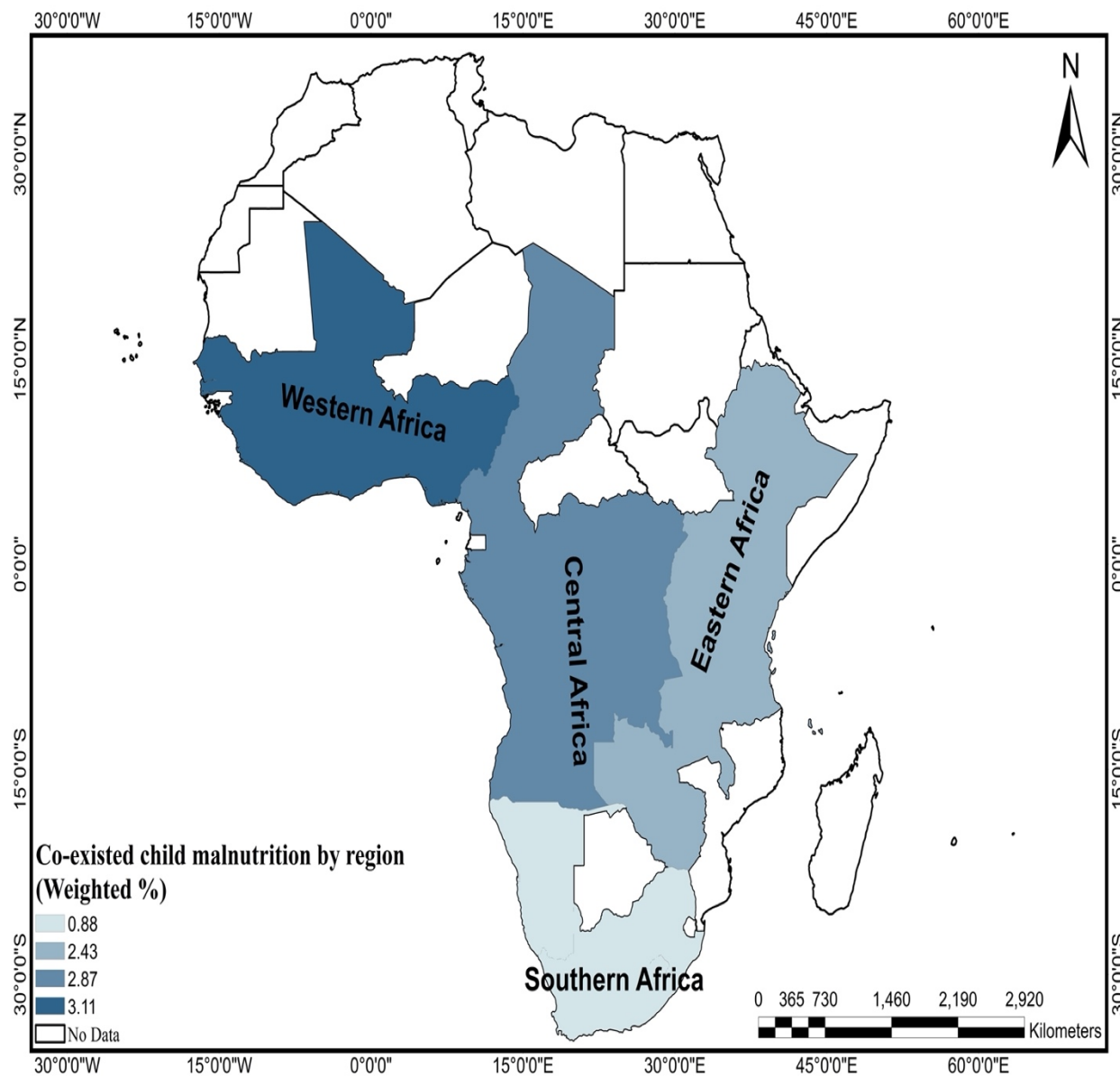


Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

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

Country (Ref: Angola)	Base outcome (Ref: Normal)					
	Single and two dimensions			Co-existence of three-dimensions		
	RRR	95% CI		RRR	95% CI	
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

BMJ Open

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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3 **1 Risk factors associated with the co-existence of stunting, underweight, and wasting in**
4 **2 children under five from 31 sub-Saharan African countries**

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44 ABSTRACT

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

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

52 **Setting:** Thirty-one sub-Saharan African countries.

53 **Participants:** Children under age five

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

57 **Results:** The prevalence of co-existence of stunting, underweight, and wasting varied
58 across countries and sub-regions, with the highest and lowest prevalence of co-existence
59 of stunting, underweight, and wasting as Benin (12.14%) and Gambia (0.58%) respectively.
60 The risk of co-existence of the three undernutrition dimensions was higher among children
61 aged 1 year (RRR=3.714; 95%CI 3.319-4.156) compared to those aged 0. The risk of co-
62 existence of the three dimensions was lower among female children (RRR=0.468 95% CI
63 0.420-0.51) but higher for those with small size at birth (RRR=3.818; CI 3.383-4.308), those
64 whose mothers had no education (RRR=3.291; 95% CI 1.961-5.522), not working (RRR=1.195;
65 95% CI 1.086-1.314), had no antenatal visits during pregnancy (RRR=1.364; 95% CI 1.20-1.541),
66 children delivered at home (RRR=1.372; CI 1.232-1.529), those from poor households
67 (RRR=1.408; 95% CI 1.235-1.605), those whose mothers had no access to media (RRR=1.255;
68 95% CI 1.144-1.377), and living in households with an unimproved toilet facility (RRR=1.158;
69 95% CI 1.032-1.300).

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

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

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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.

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85 INTRODUCTION

86 Undernutrition among children under 5 years remains a major public health problem
87 across many low-and middle-income countries¹⁻³. Factors such as insufficient food intake,
88 diarrhoea, recurring infections, poor sanitation practices, and low parental education have
89 been identified as significant contributors to the high prevalence of undernutrition during
90 childhood^{4,5}. Despite the numerous interventions rolled out to address childhood
91 undernutrition especially in sub-Saharan Africa where the phenomenon is quite pervasive,
92 the progress seems to be insignificant^{6,7}. For example, a study reported that child
93 undernutrition accounted for nearly half (45%) of the child mortality rate in low-and middle-
94 income countries⁸. Aside from that, it was reported in 2018 that about 149 million and 49
95 million children under age 5 were stunted and wasted respectively⁹.

96 Three main indicators that are often used to represent undernutrition are underweight or
97 low weight for age, stunting or low height for age, and wasting or low weight for height^{2,10-}
98 ¹². Among the three indicators of undernutrition, stunting has been identified as the
99 problem with the greatest magnitude among under 5 children in developing countries^{2,3}.
100 Even though the prevalence of stunting in sub-Saharan Africa is declining, it is worth noting
101 that it is still above 30%¹³ which is undeniably high. Research also indicates that the country-
102 specific prevalence of stunting, underweight and wasting is still high^{2,3}. For instance, in
103 Ethiopia, the prevalence of wasting and stunting were 10% and 38% respectively¹⁴.
104 Additionally, the prevalence of stunting, underweight and wasting among children in
105 South Africa were 35.8%, 20.5%, and 17.2%³. Likewise, Anin et al.² reported 33.2%, 14.1%, 27%
106 and 2.6% of prevalence in stunting, wasting, underweight and overweight among infants
107 (6-23 months) across Northern Ghana.

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

116 Apart from studies that have examined the factors associated with either stunting,
117 underweight, and wasting, some scholars have begun looking at predictors of the co-
118 existence of any two or three of the indicators of malnutrition. A study in 84 countries that
119 examined the prevalence and predictors of co-existence of stunting and wasting found
120 sex and age of children as significant predictors¹⁹. Other studies in Ghana²⁰ and India²¹ also
121 examined the co-existence of stunting, underweight, and wasting and found birth interval,
122 birth weight, dietary diversity, place of delivery, wealth index, mother's BMI, mother's
123 educational level, and partners' educational level as associated factors. The need to
124 examine the co-existence of stunting, underweight and wasting is important because not
125 much work has been done on that subject and hence children who concurrently suffer
126 from stunting, underweight, and wasting are less likely to be reached in malnutrition
127 prevention programmes, especially in SSA. For instance, some scholars have indicated that
128 despite evidence that wasting and stunting are global public health problems that
129 frequently co-exist, they are usually separated in terms of policy, guidance, programming

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3 130 and financing²². This creates a gap in the literature that needs to be filled. Despite the
4 131 detrimental consequences of undernutrition on the health and wellbeing of children under
5 132 5 in SSA, studies utilizing current, and nationally representative data to investigate the risk
6 133 factors associated with the co-existence of stunting, underweight, and wasting among this
7 134 age group are absent in the literature. Studies presenting empirical analyses of the co-
8 135 existence of these three indicators of child undernutrition in SSA are absent in extant
9 136 literature making it difficult for policymakers and nutritional experts to provide up-to-date
10 137 trends with appropriate strategies to curb the situation in the sub-region. This research lag
11 138 presents a void in extant literature which this study seeks to bridge. Therefore, the study
12 139 investigated the risk factors of the co-existence of stunting, underweight, and wasting
13 140 among children under age 5 in sub-Saharan Africa using data from the Demographic Health
14 141 Survey (DHS) conducted in 31 countries between 2010 and 2019. The findings of the study
15 142 could contribute to the formulation of policies and interventions to respond to the
16 143 nutritional needs of children under 5 years and also suggest pragmatic ways of reducing
17 144 undernutrition among children in the sub-region.
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146 **METHODS**

147 **Data Source**

148 The dataset included 127,487 children under the age of 5 years from 31 sub-Saharan African
149 countries (Figure 1) were pooled from the most current Demographic and Health Surveys
150 (DHS) conducted between 2010 and 2019 (Appendix 1). Specifically, the data were pooled
151 from the children's files in each of the countries. The DHS Program has conducted over
152 400 surveys in over 90 developing countries around the world since 1984 every five years²³.
153 The program implements cross-sectional surveys to gather nationally-representative data,
154 analyze and disseminate accurate information on important demographic and health
155 indicators spanning population, nutrition, and diseases. For all surveys, standardized
156 protocols designed for each target group including children, women, and men at the
157 household level are employed to allow for cross-national comparisons. Stratified two-
158 stage sampling involves first, the listing of enumeration areas and selection of clusters,
159 and then a random selection of households in each cluster. The detailed sampling method
160 can be found in a previous study²⁴. The dataset is freely available for download at:
161 <https://dhsprogram.com/data/available-datasets.cfm>²⁵. The Strengthening Reporting of
162 Observational Studies in Epidemiology (STROBE) guidelines were followed in writing the
163 manuscript²⁶.

164 **Study Variables**

165 **Outcome Variable**

166 The outcome variable considered in this study is derived from three child anthropometric
167 variables including stunting (height-for-age z-scores); underweight (weight-for-age z-
168 scores) and wasting (weight-for-height z-scores). The DHS (2021) specifies categorization
169 for each of these variables following the WHO child growth standard. Each of the three
170 variables we coded into "0" for "Normal" and "1" for "Stunting", "underweight" and
171 "Wasting" respectively.
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3 172 These three variables were then added to generate the outcome variable “Co-existed
4 173 undernutrition” with scores (discrete) ranging from 0 to 3 where 0 implies “Normal”, that
5 174 is, children with none of the three conditions; 1 implies “Single burden”, that is, the child
6 175 suffers from one of the three conditions; 2 indicates that child suffers from “Two burdens”
7 176 out of the three; and 3 shows “Co-existed”, that is, the child suffers from all three
8 177 conditions of undernutrition. For parsimony, children who suffered from “Single burden”
9 178 and those who suffered from “Two burdens” were added resulting in the variable “Co-
10 179 existed undernutrition” with three response categories: 0=Normal; 1=One or two burdens;
11 180 and 3=co-existed.

15 181 **Independent Variables**

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17 182 Several risk factors spanning compositional to contextual factors have been associated
18 183 with child undernutrition. The relevant biosocial characteristics and sociocultural factors
19 184 related to the child, mother, household head and the household together form
20 185 compositional factors^{27,28}. Factors that describe location or “place-based” variables are
21 186 contextual factors^{20,27,29,30}. The relevant compositional factors considered include the age
22 187 of the child; sex of the child; birth order of child; perceived size at birth; mother’s age;
23 188 educational attainment; working status; antenatal visits during pregnancy; postnatal
24 189 check within 2 months; and place of delivery. At the household level, relevant variables
25 190 included are the wealth status; the age of household head; sex of household head (male
26 191 and female); access to electricity; and access to media which was derived from the three
27 192 variables “access to television”, “radio” and “newspaper”. Household basic needs include
28 193 the type of toilet facility (re-coded into “improved” and unimproved”²⁹; source of drinking
29 194 water (re-coded as “improved” and “unimproved”²⁹, and type of household cooking fuel
30 195 (re-coded into “clean” and “unclean”^{29,31} are also considered. The contextual factors
31 196 considered are urbanicity and the country of origin of the participant.

36 197 **Data Analyses**

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38 198 The statistical analysis of the data was performed using the Stata SE software version 14.2.
39 199 The “svyset” command was first used to declare the data as survey data to prevent the
40 200 potential effects of the complex sampling techniques on the analyses. The sample weight
41 201 variable in the DHS was used to provide weighted samples in the analyses. To understand
42 202 the distributions of the variables, the data were summarized and presented in tables using
43 203 descriptive statistics (frequencies, weighted percentages, and 95% confidence intervals
44 204 (CIs) of percentages). We further integrated the data into a GIS environment and
45 205 presented the distribution of key variables across the study countries and geographic
46 206 regions in map images (Figure 1 and Figure 2). This approach enhances the visualization of
47 207 the data and understanding of the context of the study. The associations between the co-
48 208 existence of undernutrition and each of the risk factors considered were assessed using
49 209 the chi-square test of independence, with results presented in a contingency table. The
50 210 risk factors as independent variables were then subjected to collinearity diagnosis tests,
51 211 including Variance Inflation Factors (VIF), Square VIF, Tolerance, and R-squared. This was
52 212 done to ascertain whether the independent variables were actually “independent”, that
53 213 is, are not correlated with one another and will not share variance in the outcome variable.
54 214 Results from the multicollinearity diagnoses test (See Appendix 2) show that the variables
55 215 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 49 years while only 7.13% were born to mothers aged 15 to 19 years. 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

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

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

267 *****Table 3*****

268 **DISCUSSION**

269 The study investigated the risk factors of the co-existence of stunting, underweight, and
270 wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted
271 in 31 countries between 2010 and 2019. The study found that the countries with the highest
272 and lowest prevalence of co-existence of stunting, underweight, and wasting were Benin
273 and Gambia respectively. In terms of geographic region, the highest prevalence of co-
274 existence of stunting, underweight, and wasting was observed in Western Africa and the
275 lowest prevalence in Southern Africa. The disparities in the prevalence among the
276 countries and geographical regions could be attributed to the nutritional practices and
277 beliefs practised in the countries and geographical regions. Differences in the health
278 policies provided by governments in the various countries could also account for the
279 disparities noted. This finding implies that countries that have high prevalence should take
280 critical lessons from the countries that are doing well regarding the implementation of
281 nutritional policies and interventions (e.g., increasing dietary supplementation, increasing
282 dietary diversity) that target the reduction of the co-existence of stunting, underweight,
283 and wasting among children under age 5 in sub-Saharan Africa².

284 Similar to previous studies^{1,3}, this study found that children aged 1 year, 2 years, and 3 years
285 were at greater risk of having co-existence of all the three forms of undernutrition
286 compared to those aged 0. A plausible reason for this finding could be that as children
287 grow their energy needs also increase¹, increasing their risk of having all three nutritional
288 conditions. Alternatively, since these nutritional conditions may manifest after long
289 durations of improper nutritional practices or undernutrition^{1,3}, older children may be at
290 higher risk of having all three nutritional conditions. The finding suggests that
291 complementary foods given to children as they grow are inadequate. To reduce the risk of
292 co-existence of stunting, underweight, and wasting among under 5 children, the health
293 sectors in the various countries should invest heavily in providing adequate
294 complementary feeding to this category of children.

295 Corroborating the findings of other studies^{1,3,32,33}, this study also found that children who
296 were females were less likely to have a co-existence of the three dimensions of
297 undernutrition compared to their male counterparts. An acceptable explanation for this
298 finding could be the biological variations in morbidity between males and females at that
299 young age³. It is also possible that since male children have higher birth weight compared
300 to females, they require more energy^{1,34}, which increases the risk of males having all three

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3 301 nutritional conditions. Moreover, male children are perceived to be hungrier than females,
4 302 therefore breastfeeding alone could be insufficient or inadequate^{3,35}, increasing their
5 303 susceptibility to having the three nutritional conditions. The finding suggests that male
6 304 children should be given critical attention in the development and implementation of
7 305 nutritional programs (e.g., dietary supplementation) to mitigate the co-existence of
8 306 stunting, underweight, and wasting among these male children under 5 years.

11 307 The study found that the risk of co-existence of the three dimensions of undernutrition
12 308 was higher among children with the average size at birth and small size at birth compared
13 309 to children with large size at birth. It has been proven that undernutrition in children is
14 310 partly influenced by maternal nutrition practices. Hence, mothers' appropriate nutritional
15 311 behaviours during the prenatal and postnatal periods are key to improving child growth.
16 312 Conversely, maternal undernutrition causes low maternal BMI, which in turn affects the
17 313 foetus to poor development often associated with a small birth size and low birth
18 314 weight^{1,3,21,36}. This finding indicates that mothers of children under 5 should continuously
19 315 be educated on the best nutritional practices such as exclusive breastfeeding,
20 316 complementary feeding, and dietary supplementation. These strategies will help
21 317 ameliorate the risk of acquiring health conditions associated with undernutrition among
22 318 children under 5.

26 319 The risk of co-existence of the three dimensions was higher among children whose
27 320 mothers had no education and primary education compared to those whose mothers had
28 321 higher education. Mothers who have attained higher education are better informed about
29 322 improved childcare practices³⁷, are more empowered to make health decisions³⁸, practice
30 323 good personal hygiene³⁸, are more likely to use the health facility³⁹, proper feeding
31 324 practices³⁶ and childcare in times of illness^{36,40}. This finding suggests that mothers with no
32 325 formal or little education are neglected in nutritional programs that help to eliminate
33 326 stunting, underweight, and wasting. Hence, they should be given the needed
34 327 consideration to deal with this persistent health issue.

38 328 This study also found that the risk of co-existence of the three dimensions was higher
39 329 among children whose mothers were not working compared to those whose mothers
40 330 were working. Women's employment status indicates their ability to afford proper
41 331 nutritional products and health care services^{36,40}. Therefore, if mothers are not employed,
42 332 the children become highly susceptible or vulnerable because mothers are unlikely to meet
43 333 their nutritional needs or requirements. Mothers with children under 5 with such
44 334 disadvantaged backgrounds should be given subsidies on children's nutritional products
45 335 and perhaps, free access to health care services by governmental and non-governmental
46 336 organizations. This step will be significant in reducing the risks of the co-existence of
47 337 stunting, underweight, and wasting among children under 5 years.

51 338 The risk of co-existence of the three dimensions was higher among children whose
52 339 mothers had no antenatal visits during pregnancy compared to those whose mothers had
53 340 antenatal visits during pregnancy. Specifically, mothers who attend antenatal services are
54 341 usually educated on the best practices of nutrition and general healthcare, which hitherto
55 342 would not be known by these mothers³⁸. Therefore, mothers who did not have antenatal
56 343 visits may lack some knowledge about proper nutritional practices, increasing their
57 344 children's risk of having these undernutrition-related challenges. Regular antenatal visits
58 345 could reduce children's risk of stunting, being underweight, and wasting, therefore,

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

348 Children who were delivered at home compared to children who were delivered at a health
349 facility were found to have a higher risk of co-existence of the three dimensions. Since
350 mothers who deliver at home do not receive any expert nutritional advice from a qualified
351 health practitioner³⁷, the children of such mothers are at higher risk of having these
352 conditions because of poor and/ or inadequate dietary practices. This finding shows that
353 facility delivery may help reduce the risk of co-existence of stunting, underweight, and
354 wasting among children under 5. Therefore, mothers should regularly be educated on the
355 need to opt for facility delivery because of its positive implications on children's growth.

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

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

378 Children whose mothers had unimproved toilet facilities were found to have a higher risk
379 of co-existence of the three dimensions of child undernutrition compared to those whose
380 mothers had improved toilet facilities. Insanitary or unhygienic toilet conditions may
381 increase mother-child-environment interactions that may result in increased exposure to
382 childhood diseases and other opportunistic infections (e.g., diarrhoeal episodes, fever)
383 either through consumption of contaminated foods, drinking water or poor
384 environmental sanitation²¹. These conditions have been shown to cause growth
385 retardation in children. Government and non-governmental organizations should support
386 the provision of improved household toilet facilities for poorer communities to help
387 minimize the risks of the co-existence of child undernutrition indicators.

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

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3 390 hand, countries such as Benin, Cameroon, Congo, Gabon, Ghana, Guinea, Kenya, Lesotho,
4 391 Malawi, Senegal, Zambia, Uganda, Tanzania, Sierra Leone, Zimbabwe, and South Africa
5 392 had a lower risk among their children having co-existence of the three undernutrition
6 393 dimensions. The sub-regional and country-specific variations in socio-economic, agro-
7 394 ecological and geographical characteristics may strongly influence the nutritional status of
8 395 children because of inadequate food supplies, limited access to arable land for agriculture,
9 396 unfavourable climatic conditions (e.g., desertification), rapid population growth, and
10 397 increasing cost of living may determine food access, availability and production in studied
11 398 countries in SSA^{41,42}. Governmental priorities should intensify efforts to minimize the risk
12 399 of co-existence of stunting, underweight, and wasting among children under age 5 with
13 400 sound socio-economic and sustainable human capital development.

17 401 **Strength and limitations**

19 402 The use of relative large nationally representative data of under-five children from 31 SSA
20 403 countries is the main strength of the study. We also employed rigorous statistical
21 404 analytical techniques to analyse the data. A broad range of potential risk factors a various
22 405 levels were considered in our analysis. Despite these, the DHS employs cross-sectional
23 406 designs which restrict causality on the noted outcomes. Self-reported variables used are,
24 407 therefore, susceptible to biases from recall and other social desirability issues. The surveys
25 408 were also conducted in different years.

28 409

30 410 **Conclusions and implications**

32 411 The study investigated the risk factors of the co-existence of stunting, underweight, and
33 412 wasting among children under age 5 in sub-Saharan Africa using data from DHS conducted
34 413 in 31 countries between 2010 and 2019. The study found that the prevalence of co-
35 414 existence of stunting, underweight, and wasting ranged from 0.58 % in the Gambia to
36 415 12.14% in Benin. The study also found that the prevalence of co-existence of stunting,
37 416 underweight, and wasting was high in Western Africa (41.78%) but low in Southern Africa
38 417 (5.3%). The significant findings show that the disadvantaged have more risks of the co-
39 418 existence of stunting, underweight, and wasting among under 5 children in selected SSA
40 419 countries. These findings demonstrate the urgent need for consideration of the co-
41 420 existence of stunting, wasting and underweight among under-five children in policy design
42 421 and programming of interventions to eradicate child malnutrition in SSA. In the short-term,
43 422 national-level policies and interventions needs to be well-tailored considering the
44 423 compositional characteristics including child's age, sex, birth size; maternal education,
45 424 working status, place of delivery, antenatal visit; and household's wealth status, access to
46 425 media and improved toilet facility are required. For instance, such programs could be
47 426 geared towards improving females' access to education, reducing unemployment,
48 427 expanding access to the media and using it to promote education on the need for
49 428 antenatal care. In the long-term, regional policies and coordinated interventions among
50 429 governments of SSA countries need to be designed to address the disparate prevalence
51 430 of the co-existence of stunting, wasting and underweight in under-five children across the
52 431 four geographic regions. The implementation of these at the local level should consider
53 432 rural-urban differences in the prevalence of the condition and the risk factors elicited.
54 433

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437 AS, ED, JBF, JEH, RGA, BA, CA and BOA drafted and revised the manuscript critically for its
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443 **Competing interests:** None

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

449 **Ethics approval and consent to participate**

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

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31 589 **Figures**32
33 590 **Figure 1:** Percentage distribution of co-existence of stunting, underweight, and
34 591 wasting (SUW) in children from the 31 study countries in SSA35
36 592 **Figure 2:** Percentage distribution of co-existence of stunting, underweight, and
37 593 wasting (SUW) in children by regions of SSA38
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607 Tables

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

609

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		Type of toilet facility	
No education	41.82	Improved	42.47
Primary	31.26	Unimproved	57.53
Secondary	23.82	Source of drinking water	
Higher	3.10	Improved	65.63
Working status		Unimproved	34.37
No	35.49	Type of cooking fuel	
Yes	64.51	Clean	89.76
Antenatal visits during pregnancy		Unclean	10.24
No	10.76	Geographic region	
Yes	89.24	Western	41.78
Postnatal check within 2 months		Eastern	32.84
No	58.49	Central	20.08
Yes	41.51	South Africa	5.30
Access to media (tv/radio/newspaper)			
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 Cote d'Ivoire	0.98 (0.7-1.5)
Birth order (p<0.001)		Young-adults	2.65 (2.5-2.8)	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)	Liberia	2.37 (1.7-3.1)
	20-49	Yes	2.71 (2.6-2.8)	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)	
	Primary	Improved	2.09 (2.0-2.2)	Namibia	1.99 (1.2-3.1)
	Secondary	Unimproved	1.22 (1.1-1.3)	Nigeria	4.1 (3.7-4.6)
			3.43 (3.3-3.6)	Rwanda	6.17 (5.5-6.9)
		Source of drinking water (p<0.001)			
	Higher		0.66 (0.4-1.0)	Senegal	2.43 (1.8-3.2)
		Improved	2.54 (2.4-2.6)	Sierra Leone	1.94 (1.4-2.5)
	Working status (p<0.001)	Unimproved	3.06 (2.9-3.2)	South Africa	0.18 (0.02-0.8)
	No		3.13 (3.0-3.3)	Tanzania	1.86 (2.1-3.5)
	Yes		2.48 (2.4-2.6)	Type of cooking fuel (p<0.001)	
		Clean	0.98 (0.8-1.2)	Togo	2.72 (2.1-3.4)
	Antenatal visits during pregnancy (p<0.001)	Unclean	2.92 (2.8-3.0)	Uganda	1.2 (0.8-1.7)
	No		5.41 (5.0-5.8)	Urbanicity (p<0.001)	
	Yes		2.39 (2.3-2.5)	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	Rural	2.93 (2.8-3.1)	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)						
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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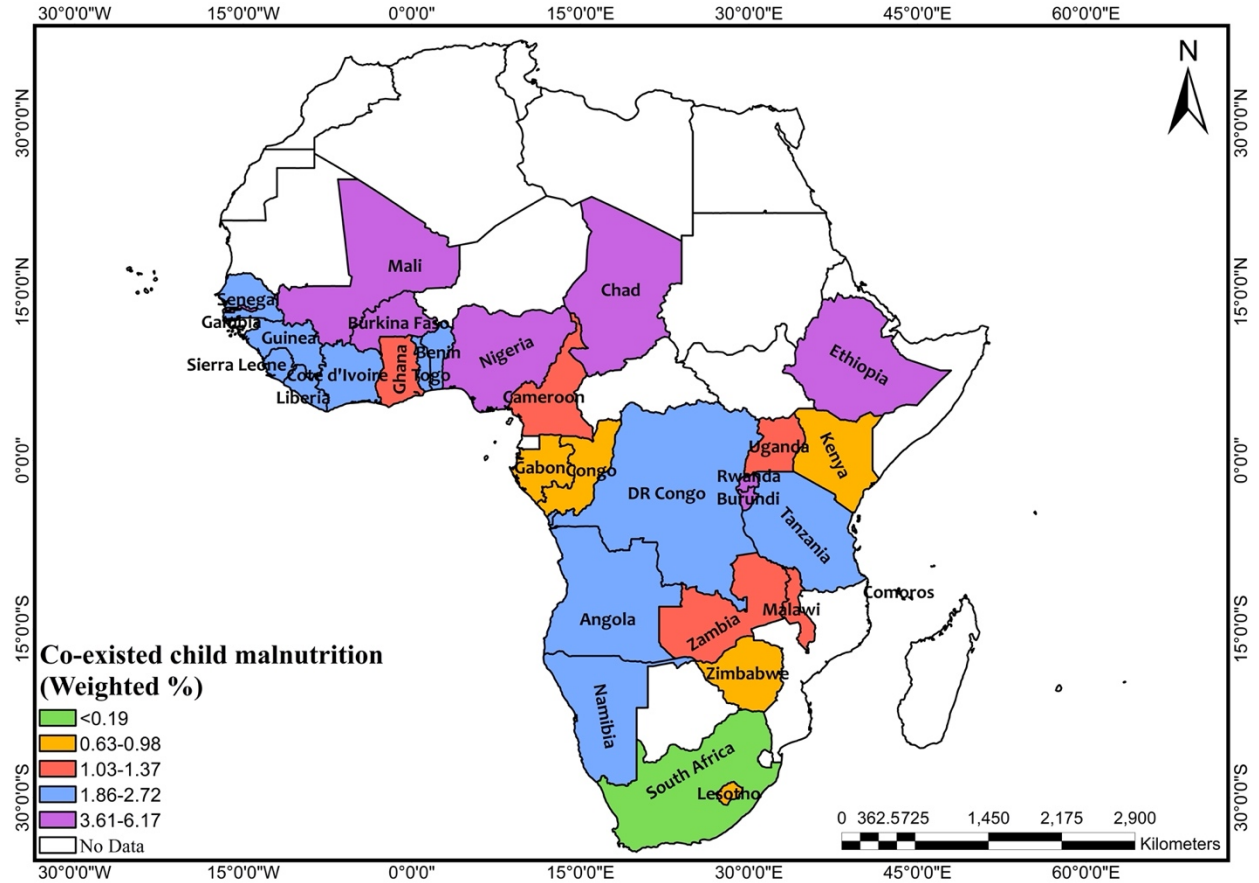


Figure 1: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children from the 31 study countries in SSA

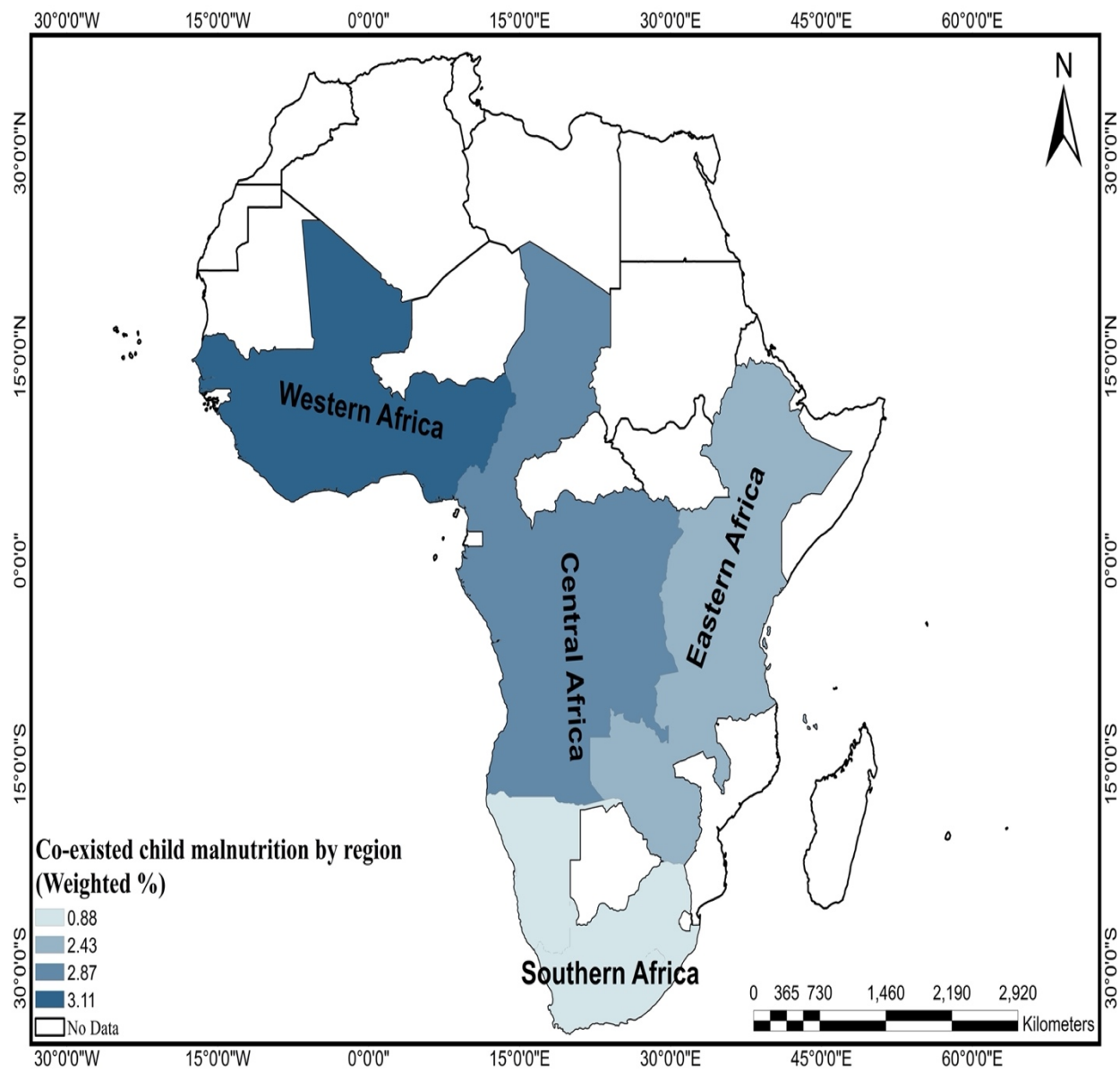


Figure 2: Percentage distribution of co-existence of stunting, underweight, and wasting (SUW) in children by regions of SSA

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) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5	
		<i>Case-control study</i> —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		
		<i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants		
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed		
		<i>Case-control study</i> —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) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —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) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —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.