ORIGINAL RESEARCH

Prevalence and associated factors of low serum zinc concentration in adolescents of Gambella city, Southwest Ethiopia

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Background: Zinc deficiency is a major public health problem in many developing countries. It has been linked with reduced growth and development in adolescents. The deficiency increases vulnerability to infections, immune dysfunction, hypogonadism, and abnormal neurosensory changes. However, this problem has not received due attention, especially in Ethiopia. Therefore, this study is aimed to assess the prevalence and factors associated with low serum zinc concentration in high school adolescents of Gambella city, Southwest Ethiopia.

Methods: An institution-based cross-sectional study was conducted in Gambella city in April 2015. A total of 346 high school adolescents were randomly selected and invited to participate in the study. Data were gathered using a structured questionnaire after obtaining a written consent and assent. The concentration of zinc in serum was measured by atomic absorption spectrometry. Logistic regression was used for statistical analysis.

Results: Three-hundred and two high school adolescents were included in the study, with a response rate of 87.3%. The mean (± standard deviation [SD]) age of the respondents was 17 (±1) years. The mean (±SD) serum zinc concentration of the respondents was 134.1 (±48) μg/dL, while the prevalence of low serum zinc concentration was 9.6% (95% confidence interval [CI]: 6.3–12.9). The prevalence of low serum zinc concentration was 11.2% (95% CI: 5.9–16.4) in females and 8.2% (95% CI: 3.9–12.5) in males. Frequency of malaria attack in the last 2 weeks preceding the study (adjusted odds ratio [AOR]=4.12; 95% CI: 1.58–10.66), increased physical activity (AOR=1.97; 95% CI: 1.43–6.39), low dietary diversity scores (AOR=4.23; 95% CI: 1.52–12.29), poor wealth status (AOR=4.68; 95% CI: 1.41–9.49), and being stunted (AOR=2.84; 95% CI: 1.29–7.46) were significantly associated with low serum zinc concentration.

Conclusion: The prevalence of low serum zinc concentration was not high in the study population. The frequency of malaria attacks in the last 2 weeks, physical activity, low dietary diversity, poor wealth status, and being stunted were associated with low serum zinc concentration. Developing strategies to prevent malaria infection, enhancing physical activities, and optimizing dietary diversity scores are recommended to improve the serum zinc concentrations of adolescents.

Keywords: adolescents, zinc deficiency, serum zinc concentration, Ethiopia

Background

According to the World Health Organization (WHO), adolescence ranges from 10 to 19 years of age.[1] Adolescents are the vulnerable groups of the population in terms of developing nutritional problems.[2] Zinc is one of the essential trace elements and a vital micronutrient with diverse physiologic and metabolic functions.[3] Zinc participates in major biochemical pathways of the human body and has a role in the proliferation and differentiation of cells.[4] It is vital for optimal growth, development, and sexual maturation.[5,6]

In 2013, the global prevalence of micronutrient deficiency in adolescents was 60%–80% and zinc deficiency (ZD) was considered as the main micronutrient deficiency among the adolescent population.[7] ZD in adolescents was associated with poor growth, frequent infections, hypogonadism, immune dysfunction, and abnormal neurosensory changes.[8,9] Adolescents are at higher risk of developing ZD due to their increased zinc demand owing to their pubertal growth spurt.[5]

The global prevalence of ZD was 31% in 2004, ranging from 4% to 73% across the subregions.[10] Studies conducted in Ethiopia,[11,12] India,[7,13] Palestine,[14] Nepal,[15] and Iran[16] reported a high prevalence of ZD in adolescents.

According to the estimation of the International Zinc Nutrition Consultative Group, the proportion of Ethiopian population with an inadequate zinc intake was 21.1%.[4] Two cross-sectional surveys in northern Ethiopia also reported ZD in adolescents. The prevalence of low serum zinc concentration was 49.2% in Tigray and 47% in Gondar.[11,12]

According to literature, the prevalence of low serum zinc concentration among adolescents is unknown at Gambella city. Factors such as sociodemographic variables, economic status, feeding habits, and health status are reported to affect the serum zinc concentration in studies done elsewhere.[11–16]

Thus, this study set out to assess the prevalence and factors associated with low serum zinc concentration among high school adolescents in Southwest Ethiopia, where the prevalence of ZD is not known.

Methods
Study area
This study was conducted at Gambella city located 768 km to the southwest of the country. With its elevation ranging from 400 to 600 m above the sea level and predominantly hot climate, the region covers an area of 23,127 km^2 and has 306,916 inhabitants; according to the national census of 2007. The town has three high schools with 1903 students, 1396 of whom are 10–19 years of age.

Study design and period
An institution-based cross-sectional study was carried out in April 2015.

Sample size
The single population proportion formula was used to calculate the sample size, with the following assumptions: 95% of confidence level, 5% of margin of error, a nonresponse rate of 15%, and 50% of ZD prevalence because no previous study reported on this problem. The calculated sample size was 442. Since the source population was <10,000, we used a correction formula and obtained a final sample of 346.

Sample size adequacy for key factors affecting ZD (sex, dietary diversity score [DDS], and anthropometric measurements) was assessed using the double proportion sample size calculation formula. Inputs of 95% confidence level, 1:1 ratio between cases and controls, and 80% power of study were considered for the calculation of sample size, which make it adequate for factors affecting ZD. Findings of deferent studies were used to determine the expected prevalence figures of exposure factors in cases and controls.[16,17] Eventually, the sample size calculated by using the prevalence of ZD was adequate to study the factors affecting ZD.

Sampling technique
First, lists of students in three high schools were obtained from the school principal and compiled to develop a sampling frame. Second, the calculated sample size was proportionally allocated to each school depending on their adolescent students' size. Finally, 346 study subjects were selected by using the simple random sampling technique. Adolescents sampled from Gambella, Elay, and New Land High Schools were 153, 104, and 89, respectively.

Data collection method
We used a structured questionnaire to assess the factors contributing to low serum zinc concentration among adolescents. The tool used for assessing the DDS was adopted from the Food and Agriculture Organization[18] and was assessed by the 24-hour recall method. Nine food groups were used to assess DDS, which included: 1) starchy staple, 2) legumes/nuts, 3) vitamin A rich fruits and vegetables, 4) other fruits, 5) other vegetables, 6) meat poultry and fish, 7) eggs, 8) milk and milk products, and 9) oils and fats.

A pretest was done at Bonga High School on 17 adolescents to monitor the reliability of the tool. The necessary language modifications were made after the pretest.

Data were collected from the adolescents at the schools by using trained data collectors. The data collectors were supervised by the principal investigators, and problems faced during data collection were solved on time. The filled questionnaires were checked by the primary investigators, and solutions to problems were sought through discussion with data collectors. All finished questionnaires were signed by the supervisors after they were checked for their completeness. The questionnaire was self-administered in the local language (Amharic), which is the working language in the region. Data collectors gave some assistance to the students who faced difficulties in filling the questionnaire. Two trained and experienced health extension workers (low-level community health workers) were employed to measure the height and weight of the study

subjects. Anthropometric measurements were taken using standard procedures and calibrated Seca® scales. Weight was measured in light clothing using a beam balance and was recorded to the nearest 0.1 kg; height was taken in a standing position without shoes and recorded to the nearest 0.1 cm. Two separate measurements of weight and height were recorded and the means were reported. To ensure accuracy, the scale was checked and calibrated frequently. Students whose height for age was below −2 Z scores from the median value of the WHO reference data were considered as stunted. Students with <−2 standard deviation (SD) of body mass index (BMI)-for-age Z score were considered as thin/wasted. Students whose BMI-for-age was below the 5th percentile (≤−1 Z score) from WHO reference data were considered as underweight. Students whose BMI-for-age was between the 5th and 85th percentile (between −1 and 1 Z score) of the WHO reference data were considered as having normal weight. Students whose BMI-for-age was between the 85th and 95th percentile (between 1 and 2 Z score) of the WHO reference data were considered as overweight, and students with a BMI-for-age greater than the 95th percentile (>2 Z score) were considered as obese. The Physical Activity Questionnaire for Adolescents was used to assess the physical activity level of the respondents which was categorized as follows: 1) inactive if a respondent answers "no" to the no leisure time physical activity question, or the respondent reports performing an aerobic physical activity, but for <10 minutes in duration, or the respondent reports performing a nonaerobic activity; 2) insufficiently active if a respondent reports >0 and ≤149 minutes of aerobic activity per week; 3) active if a respondent reports at least 150 minutes per week of moderate intensity activity, or at least 75 minutes per week of vigorous intensity activity, or an equivalent combination of moderate intensity and vigorous intensity activities (multiplied by 2), totaling at least 150 minutes per week; and 4) highly active if a respondent reports >300 minutes per week of moderate intensity activity, >150 minutes per week of vigorous intensity activity, or an equivalent combination of moderate- and vigorous-intensity activities (multiplied by 2), totaling more than 300 minutes per week.

For the assessment of the prevalence of malaria, questions about the major symptoms of malaria were asked and history of being treated for malaria in the last 2 weeks was taken. To assess diarrhea, history of passing loose stools was noted.

Assessment of zinc level in extracted serum

The plain Sarstedt Monovette® system was used to collect venous blood, and a stainless steel needle was used to take random blood samples. The collected blood sample was clotted for 20 minutes and centrifuged at 3000 ×g for 10 minutes. If hemolyzation was visable they were discarded. Then, the extracted serum was transferred to screw-top vials. Cold chain was used to keep and transport the samples. Within the same day, the samples were stored at −20°C and taken to the Ethiopian Public Health Institute to determine the serum zinc concentration using the Varian SpectrAA® Flame Atomic Absorption Spectrometer. A serum zinc level of <70 µg/dL was declared ZD.[19]

Data analysis

Data were entered using Epi-Info version 7, and analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 20 statistical package. Mean, frequency, and percentage were used to describe the study population. Principal component analysis was used to compute the wealth index quintiles, which were constructed using the household asset data. Since the study subjects were from the town, the household asset data included the presence of electricity, television sets, radio recorders, mobile phones, refrigerators, family monthly income, and accessibility to clean and safe water. The DDS of the respondents was categorized into three groups, that is, "low" for scoring <4 food groups, "medium" for scoring 4–5 food groups, and "high" for ≥6 food groups, by using the nine food groups. Binary logistic regression analyses were carried out to identify the important predictors of ZD. Variables with a P-value of <0.05 in the multivariable model were considered as significant. Hosmer–Lemeshow statistic was calculated to see the fitness of the model.

Ethical statement

Ethical approval was obtained from the Institutional Review Board of the University of Gondar, Institute of Public Health. The reference number was 264/2014. Written consent (assent) depending on age was obtained from the participants. This means, assent was obtained from adolescents aged 13–17 years, and a written consent was taken from those aged >18 years. The consent form was taken home by the participants 1 day before the actual data collection written consent from parents/guardians was obtained. Students were informed of their full freedom of participating or not participating in the study. The data collectors approached the selected respondents by greeting and explaining about the aims of the study. The data collectors informed the respondents what they needed from them. Information was collected after the consent was obtained. The privacy of participants during the anthropometric measurements was maintained, and the confidentiality of the results was ensured. The Institutional Review Board approved the consent procedures of the study. Standard procedures were followed for needle safety.

Results

Sociodemographic characteristics of subjects

Data were collected form 302 high school adolescents, with a response rate of 87.3%. About 47.4% of the respondents were females. The mean (±SD) age of the participants was 17.17 (±1.15), with the range being 10–19, and nearly half (49.3%) of them were Orthodox Christians. The mean family size was 5.21 (±1.520). About 29% of the participants were living in poor wealth status (Table 1).

Prevalence of ZD among participants

The overall prevalence of low serum zinc concentration was 9.6% (95% confidence interval [CI]: 6.3–12.9); adolescents with a serum zinc level of below 70 µg/dL more considered as deficient. However, the mean (±SD) serum zinc concentration of the respondents was 134.1 (±48) µg/dL. The prevalence of ZD was 11.2% (95% CI: 5.9–16.4) among females and 8.2% (95% CI: 3.9–12.5) in males.

Physical activity level of subjects

About 33.1% of the participants reported that they had done a heavy physical activity 24 hours before the study (Figure 1). Of the total adolescents participating in the study, 14 (5%) had history of diarrhea in the past 2 weeks. The prevalence of malaria based on a 2-week recall was 21% (Table 2).

DDS of the participants

By using the 24-hour recall method, the number of food groups eaten by the high school adolescents ranged from 2 to 7. About 32% of the participants reported that they had eaten <4 food groups, ranging between 2 and 7. The proportions of the adolescents with medium and high DDS were 48% and 20%, respectively. Only 22.8%, 5%, and 2.3% of the participants ate meat, eggs, and milk, respectively.

Nutritional status of the participants

Considering both height-for-age Z score and BMI-for-age Z score <−2 as stunted and wasted, 7.9% and 11.3% of adolescents were stunted and wasted, respectively (Figure 2).

Factors associated with ZD among high school adolescents

On the bivariate analysis, sex, wealth status, prevalence of malaria based on a 2-week recall, DDS, meat intake, stunting, and physical activity levels were significantly associated with low serum zinc concentration among adolescents. However, on the multivariate analysis, wealth status, prevalence of malaria based on a 2-week recall, DDS, stunting, and physical

Table 1 Sociodemographic characteristics of high school adolescents in Gambella city, Southwest Ethiopia, April 2015

Variables	Frequency	Percent
Sex (N=302)		
Male	159	52.6
Female	143	47.4
Marital status		
Single	298	98.7
Married	3	1.3
Residence		
Urban	300	99.3
Rural	2	0.7
Grade level		
Nine	183	60.6
Ten	119	39.4
Religion		
Orthodox	149	49.3
Protestant	103	34.1
Muslim	40	13.2
Catholic	10	3.3
Ethnicity		
Oromo	82	27.2
Amara	64	21.2
Tigre	36	11.9
Agnuak	45	14.9
Nuer	27	8.9
Kambata	21	7.0
Others[a]	27	8.9
Wealth status		
Poor	88	29.1
Middle	92	30.5
High	112	40.4

Note: [a]Wolayita, Hadiya, Gurage, Kafa, Sheka, Silte.

activity levels were significantly associated with low serum zinc concentration among high school adolescents.

The odds of low serum zinc concentration were more than four times higher among adolescents with a history of malaria based on a 2-week recall than in adolescents who had no history (adjusted odds ratio [AOR]=4.12; 95% CI: 1.58–10.66). The odds of low serum zinc concentration were more than four times higher among adolescents with the lowest DDS compared with those with high DDS (AOR=4.23; 95% CI:
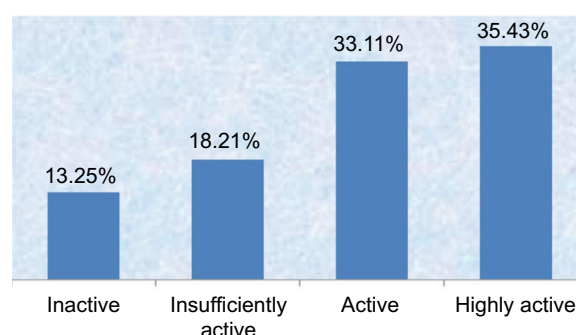
Figure 1 Physical activity levels of high school adolescents in Gambella city, Southwest Ethiopia, April 2015.

Table 2 Bivariate and multivariate logistic regression models of factors associated with zinc deficiency among high school adolescents in Gambella city, Southwest Ethiopia, April 2015

Variables	Zinc deficiency		Crude OR	Adjusted OR	P-value
	Yes	No	(95% CI)	(95% CI)	
Sex (N=302)					
Male	13	146	1.00	1.00	
Female	16	127	1.41 (1.04–3.17)	1.21 (0.74–3.14)	0.09
Malarial history					
Yes	14	49	4.27 (1.93–9.41)	4.12 (1.58–10.66)*	0.00
No	15	224	1.00	1.00	
DDS					
Lowest	19	79	4.74 (1.91–11.78)	4.23 (1.52–12.29)*	0.00
Medium	7	138	4.49 (1.27–15.90)	4.11 (0.88–19.19)	0.07
Highest	3	56	1.000	1.000	
PA levels					
Inactive/insufficiently active	6	89	1.00	1.00	
Active	10	90	1.65 (1.45–8.15)	1.54 (1.29–5.54)*	0.00
Highly active	13	94	2.05 (1.55–8.42)	1.97 (1.43–6.39)*	0.00
HAZ					
Stunted	6	18	3.69 (1.34–10.23)	2.84 (1.29–7.56)*	0.01
Not stunted	23	255	1.00	1.00	
Wealth status					
Poor	15	73	6.06 (1.91–21.69)	4.68 (1.41–9.49)*	0.00
Middle	10	82	3.59 (2.00–20.74)	2.85 (1.18–8.65)*	0.00
High	4	118	1.00	1.00	
Meat intake					
Yes	2	67	0.23 (0.053–0.993)	0.21 (0.05–1.69)	0.17
No	27	206	1.000	1.000	

Note: *P-value ≤0.05 on multivariate analysis.
Abbreviations: CI, confidence interval; DDS, dietary diversity score; HAZ, height-for-age Z score; OR, odds ratio; PA, physical activity.

1.52–12.29). The odds of low serum zinc concentration were more than 1.5 times (AOR 1.54; 95% CI: 1.29–5.54) and nearly two times (AOR=1.97; 95% CI: 1.43–6.39) higher among physically active and highly active adolescents compared to the inactive adolescents, respectively. The odds of low serum zinc concentration were nearly five times (AOR=4.68; 95% CI: 1.41–9.49) and three times (AOR=2.85; 95% CI: 1.18–8.65) higher among adolescents of poor wealth status and middle wealth status compared to adolescents with high wealth status, respectively. Low serum zinc concentration was 2.84 times higher among stunted adolescents, as compared to the nonstunted group (AOR=2.84; 95% CI: 1.29–7.46; Table 2).

Discussion

The present study revealed that the mean zinc concentration of adolescents in the study area was high. However, the prevalence of low zinc concentration was lower than that reported in other similar studies conducted elsewhere.[11,12,14] On the other hand, the prevalence is similar to those reported from Sudan and Iran, where the prevalence of ZD was 9% and 7.9%, respectively.[20,21] The reason for the similarity may be the feeding habits and differences in the soil zinc levels in the study areas. Unlike our finding, a high prevalence of ZD was reported in adolescents of northern Ethiopia. It was reported that ZD was 47% in Gondar and 49.2% in Tigray.[11,12] A study conducted in Gaza Strip also showed a high prevalence (42.5%) of ZD among adolescents.[14] The difference could be due to differences in the age groups of subjects, residence, and experience of different food habits and exposure to different food sources among the study population. The majority of the participants in the present study were in the age range of late adolescence, whose zinc requirements are lower than those of early adolescents. Zinc requirements are increased in early adolescence to fulfill the rising demands for attaining growth spurt.[22] Increased consumption of fish and other animal source foods which are rich in zinc[23] in the study area may explain the lower prevalence of serum ZD as compared to northern Ethiopia where cereal-based meals are taken.[23] The sociodemographic and economic differences may also explain the discrepancy between the prevalence of serum ZD.

In this study, ZD was higher among adolescents with a history of malaria infection in the last 2 weeks. This is supported by a study done at Douala, Cameroon, in which it was found that plasma zinc concentrations varied inversely with malaria parasitemia and that zinc status was lower in 27.3% of malaria patients.[24] This might be due to the redistribution of zinc from plasma to the lymphocytes and liver during the acute phase response.[25] Moreover, fever and excessive sweating, which are the common clinical features of malaria, may increase zinc loss from the body of adolescents affected by malaria.[4,23]

Adolescents with the lowest DDS showed a low serum zinc level in this study. A study conducted in Iran reported that 65.6% of the respondents with poor DDSs had experienced low zinc intake.[16] Another study conducted at Gaza Strip, Palestine, using a food frequency questionnaire, concluded that serum zinc level and dietary habits are correlated in adolescents.[17] The consumption of diversified food improves the micronutrient status of adolescents, since these food items are rich sources of zinc and other essential nutrients.[26] Another possible reason may be that as the number of food items consumed increases, the chance of including animal source food in the diet may be high, which is a good source
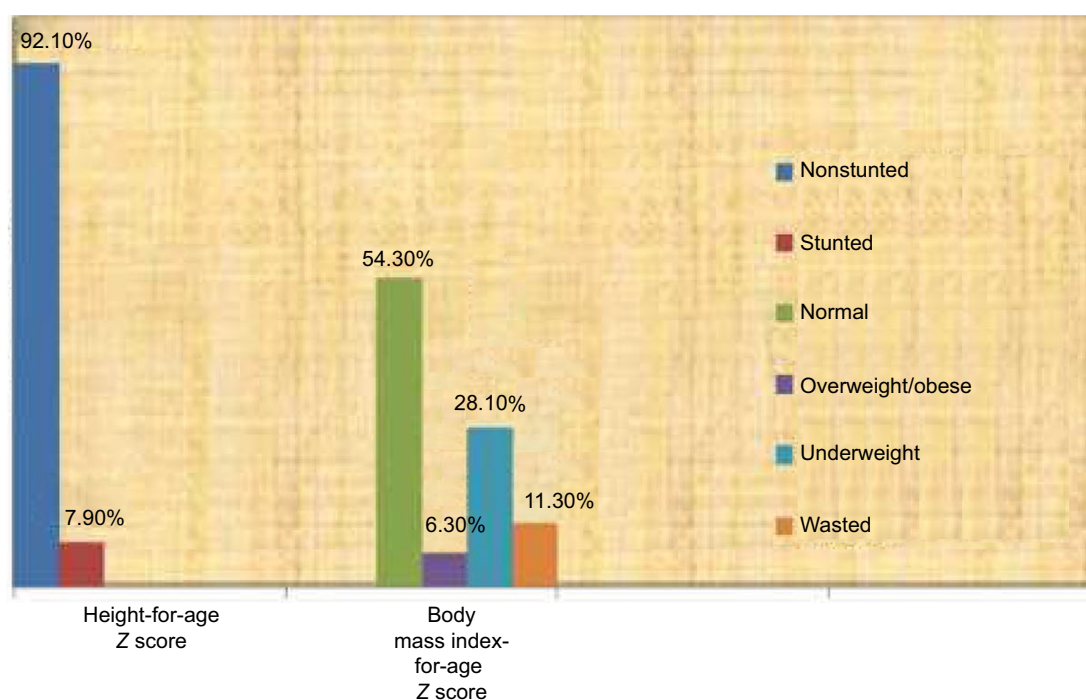
Figure 2 Nutritional status of high school adolescents in Gambella city, Southwest Ethiopia, April 2015.

of zinc.[23] Hence, greater DDS may be associated with better nutritional outcomes and improved micronutrient intake.[27] This was true in our study because the odds of ZD were more than four times higher among adolescents with the lowest DDS, compared to those with high DDS.

In this study, physical activity of high school adolescents was another significant factor of low serum zinc concentration. The result revealed that active and highly active adolescents were 1.54 and 1.97 times, respectively, more likely to have the chance of developing low serum zinc concentration than inactive adolescents. This may be due to the fact that intense physical exercise increases the loss of zinc through sweating.[28] Zinc has a role in producing specific enzymes which facilitate physical activity,[29] so intense physical activity may have the tendency to decrease the serum zinc level because of the high demand of zinc for the formation of enzymes.

In the present study, stunting was significantly associated with low serum zinc concentration. This finding is in line with that of a study conducted in northern Ethiopia.[11] Similarly, a study conducted in East Iran found a significantly higher prevalence of low serum zinc concentration (35.8%) among stunted school-age children.[8] This may be due to the fact that ZD may improve fat accumulation and depletion of lean tissue.[30] There is a synergy between ZD and reduced physical growth, since zinc has an essential role in the physical growth and development of human tissues.[19]

In this study, wealth status was positively associated with the serum zinc level of adolescents. But a study done in Delhi,

India, in 2011, found no difference in ZD among economic groups.[13] The diet of poor people is mainly composed of cereals and legumes, which contain a high amount of phytate. So, phytate inhibits the absorption of the mineral zinc, and these people face an increased risk of ZD.[19] Also, diarrheal diseases which may deplete the zinc store in the body may be the possible reason for the high prevalence of ZD in low-income courtiers.[4]

The limitation of this study is its cross-sectional design, which might fail to show temporal relationships, preventing the observed associations from being necessarily causal. Lack of details on exposures could be the other limitation of this study, and some of the information had to be based on self-reporting, which is subject to recall bias. The fact that the prevalence of malaria was determined on unconfirmed diagnosis through blood test is also a limitation of the study. The findings of the study should be interpreted by considering the above limitations, but the study can be regarded as an eye opener for further research on ZD in Ethiopia.

Conclusion

The prevalence of low serum zinc concentration was low in the study population. Malaria attack in the last 2 weeks, physical activity, low dietary diversity, poor wealth status, and being stunted were associated with low serum zinc concentration. Developing strategies to prevent malaria infection, enhancing physical activities, and optimizing DDSs are recommended to improve the serum zinc concentrations of adolescents. Further research to ascertain the

associations between stunting and zinc status in adolescents is also recommended.

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Author contributions

DGM participated in proposal development, data collection, data analysis, and manuscript write-up. SMA and MMW participated in proposal development, data analysis, and manuscript write-up. FMA participated in data analysis and manuscript write-up. All authors read and approved the final manuscript.

Disclosure

The authors report no conflicts of interest in this work.

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