

The burden and correlates of childhood undernutrition in Tanzania according to composite index of anthropometric failure

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Abstract

Background

Undernutrition is a public health problem worldwide. Tanzania has made significant achievements in the reduction of childhood undernutrition over the past two decades. However, the exact burden of undernutrition was under-estimated when using conventional indices of stunting, wasting and underweight. The objective of this study was to determine the overall prevalence of undernutrition, describe the trends and examine the correlates associated with undernutrition among children under the age of five years using the composite index of anthropometric failure (CIAF). This study aims to understand the real burden and drivers of undernutrition to improve design, implementation and monitoring of appropriate interventions to ameliorate childhood undernutrition in the country.

Methods

We retrieved and analyzed the data of mother-child pairs from the Tanzania Demographic and Health Surveys (TDHS) of 1991, 1996, 1999, 2004-05, 2009-10, and 2015-16 using Stata and SPSS software. Data for 1991 to 2015 were used to determine the burden and trends of undernutrition. The recent TDHS surveys of 2004-05, 2010 and 2015-16 were used to determine the correlates of undernutrition. The main outcome of interest was undernutrition measured using CIAF. This is an aggregated index of conventional indices of stunting, wasting and underweight of children aged below 59 months. We used multivariate logistic regression analysis to identify the correlates associated with CIAF, whereby both crude and adjusted odds ratios (OR) with 95% confidence intervals (CI) were determined.

Results

About one in every three (38.2%) of the surveyed children had anthropometric failure in 2015 compared to half of them (50%) in 1991. The odds of anthropometric failure were significantly higher for boys, older children, living in rural areas, living in poorer households, and being born with non-educated or undernourished mothers. Female-headed households were more likely to have children with anthropometric failure, while age of the household head was negatively associated with anthropometric failure. Children who were born at home, with low birth weight, or having episode of illnesses such as diarrhea or fever were most likely to have anthropometric failure.

Conclusion

One in every three under 5 years old children are suffering from either one or multiple forms of anthropometric failure in Tanzania as revealed by CIAF. Multiple factors including those related to mothers, children and household socio-economic characteristics have the potential to influence childhood anthropometric failure. Efforts to reduce the burden of undernutrition should focus on reducing poverty and raising people's living standards.

Background

Undernutrition remains one of the biggest health problems for developing countries [1]. Recent global estimates reported that 45% of all child deaths are due to various forms of undernutrition [4]. These rates are persistently higher in the Sub-Saharan Africa region [5]. Over the past two decades, Tanzania has seen a significant achievement in reduction of undernutrition owing to rapid decline in stunting and underweight. Despite the significant progress made in the country, the levels are still high [2, 3]. In 2015, the Tanzania Demographic and Health Survey report showed that the prevalence of chronic undernutrition (stunting) was 34.4%, acute malnutrition (wasting) was 4.5%, and underweight was 13.6% [3]. Moreover, the recent national nutrition survey found that 10% of children under 5 years old were severely stunted, and 2.7% were severely underweight [4]. Given the

negative consequences of undernutrition on child health outcomes, there is certainly a need for actions to drawn up policies and programs to identify and implement solutions that will prevent all forms of childhood undernutrition.

The current body of evidence of the prevalence of undernutrition in Tanzania has focused on a single conventional indices such as wasting, stunting and underweight as proposed by the World Health Organisation [5]. Studies have shown that conventional indices when used alone, failed to give a true estimates of the real burden of childhood undernutrition. This is because, these indices may overlap, meaning that the same child could show signs of having two or more of these indicators simultaneously [6], and are therefore insufficient for determining the overall burden of undernutrition among children. To compensate, Peter et al. [7] developed a model known as composite index of anthropometric failure (CIAF) that classifies undernutrition into mutually exclusive groups, enabling the identification of children with more than one form of anthropometric failure [7]. Importantly, this model was evaluated and found to better provide the information on the true proportion of undernutrition, and thus helps detect children with multiple anthropometric deficit [7–9]. Furthermore, the above model has been used in several studies [10, 11], and it has been concluded that CIAF identifies a greater percentage of undernourished children compared to conventional indices [12, 13]. Countries such as China, Malawi and others have adopted the CIAF model to redefine their children’s nutrition situation [8, 9, 14–18]; but such national wide studies are lacking in Tanzania.

The causes for undernutrition in children are complex and multifaceted. Poor socioeconomic conditions, food insecurity, poverty, and adverse conditions such as illness or inadequate feeding practices can drastically alter the growth pattern of children [19, 20]. According to the UNICEF conceptual framework [21], undernutrition can be caused by insufficient diet intake, infections, poor breastfeeding or inadequate complementary foods. To date, numerous studies have been conducted to examine the determinants of undernutrition in Tanzania [2, 22–24] and elsewhere [15, 17, 25–27]. However, available studies in the country have used conventional indices, rather than aggregated indicator of CIAF. More studies are therefore needed to reveal the associated factors of anthropometric failure particularly among children in Tanzania.

This study aimed to determine the prevalence of child undernutrition using aggregated index of CIAF from the large datasets of the Tanzania Demographic and Health Surveys (TDHS), and describe the trends from 1991 to 2015. We hypothesized that CIAF will identify significantly higher numbers of children who are undernourished compared to conventional indices. We also sought to examine the correlates of childhood undernutrition according to CIAF. To our knowledge, this is the first attempt to explore the potential correlates of undernutrition using CIAF in Tanzania. This study is crucial to understand the real burden of undernutrition in the country to improve the design, implementation and monitoring of appropriate interventions and ameliorate undernutrition. Moreover, the results will help to track the progress of the country in the attainment of the current World Health Assembly Global Nutrition targets for 2025 [28], and Sustainable Development Goals (SGD 2) by 2030 [29].

Methods

Sources of Data

The data for this study originates from the Tanzania Demographic and Health Surveys (TDHS) dataset. These nationally representative cross-sectional surveys are administered by Inner City Fund (ICF) International since 1991. Six TDHS surveys have been conducted in Tanzania to date (April 2020). These surveys are done regularly every five years to determine levels, patterns, and trends in demographic and health indicators [4]. The description of the six surveys is shown in Table 1.

Table 1
Demographic and Health Surveys conducted to date and used for the study

Year	Name of the survey
1991	Tanzania Demographic and Health Survey (TDHS, 1992)
1996	Tanzania Demographic and Health Survey (TDHS, 1996)
1999	Tanzania Reproductive and Child Health Survey (TRCHS),
2004-05	Tanzania Demographic and Health Survey (TDHS 2005)
2010	Tanzania Demographic and Health Survey (TDHS 2010)
2015	Tanzania Demographic and Health Survey – Malaria Indicator Survey (2015/16)

TDHS Sampling

The TDHS is a national socio-demographic survey that collects information based on a stratified two-stage cluster sampling design. First, sample clusters are selected followed by households selection from each of the selected clusters using equal probability systematic sampling. All men aged 15–59 years and women aged 15–49 years old in the selected households are eligible to be interviewed if they were either usual residents of that household or visitors on the night before the survey. Among the variables collected by the TDHS is information on the mothers and their children aged 0 to 59 months, such as anthropometry, feeding practices, vaccination status, birth interval, childhood morbidity and mortality, and use of maternal and child health services [4]. We managed to extract the information of mother-child pairs in TDHS across the years as follows; 1992 (n = 6,177), 1996 (n = 5,226), 1999 (n = 2,825), 2004-05 (n = 7,107), 2009-10 (n = 6,774), and 2015-16 (n = 8,913). However, in this study only recent TDHS surveys of 2004-05, 2010 and 2015-16 were used to determine the correlates of undernutrition because they have variables that were collected and presented in a similar manner.

Anthropometric measurements

In all TDHS surveys, anthropometric measurements were taken according to international and national recommended procedures by the WHO. Body weight and height/length of all eligible children were measured according to standard procedures, and the nutritional status of the children (under 5 years old) was calculated. All subjects with Z-scores of Height for age (HAZ), weight-for height (WHZ) or weight-for age (WAZ) below - 2 standard deviations (SD), with respect to the standards of the WHO were considered being stunted, underweight or wasting; respectively.

Determination of the Composite Index of anthropometric failure (CIAF)

The main outcome of interest was undernutrition as measured by using CIAF. This index identifies seven groups used to classify undernutrition as follows: A (no anthropometric failure), B (wasting only), C (wasting and underweight), D (wasting, stunting and underweight), E (stunting and underweight) and F (stunting only), and Y (Underweight only) [7, 9]. The CIAF is calculated by subtracting the group A children from the total number. Therefore, a child is regarded as undernourished as measured by CIAF if he/she suffered any anthropometric failure above. The CIAF is a binary variable, which is 1 if a child is either stunted, underweight, wasted or any combination of the three and 0 if not, as described in Table 2.

Table 2
Classification of composite index of anthropometric failure (CIAF)

Group	Descriptions	Description of the levels	Wasting	Stunting	Underweight
A	No failure	Normal WAZ, HAZ, WHZ	No	No	No
B	Wasting only	WAZ<-2SD, normal HAZ, and WHZ	Yes	No	No
C	Wasting and underweight	WHZ and WAZ <-2SD but HAZ normal	Yes	No	Yes
D	Wasting, Stunting and underweight	WAZ, HAZ, and WHZ <-SD	Yes	Yes	Yes
E	Stunting and underweight	HAZ and WHZ<-2SD, normal WAZ	No	Yes	Yes
F	Stunting only	HAZ<-2SD, normal WHZ and WAZ	No	Yes	No
Y	Underweight only	WHZ<-SD but normal HAZ and WHZ	No	No	Yes
CIAF = B + C + D + E + F + Y					
Source: Nandy and Svedberg, 2012; HAZ = Height-for-Age Z-scores; WHZ = Weight-for Height Z-scores, WAZ = Weight-for-Age Z-scores, SD = Standard deviation.					

Other independent variables

We adopted other covariates as suggested by the UNICEF conceptual framework of malnutrition and after reviewing available literature [2]. Covariates include indicator variables for the age and gender of the child. Child age was classified into four categories : <6 months, between 6–23 months, 24–35 months, and > 35 months. Further covariates included place of residence of the household (including rural versus urban), marital status of the mother as category: married, single, divorced/death. We selected categorized initiation of breastfeeding either within one hour after birth, after one hour, or after one day. Other child's characteristics as reported by the mother included mother's perceived birth size (size of child as reported by the mother), place of delivery (home, health facility or other places), and symptoms of fever and/or diarrhea in the child in the past two weeks before the interview (Yes/No). Mothers characteristics like age at first birth (years), highest level of education (primary, secondary or higher), employment status, and number of children born in the past 5 years were also included, as reported and categorised in the previous studies [2, 23]. Mother's body mass index (BMI) was determined using the WHO cut-off point of : < 18.5 kg/m² as underweight, 18.5–25 kg/m² as normal, 25–30 kg/m² as overweight, and above 30 kg/m² as obese. Other household information included are gender (Male/Female) and age of the household head categorized into: 15–29 years, 30–49 years and ≥ 50 years. Wealth index derived from principal component analysis from TDHS were used in this analysis, and it was divided into quintiles of poorest, poorer, middle, richer and richest [2–4].

Dietary diversity determination

Children aged 6 to 23 months with complementary feeding information such as food groups consumed in the previous day were selected for sub-group analysis. A minimum dietary diversity (MDD) was used to determine the diversity of complementary foods as suggested by the WHO infant and young child feeding guideline [30]. The MDD was attained if a child had consumed four or more food groups out of the seven. The details of how the MDD was constructed can be found in our previous study [31].

Statistical analysis

Data analysis was conducted using the Statistical Package for Social Sciences (Version 23.0; IBM Corp., Armonk, NY, USA). Data extraction and cleaning was conducted using Stata version 13 (Stata SE/13). Descriptive statistics was used to obtain prevalence estimates of CIAF among children of 0 to 59 months using data from all six TDHS studies (1991 to 2015). Then, a dichotomous CIAF was created (1 = Yes; 0 = No). We used multivariate logistic regression models to identify the correlates of CIAF. Both crude and adjusted odds ratios (AOR) with 95% confidence intervals (CI) were determined. At first, univariate logistic regression analysis was performed to identify variables associated with CIAF. Next, multivariate logistic regression allowed us

to control for confounders by entering all variables in the model. Stepwise elimination procedures were performed to select variables that are significant predictors of CIAF. Variables with $p < 0.05$ in the multivariate model were considered to be correlates of CIAF.

Results

Background characteristics of the included mother and children in TDHS 2005–2015

A total of 22,794 mother-child pairs were included in the analysis from 2005 to 2015, where with ~ 50% of children being girls. The majority of the children were between the ages of 24 to 35 months old, as shown in Table 3. The majority of the children (about 45 to 50%) had normal weight at birth, just less than 3% were below the normal birth weight. More than 70% of all children were recorded to live in rural areas for all surveys. Less than 20% of the sampled children had diarrhea and/or symptoms of fever within two weeks preceding the survey.

Table 3
Descriptive characteristics of the included mothers and children in the Tanzania Demographic and Health Survey (2005–2015)

Variables	2014-15	2010	2004-05
	(N = 8,913)	(N = 6,774)	(N = 7,107)
	n (%)	n (%)	n (%)
Residence			
Urban	2013 (22.6)	1231(18.2)	1210(17)
Rural	6900 (77.4)	5543(81.8)	5897(82.9)
Mothers BMI			
Underweight	643 (7.2)	663(9.8)	622(8.8)
Normal	5990 (67.2)	4768(70.4)	5390(75.8)
Overweight	1548 (17.4)	1000(14.8)	825(11.6)
Obesity	732 (8.22)	343(5.1)	270(3.8)
Age of mother			
15–24	2589 (29.1)	1824(26.9)	2051(28.8)
25–39	5333 (59.8)	4211(62.1)	4424(62.3)
40–49	991 (11.1)	739(10.9)	632(8.9)
Mothers age at first birth			
< 15	220(2.5)	202(2.9)	246(3.5)
15–29	8590(96.4)	6516(96.2)	6811(95.8)
30–50	103(1.15)	56(0.8)	50(0.7)
Number of birth			
One	3827(42.9)	2650(39)	2723(38.3)
Two	4059(45.6)	3294(48.5)	3454(48.5)
Three and above	1027(11.5)	848(12.5)	930(13.1)
Gender of household head			
Male	7501(84.2)	5681(83.9)	5974(84)
Female	1412(15.8)	1093(16.1)	1133(15.9)
Age of the household head			
15 to 29	1462(16.4)	1095(16.2)	1426(20.1)
30 to 49	5269(59.1)	4142(61.1)	4099(57.7)
Above 50	2185(24.5)	1537(22.7)	1582(22.2)
Education of mother			
No education	1948(21.8)	1734(25.5)	1949(27.4)

Variables	2014-15	2010	2004-05
	(N = 8,913)	(N = 6,774)	(N = 7,107)
	n (%)	n (%)	n (%)
Primary	5359(60.1)	4271(63)	4564(64.2)
Secondary	1528(17.2)	751(11.2)	510(7.2)
Higher	80(0.9)	18(0.3)	84(1.2)
Marital status of mother			
Single	418(4.7)	279(4.1)	267(3.7)
Married/with partner	7607(85.3)	5910(87.2)	6286(88.4)
Divorced/separated	888(9.9)	585(8.6)	554(7.8)
Wealth status			
Poorest	2064(23.2)	1387(20.5)	1569(22.1)
Poorer	1859(20.9)	1561(22.9)	1421(19.9)
Middle	1740(19.5)	1449(21.4)	1439(20.2)
Richer	1836(20.6)	1389(20.5)	1573(22.2)
Richest	1414(15.9)	988(14.7)	1105(15.5)
Age of child (months)			
< 6	975(10.9)	738(10.9)	758(10.6)
6 to 23	3070(34.4)	2207(32.6)	2399(33.7)
24–35	1728(19.4)	1268(18.8)	1460(20.6)
> 35	3140(35.2)	2561(37.8)	2490(35.1)
Gender of child			
Male	4471(50.2)	3365(49.7)	3556(50)
Female	4442(49.8)	3409(50.3)	3551(49.9)
Birth weight			
Above 2500 g	5148(57.8)	3260(48.2)	3202(45)
Below 2500 g	347(3.9)	215(3.2)	245(3.4)
Not reported	3418(38.5)	3299(48.7)	3660(51.5)
Employment of mother			
Not working	2257(25.3)	1409(20.8)	964(13.6)
Last year	420(4.7)	147(2.2)	302(4.3)
Working currently	6236(69.9)	5218(77)	5841(82.1)
Place of delivery			
Health facility	5462(61.3)	3258(48.1)	3230(45.4)

Variables	2014-15	2010	2004-05
	(N = 8,913)	(N = 6,774)	(N = 7,107)
	n (%)	n (%)	n (%)
At home	3314(37.2)	3430(50.6)	3871(54.5)
Other places	139(1.6)	86(1.2)	4(0.1)
Diarrhea			
No	7837(97.9)	5813(85.8)	6120(86.2)
Yes	1081(12.1)	961(14.2)	987(13.8)
Symptoms of fever			
No	7317(82.1)	5244(77.5)	5105(71.9)
Yes	1596(17.9)	1524(22.5)	1999(28.1)
Not reported			
Initiation of breastfeeding			
Within an hour	3344(37.5)	2296(33.8)	3946(55.5)
After an hour	2699(30.3)	2090(30.8)	2559(35.9)
After one day	2870(32.2)	2394(35.3)	602(8.5)

Among mothers, more than half were between the ages of 25 to 39 years. The proportion of mothers without any formal education had decreased from 27% in 2004-05 to 21% in 2015–2016. Nevertheless, in the same period, the proportion of mothers who attained higher education, past primary school remained the same. Some of them initiated breastfeeding within an hour after birth, however, the proportion declined from 55.5–37.5% in 10 years. The proportion of mothers who gave birth below the age of 15 years had slightly declined from 3.5% in 2005 to 2.5% in 2015. Moreover, the proportion of mothers with three or more children declined from 13.1% in 2005 to 11.5% in 2015. According to their nutritional status, the proportion of underweight mothers ($< 18.5 \text{ kg/m}^2$) declined slightly from 8.8% in 2005 to 7.2% in 2015, while the proportion of obesity more than doubled from 3.8–8.2%. Across all the surveys, the proportion of richest households, classified using wealth index ranged below 15%, while the poorest household were above 20%. Overall, the majority of households are headed by male and those aged between 30 to 49 years old (Table 3).

Prevalence and Trends of anthropometric failure (1991–2015)

Figure 1 shows the trends in prevalence of CIAF and conventional indices of stunting (HAZ $<$ -2SD), wasting (WHZ $<$ -2SD) and underweight (WAZ $<$ -2SD) from 1991 to 2015 in Tanzania. In 1991, about half (50%) of surveyed children had anthropometric failures compared to one in three (38.2%) in 2015. On average, about 50% of the children did not have any anthropometric failure; however, we noted some variations across the years. About 62% of children had no anthropometric failures in 2015 (Table 4). The prevalence of children who have multiple anthropometric failures (Group D) has declined from 2.2–1.5% over two and half decades. On the other hand, the prevalence of children with stunting only (Group F) increased from 20.1–23.2% from 1991 to 2015. The prevalence of children with wasting only (Group B) increased from 1.1–1.6%; meanwhile, the proportion of children with underweight only (Group Y) decreased from 2.9–0.8% 1991 to 2015.

Table 4
Prevalence of composite index of anthropometric failure in Tanzania (1991–2015)

CIAF categories	1991-92	1996	1999	2004-05	2010-11	2015-16
	(n = 6,177)	(n = 5,226)	(n = 2,825)	(n = 7,107)	(n = 6,774)	(n = 8,913)
A No failure (%)	50.0	49.0	50.2	57.8	54.1	61.7
B Wasting only (%)	1.1	1.1	0.8	0.4	1.3	1.6
C Wasting and underweight (%)	2.8	3.0	1.8	1.3	1.7	1.3
D Wasting, Stunting and underweight (%)	2.2	3.2	2.7	1.3	1.8	1.5
E Stunting and underweight (%)	21.0	21.0	21.5	16.5	11.4	9.7
F Stunting only (%)	20.1	19.3	19.5	19.9	28.8	23.2
Y Underweight only (%)	3.0	3.5	3.4	2.8	0.9	0.9
CIAF, (%)	50.0	51.0	49.8	42.2	45.9	38.2
Total (%)	100	100	100	100	100	100

Risk factors for anthropometric failure (2005–2015)

Table 5 presents the results from univariate and multivariate logistic regression analysis using 2005, 2010 and 2015 TDHS data. In the multivariate model, place of residence, mothers BMI, gender of the household head, age of the household head, education of mother, mothers employment, wealth status, birth weight, age and gender of the children, diarrhea, symptoms of fever and place of delivery were associated with anthropometric failure in various years.

Table 5

Univariate and multivariate logistic regression for risk factors of anthropometric failure among children under 5 years of age in Tanzanian Demographic and Health Surveys (2005–2015)

Variables	TDHS 2014-15		TDHS 2010		TDHS 2004-05	
	Crude OR (95% CI)	Adj OR (95% CI)	Crude OR (95% CI)	Adj OR (95% CI)	Crude OR (95% CI)	Adj OR (95% CI)
Residence						
Urban	Ref	Ref	Ref	Ref	Ref	Ref
Rural	1.70(1.54–1.89)***	1.15(1.0–1.32)*	1.65(1.46–1.86)***	1.2(1.0–1.41)*	1.74(1.54–1.97)***	0.85(0.72–1.01)
Mothers BMI						
Underweight	Ref	Ref	Ref	Ref	Ref	
Normal	0.76(0.65–0.9)**	0.77(0.66–0.91)**	0.66(0.56–0.78)***	0.71(0.6–0.84)***	0.78(0.66–0.92)**	0.77(0.65–0.92)**
Overweight	0.58(0.47–0.69)***	0.66(0.55–0.81)***	0.49(0.4–0.6)***	0.59(0.49–0.74)***	0.47(0.38–0.58)***	0.57(0.45–0.72)***
Obesity	0.59(0.5–0.71)***	0.48(0.38–0.62)***	0.58(0.48–0.71)***	0.41(0.31–0.55)***	0.68(0.56–0.83)***	0.49(0.35–0.69)***
Mothers age at first birth						
< 15	Ref		Ref		Ref	
15–29	0.78(0.59–1.02)	NA	0.99(0.75–1.3)	NA	0.89(0.69–1.15)	NA
30–50	0.69(0.43–1.13)		0.83(0.45–1.52)		0.84(0.45–1.55)	
Number of birth in the five years						
One	Ref		Ref		Ref	
Two	1.1(0.96–1.16)	NA	1.2(1.07–1.32)**	1.12(1–1.25)*	1.03(0.93–1.14)	0.95(0.85–1.1)
Three and above	1.1(0.91–1.21)		1.1(0.93–1.26)	0.98(0.83–1.15)	0.85(0.73–0.99)*	0.82(0.69–0.96)*
Gender of the head of the household						
Male	Ref	Ref	Ref		Ref	
Female	1.1(0.96–1.2)	1.14(1.01–1.28)*	1.02(0.9–1.2)	NA	1.14(1.01–1.28)*	NA
Age of the head of the household						
15 to 29	Ref	Ref	Ref		Ref	Ref
30 to 49	0.84(0.75–0.94)**	0.87(0.77–0.98)*	0.97(0.85–1.1)		0.9(0.8–1.01)	0.85(0.76–0.99)*

P < .01, *P < .05, *P < 0.001; CI = confidence interval; OR = Odd ratio, Ref = Reference group, NA = not significant in the multivariate model

	TDHS 2014-15		TDHS 2010		TDHS 2004-05	
Above 50	0.84(0.75–0.96)**	0.78(0.68–0.91)**	0.89(0.78–1.1)	NA	0.9(0.79–1.03)	0.87(0.75–1.03)
Mother education						
No education	Ref	Ref	Ref	Ref	Ref	Ref
Primary	0.87(0.78–0.96)*	0.95(0.85–1.1)	0.89(0.79–0.99)*	0.99(0.88–1.12)	0.83(0.74–0.92)***	0.99(0.88–1.12)
Secondary	0.56(0.48–0.64)***	0.81(0.68–0.9)**	0.53(0.45–0.63)***	0.78(0.63–0.95)*	0.45(0.36–0.56)***	0.77(0.61–0.98)*
Higher	0.17(0.09–0.35)***	0.32(0.16–0.67)**	0.29(0.09–0.91)*	0.56(0.19–2.0)	0.12(0.06–0.25)***	0.33(0.15–0.69)**
Mothers marriage						
Single	Ref		Ref		Ref	
Married	0.92(0.75–1.12)	NA	1.1(0.86–1.4)	NA	0.85(0.66–1.08)	NA
Separated	1.1(0.84–1.35)		1.2(0.88–1.56)		1.11(0.83–1.49)	
Wealth status						
Poorest	Ref	Ref	Ref	Ref	Ref	Ref
Poorer	1.0(0.89–1.13)	1.0(0.88–1.15)	0.84(0.73–0.96)**	0.85(0.74–0.99)*	0.97(0.84–1.11)	0.91(0.78–1.1)
Middle	0.99(0.88–1.12)	1.1(0.93–1.21)	0.78(0.68–0.91)**	0.83(0.71–0.96)*	0.84(0.73–0.96)*	0.83(0.71–0.96)*
Richer	0.68(0.6–0.77)***	0.79(0.68–0.92)**	0.64(0.56–0.74)***	0.75(0.63–0.88)**	0.65(0.57–0.74)***	0.7(0.6–0.82)***
Richest	0.45(0.39–0.51)***	0.64(0.52–0.78)***	0.43(0.36–0.51)***	0.66(0.53–0.83)***	0.29(0.25–0.34)***	0.34(0.27–0.43)***
Age of child (months)						
< 6	Ref	Ref	Ref	Ref	Ref	Ref
6 to 23	1.82(1.55–2.14)***	1.85(1.56–2.19)***	2.3(1.89–2.69)***	2.3(1.9–2.7)***	8.1(6.3–10.5)***	7.64(5.85–9.97)***
24–35	2.59(2.18–3.1)***	2.71(2.3–3.24)***	3.2(2.6–3.9)***	3.3(2.7–4.1)***	8.5(6.5–11.0)***	8.81(6.69–11.6)***
> 35	1.97(1.68–2.32)***	2(1.73–2.41)***	2.1(1.79–2.54)***	2.1(1.7–2.5)***	8.5(6.6–10.9)***	8.87(6.8–11.5)***
Gender of children						
Male	Ref	Ref	Ref	Ref	Ref	Ref
Female	0.82(0.75–0.89)***	0.9(0.81–0.99)*	0.76(0.7–0.84)***	0.71(0.64–0.79)***	0.92(0.84–1.0)	0.91(0.82–1.0)

P < .01, *P < .05, *P < 0.001; CI = confidence interval; OR = Odd ratio, Ref = Reference group, NA = not significant in the multivariate model

TDHS 2014-15			TDHS 2010			TDHS 2004-05	
Birth weight							
Above 2500 g	Ref	Ref	Ref	Ref	Ref	Ref	
Below 2500 g	2.3(1.86–2.88)***	2.55(2-3.2)***	2.01(1.52–2.66)***	2.3(1.75–3.14)***	2.4(1.84–3.11)***	2.8(2.2–3.8)***	
Mother's employment							
Not working	Ref		Ref		Ref	Ref	
Last year	0.99(0.79–1.25)	NA	0.81(0.57–1.2)	NA	1.32(1.01–1.73)*	1.1(0.8–1.43)	
Working currently	1.2(1.1–1.32)**		1.15(1.01–1.32)*		1.58(1.36–1.82)***	1.2(1.03–1.42)*	
Place of delivery							
Health facility	Ref		Ref		Ref	Ref	
At home	1.33(1.23–1.46)***	NA	1.38(1.25–1.53)***	NA	1.52(1.4–1.67)***	1.34(1.13–1.6)**	
Other places	1.0(0.71–1.43)		1.4(0.89–2.2)		0.6(0.06–5.6)	0.54(0.05–5.78)	
Presence of diarrhea							
No	Ref	NA	Ref	NA	Ref	Ref	
Yes	1.1(0.95–1.23)		1.11(0.97–1.2)		1.38(1.21–1.58)***	1.27(1.1–1.48)**	
Symptoms of fever							
No	Ref	Ref	Ref		Ref	Ref	
Yes	1.2(1.1–1.31)**	1.13(1.01–1.27)*	1.1(0.95–1.2)	NA	1.33(1.2–1.5)***	1.18(1.06–1.32)**	
Starting of breastfeeding							
Within an hour	Ref		Ref		Ref		
After an hour	1.0(0.9–1.11)	NA	1.1(0.97–1.23)	NA	1.19(1.1–1.32)***	NA	
After one day	1.2(1.1–1.3)**		1.3(1.2–1.44)***		1.24(1.1–1.39)**		
P < .01, *P < .05, *P < 0.001; CI = confidence interval; OR = Odd ratio, Ref = Reference group, NA = not significant in the multivariate model							

The odds of having anthropometric failure for rural children increased (AOR = 1.15, 95% CI, 1-1.32) in 2015, and (AOR = 1.2, 95% CI, 1-1.41) in 2010 compared to children residing in urban areas. The odds of having anthropometric failure reduced significantly based on increasing BMI of the mother. In 2015, the odds were lower when mothers were normal (AOR = 0.77, 95% CI, 0.66–0.91), overweight (AOR = 0.66, 95% CI, 0.55–0.81) or obese (AOR = 0.48, 95% CI, 0.38–0.62) compared to underweight mothers. This study also found that the odds of having anthropometric failure increased among female-headed households (AOR = 1.14, 95% CI, 1.01–1.28) in 2015. The odds significantly reduced if the age of the household head was between 30–

49 years (AOR = 0.87, 95% CI, 0.75–1.03), and above 50 years (AOR = 0.78, 95% CI, 0.68–0.91) compared to younger age of 15–29 years in 2015. Another risk factor was a household wealth status. It was found that the odds for anthropometric failure was negatively associated with wealth status from poorest families to richer (AOR = 0.79, 95% CI, 0.68–0.92) and richest families (AOR = 0.64, 95% CI, 0.52–0.78) in 2015, which is similar for other years. Children whose mothers have a higher level of education were less likely to have children with anthropometric failure (AOR = 0.32, 95% CI, 0.16–0.67) in 2015, and (AOR = 0.33, 95% CI, 0.15–0.69) in 2005, compared to children whose mothers received no formal education.

Age and gender of the children are associated with anthropometric failure. The odds of anthropometric failure increased for children aged between 6–23 months (AOR = 1.85, 95% CI, 1.55–2.14), 24–35 months (AOR = 2.71, 95% CI, 2.3–3.24) and more than 35 months (AOR = 2.0, 95% CI, 1.73–2.41) compared to children aged less than 6 months in 2015. Relatively, girls have significantly lower odds of anthropometric failure than boys (AOR = 0.9, 95% CI, 0.81–0.99) in 2015, and (AOR = 0.71, 95% CI, 0.64–0.79) in 2010. Low birth weight and anthropometric failure were strongly associated in all surveys. In comparison with normal birth weight, the low birth weight children had more than twice the odds of having anthropometric failure in 2015 (AOR = 2.55, 95% CI, 2–3.2), 2010 (AOR = 2.3, 95% CI, 1.75–3.14), and 2004–05 (AOR = 2.8, 95% CI, 2.2–3.8). In terms of infections, having diarrhea (AOR = 1.27, 95% CI, 1.1–1.48) and symptoms of fever (AOR = 1.18, 95% CI, 1.06–1.32) increased the likelihood of anthropometric failure in 2005. Moreover, the odds of anthropometric failure were significantly higher for children who were born at home than those at health facilities in 2005 (AOR = 1.34, 95% CI, 1.13–1.6). However, place of delivery was not found to be associated in a multivariate model in other surveys (Table 5). Nevertheless, the sub-group analysis of children aged 6 to 23 months revealed that, the consumption of a diversified diet was not associated with anthropometric failure in any survey as shown in Table 6.

Table 6

Univariate and multivariate logistic regression of dietary diversity and anthropometric failure among children 6–23 months of age in Tanzanian Demographic and Health Surveys (2005–2015)

Variables	TDHS 2015 (N = 3,070)			TDHS 2010 (N = 2,207)			TDHS 2005 (N = 2,399)		
	N (%)	Crude OR (95% CI)	Adj OR ^a (95% CI)	N (%)	Crude (95% CI)	Adj OR ^a (95% CI)	N (%)	Crude OR (95% CI)	Adj OR ^a (95% CI)
Dietary Diversity									
≥ 4 food groups	788 (25.6)	Ref	Ref	220 (10)	Ref	Ref	349 (14.5)	Ref	Ref
< 4 food groups	2282 (74.3)	1.18(0.99– 1.4)	1.09(0.92– 1.3)	1987 (90)	1.06(0.81– 1.41)	1.03(0.77– 1.37)	2050 (85.4)	1.08(0.86– 1.37)	1.02(0.81– 1.29)
a- Adjusted for gender and place of residence; CI = confidence interval; OR = Odd ratio, Ref = Reference group									

Discussion

This paper provides the new estimates for the prevalence of undernutrition by using an aggregate indicator of anthropometric failure and applying it to the large nationally representative datasets in Tanzania. It also describes the trends and examines the correlates associated with anthropometric failures. Our analysis shows how the conventional indices of stunting, wasting, underweight, when used on their own, miss significant numbers of children who experience multiple anthropometric deficits. We show that this can be avoided by using an aggregate measure known as the composite index of anthropometric failure (CIAF) [8]. The prevalence of CIAF stands at 38.2% among under 5 year olds in Tanzania in 2015, which declined from 50.1% in 1991. This is higher compared to the prevalence reported by conventional indices of stunting, wasting and underweight. In other countries the prevalence of CIAF was 47.8% in India [12]; 48.4% in Ethiopia [17], 48.3% in Bangladesh [15] and 21.7% in China [14]. Although the proportion of children with multiple anthropometric failure has declined from 2.2–1.5% in 2015, it was reported in another study that these children have a up to twelve times greater risk of early mortality [6]. Therefore, CIAF proves very useful in the detection of children who are at higher risk of death associated with anthropometric failure.

This study further confirms the existence of multiple factors influencing childhood undernutrition in the country. Children, maternal, and household socioeconomic factors were found to be associated with anthropometric failure, which indicates the need to strengthen both nutrition-specific and sensitive interventions that can improve livelihoods and ameliorate main drivers of undernutrition such as poverty, food insecurity and other determinants of health.

In this study, anthropometric failure in the country was strongly associated with characteristics of the household like location, wealth status, and household head characteristics. This corresponds with information from a systematic review, which reported that wealth and socio-economic factors were highly impacting the prevalence of anthropometric failure in many low- and middle-income countries including Tanzania [32]. Our study found that children living in urban areas are less likely to experience anthropometric failure compared to rural children. This is consistent with previous studies conducted in Bangladesh [15] and Myanmar [26] and is most likely linked to better living conditions, and adequate all years-round food accessibility in urban areas. In addition, our findings show that children from poorer households are at increased risk of anthropometric failure compared with children from richer households. This corresponds to many other studies done previously in developing countries like Ethiopia [17], Bangladesh [15] and India [33]. Pomati et al. [34] analysed the data of several West and Central African countries found that the risk of anthropometric failure among children in wealthier households is half than that of the poorest households. Similarly, highest wealth status was found to be associated with lower odds of undernutrition among children under 5 years old in Tanzania [2], and elsewhere [32]. This might be because poverty is closely associated with inadequate provision of nutritious food and poor sanitation. Both factors are likely to increase the risk for infections and ultimately lead to undernutrition among children [35, 36]. In addition, access to health care services may also be limited in poor households compared to the rich ones.

Households headed by older parents are less likely to have children with anthropometric failure, while household headed by women had a higher likelihood of having children with anthropometric failure. Older parents most likely have more experience concerning childcare and thus make choices that are more informed on child health, and engage themselves in different knowledge activities than younger parents. In terms of gender of the head of the household, in many cases in the country, female-headed households are single-parent families due to divorce/separation, death of or sometimes abandonment by men. Therefore, they are sole providers and are responsible for childcare duties and income generation, leaving them more vulnerable to food insecurity than male-headed households. This correspond to a study by Haidar et al [27] which found that the proportion of undernutrition was significantly higher in female-headed households. Nutrition interventions of socioeconomically disadvantaged households may thus significantly reduce the burden of undernutrition in the country, as has been stated previously by Alderman et al [37].

This study shows that both maternal and newborn health is an important factor to consider when addressing the nutrition status of children. In this study, we see that a mothers nutritional status, birth weight of children, and place of delivery were associated with anthropometric failure among children. This calls for more efforts focusing on the nutrition of first 1000 days of life, from the conception up to 2 years. This study reveals that children who were born at home have a higher risk of anthropometric failure than those born at a health facility. Similar results were found in a cross-sectional studies in Tanzania [2] and elsewhere [26]. Health facility delivery is very important because it help to receive appropriate and timely obstetric and medical care, as well as information about childcare to parents. Therefore, promoting health facility delivery can have beneficial effect not only on the mothers, but also on their children. On the other hand, good nutritional status of mothers can protect against anthropometric failure. Children of underweight mothers are more likely to get anthropometric failure than those of normal weight mothers. The plausible explanation for this may be poor nutritional status of mothers is a risk to infant deficiency and a risk factor for fetal growth restriction, resulting in low birth weight [38]. We also see that low birth weight have a strong positive relationship with anthropometric failure in this study. This is comparable with findings from Sunguya et al. [2] who reported that children born with normal birth weight were 35% less likely to be stunted than low weight children.

Furthermore, biological factors of children like age and gender can highly influence undernutrition. Children in the youngest age group of 0–6 months had a significantly lower risk of failure than in older age groups of above 6 months. These results are consistent with many other studies from other countries [15, 24] as well as in Tanzania [2, 22, 23]. This may be because of either poor feeding practice of the older children, or sometimes vulnerability to diseases when a child grows from 6 months

onwards. Another possible reason for this may be that from 6 months, termination of breastfeeding starts, and children have much physical and mental growth, and by that time, they have to attain a well balanced diet to support the development of the child's brain and body. Young children below the age of two years have to receive adequate complementary feeding in order to be healthy and maintain good growth [30]. Surprisingly, in this study we did not find the association between consumption of a diversified diet and anthropometric failure of children between 6 to 23 months of age in any of the surveys. This study did not figure out the reasons for this observation, however; in our previous analysis, we have shown that dietary diversity was a good predictor of stunting and underweight only, but not wasting among children of 6 to 23 months [31]. Similar results have been reported among under 5 years children in Myanmar [26]. We also have to take into account that, the method of collection of dietary diversity data in recent TDHS of 2010 and 2015 have changed from that of 2005 to accommodate the new indicator suggested by WHO of minimum dietary diversity (MDD) [30]. Nevertheless, this study found that boys are at higher risk of having anthropometric failure compared to girls. This is not unexpected, a study by Wamani et al. [39] conducted among sub-Saharan African countries found that male children under five years of age are more likely to become undernourished than females. There is lack of scientific evidence to justify the presence of risk for boys toward undernutrition. Perhaps the morbidity pattern between male and female children could explain the phenomenon [39].

We also found that childhood anthropometric failure is significantly associated with mother's educational attainment and employment. However, employment status was significantly associated with anthropometric failure only in 2005, but not in the recent surveys of 2010 and 2015, signifying that women employment was improved over the past 10 years in the country. We also found that, children of mothers who are more educated tend to have a lower likelihood of anthropometric failure. Briefly, educational attainment of the mother may influence the nutritional status of a child in various ways. For example, well-educated women tend to have better work opportunities and obtain higher incomes that may result to higher socioeconomic status. Another reason could be that more educated mothers could understand maternal and child care education and information provided through different media compared to mothers with low education. Endris et al. [17] evaluated the risk factors of undernutrition among children aged 0–59 months in rural Ethiopia and reported that, the odds of being undernourished was 1.32 times higher for children whose mothers did not have any basic education compared to children whose mothers attended primary education. This observation is comparable to our results. The relationship between mother's education and child nutritional status has been well documented in several other studies [25, 40–42]. This study together with the above literature highlight the importance of women education in improving child nutrition status.

Although this study provides a clear picture on the trends of CIAF and the possible correlates from the national data in Tanzania, some general limitations should be mentioned. Analysis on the prevalence and trends included six surveys while factors associated with CIAF were only identified from three recent surveys. It is possible that older surveys could show different associated factors compared to most recent studies. However, the three surveys included that were the most recent ones provide information on the possible areas of intervention. In addition, data on other factors that may contribute to CIAF were not collected during the surveys, for example, data on water hygiene and sanitation and other childcare practices that may contribute to CIAF. It is therefore important to consider these factors in future studies. Despite the above limitations, we hope this study will shed light on key areas for interventions in Tanzania. In addition, this study used large population based data with a representative sample size at national, regional, rural and urban areas, which provides most robust estimates of the whole country, so it can be easily generalised.

Conclusion

There is a significant decrease in the overall burden of undernutrition in Tanzania as measured by CIAF. One in every three children are suffering from various forms of anthropometric failure in Tanzania. Multiple factors including those related to mothers, children and household socioeconomic characteristics have the potential to influence childhood undernutrition. Therefore, efforts to reduce the burden of undernutrition should focus on reducing poverty and raising people's living standards and women's education. This will include improving the quality of their homes, providing education, and provide equal access to maternal and child health care services for both rural and urban areas.

Abbreviations

AOR
Adjusted Odd Ratio
BMI
Body mass Index
CI
Confidence Intervals
CIAF
Composite index of anthropometric failure
HAZ
Height-for-Age Z-scores
IYCF
Infant and Young Child Feeding
ICF
Inner City Funds
MDD
Minimum Dietary Diversity
OR
Odd Ratio
SD
Standard deviation
TDHS
Tanzania Demographic and health survey
WAZ
Weight-for-Age Z-scores
WHO
World Health Organisation

Declarations

Ethical consideration

Relevant authorities in Tanzania mainland and Zanzibar approved the TDHS protocols and data collection procedures. These include the National Institute of Medical Research (NIMR), Zanzibar Medical Research Ethical Committee (ZAMREC), the Institutional Review Board of ICF International, and the Centers for Disease Control and Prevention in Atlanta [4]. Since we only used secondary data, personal consents was not required, as well as no any personal identity was being identified from the data files. The data were completely anonymous.

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Conflict of interest

The authors declare that there is no any conflict of interest

Contribution

AGK and **AWM** conceived the study and wrote the manuscript. **AGK** analyzed and interpreted the data. **KK** and **GK** critically revised and edited the manuscript.

Consent for publication

Not applicable for this study

Availability of data and material

Data for this study are available upon request from the DHS portal

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Figures

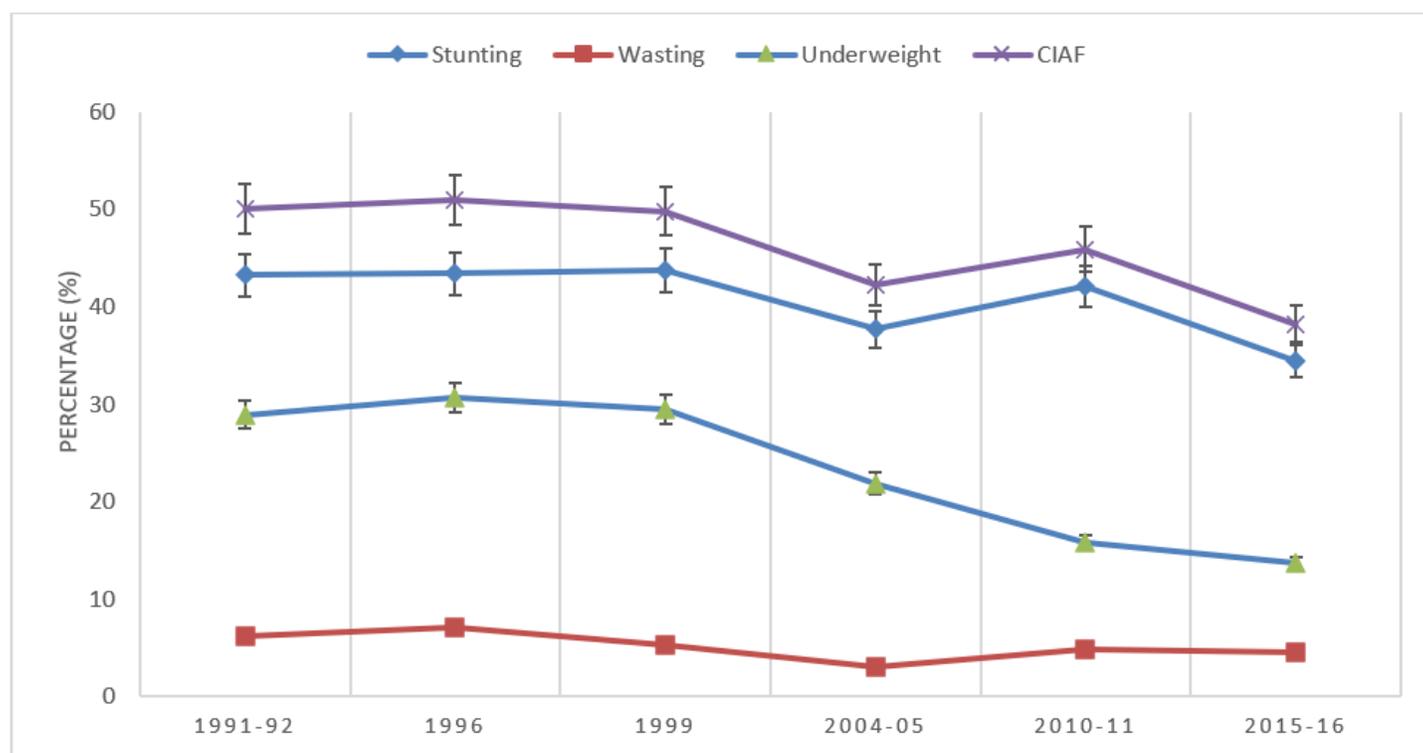


Figure 1

Trends of undernutrition in Tanzania as classified by CIAF and conventional indices of stunting (HAZ<-2SD), wasting (WHZ<-2SD) and underweight (WAZ<-2SD) from 1991 to 2015.