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

Ahmed Gharib Khamis^{1*} , Akwilina Wendelin Mwanri², Katharina Kreppel^{3,4} and Gideon Kwesigabo¹

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-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 all form of childhood undernutrition in the country.

Methods: About 37,205 mother-child pairs were retrieved and analyzed from the Tanzania Demographic and Health Surveys (TDHS) conducted in various years from 1991, 1996, 1999, 2004–05, 2009–10, to 2015–16. The anthropometric data of children under-five years were used to determine the overall burden and trends of undernutrition using CIAF. The recent TDHS surveys from 2005 to 2015 were used to examine the correlates of CIAF. To determine the correlates, multivariate analysis was conducted to estimate the prevalence ratios (PR) with 95% confidence intervals (CI) using Poisson regression with robust variance.

Results: The prevalence of CIAF declined significantly from 50% in 1991 to 38.2% in 2015 ($p < 0.001$). The correlates of CIAF vary across surveys. The multivariate analysis of recent 2015 survey revealed that the prevalence of CIAF was significantly higher for older children ($p < 0.001$), children living in rural areas ($p = 0.028$), and those born with non-educated ($p = 0.009$) or single mothers ($p = 0.008$). The prevalence of CIAF was significantly lower for girls ($p < 0.001$), being born with overweight/obese mothers ($p < 0.001$), living with older head of the household ($p < 0.001$) or living in richest household ($p < 0.001$). Moreover, children who were born with low birth weight ($p < 0.001$), or having fever ($p = 0.044$) were most likely to have anthropometric failure. However, consumption of diversified diet was not found to be associated with anthropometric failure ($p > 0.05$).

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* Correspondence: ahmadboycd@gmail.com

¹Department of Epidemiology and Biostatistics, Muhimbili University of Health and Allied Sciences, Dar-es-Salaam, Tanzania

Full list of author information is available at the end of the article



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Conclusion: About one in every three under-five years children are suffering from either one or multiple forms of anthropometric failure in Tanzania. There is a significant decline trends in overall burden of undernutrition in Tanzania from the past 25 years, as measured by CIAF. Multiple factors including those related to mothers, children and household socio-economic characteristics have the potential to influence childhood undernutrition. Efforts to reduce the burden of undernutrition should mainly focus on reducing poverty and raising people's living standards.

Keywords: Children, Stunting, Wasting, Underweight, Anthropometric failure, CIAF, Tanzania

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 [2]. These rates are persistently higher in the Sub-Saharan Africa region [3]. 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 [4, 5]. 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% [5]. Moreover, the recent national nutrition survey conducted in Tanzania found that 10% of children under-5 years old were severely stunted, and 2.7% were severely underweight [2]. Given the negative consequences of undernutrition on child health outcomes, there is certainly a need for actions to draw 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 organization (WHO) [3]. 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 under-five children. To compensate, Svedberg 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 prevalence of undernutrition, and thus helps detect children with multiple anthropometric failure [7–9]. Furthermore, the above model has been used in several studies [10, 11], and it has been concluded that CIAF invariably 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 re-define their children's nutrition situation [8, 9, 14–18]; but such national wide studies are lacking in Tanzania.

The causes for undernutrition in under-five children are complex and multifaceted. Poor socio-economic 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 [4, 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 (6) TDHS surveys have been conducted in Tanzania to date (April 2020). These surveys are done regularly after every 5 years to determine levels, patterns, and trends in demographic and health indicators [2]. All enumerators of TDHS received well training before data collection to ensure that all procedure are well followed to achieve comparable results in different countries. The description of the six surveys conducted in Tanzania is shown in Table 1.

TDHS sampling

The TDHS are national socio-demographic surveys that collect 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 [2]. We managed to extract the information of mother-child pairs in TDHS across the years as follows; 1991 ($n = 6177$), 1996 ($n = 5226$), 1999 ($n = 3008$), 2004–05 ($n = 7107$), 2009–10 ($n = 6774$), and 2015–16 ($n = 8913$). However, in identifying correlates of CIAF only recent TDHS surveys of 2004–05, 2010 and 2015–16 were used because they have many 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 developed by WHO and UNICEF, and the nutritional status of the children (under 5 years old) was calculated. We extracted

anthropometric information of all children in the children datasets. According to the WHO, all children 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 (dependent) variable 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 (B to Y). 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.

Other independent variables

We adopted other covariates as suggested by the UNICEF conceptual framework of malnutrition and after reviewing available literature [4]. Covariates include variables for the age and gender of the child. Child age was classified into four categories: < 6 months, between 6 and 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 1 h after birth, after 1 h, or after 1 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 2 weeks before the interview (Yes/No). Mothers characteristics like age at first birth (years), highest level of education (primary,

Table 1 Demographic and Health Surveys conducted in Tanzania to date and the number of children included for the study

Year	Name of the survey	Number of children included in the study (N)
1991	Tanzania Demographic and Health Survey (TDHS, 1991–92)	6177
1996	Tanzania Demographic and Health Survey (TDHS, 1996)	5226
1999	Tanzania Reproductive and Child Health Survey (TRCHS)	3008
2004–05	Tanzania Demographic and Health Survey (TDHS 2004–05)	7107
2010	Tanzania Demographic and Health Survey (TDHS 2010)	6774
2015	Tanzania Demographic and Health Survey – Malaria Indicator Survey (2015–16)	8913

Table 2 Prevalence of composite index of anthropometric failure in Tanzania (1991–2015)

CIAF categories	1991	1996	1999	2004–05	2010–11	2015–16	P-value*
A No failure (%)	50.0	49.0	50.2	57.8	54.1	61.7	< 0.001
B Wasting only (%)	1.1	1.1	0.8	0.4	1.3	1.6	< 0.001
C Wasting and underweight (%)	2.8	3.0	1.8	1.3	1.7	1.3	< 0.001
D Wasting, Stunting and underweight (%)	2.2	3.2	2.7	1.3	1.8	1.5	< 0.001
E Stunting and underweight (%)	21.0	21.0	21.5	16.5	11.4	9.7	< 0.001
F Stunting only (%)	20.1	19.3	19.5	19.9	28.8	23.2	< 0.001
Y Underweight only (%)	3.0	3.5	3.4	2.8	0.9	0.9	< 0.001
CIAF, (%) ^a	50.0	51.0	49.8	42.2	45.9	38.2	< 0.001
Total (%)	100	100	100	100	100	100	

*P-value for trends from 1991 to 2015

a = CIAF = B + C + D + E + F + Y

secondary or higher), employment status, and number of children born in the past 5 years were also included, as reported and categorized in the previous studies [4, 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, 5].

Dietary diversity determination

Children aged 6 to 23 months with dietary intake information such as food groups consumed in the previous day were selected for sub-group analysis. The dietary intake information was extracted in the mother dataset. In TDHS, all mothers were asked to report different types of foods given to their children in the previous 24 h before the interview. A minimum dietary diversity (MDD) was used to determine the diversity of complementary foods as suggested by the WHO's 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 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). Both descriptive and regression analysis were used in this study. Firstly, descriptive statistics was used to obtain prevalence estimates and trends of CIAF among children of 0 to 59 months using data from all six TDHS studies (1991 to 2015) using a binary variable (1 = Yes; 0 = No).

Differences in prevalence rates between survey-years were examined using chi-squared test. In the second part, we used Poisson regression with robust variance to identify the correlates of CIAF in order to have a better estimate of the associations. This is because the outcomes is common with high prevalence of more than 10% [32]. Both crude and adjusted prevalence ratios (PR) with 95% confidence intervals (CI) were estimated. At first, crude PR was estimated to identify variables associated with CIAF. Next, Multivariable analysis was conducted; adjusted prevalence ratios (APR) were estimated by entering all variables in the model. Variables with $p < 0.05$ in the multivariate model were considered to be a significant correlates of CIAF.

Results

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

About 37,205 children-mothers pairs were extracted from TDHS from 1991 to 2015. Table 3 presents the background characteristics of the included mother-child pairs from the recent surveys from 2005 to 2015. The majority of the included children ~ 50% were girls. About one third (~ 30%) of the children were between the ages of above 35 months followed by 6 to 23 months old. The majority of the children (about 45 to 50%) had normal weight at birth, just less than 4% were below the normal birth weight, and some have not reported their birth weight (~ 30–50%). 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 2 weeks preceding the survey.

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

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

Variables	2014–15 (<i>N</i> = 8913) <i>n</i> (%)	2010 (<i>N</i> = 6774) <i>n</i> (%)	2004–05 (<i>N</i> = 7107) <i>n</i> (%)
Household's Characteristics			
Residence			
Urban	2013 (22.6)	1231(18.2)	1210(17)
Rural	6900 (77.4)	5543(81.8)	5897(82.9)
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 (years)			
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)
Household wealth			
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)
Mother's Characteristics			
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 (years)			
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)
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)
Mothers age at first birth (years)			
< 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)
Education of mother			
No education	1948(21.8)	1734(25.5)	1949(27.4)

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

Variables	2014–15 (<i>N</i> = 8913) <i>n</i> (%)	2010 (<i>N</i> = 6774) <i>n</i> (%)	2004–05 (<i>N</i> = 7107) <i>n</i> (%)
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)
Children's Characteristics			
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)
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)
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)

hour after birth, however, the proportion declined from 55.5 to 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 to 8.2%. Across 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. This analysis observed a significant declining trends of anthropometric failure from the past 25 years in Tanzania ($p < 0.001$). In 1991, about half (50%) of surveyed children had anthropometric failures compared to one in three (38.2%) in 2015. Similarly, for the wasting, stunting and underweight ($p < 0.001$). However, during 2005–2010 the prevalence of stunting and wasting and CIAF worsen slightly. In 1991, about half (50%) of the surveyed children did not have any form of anthropometric failure (Group A); whereas, more than half (62%) of children had no anthropometric failures in 2015 (Table 2). The prevalence of children who have multiple anthropometric failures (Group D) significantly declined from 2.2 to 1.5% over two and half decades ($p < 0.001$), however, it worsened slightly in 1996 (3.2%) and 1999 (2.7%). On the other hand, the prevalence of children with stunting only (Group F) disproportionally changes from 1991 (20.1%) to 2015 (23.2%). The prevalence of children with wasting only (Group B) significantly inclined from 1.1 to 1.6%; meanwhile, the proportion of children with underweight only (Group Y) significantly declined from 3 to 0.9% 1991 to 2015.

Factors associated with anthropometric failure (2005–2015)

Table 4 presents the results from univariate and multivariate Poisson regression analysis using 2005, 2010 and 2015 TDHS data. In the multivariate model, place of residence, mothers BMI, age of the household head, mother marriage status, education of mother, 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.

The prevalence of anthropometric failure for rural children increased significantly (APR = 1.11, 95% CI, 1.01–1.21, $p = 0.028$) in 2015. The prevalence of having anthropometric failure reduced significantly based on increasing BMI of the mother. In 2015, the prevalence were lower when mothers were normal (APR = 0.86, 95% CI, 0.79–0.95, $p = 0.001$), overweight (APR = 0.79, 95% CI, 0.71–0.88, $p < 0.001$) or obese (APR = 0.65, 95% CI, 0.56–0.76, $p < 0.001$) compared to underweight mothers. This result shows that the prevalence of having anthropometric failure reduced among married mothers compared to single mothers in 2015 (APR = 0.84, 95% CI, 0.74–0.96, $p = 0.008$). The prevalence also reduced if the age of the household head was between 30 and 49 years (APR = 0.92, 95% CI, 0.85–0.98, $p = 0.015$), and above 50 years (APR = 0.85, 95% CI, 0.78–0.92, $p < 0.001$) compared to younger age of 15–29 years in 2015. Moreover, household wealth status was strongly associated with anthropometric failure in all years. In 2015, results show that the prevalence of anthropometric failure reduced significantly from poorest families to richer (APR = 0.86, 95% CI, 0.79–0.94, $p = 0.002$) and richest

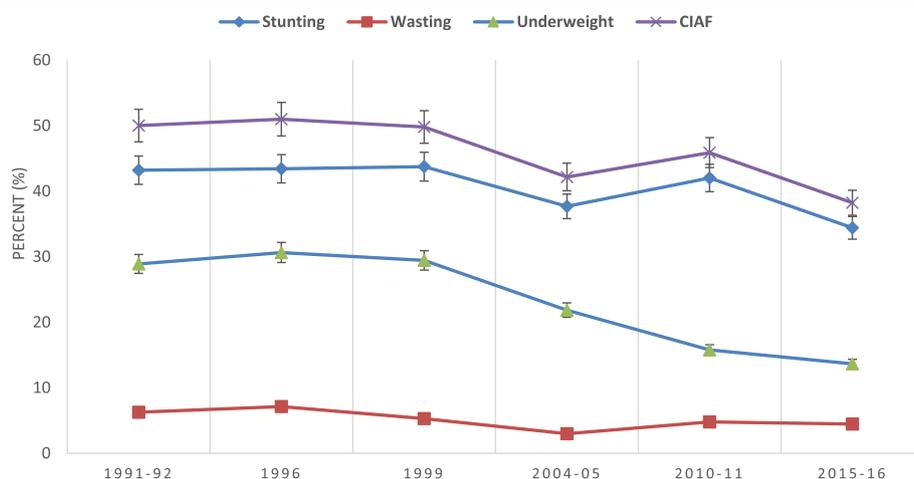


Fig. 1 Trends in prevalence of under-nutrition in Tanzania as classified by CIAF and conventional indices of stunting (HAZ < -2SD), wasting (WHZ < -2SD) and underweight (WAZ < -2SD) from 1991 to 2015. P -values for trend in stunting ($\chi^2=267.42$, $p < 0.001$); wasting ($\chi^2=117.73$, $p < 0.001$); underweight ($\chi^2=988.89$, $p < 0.001$), and CIAF ($\chi^2=413.67$, $p < 0.001$).

Table 4 Crude and adjusted factors associated with 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	
	PR (95% CI)	Adjusted PR (95% CI)	PR (95% CI)	Adjusted PR (95% CI)	PR (95% CI)	Adjusted PR (95% CI)
Residence						
Urban	1.0	1.0	1.0	1.0	1.0	NA
Rural	1.39(1.29–1.51)***	1.11(1.01–1.21)*	1.36(1.25–1.47)***	1.12(1.01–1.23)*	1.36(1.25–1.49)*	
Mothers BMI						
Underweight	1.0	1.0	1.0	1.0	1.0	
Normal	0.86(0.78–0.94)**	0.86(0.79–0.95)**	0.82(0.76–0.88)***	0.85(0.79–0.92)***	0.87(0.81–0.95)***	0.88(0.82–0.95)**
Overweight	0.72(0.64–0.79)***	0.79(0.71–0.88)***	0.69(0.62–0.76)***	0.78(0.70–0.86)***	0.64(0.56–0.73)***	0.74(0.65–0.84)***
Obesity	0.52(0.45–0.61)**	0.65(0.56–0.76)***	0.51(0.42–0.61)***	0.61(0.51–0.74)***	0.48(0.38–0.60)***	0.66(0.53–0.82)***
Mothers age at first birth						
< 15	1.0	NA	1.0	NA	1.0	NA
15–29	0.86(0.74–1.00)		0.99(0.85–1.16)		0.94(0.81–1.08)	
30–50	0.80(0.59–1.08)		0.90(0.64–1.27)		0.90(0.63–1.30)	
Number of birth in the five years						
One	1.0	NA	1.0	NA	1.0	NA
Two	1.03(0.97–1.09)		1.1(1.04–1.16)**		1.01(0.96–1.08)	
Three and above	1.03(0.95–1.13)		1.05(0.96–1.14)		0.90(0.82–0.99)	
Gender of the head of the household						
Male	1.0	NA	1.0	NA	1.0	NA
Female	1.06(0.99–1.14)		1.01(0.94–1.09)		1.09(1.02–1.17)*	
Age of the head of the household						
15 to 29	1.0	1.0	1.0	NA	1.0	1.0
30 to 49	0.91(0.85–0.98)*	0.92(0.85–0.98)*	0.98(0.91–1.05)		0.93(0.86–0.99)*	0.92(0.86–0.98)*
Above 50	0.88(0.81–0.95)***	0.85(0.78–0.92)***	0.92(0.85–1.00)		0.94(0.86–1.02)	0.91(0.84–0.98)*
Mother education						
No education	1.0	1.0	1.0	NA	1.0	
Primary	0.92(0.86–0.97)**	0.96(0.91–1.03)	0.94(0.88–0.99)*		0.89(0.84–0.95)***	0.99(0.93–1.05)
Secondary	0.69(0.63–0.75)***	0.86(0.77–0.96)**	0.68(0.61–0.76)***		0.59(0.52–0.69)***	0.85(0.73–0.98)*
Higher	0.26(0.14–0.49)***	0.43(0.23–0.82)*	0.45(0.19–1.07)		0.20(0.11–0.39)***	0.40(0.21–0.76)**
Mothers marriage						
Single	1.0	1.0	1.0	NA	1.0	1.0
Married	0.95(0.84–1.07)	0.84(0.74–0.96)**	1.06(0.92–1.22)		0.91(0.79–1.05)	0.85(0.74–0.96)*
Separated	1.04(0.90–1.20)	0.90(0.78–1.04)	1.09(0.93–1.29)		1.06(0.90–1.24)	0.92(0.79–1.07)
Wealth status						
Poorest	1.0	1.0	1.0	1.0	1.0	1.0
Poorer	1.01(0.93–1.08)	0.99(0.92–1.06)	0.92(0.85–0.98)*	0.94(0.87–1.00)	0.96(0.89–1.03)	0.96(0.89–1.03)
Middle	1.01(0.94–1.09)	1.02(0.95–1.11)	0.88(0.83–0.95)**	0.93(0.86–0.99)*	0.89(0.83–0.96)**	0.92(0.86–0.99)*
Richer	0.79(0.73–0.86)***	0.86(0.79–0.94)**	0.78(0.72–0.84)***	0.87(0.78–0.95)**	0.79(0.73–0.86)***	0.85(0.78–0.92)***
Richest	0.68(0.53–0.65)***	0.74(0.64–0.84)***	0.62(0.56–0.68)***	0.79(0.69–0.91)**	0.44(0.39–0.49)***	0.53(0.46–0.61)***
Age of child (months)						
< 6	1.0	1.0	1.0	1.0	1.0	1.0
6 to 23	1.51(1.34–1.71)***	1.48(1.31–1.67)***	1.65(1.46–1.88)***	1.64(1.44–1.86)***	4.99(3.96–6.28)***	4.61(3.66–5.80)***

Table 4 Crude and adjusted factors associated with anthropometric failure among children under 5 years of age in Tanzanian Demographic and Health Surveys (2005–2015) (Continued)

Variables	TDHS 2014–15		TDHS 2010		TDHS 2004–05	
	PR (95% CI)	Adjusted PR (95% CI)	PR (95% CI)	Adjusted PR (95% CI)	PR (95% CI)	Adjusted PR (95% CI)
24–35	1.89(1.67–2.13)***	1.86(1.64–2.11)***	1.99(1.75–2.26)***	1.98(1.74–2.25)***	5.14(4.07–6.49)***	4.97(3.92–6.27)***
> 35	1.59(1.41–1.79)***	1.59(1.40–1.81)***	1.61(1.42–1.82)***	1.57(1.37–1.80)***	5.13(4.07–6.46)***	4.99(3.96–6.27)***
Gender of children						
Male	1.0	1.0	1.0	1.0	1.0	1.0
Female	0.88(0.83–0.93)***	0.87(0.83–0.92)***	0.85(0.81–0.89)***	0.84(0.80–0.88)***	0.94(0.89–0.99)*	0.95(0.89–0.99)*
Birth weight						
Above 2500 g	1.0	1.0	1.0	1.0	1.0	1.0
Below 2500 g	1.64(1.48–1.81)***	1.65(1.48–1.82)***	1.47(1.31–1.66)***	1.51(1.34–1.69)***	1.65(1.47–1.85)***	1.59(1.42–1.79)***
Mother's employment						
Not working	1.0	NA	1.0	NA	1.0	NA
Last year	0.99(0.86–1.15)		0.88(0.70–1.09)		1.19(1.01–1.41)*	
Working currently	1.10(1.02–1.18)*		1.08(1.00–1.17)*		1.32(1.21–1.46)***	
Place of delivery						
Health facility	1.0	NA	1.0	NA	1.0	1.0
At home	1.19(1.13–1.26)***		1.18(1.13–1.25)***		1.27(1.20–1.35)***	1.16(1.06–1.27)***
Other places	1.00(0.79–1.25)		1.24(1.00–1.53)*		0.68(0.12–3.76)	0.69(0.16–3.03)
Presence of diarrhea						
No	1.0	NA	1.0	NA	1.0	1.0
Yes	1.05(0.97–1.14)		1.06(0.98–1.14)		1.21(1.13–1.29)***	1.12(1.04–1.20)**
Symptoms of fever						
No	1.0	1.0	1.0	NA	1.0	1.0
Yes	1.10(1.03–1.18)**	1.07(1.00–1.14)*	1.03(0.97–1.09)		1.17(1.11–1.24)***	1.08(1.02–1.15)**
Starting of breastfeeding						
Within an hour	1.0	NA	1.0	NA	1.0	NA
After an hour	1.0(0.94–1.07)		1.05(0.98–1.13)		1.11(1.04–1.17)**	
After one day	1.10(1.03–1.17)**		1.15(1.08–1.23)***		1.12(1.02–1.24)*	

** $P < .01$, * $P < .05$, *** $P < 0.001$; 1.0 = Reference category, CI = Confidence interval; PR Prevalence ratio, NA = Not significant in the multivariate model

families (APR = 0.74, 95% CI, 0.64–0.84, $p < 0.001$). Mothers having a higher level of education showed less prevalence of anthropometric failure (APR = 0.43, 95% CI, 0.23–0.82, $p = 0.009$) compared to mothers with no formal education in 2015.

Both age and gender of the children are associated with anthropometric failure across all years. The prevalence of anthropometric failure increased for children aged between 6 and 23 months (APR = 1.48, 95% CI, 1.31–1.67, $p < 0.001$), 24–35 months (APR = 1.86, 95% CI, 1.64–2.11, $p < 0.001$) and more than 35 months (APR = 1.59, 95% CI, 1.40–1.81, $p < 0.001$) compared to children aged less than 6 months in 2015. Girls have comparatively lower prevalence of anthropometric failure than boys in 2015 (APR = 0.87, 95% CI, 0.83–0.92,

$p < 0.001$). Birth weight was significantly associated with anthropometric failure in all surveys. In comparison with normal birth weight, the low birth weight children had higher prevalence of anthropometric failure in 2015 (APR = 1.65, 95% CI, 1.48–1.82, $p < 0.001$). In terms of diseases, both having diarrhea (APR = 1.12, 95% CI, 1.04–1.20, $p = 0.002$) and fever (APR = 1.08, 95% CI, 1.02–1.15, $p = 0.008$) were associated with higher prevalence of anthropometric failure in 2005, and in 2015 (APR = 1.07, 1.0–1.14, 95% CI, $p = 0.044$). Moreover, the prevalence of anthropometric failure were significantly higher for children who were born at home than those at health facilities in 2005 (APR = 1.16, 95% CI, 1.06–1.27, $p = 0.001$) (Table 4). Nevertheless, the sub-group analysis of children aged 6 to 23 months revealed that,

Table 5 Crude and adjusted association between dietary diversity and anthropometric failure among children of 6–23 months of age in Tanzanian Demographic and Health Surveys (2005–2015)

Variables	TDHS 2015 (N = 3070)			TDHS 2010 (N = 2207)			TDHS 2005 (N = 2399)		
	N (%)	Crude PR (95% CI)	Adjusted PR ^a (95% CI)	N (%)	Crude PR (95% CI)	Adjusted PR ^a (95% CI)	N (%)	Crude PR (95% CI)	Adjusted PR ^a (95% CI)
Dietary Diversity									
≥ 4 food groups	788 (25.6)	1.0	1.0	220 (10)	1.0	1.0	349 (14.5)	1.0	1.0
< 4 food groups	2282 (74.3)	1.11(0.99–1.24)	1.11(0.99–1.24)	1987 (90)	1.04(0.88–1.21)	1.05(0.89–1.22)	2050 (85.4)	1.05(0.92–1.19)	1.05(0.92–1.19)

a- Adjusted for gender, diarrhea, fever and place of residence; 1.0 = Reference category, CI = confidence interval; PR = Prevalence ratio

the consumption of a diversified diet was not associated with anthropometric failure ($p > 0.05$) in any survey as shown in Table 5.

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%, which is significantly higher compared to the prevalence reported by conventional indices of stunting (34.4%) wasting (4.5%) and underweight (13.6%) in 2015 [5]. 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 to 1.5% in 2015, it was reported in another study that these children have up to twelve times greater risk of early mortality [6]. Therefore, measurement of CIAF is very useful in the detection of children who are at higher risk of death associated with anthropometric failure.

This study further reports the existence of multiple factors influencing childhood undernutrition in Tanzania. Children, maternal, and household socio-economic factors were found to be associated with anthropometric failure in various years. In comparison, a recent study conducted by Sunguya et al. [4], which aimed to examine the trends and factors associated with stunting in Tanzania revealed the risk factors that are similar to this study. Clearly, interventions targeting anthropometric failure would therefore be important for stunting reduction, especially given the close relationship

between trends in prevalence of stunting and CIAF, as displayed in Fig. 1. Additionally, the datasets used and the number of children included by Sunguya et al. [4] are somewhat similar to this study. However, the study done by Sunguya et al. [4] may be suitable to inform interventions targeting at reduction of chronic undernutrition only, whereby, this study has the potential to ameliorate main drivers of all forms of undernutrition in the country.

In this study, anthropometric failure was strongly associated with characteristics of the household such as location, wealth status, and household head characteristics. This corresponds with findings 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 [33]. Our study found that children living in rural areas have more prevalence of anthropometric failure compared to urban 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 more likely to experience 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 [34]. Pomati et al. [35] analyzed 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 [4], and elsewhere [33]. 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 [36, 37]. In addition, access to health care services may also be limited in poor households compared to the rich ones.

We found that households headed by older parents are less likely to have 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 marriage, we found that single mothers are more likely to have children with anthropometric failure than for married mothers. This is because, in many cases in the country, single mothers have low socioeconomic status 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 married mothers. Therefore, 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. [38].

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, mother's nutritional status, birth weight of children, and place of delivery were associated with anthropometric failure in Tanzania. 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 prevalence of anthropometric failure than those born at a health facility. This corresponds with a cross-sectional studies in Tanzania [4] 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 [39]. We also found that low birth-weight have a strong positive relationship with anthropometric failure. This is comparable with findings from Sunguya et al. [4] 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 prevalence of anthropometric 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 [4, 22, 23]. This may be due to breastfeeding practice for the younger children, as it is well established that adequate nutrition received from breast milk is enough even when a mother is undernourished. Available evidences are showing that in many countries, complementary feeding is inadequate and termination of breastfeeding starts before 6 months. Young children below the age of 2 years have to receive a diversified and 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; previous analysis have shown that dietary diversity was independent 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]. The WHO has recommended that an infant should receive a minimum diet diversity of at least four food groups out of seven in order to maintain proper growth and development [30]. We found that the majority (~70%) have not reached this recommendation, which implies low diet quality and finally may lead to undernutrition. Nevertheless, this study found that boys have higher prevalence of anthropometric failure compared to girls. This is not unexpected, a study by Wamani et al. [40] conducted among sub-Saharan African countries found that male children under-5 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 [40].

We also found that childhood anthropometric failure is significantly associated with mother's educational attainment. Children of mothers who are more educated tend to have a lower prevalence of anthropometric failure than those of uneducated mothers. 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 results to higher socioeconomic status. Another reason could be that more educated mothers could understand maternal and childcare 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 have been well documented in several other studies [25, 41–43]. 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 burden and correlates of CIAF from the national representative data in Tanzania, some general limitations should be considered. 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 included in this study, 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 generalized.

Conclusion

One in every three under-five children are suffering from various forms of anthropometric failure in Tanzania. There is a decline in the overall burden of undernutrition in Tanzania as measured by CIAF. 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

APR: Adjusted prevalence ratio; BMI: Body mass index; CI: Confidence intervals; CIAF: Composite index of anthropometric failure; HAZ: Height-for-age Z-scores; ICF: Inner city funds; IYCF: Infant and young child feeding; MDD: Minimum dietary diversity; SD: Standard deviation; TDHS: Tanzania demographic and health survey; UNICEF: United Nations international children's fund; WAZ: Weight-for-age Z-scores; WHO: World health organization; WHZ: Weight-for-height Z-scores

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Authors' contributions

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. All authors have reviewed and approved last version of the manuscript.

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Availability of data and materials

Data for this study are available upon request from the DHS portal (www.dhsprogram.com).

Ethics approval and consent to participate

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 [2]. Since we only used secondary data, personal consents was not required, as well as no any personal identity being identified from the data files. The data were completely anonymous. We would like to acknowledge the ICF International (www.dhsprogram.com) to give us access to the dataset.

Consent for publication

Not applicable for this study.

Competing interests

The authors declare that there is no any conflict of interest.

Author details

¹Department of Epidemiology and Biostatistics, Muhimbili University of Health and Allied Sciences, Dar-es-Salaam, Tanzania. ²Department of Food Technology, Nutrition and Consumer Sciences, Sokoine University of Agriculture, Chuo Kikuu, Morogoro, Tanzania. ³School of Life Sciences and Bio-Engineering, Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania. ⁴Department of Environmental Health and Ecological Sciences, Ifakara Health Institute, Dar-es-Salaam, Tanzania.

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