RESEARCH ARTICLE

Nutritional status of children under five years old involved in a seasonal malaria chemoprevention study in the Nanyumbu and Masasi districts in Tanzania

Bruno P. Mmbando[1]*, Richard O. Mwaiswelo[2], Frank Chacky[3], Fabrizio Molteni[3], Ally Mohamed[3], Samwel Lazaro[3], Billy Ngasala[4]

1 National Institute for Medical Research, Tanga Centre, Tanga, Tanzania, 2 Department of Microbiology, Immunology and Parasitology, Hubert Kairuki Memorial University, Dar es Salaam, Tanzania, 3 National Malaria Control Programme, Ministry of Health, Dodoma, Tanzania, 4 Department of Parasitology and Medical Entomology, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania

* b.mmbando@yahoo.com

Abstract

Background

Malnutrition and malaria are common co-morbidities in low-income countries, especially among under-fives children. But the malnutrition situation in Masasi and Nanyumbu districts, its interaction with malaria infection and the influence of socioeconomic factors are not well understood.

Methods

Children aged between 3–59 months in Masasi and Nanyumbu were screened for nutritional status and malaria infection in the community. Nutritional status was determined using age and anthropometric parameters. Z-scores (weight for age (WAZ), height for age (HAZ) and weight for height (WHZ)) were calculated based on the World Health Organisation (WHO) growth reference curves. Malaria infection was determined using malaria rapid diagnostic test and microscopy. Hemoglobin concentration was assessed using HemoCue spectro-photometer, and anemia was classified as hemoglobin concentration < 11.0g/dL. Structured questionnaire was used to collect socio- demographic information electronically.

Results

A total of 2242 children, 1539 (68.6%) from Masasi and 1169 (52.1%) females were involved in the study. The mean z-scores (WAZ = -0.60 and HAZ = -1.56) were lower than the WHO reference population. The overall prevalence of malnutrition was 49%, and it was significantly higher in Nanyumbu (52.5%) than in Masasi (47.3%), ($x2 = 5.045$, $p = 0.025$). Prevalence of malnutrition was higher in boys (53.0%) than in girls (45.0%) ($x2 = 13.9$, $p < 0.001$). Stunting was the most prevalent component of undernutrition; it was slightly prevalent in Nanyumbu (46.5%) compared to Masasi (42.0%), ($x2 = 3.624$, $p = 0.057$) and in boys (48.2%) than in girls (39.1%), $x2 = 17.44$, $p<0.001$. Only 15.8% of the undernourished

children had malaria infection. Sex, age group and anaemia were significantly associated
with undernourishment (p<0.05), while district and malaria infection were marginally
(p≤0.06) associated with undernourishment. None of the undernutrition indices was associ-
ated with malaria infection.

Conclusion

Undernutrition was highly prevalent in the study population and was influenced sex, age,
anaemia and malaria infection. More emphasis is needed to address the malnutrition prob-
lem especially stunting in Masasi and Nanyumbu districts.

Background

Malnutrition and malaria are conditions of major global public health importance, affecting
especially under-five children [1–5]. Malnutrition and malaria independently contribute to a
substantial proportion of morbidity and mortality in the age group [6]. Malnutrition, has mul-
tiple causes including poverty, food insecurity, lack of diversity in diet, infections, poor access
to clean water and inadequate sanitation and hygiene [7]. Malaria, on the other hand, is an
infectious disease caused by *Plasmodium* parasites [8,9]. But the fundamental relationship
between malnutrition and malaria is complicated [4,6], as there is no consistent association
between them [6].

Malaria infections lead to individual energy loss with reduced productivity, and in a long
run lead to a spiral of malnutrition and poverty [10,11]. Metabolic activities of the parasite and
host also increase the demand for nutrients [10], and the disease accompanying clinical condi-
tions such as intestinal malabsorption and diarrhea perpetuate malnutrition [11]. Malnutrition
on the other hand, suppresses the immunity [10,11], and in severe cases both acquired and
innate immunity are impaired [10,12]. This immunodeficiency impairs ability to mount effec-
tive immune response [11–13] and also increases susceptibility to infections [10]. But whereas
some studies indicate malnutrition to increase susceptibility to malaria [14,15], others found
malaria to increase the risk of malnutrition [6], and other studies have found no association
between the two conditions [6], while others have found malnutrition to be protective against
malaria [6,16]. For instance, studies have found a significant increase in risk of malaria infec-
tion in stunted [1,3,17,18], but not in wasted [1,3], and underweight children [3]. Parasite den-
sity is also found to be higher in wasted than in stunted, underweight and normal children,
whereas clinical malaria is higher in stunted [1,19], and underweight children [1,12]. Anemia
prevalence is also higher in stunted and underweight children [14,19]. Undernutrition also
leads to poor malaria outcomes [20], including an increased death risk [21]. On the contrary,
other studies have found stunting [14,16,22], underweight [16,17,22,23], and wasting
[16,17,23] to have no association with increased risk of malaria infection. Instead, one study
has found a protective effect of stunting against *falciparum* malaria [13], although another
study found no protective effect of undernutrition against malaria [16]. Likewise, whereas one
study found malaria to have no effect on nutritional status [17], others have found the infec-
tion to predispose individuals to malnutrition [5,24]. However, the situation of malnutrition
in Masasi and Nanyumbu is not well known, and it is not clear how the two conditions interact
to influence one another in the districts.

Importantly, socioeconomic factors that influence malnutrition also influence malaria
infection. Indeed, these factors probably modulate the way the two conditions interact to the
extent that it is difficult to see a consistent association between them. For instance, studies

have found that living in rural areas and low economic status [3,5,15,25–27], lack of formal education of caregivers [3,15,28], gender of child especially male [1,3,5,15,26,27], source of water for domestic use and its distance [27,29], extended larger families [26], occupation of the mother [5,15,26,28], and floor of the house [25] to influence both malnutrition and malaria infection in under-five children. It is however not clear what are the socioeconomic factors influencing malnutrition that may modulate the interaction between malnutrition and malaria infection in Masasi and Nanyumbu districts. This study therefore, intended to assess the situation of malnutrition in under-five children in Masasi and Nanyumbu districts, how it interacts with malaria, and the influence of socioeconomic factors on the condition.

Material and methods

Study area

The study was conducted in Nanyumbu and Masasi districts, Mtwara region. Nanyumbu is divided into 14 wards and 89 villages, whereas Masasi is divided into 22 wards and 159 villages.

Nanyumbu has a total population of 166,277, and Masasi has 269,590. The districts had a projected population of 82,740 children aged 3–59 months in 2019, of which 31,564 were in Nanyumbu and 51,176 in Masasi district. Subsistence farming, petty trade, fishing, and small-scale mining are the major economic activities in both districts.

The districts have annual rainfall averaging 939mm and temperature of 25.4˚C. The rainy season is between January and April, and accounts for > 60% of the average annual rainfall. Both districts have high seasonal malaria transmissions where > 60% of cases occur between March and July. *P. falciparum* is the predominant malaria parasite, and *Anopheles arabiensis* the major vector. Insecticide treated bed-nets and, diagnosis and treatment with antimalarial drugs are the major malaria control measures in the area. The prevalence of stunting in children below 5 years of age in Tanzania is 31.8%, and severe stunting is 10.8%, whereas that of underweight is 14.6% [30]. Mtwara region has a stunting prevalence of 29.6%, and that of underweight is 10.7% [30]. The incidence rate of poverty ranges from 31–37% and 38–67% in Masasi and Nanyumbu district, respectively [31]. In Mtwara region the use of improved toilet facility not shared is at 21.5%, and that of shared is 5.8%, whereas that of unimproved toilet/public toilet is at 72.7% [30].

Study design

This was a community-based cross-sectional survey with wards used as sampling units. Health facilities nearest to the centroid of the selected wards were identified (index facilities) and the catchment population estimated. A study village(s) within the health facility catchment area was identified (index village(s) and demographic survey was carried out to determine the population structure and the number of possible study children. After that, malariometric, household socioeconomic, and nutritional surveys were conducted in all the selected villages.

Study population

Children aged 3–59 months were involved in the malariometric and nutritional surveys, where household heads were involved in the household survey. The inclusion criteria for malariometric and nutritional surveys also included living within the catchment area and willingness to participate in the study. The exclusion criteria were presence of severe illness, history of intake of antimalarial drug within the previous 30 days and being under cotrimoxazole prophylaxis [32].

Inclusion criteria for the household survey included living within the catchment area, willingness to participate in the study, and having a child who has participated in the malariometric and nutrition surveys. The head of the household was defined as a person who is perceived by household members to be the primary decision maker in the family, and the household was defined as individuals living together and taking meals from a common cooking facility [33]. In the absence of the head of the household, a responsible person above 18 years was interviewed.

Procedures

Malariometric and nutritional survey. The survey was carried out at the index health facilities whereby all the children of the required age were brought for clinical and laboratory assessments. The survey was conducted for three days at each ward.

Clinical assessment involved taking history of clinical symptoms, history of antimalarial drugs consumption within past 30 days, use of cotrimoxazole as prophylaxis, clinical examination including measurement of axillary temperature and anthropometric measurements. The anthropometric measurements including height/length, weight and mid upper arm circumference (MUAC) were recorded for each child by the same investigator using standard techniques. Height was recorded to the nearest 0.1 cm using anthropometric height rod. For children below 24 months of age, length was measured using infant-meter. Weight measurements were recorded to the nearest 100g using SECA electronic weighing scale. Repeated measurements were made for 20 children to periodically correct for the intra observer error. The z-scores (weight-for-age (WAZ), height-for-age (HAZ) and weight- for-height (WHZ)) were then calculated using the WHO2006 growth reference standards [34]. Nutritional statuses were defined as underweight if WAZ < - 2 standard deviation (SD), stunting if HAZ < -2SD, wasting if WHZ < -2SD or MUAC < 115, thin if BAZ < -2SD and obese if BAZ >2SD. A child was considered undernourished if either was stunted, wasted or underweight [34].

Laboratory assessment involved collection of finger-prick blood samples that were used to determine presence of malaria infection using malaria rapid diagnostic test (mRDT), prepare thick film for microscopy to assess density of asexual parasitemia and gametocytemia, and thin film for asexual parasite species determination. The blood samples were also used to measure haemoglobin concentration.

Thin films were fixed using methanol. Both thin and thick films were air-dried, stained using 3% Giemsa stain for 1 hour, and examined for malaria parasites at 100 high power fields under immersion oil. Parasitemia was determined by counting the number of parasites present per 200 white blood cells (WBC) on a thick smear, and the number obtained was multiplied by 40 assuming a WBC count of 8,000 per milliliter of blood. If no parasite was seen after examining 100 fields, then a blood slide was considered negative. Two independent laboratory technicians who were unaware of the mRDT results read the slides. In case of a discrepancy (positive versus negative or a difference in parasite density greater than 30%), a third reading was requested and the average parasite density of two or three readings was used. Microscopists at the National Institute for Medical Research (NIMR) read 10% of the slides for quality control.

A portable spectrophotometer, HemoCue Hb 301+ (HemoCue AB, Ängelholm Sweden) with a precision of +/- 0.3g/dL was used to measure hemoglobin concentration. The HemoCue was calibrated every morning using a control cuvette at 16.0+/-0.3g/dL according to manufacturer's instruction. Anaemia was classified as hemoglobin level < 11g/dL [35].

Socioeconomic survey

It was carried out in catchment villages of the selected wards. Community health workers (CHWs) conducted the household survey using a structured questionnaire with both close and

open ended questions. The questionnaire inquired information on demographic characteristics of the household, socioeconomic status including building materials used in the main house (type of roof, type of window, type of floor, type of walls), occupation of head of household and household assets such as ownership of radio, bicycle and mobile phone, ratio of number of sleeping bedrooms to number of household dwellers, type and number of animals, source of power for lighting and cooking, and size of cultivated land owned by the family. These variables were selected as a proxy for socio-economic status because is difficult to obtain household income data [36].

Study outcomes

The primary outcome was the prevalence of malnutrition in under-five children surveyed. Secondary outcomes include: i) prevalence of any indicator of malnutrition, ii) prevalence of malaria infection, iii) prevalence of anaemia defined as a haemoglobin concentration of less than 11g/dL, (iv) prevalence of socioeconomic factors influencing malaria transmission and malnutrition.

Ethical consideration

The study was conducted in accordance with the declaration of Helsinki, good clinical practices, and regulations in Tanzania. The approval was obtained from the ethics committee of the Muhimbili University of Health and Allied Sciences with ethical clearance no: MUHAS-REC-10-2019-062. Members of the study team held meetings with community, administrative, and religious leaders to explain the aims and activities of the study and sought community approval. Project CHWs then visited the households to explain the aim of the study, provided information sheets, and sought signed consent from parents or guardians of the children who were involved in the survey. The caregivers also provided the consent to participate in the socioeconomic survey.

Statistical analysis

This was a baseline survey for seasonal malaria chemoprevention (SMC) study, thus sample size calculation was based on the estimations made for SMC, and is presented elsewhere [37].

Briefly, a samples size of 120 children in each of 20 wards selected was anticipated to provide a power of 80% and an alpha (type one error) of 0.05 with an attrition rate of 20% in explaining the variation of malaria incidence between the two districts. All the households with child/children were invited to participate in the socioeconomic status (SES) survey. Principal component analysis was used to estimate the scores for the socio-economic status of the households using household characteristics and assets. The SES scores of the first principal component were categorized into three groups of percentiles (low [0-39th], medium [40th-79th] and high SES [80th-100th]) for easy interpretation of results [36].

Data were collected electronically in open data kit (ODK) software using tablets computers. Spatial data (point coordinates for households and other features from the study areas) were collected during the household visit using Global Positioning System (GPS). Quality control and assurance of the data were maintained at all stages of data collection to archiving. Data were cleaned and analysed using STATA version 13 statistical packages. Categorical variables were presented in proportions and compared using $\chi2$-tests while continuous variables were summarised as medians with associated range of inter-quartile range (IQR), means with standard deviations and 95% confidence intervals (95%CI). For continuous variables which were non-normal distributed, medians were compared using Wilcoxon rank-sum test while for normal distributed continuous variables, means were compared using t-test. A $\chi2$-test was also

used to assess the trend of continuous and categorical variables. Logistic regression analysis was used to assess the association between binary response variables (such as malnutrition indices) and risk factors in a univariate and multivariate models. Only variables that had a p-value <0.1 were included in the multivariable model. Variance inflation factor (VIF) was used to assess for multi-collinearity of independent variables, where a VIF<5 was considered a moderate correlation not requiring intervention. R-squared was used to assess how best the regression model fitted the data. A *p*-value < 0.05 was considered statistically significant.

Results

Baseline demographic and anthropometric characteristics

A total of 2242 children with median age of 27 months (range: 3.0–59.9) were involved in the study. 1539 (68.6%) of the study participants came from Masasi and 1169 (52.1%) of them were females. The baseline characteristics of the children are presented in Table 1 and supplementary data (S1). Compared to the WHO standard, children from the study area had higher BMI-for-age and weight-for-height but lower mean weight-for-age and height-for-age. Of the recruited children 48.9% (1064/2178) were undernourished. A significant proportion of children in Nanyumbu district (52.5%, 348/663) were undernourished compared to those in Masasi (47.3% (716/1515), ($x2$ = 5.045, p = 0.025).

Relationship between anthropometric characteristics and gender

The relationship between anthropometric characteristics and the sex of the children is presented in Table 2. Overall, boys were significantly undernourished than girls. The prevalence of stunting and obesity was also significantly higher in boys than girls.

Table 1. Demographic and anthropometric characteristics of the study population by district.

Variable	Overall	Masasi	Nanyumbu	Test, *p*-value
Female sex, n (%)	1169 (52.1)	820 (53.3)	349 (49.6)	2.60[δ], 0.110
Median age in years, (IQR)	2.32 (1.31–3.5)	2.25 (1.17–3.42)	2.25 (1.25–3.42)	-0.206[α], 0.837
Mean weight, kg (SD)	11.42 (3.10)	11.47 (3.17)	11.31 (2.94)	1.1[β], 0.267
Mean height, cm (SD)	81.97 (13.08)	82.20 (12.92)	81.46 (13.45)	1.25[β], 0.212
MUAC (SD)	146.16 (12.52)	144.48 (12.89)	149.84 (10.81)	-9.592[β], <0.001*
Mean BMI-for-age, (SD)	0.60 (1.60)	0.60 (1.55)	0.62 (1.69)	-0.243[β], 0.808
Mean WAZ, (SD)	-0.60 (1.19)	-0.60 (1.23)	-0.66 (1.11)	1.56[β], 0.119
Mean HAZ, (SD)	-1.56 (1.54)	-1.521 (1.54)	-1.64 (1.54)	1.83[β], 0.067
Mean WHZ, (SD)	0.21 (1.38)	0.231 (1.37)	0.154 (1.40)	1.232[β], 0.218
Underweight [WAZ< -2SD], n (%)	239 (11.1)	169 (11.30)	70 (10.6)	0.217[δ], 0.641
Stunted [HAZ< -2SD], n (%)	900 (43.4)	608 (42.0)	292 (46.5)	3.624[δ], 0.057
Wasted [WHZ< -2SD/ MUAC<115], n (%)	142 (7.4)	92 (6.8)	50 (8.9)	2.572[δ], 0.109
Stunted and Wasted, n (%)	26 (1.2)	17 (1.1)	9 (1.3)	0.130[δ], 0.719
Thin [BAZ< -2SD], n (%)	129 (6.1)	85 (5.8)	44 (6.9)	0.901[δ], 0.343
Undernourished, n (%)	1064 (48.9)	716 (47.4)	348 (52.5)	5.045[δ], 0.025*
Obese, n (%)	405 (19.3)	259 (17.7)	146 (22.8)	7.61[δ], 0.006*

Δ: *X2*-test

α: Wilcoxon rank-sum-test

β: *t*-test

*significant at p<0.05.

https://doi.org/10.1371/journal.pone.0267670.t001

Table 2. Anthropometric characteristics in relation to the sex of study children.

Variable	Overall	Male	Female	Test, p-value
Mean weight, kg (SD)	11.42 (3.10)	11.57 (2.94)	11.28 (3.23)	2.19^{β}, 0.028*
Mean height, cm (SD)	81.97 (13.08)	81.81 (12.62)	82.12 (13.50)	-0.56^{β}, 0.576
Mean MUAC	146.16 (12.52)	146.74,(11.87)	145.62 (13.10)	2.11^{β}, 0.035*
Mean BMI for age, (SD)	0.60 (1.60)	0.71 (1.62)	0.50 (1.58)	3.11^{β}, 0.002*
Mean weight-for-age, (SD)	-0.60 (1.19)	-0.64 (1.20)	-0.57 (1.18)	-1.38^{β}, 0.166
Mean height-for-age, (SD)	-1.56 (1.54)	-1.64 (1.56)	-1.48 (1.51)	-2.59^{β}, 0.010*
Mean weight-for-height, (SD)	0.21 (1.38)	0.29 (1.43)	0.13 (1.34)	2.73^{β}, 0.006*
Stunted, n (%)	900 (43.4)	468 (48.2)	432 (39.1)	17.44^{δ}, <0.001*
Wasted, n (%)	142 (7.4)	65 (7.0)	77 (7.8)	0.426^{δ}, 0.514
Underweight, n (%)	239 (11.1)	122 (11.9)	117 (10.4)	1.20^{δ}, 0.273
Stunted and Wasted, n (%)	26 (1.2)	11 (1.0)	15 (1.3)	0.33^{δ}, 0.569
Thin, n (%)	129 (6.1)	62 (6.2)	67 (6.1)	0.02^{δ}, 0.887
Obese, n (%)	405 (19.3)	221 (22.1)	184 (16.7)	10.174^{δ}, 0.001*
Undernourished, n (%)	1064 (48.9)	550 (53.0)	514 (45.0)	13.878^{δ}, <0.001*

β: t-test

δ: $x2$-test

*significant at p<0.05.

Conversely, severe stunting, severe wasting and severe underweight occurred in 18.8% (391/2077), 2.6% (49/1917), 2.9% (63/2157) of the children. With the exception of severe stunting ($x2 = 21.6$, <0.001), the prevalence of severe wasting ($x2 = 3.01$, $p = 0.39$) and severe underweight ($x2 = 2.52$, 0.47) was not significantly different between boys and girls.

Relationship between nutritional indices and age of children

Table 3 presents the relationship between nutritional indices and age groups of the children. The prevalence of stunting was highest among children aged 1 year, whereas that of wasting, thinness and obesity was highest in those aged less than 1 year, while that of underweight was highest in those aged 4 years. The trend of prevalence of stunting (trend $x2 = 53.86$, $p<0.001$), wasting (trend $x2 = 36.53$, $p<0.001$), thinness (trend $x2 = 14.42$, $p = 0.006$) and obesity (trend $x2 = 69.11$, $p<0.001$) was decreasing significantly with an increasing age, whereas that of underweight (trend $x2 = 11.43$, $p = 0.022$) was increasing with increasing age. It was interesting to note that underweight and obesity had linear relationship with age; the increase in age was associated with the increase in the risk of underweight and vice versa for the obesity, Fig 1. Contrarily, stunted, wasted and thin showed quadratic relation with age, whereby while the

Table 3. Nutritional characteristics of the study population in relation to age groups.

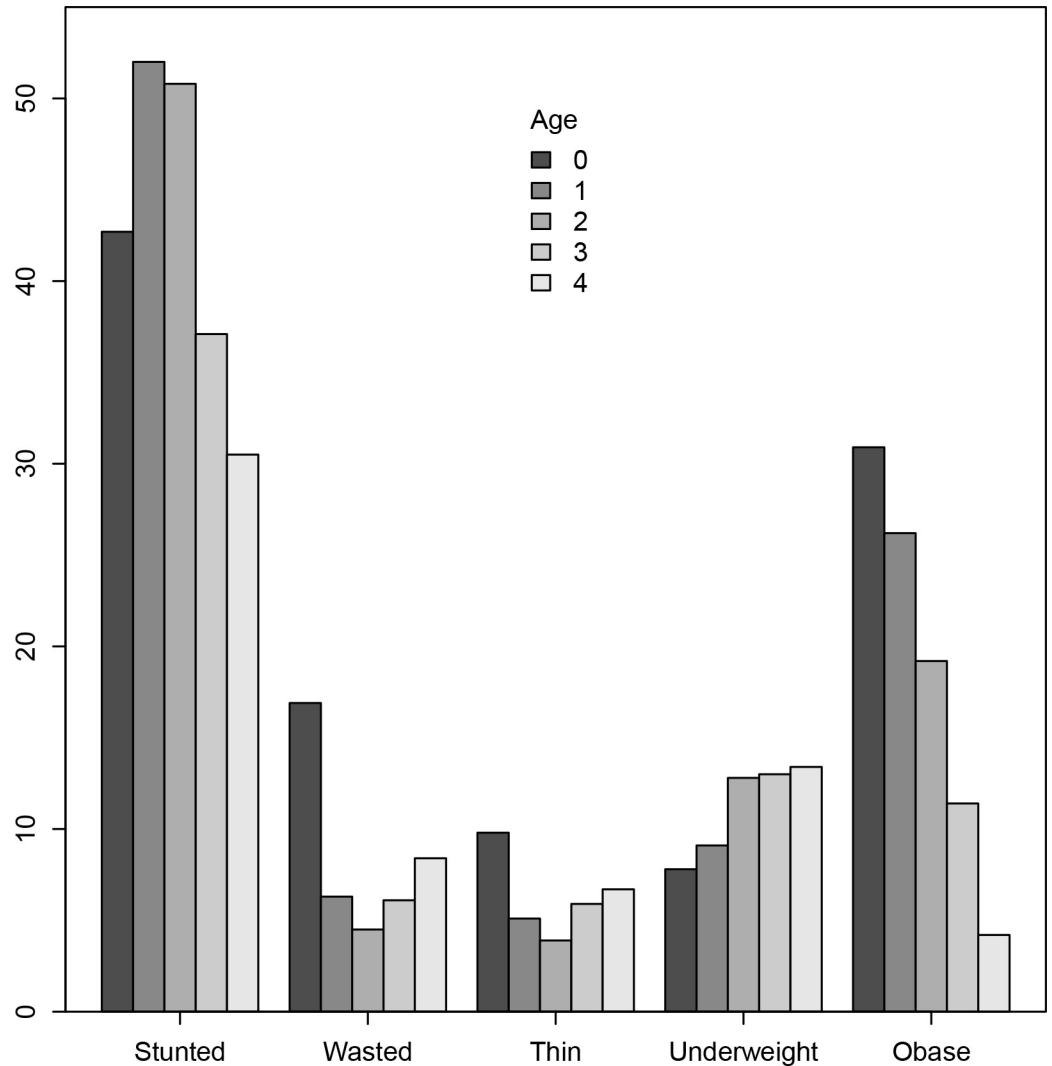| Age group	Nutritional characteristic				
	Stunted, n(%)	Wasted, n (%)	Underweight, n (%)	Thin, n (%)	Obese, n (%)
0	172 (42.7)	37 (16.9)	33 (7.8)	39 (9.8)	130(30.9)
1	245 (52.0)	30 (6.3)	45 (9.1)	25 (5.1)	127 (26.2)
2	229 (50.8)	21 (4.5)	60 (12.8)	18 (3.9)	87 (19.2)
3	150 (37.1)	25 (6.1)	54 (13.0)	24 (5.9)	47 (11.4)
4	104 (30.5)	29 (8.4)	47 (13.4)	23 (6.7)	14 (4.2)
$x^2_{(4d.f.)}$, p-value	53.86, <0.001	36.53, <0.001	11.43, 0.022	14.42, 0.006	116.39, <0.001

Fig 1. Nutritional characteristics of the study population in relation to age groups.

risk of stunted was elevated at the age of 1–2 years, the risk of being wasted and thin was lowest at the age of two years, Fig 1.

Relationship between nutritional status and malaria infection

Fourteen percent (312/2179) of the children had malaria infection. Only 15.8% (168/1064) of the undernourished children had malaria infection. The relationship between nutritional status and malaria infection is presented in Table 4. None of the nutritional indices was significantly associated with malaria infection in the study population ($p > 0.05$), although children who were wasted (10.1% vs. 6.9%, $p = 0.06$) and thin (8.5 vs. 5.7, $p = 0.06$) had slightly higher risk of malaria infection.

Relationship between socio-demographic factors and undernourishment

In a univariate analysis district, sex of the children, age group anaemia and malaria were the factors found to be associated with undernourishment. The multivariate analysis on the other

Table 4. Nutritional status in relation to malaria infection.

Nutritional status	Malaria infection status		$x2$-test, p-value
	mRDT positive, n (%)	mRDT negative, n (%)	
Stunted	135 (45.8)	767 (42.9)	0.81, 0.370
Wasted	29 (10.1)	113 (6.9)	3.58, 0.058
Stunted and wasted	7 (2.1)	23 (1.4)	0.78, 0.378
Underweight	40 (12.9)	199 (10.8)	1.22, 0.269
Thin	26 (8.5)	103 (5.7)	3.54, 0.06
Obese	58 (14.3)	247 (14.5)	0.01, 0.908
Undernourished, n (%)	168 (53.8)	896 (48.0)	3.63, 0.057

https://doi.org/10.1371/journal.pone.0267670.t004

hand indicated sex, age group and anaemia were significantly associated with undernourishment (p<0.05), while district and malaria infection were marginally (p≤0.06) associated with undernourishment. The relationship between socio-demographic factors and undernourishment is presented in Table 5.

Discussion

Malnutrition and malaria are among the major public health challenges in Tanzania. This study assessed the situation of malnutrition among underfive children in Masasi and Nanyumbu districts, its interaction with malaria infection and how it is influenced by socio-economic factors. Nearly half of the recruited children were undernourished. Similar high prevalence of undernutrition has been reported in Cameroon [15,38]. The prevalence of undernutrition was significantly higher in Nanyumbu than Masasi district. Of the undernutrition indices stunting was the most prevalent, and it was significantly more prevalent in Nanyumbu than Masasi district. Higher prevalence of stunting has also been reported in other parts of Tanzania [38,39], and in other countries [3,15,25,34]. The prevalence of stunting in this study population was however much higher than the national average of 31.8% reported in 2018 [30]. Other indices namely wasting and thinness were more prevalent in Nanyumbu district, however underweight was more prevalent in Masasi district. On the other hand boys were more undernourished than girls, a finding similar to that reported in Nigeria [3]. In addition, stunting was significantly more prevalent in boys than girls. Studies in other parts of Tanzania [39,40], and in Cameroon [1], have also indicated higher prevalence of stunting in males than in females. It is not clear why in this study more males were undernourished and stunted than females. However, other studies have linked it with more boys given complementary food than girls [38,41], early weaning for boys [38,42], and children behavior where girls might stay closer to home than boys and have more access to food being cooked [43]. Severe stunting occurred in about 19% of the children, whereas severe wasting and severe underweight occurred only in 2.6% and 2.9% of the children, respectively. The prevalence of severe stunting in this study population was much less than that reported in other parts of Tanzania [38], but was nearly four times higher than that reported in Nigeria [1] and Ghana [12]. Presence of severe stunting in a population is a cause of concern since it indicates chronic malnutrition, and results from poor nutrition in early childhood that leads to failure to grow both physically and mentally [12,14]. Proper nutrition is crucial for enhancing brain function and improving learning [44]. Childhood with early-onset persistent stunting can have long-term effects on mental development, academic performance, economic productivity in adulthood and maternal reproductive outcomes [43,45,46]. On the other hand, other undernutrition indices including wasting, underweight and thinness were not significantly different between genders.

Table 5. Relationship between socioeconomic factors and undernutrition using logistic regression models.

Variable	Univariate	Multivariate*
	OR (95%CI), *p*-value	aOR (95%CI), *p*-value
District—Masasi	1	1
• Nanyumbu	1.25 (1.05–1.5), 0.014	1.20 (0.99–1.44), 0.062
Sex of child–Male	1	1
• Female	0.72 (0.61–0.85), <0.001	0.75 (0.63–0.89), 0.001
Number of people: 1–5	1	
• More than 5	1.10 (0.86–1.4), 0.451	
Number of <5 children: One	1	
• More than one	1.08 (0.83–1.41), 0.56	
Marital status of household head		
• Single	1	
• Couple	0.84 (0.67–1.05), 0.125	
• Others	0.97 (0.60–1.5), 0.902	
Education of head: Secondary	1	
• None	1.09 (0.68–1.74), 0.727	
• Primary	1.20 (0.85–1.70), 0.307	
Occupation of head: Farmers	1	
• Petty trader	0.79 (0.52–1.19), 0.257	
Household SES of score category		
Upper [80th -100th]	1	
Low [0-39th]	1.03 (0.78–1.36), 0.84	
Middle [40th-79th]	0.96 (0.73–1.27), 0.764	
Age group of children (years)		
• 4	1	
• 0	1.72 (1.30–2.29), <0.001	1.63 (1.20–2.21), 0.002
• 1	2.20 (1.66–2.90), <0.001	2.17 (1.61–2.92), <0.001
• 2	1.91 (1.44–2.53), <0.001	1.87 (1.39–2.50), <0.001
• 3	1.31 (0.98–1.75), 0.069	1.32 (0.98–1.79), 0.066
Anaemia in children: Normal	1	1
• Anemic	1.45 (1.22–1.73), <0.001	1.22 (1.01–1.47), 0.039
mRDT negative	1	1
• mRDT positive	1.26 (1.01–1.58), 0.044	1.26 (0.99–1.59), 0.058

OR: Odds ratio

aOR: Adjusted odds ratio

CI: Confidence Interval

*Mean VIF = 1.63, range (1.25–2.45).

https://doi.org/10.1371/journal.pone.0267670.t005

Contrary to the findings in this study, a study in Rwanda has found underweight to be more prevalent in males [25].

Stunting was highest in 1 year old age group followed by 2 years old group, whereas wasting, thinness and obesity were highest among children aged less than 1 year group, and underweight was highest among children in 4 years age group. Similar findings have been reported in other countries [3,24] However, whereas stunting, wasting, thinness and obesity were decreasing with increasing age, underweight was increasing with increasing age. The variation in prevalence of undernutrition indices with age groups may be explained by the availability of nutrients at these different stages. As infants grow especially around 1 year old the nutrients

obtained from breast milk becomes inadequate, whereas during weaning the infants fail to eat adequately, and also probably the alternative foods may not have adequate nutrients thus predisposing them to stunting. Inadequate nutrients may also lead to underweight, and if continues may lead to the increased prevalence of underweight and decreasing prevalence of obesity with increasing age. On the other hand, as the child grow and start to adopt to weaning foods they get enough nutrients to support their growth, and this may explain the decreasing prevalence of stunting, wasting and thinness with increasing age.

Only about 16% of the undernourished children had malaria infection. Furthermore, all the malnutrition indices including stunting, wasting, underweight and obesity had no association with malaria infection. Similar to the findings in this study, other studies have also found stunting [14,16,22], underweight [16,17,22,23], and wasting [16,17,23] to have no association with malaria infection. Nevertheless, some studies have found a significant association between stunting [1,3,17,18] and underweight [1,12] on one hand with malaria infection on the other hand. However, intriguingly although not statistically significantly different to the none-undernourished children, more than half of the malaria infected children were also undernourished. Furthermore, whereas in the univariate analysis malaria infection was not associated with undernutrition, in the multivariate analysis the infection was statistically significantly associated with undernutrition. A strong association between undernutrition and malaria infection has also been reported in other studies [5,15,24], with some studies indicating undernutrition to increase susceptibility to malaria infection [14,15], whereas others found malaria to increases the risk of malnutrition [6]. However, other studies have indicated lack of association between malaria infection and undernutrition [17,25,47]. Undernutrition suppresses the body immunity [10–12], therefore, increasing the risk of infection including malaria [14,15]. Likewise, malaria infection leads to individual energy loss with reduced productivity, and in a long run leads to a spiral of malnutrition, infections and poverty [10,11].

In the study districts especially Nanyumbu, male gender, age group of children below 3 years and anaemia were the only other factors associated with malnutrition. Other studies have also found male gender [1,3,15,26,27] location, age group and anaemia to be associated with malnutrition [1]. However, in this study other factors including household income level, caregiver education level, caregiver marital status, number of household occupants and household number of underfive children were not associated with undernutrition. Similar findings have been reported in another study [24]. Contrary to the findings in this study, other studies have found low household level of income [3,5,15,25–28], lack of formal education of caregivers [3,15,28], source of water for domestic use and its distance [27,29], extended larger families [26], and occupation of the mother [5,15,26,28] to influence malnutrition in underfive children. This clearly shows that the level of influence the socioeconomic factors impose on malnutrition varies from one setting to another, probably also indicating that other factors than socioeconomic are influencing the occurrence of malnutrition.

Conclusion

Undernutrition was highly prevalent in the study population and was influenced by sex, age, anaemia and malaria infection. More emphasis is needed to address the malnutrition problem especially stunting in Masasi and Nanyumbu districts.

Supporting information

S1 File. Anthropometric measurements by age and sex.
(XLS)

Acknowledgments

The authors extend their appreciation to the children and parents/guardians for participating in the study. Authors would also like to extend their appreciation to the local authorities for their support in all the steps of this study.

Author Contributions

References

1. Sumbele IUN, Bopda OSM, Kimbi HK, Ning TR, Nkuo-Akenji T. Nutritional status of children in a malaria meso endemic area: Cross sectional study on prevalence, intensity, predictors, influence on malaria parasitaemia and anaemia severity. BMC Public Health. 2015; 15. https://doi.org/10.1186/s12889-015-2462-2 PMID: 26541669

2. Sousa-Figueiredo JC, Gamboa D, Pedro JM, Fançony C, Langa AJ, Magalhães RJS, et al. Epidemiology of malaria, schistosomiasis, geohelminths, anemia and malnutrition in the context of a demographic surveillance system in northern Angola. PLoS One. 2012; 7. https://doi.org/10.1371/journal.pone.0033189 PMID: 22493664

3. Mann DM, Swahn MH, McCool S. Undernutrition and malaria among under-five children: findings from the 2018 Nigeria demographic and health survey. Pathog Glob Health. 2021; e1916729. https://doi.org/10.1080/20477724.2021.1916729 PMID: 33944705

4. Teh RN, Sumbele IUN, Meduke DN, Ojong ST, Kimbi HK. Malaria parasitaemia, anaemia and malnutrition in children less than 15 years residing in different altitudes along the slope of Mount Cameroon: Prevalence, intensity and risk factors 11 Medical and Health Sciences 1117 Public Health and Health Services. Malar J. 2018; 17. https://doi.org/10.1186/s12936-018-2492-1 PMID: 30249261

5. Gone T, Lemango F, Eliso E, Yohannes S, Yohannes T. The association between malaria and malnutrition among under-five children in Shashogo District, Southern Ethiopia: A case-control study. Infect Dis Poverty. 2017; 6. https://doi.org/10.1186/s40249-016-0221-y PMID: 28081711

6. Debashish D, Grais R, Emelda O, Kasia S, Rashid M, Saskia van der K, et al. Complex and vicious interactions between malaria and malnutrition: a systematic review. BMC Med. 2018; 16.

7. FAO, IFAD, UNICEF, WFP and WHO 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. The State of Food Security and Nutrition in the World 2020. Rome: Food and Agriculture Organization; 2017. https://doi.org/10.4060/ca9692en

8. WHO. World malaria report 2020. Geneva: World Health Organization; 2020.

9. WHO. World malaria report 2019. Geneva; 2019.

10. Schaible UE, Kaufmann SHE. Malnutrition and infection: Complex mechanisms and global impacts. PLoS Med. 2007; 4: e115. https://doi.org/10.1371/journal.pmed.0040115 PMID: 17472433

11. Scrimshaw NS, SanGiovanni JP. Synergism of nutrition, infection, and immunity: An overview. Am J Clin Nutr. 1997; 66. https://doi.org/10.1093/ajcn/66.2.464S PMID: 9250134

12. Ehrhardt S, Burchard GO, Mantel C, Cramer JP, Kaiser S, Kubo M, et al. Malaria, anemia, and malnutrition in African children—Defining intervention priorities. J Infect Dis. 2006; 194: 108–114. https://doi.org/10.1086/504688 PMID: 16741889

13. Genton B, Al-Yaman F, Ginny M, Taraika J, Alpers MP. Relation of anthropometry to malaria morbidity and immunity in Papua New Guinean children. Am J Clin Nutr. 1998; 68: 734–741. https://doi.org/10.1093/ajcn/68.3.734 PMID: 9734755

14. Wilson AL, Bradley J, Kandeh B, Salami K, D'Alessandro U, Pinder M, et al. Is chronic malnutrition associated with an increase in malaria incidence? A cohort study in children aged under 5 years in rural Gambia. Parasites and Vectors. 2018; 11. https://doi.org/10.1186/s13071-018-3026-y PMID: 30081945

15. Sakwe N, Bigoga J, Ngondi J, Njeambosay B, Esemu L, Kouambeng C, et al. Relationship between malaria, anaemia, nutritional and socio-economic status amongst under-ten children, in the North Region of Cameroon: A cross-sectional assessment. PLoS One. 2019; 14: 0218442. https://doi.org/10.1371/journal.pone.0218442 PMID: 31226133

16. Snow RW, Byass P, Shenton FC, Greenwood BM. The relationship between anthropometric measurements and measurements of iron status and susceptibility to malaria in Gambian children. Trans R Soc Trop Med Hyg. 1991; 85: 584–589. https://doi.org/10.1016/0035-9203(91)90351-x PMID: 1780980

17. Deen JL, Walraven GEL, von Seidlein L. Increased risk for malaria in chronically malnuurished children under 5 years of age in rural gambia. J Trop Pediatr. 2002; 48: 78–83. https://doi.org/10.1093/tropej/48.2.78 PMID: 12022433

18. Kang H, Kreuels B, Adjei O, Krumkamp R, May J, Small DS. The causal effect of malaria on stunting: A Mendelian randomization and matching approach. Int J Epidemiol. 2013; 42: 1390–1398. https://doi.org/10.1093/ije/dyt116 PMID: 23925429

19. Friedman JF, Kwena AM, Mirel LB, Kariuki SK, Terlouw DJ, Phillips-Howard PA, et al. Malaria and nutritional status among pre-school children: Results from cross-sectional surveys in western Kenya. Am J Trop Med Hyg. 2005; 73: 698–704. https://doi.org/10.4269/ajtmh.2005.73.698 PMID: 16222012

20. Olumese PE, Sodeinde O, Ademowo OG, Walker O. Protein energy malnutrition and cerebral malaria in Nigerian children. J Trop Pediatr. 1997; 43: 217–219. https://doi.org/10.1093/tropej/43.4.217 PMID: 9283124

21. Müller O, Garenne M, Kouyaté B, Becher H. The association between protein-energy malnutrition, malaria morbidity and all-cause mortality in West African children. Trop Med Int Heal. 2003; 8: 507–511. https://doi.org/10.1046/j.1365-3156.2003.01043.x PMID: 12791055

22. Donovan C V., McElroy P, Adair L, Pence BW, Oloo AJ, Lal A, et al. Association of malnutrition with subsequent malaria parasitemia among children younger than three years in Kenya: A secondary data analysis of the Asembo Bay cohort study. Am J Trop Med Hyg. 2021; 104: 243–254. https://doi.org/10.4269/ajtmh.20-0002 PMID: 33200723

23. Deribew A, Alemseged F, Tessema F, Sena L, Birhanu Z, Zeynudin A, et al. Malaria and under-nutrition: A community based study among under-five children at risk of malaria, South-West Ethiopia. PLoS One. 2010; 5: e10775. https://doi.org/10.1371/journal.pone.0010775 PMID: 20505829

24. Gari T, Loha E, Deressa W, Solomon T, Lindtjørn B. Malaria increased the risk of stunting and wasting among young children in Ethiopia: Results of a cohort study. PLoS One. 2018; 13: e0190983. https://doi.org/10.1371/journal.pone.0190983 PMID: 29324840

25. Kateera F, Ingabire CM, Hakizimana E, Kalinda P, Mens PF, Grobusch MP, et al. Malaria, anaemia and under-nutrition: Three frequently co-existing conditions among preschool children in rural Rwanda. Malar J. 2015; 14. https://doi.org/10.1186/s12936-015-0973-z PMID: 26542672

26. Abdulla MM. Assessment and Determinants of Nutritional Status in a Sample of Under Five-Year-Old Iraqi Children. Eur J Biol Med Sci Res. 2016; 4.

27. Awosolu OB, Yahaya ZS, Farah Haziqah MT, Simon-Oke IA, Fakunle C. A cross-sectional study of the prevalence, density, and risk factors associated with malaria transmission in urban communities of Ibadan, Southwestern Nigeria. Heliyon. 2021; 7: e05975. https://doi.org/10.1016/j.heliyon.2021.e05975 PMID: 33521357

28. Ong'echa JM, Keller CC, Were T, Ouma C, Otieno RO, Landis-Lewis Z, et al. Parasitemia, anemia, and malarial anemia in infants and young children in a rural holoendemic Plasmodium falciparum transmission area. Am J Trop Med Hyg. 2006; 74: 376–385. https://doi.org/10.4269/ajtmh.2006.74.376 PMID: 16525094

29. Ayele DG, Zewotir TT, Mwambi HG. Prevalence and risk factors of malaria in Ethiopia. Malar J. 2012; 11. https://doi.org/10.1186/1475-2875-11-195 PMID: 22691364

30. TNNS. Tanzania National Nutrition Survey 2018. Tanzania Natl Nutr Surv. Dodoma, Tanzania; 2018.

31. WB. Tanzania Mainland Poverty Assessment. Tanzania Mainl Poverty Assesment. Washington; 2019.

32. WHO. Methods for surveillance of antimalarial drug efficacy. World Heal Organ. 2009.

33. Mazigo HD, Obasy E, Mauka W, Manyiri P, Zinga M, Kweka EJ, et al. Knowledge, Attitudes, and Practices about Malaria and Its Control in Rural Northwest Tanzania. Malar Res Treat. 2010; 2010. https://doi.org/10.4061/2010/794261 PMID: 22332023

34. Organization WH, others. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. World Health Organization; 2006.

35. World Health Organisation, WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Geneva, Switz World Heal Organ. 2011.

36. Vyas S, Kumaranayake L. Constructing socio-economic status indices: How to use principal components analysis. Health Policy Plan. 2006; 21. https://doi.org/10.1093/heapol/czl029 PMID: 17030551

37. Mwaiswelo RO, Mmbando BP, Chacky F, Molteni F, Mohamed A, Lazaro S, et al. Malaria infection and anemia status in under-five children from Southern Tanzania where seasonal malaria chemoprevention is being implemented. PLoS One. 2021; 16. https://doi.org/10.1371/journal.pone.0260785 PMID: 34855878

38. Nkuo-Akenji TK, Sumbele I, Mankah E, Njunda A, Samje M, Kamga L. The burden of malaria and malnutrition among children less than 14 years of age in a rural village of Cameroon. African J Food Agric Nutr Dev. 2008; 8: 291–303.

39. Chirande L, Charwe D, Mbwana H, Victor R, Kimboka S, Issaka AI, et al. Determinants of stunting and severe stunting among under-fives in Tanzania: evidence from the 2010 cross-sectional household survey. BMC Pediatr. 2015; 15. https://doi.org/10.1186/s12887-015-0482-9 PMID: 26489405

40. Tshiya Y, Magoha H. Prevalence and Risk Factors of Malnutrition among Children of Ages 6 to 59 Months in Manyovu, Buhigwe District Kigoma-Tanzania. J Food Nutr Res. 2020; 8: 320–328. https://doi.org/10.12691/jfnr-8-7-3

41. Kamugisha MI, Crawford N, Savaeli Z, Msangeni H, Massaga JJ, Mmbando BP, et al. Malaria and nutritional status in children living in the East Usambara. Tanzan J Health Res. 2005; 8: 56–61. https://doi.org/10.4314/thrb.v8i2.14273

42. Bork KA, Diallo A. Boys are more stunted than girls from early infancy to 3 years of age in rural senegal. J Nutr. 2017; 147: 940–947. https://doi.org/10.3945/jn.116.243246 PMID: 28298540

43. Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, et al. Boys are more likely to be undernourished than girls: A systematic review and meta-analysis of sex differences in undernutrition. BMJ Glob Heal. 2020; 5: 1–17. https://doi.org/10.1136/bmjgh-2020-004030 PMID: 33328202

44. Ekholuenetale M, Barrow A, Ekholuenetale CE, Tudeme G. Impact of stunting on early childhood cognitive development in Benin: evidence from Demographic and Health Survey. Egypt Pediatr Assoc Gaz. 2020; 68. https://doi.org/10.1186/s43054-020-00043-x

45. Dewey KG, Begum K. Long-term consequences of stunting in early life. Matern Child Nutr. 2011; 7: 5–18. https://doi.org/10.1111/j.1740-8709.2011.00349.x PMID: 21929633

46. Alam MA, Richard SA, Fahim SM, Mahfuz M, Nahar B, Das S, et al. Erratum: Impact of early-onset persistent stunting on cognitive development at 5 years of age: Results from a multi-country cohort study (PLoS One (2020) 15:1 (e0227839) DOI: 10.1371/journal.pone.0227839). PLoS One. 2020; 15: e0227839. https://doi.org/10.1371/journal.pone.0229663 PMID: 31978156

47. Ferreira EDA, Alexandre MA, Salinas JL, De Siqueira AM, Benzecry SG, De Lacerda MVG, et al. Association between anthropometry-based nutritional status and malaria: A systematic review of observational studies. Malar J. 2015; 14: 1–23. https://doi.org/10.1186/1475-2875-14-1 PMID: 25557741