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*Original article*

# The Status of Trace Elements in Malnourished Children in Nyala City, Southern Darfur, Sudan

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**Keywords**.
Trace Elements, Malnourished, Nyala City, Southern Darfur. Sudan.

**ABSTRACT**
Malnutrition is a massive global public health problem that remains a major cause of child mortality worldwide and may also cause growth failure. Serum trace element disturbances in malnourished children may be subclinical but become obvious during diarrheal illness. This study aimed to determine the serum zinc, copper, magnesium, calcium, and albumin levels among malnourished children. A cross-sectional hospital-based study was conducted at Nyala Teaching Hospital, Southern Darfur, Sudan. During the period from April 2020 to June 2021. A total of one hundred children diagnosed with moderate acute malnutrition MAM presented to the Pediatric Clinic of Malnutrition at Nyala Teaching Hospital. Serum parameters of albumin, calcium, and magnesium were estimated using (Mindray-200, China), while serum copper and zinc were measured by Atomic Absorption Spectrophotometry AAS. The data were analyzed using SPSS version (21.0). Malnourished children 52(52%) female and 48(48%) male. Mother of malnourished 78(78%) of mothers were normal BMI >18.5 kg/m$^2$ and the other 22% were <18.5 kg/m$^2$. Serum minerals and albumin among malnourished children were significantly lower when compared with the reference value p - value of all (< 0.05). Serum parameters of trace elements were not affected by gender, age, and with and without malaria. Correlation between serum minerals (zinc, copper, Calcium and Magnesium) and BMI was positively correlated p-value = (0.001, 0.001, 0.001, 0.001), respectively. Serum trace elements were found to be low among malnourished children, but were not affected by (gender, age, with and without malaria). Mineral levels should be measured in all malnourished cases to detect their asymptomatic imbalance. Correlations between BMI and serum mineral levels were positive.

## Introduction

Malnutrition is defined as a deficiency or imbalance of a person's energy and nutrient intake; it can be seen as wasting, stunting, and being underweight [1]. Malnutrition involves an imbalance between the availability of nutrients and energy and their requirements by the body for normal growth and body tissue functions. Malnutrition is the number one contributor to childhood illnesses globally [2]. The most common form of malnutrition in children is protein-energy malnutrition, which is defined as a pathological condition characterized by insufficient intake of calories and proteins. There were 6.9 million deaths in children under the age of 5 years worldwide in 2011, out of which one-third were due to increased vulnerability to illnesses in protein-energy malnutrition PEM. According to the World Health Organization (WHO) (2020), in 2013, there were 178 million malnourished children globally, with 20 million suffering from severe malnutrition at any given time [3].

By 2018 alone, 5.3 million children under the age of 5 died, and 45% of the children's deaths were attributed to nutrition-related factors [4]. Severe acute malnutrition (SAM) in children under five is defined by the following three anthropometric parameters: Weight-for-height/length ratio < 70% of median or less than – 3 z - score, by MUAC < 115 mm with Length > 65 cm and/or by the presence of bilateral pitting edema with medical complications or a fail in the appetite test (WHO, 2013)[5], while moderate acute malnutrition MAM was defined according to WHO criteria as weight-for-Hight/ length, Z-score between (-2SD and -3SD), MUAC 11.5 and 12.5cm. Trace elements are required in minute quantities but play a vital role in maintaining the integrity of various physiological and metabolic processes occurring within living tissues. The role of trace elements in human health and nutrition has attracted interest in recent times. Among trace elements, some are


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widely investigated, and their roles in growth and metabolism have been established. In addition to deficiencies of energy and proteins, children with protein-energy malnutrition (PEM) are deficient in micronutrients [6, 7] and the causes of malnutrition include, inadequate intake as a result of insufficient or inappropriate supply of food, early cessation of breastfeeding, cultural and religious beliefs, poor sanitation, increased armed conflicts and chronic diseases [8], Magnesium element modulates various tasks in the body, serves with a group of enzymes as co-factor, neurochemical transmitter and in peripheral vasodilation [9].

Magnesium deficiency often develops in a wide variety of clinical conditions. These clinical conditions may be protein-energy malnutrition, malabsorption, hypoalbuminemia, sepsis, and conditions that are commonly seen in children in developing countries [9]. Deficiencies of phosphorus, magnesium and other minerals are common in children with severe acute malnutrition. Feeding with diets rich in carbohydrate but with an inadequate amount of phosphorus and magnesium can result in re-feeding syndrome, that characterized by hypophosphatemia and hypomagnesaemia, sometimes resulting in respiratory or circulatory failure or even death. Although concentrations of serum phosphate and magnesium may not adequately reflect body status, where low levels may still be suggestive of inadequate intake [10]. Micronutrients such as zinc, copper, and selenium have been implicated in the function of the nervous system, and their deficiencies are a critical concern among cerebral palsy Children [11]. Each of these micronutrients is involved in brain development and deficiencies are likely to impair cognitive, motor, and socio-emotional abilities [12].

Calcium serves a major role in muscle contraction and regulation of water balance intracellularly; its plasma imbalance disturbance fluctuates the blood pressure [9]. The lack of information on the nutrition of children specialized in Southern Darfur State in general and Nyala City in particular focuses attention on the importance of nutritional status. Although there are very limited studies across the globe on trace elements and electrolyte imbalance in children with malnutrition, therefore locally no study regarding this topic essential elements, covering baseline levels in the general population, and especially in children under malnutrition are lacking. The objective of the present study was to evaluate the serum of zinc, copper, magnesium, calcium, and albumin among malnourished children in Nyala City Teaching Hospital, Southern Darfur.

## Methods

This cross-sectional hospital-based study was conducted in Nyala Teaching Hospital, Southern Darfur State, Sudan. According to WHO criteria, eligible children attending the pediatric health clinic during the study period (April 2020 to June 2021) were recruited consecutively until the required sample size was obtained, and one hundred children participated. All of the study participants were within moderate acute malnutrition MAM whose defined according to WHO criteria as weight for height/ length, Z-score between -2SD and -3 SD and/or MUAC 11.5, and 12.5 cm". without edema (WHO, 2024) [5]. WHZ-score is a standardized measure used to assess a child's nutritional status by comparing their weight relative to their height with a reference population of well-nourished children of the same height and sex. Interpretation of Z-score results as follows: when the Z-score is greater than -2 indicates normal; a Z-score between -3 and <-2 indicates MAM, Z-score less than -3 indicates SAM.

This study did not adjust for potential confounding factors such as age, gender, malaria infection, inflammatory status, and severity of malnutrition.

### *Sample Size*

The sample was selected using a convenience sampling method, and participation in the study was obtained after verbal consent from mothers of children under 5 years (9-48 months) who attended pediatric and child health clinics in Nyala-City Hospital. The sample size for this study was calculated by the formula:

$$N = \frac{Z^2 \times P \times Q}{d^2}$$

Where; n= Sample size; Z= standard, corresponding to 95% confidence; 1.96 constant factor

P= probability of phenomena

Q= 1-p , and d = sampling error = 0,05, 95% confidence interval.

The sample size was calculated using a prevalence of malnutrition in Southern Darfur 13.7%, obtained from (Geoffrey Babughirana et al, 2026)[13]. The minimum required sample size was 18. To compensate for incomplete data, the final sample size was increased to 100 participants.

### *Inclusion Criteria*

Malnourished children between the age (9 – 48 month) with or without Fever, Malaria, and diarrhea, were enrolled in this study.


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***Exclusion Criteria***

Any of the children with bone disease, renal disease, thyroid disease, children having neurological disorders like inflammatory brain disease, degenerative brain disease, intracranial space occupying lesion, encephalopathy due to well defined causes were excluded, as well, children with chronic medical disorder (chronic liver disease, congenital heart disease, parathyroid disease, and any disorders that may affect the levels of calcium and other trace elements were also excluded.

***Ethical Clearance***

The study was approved by the scientific committee of the Faculty of Medical Laboratory Science, Clinical Chemistry Department, Alneelain University, Khartoum-Sudan on January 2020.

***Data Collection and blood sample***

The protocol of the study was approved by the Ethical Committee of the College of Medical Laboratory Sciences, Alneelain University, and the administrative of Nyala Hospital do not refuse to allow the study, as there is no previously a such study carried on malnourished children. In the local language, all mothers gave oral consent before participated after they received oral information about the study and examinations, because some of them came from rural areas (villages around Nyala City). The questionnaire included general information (gender, age), height, weight, and other related factors was collected using a pre-test questionnaire. The questionnaire was initially prepared in English and translated into the local Arabic language. After verballing informed consent. Five milliliters of random blood sample was withdrawn into heparinized containers from each of one hundred malnourished children, priory antiseptic precautions were taken in account. The blood was centrifuged for 5 minutes at 3500rpm, and the plasma was separated, and immediately albumin, calcium and magnesium were measured by a fully Automated Biochemistry Analyzer (Mindray BS-200, China), while Plasma stored at -70c° and Atomic Absorption Spectrophotometry was used for determination of zinc and copper. Calibration of the automation Mindray200 was adjusted before the run took place for patients' samples and controls. For the accuracy and precision of results, pathological and normal control sera included while performing patient sample testing.

***The reference value***

This study did not include a healthy control group; therefore, comparisons were applied against paediatric the reference ranges. The mean of reference value of each trace element was obtained from WHO recommendations cited under the title Trace Elements in Human Nutrition and Health; it is applicable to children aged (6 month- 8years) viewed in Juli 2026 at.http://www.WHO.int.[14]. The mean was calculated as follows:
The low limit of the reference value Plus upper limit divided by two. The mean of the trace elements of the patients was compared with the corresponding mean of the reference values R.V**.**

***Table 1. Reference values of trace elements***

| Parameters | Mean (R.V) |
|---|---|
| Zn (µgm/dl) | 90 (60 - 120) |
| Cu (µgm/dll) | 107.5 (70 -145 ) |
| Magnesium (mg/dl) | 1.7 (1.4 - 2) |
| Calcium (mg/dl) | 9.9 (8.6 - 11.2) |
| Albumin (g/dl) | 4.5 (3.5 - 5.5) |

***Statistical and Data Analysis***

The data obtained were expressed as mean ± SD. Statistical analysis was performed using SPSS version 21.0 (Statistical Package for the Social Sciences). Differences in mean values between groups were compared by in dependent t-test. Mean values of trace elements were compared with the reference values of categorized patients. Data normality was assessed using the Shapiro-Wilk test. Variables with a normal distribution were analyzed using Pearson's correlation coefficients and significant differences were considered as P-value ≤0.05.

## Results

The majority (52%) of malnourished children were females, and the other (48%) were males (Figure. 1). (Figure 2). Showed nutritional status of mother of malnourished children enrolled in this study. Seventy-eight (78%) of mothers had been normal BMI > 18.5 kg/m$^2$, and the other 22% have BMI< 18.5 kg/m$^2$. The mean serum levels of Zinc, Cu, Mg, Ca, albumin and BMI (64.23±11.42 ,45.72±13.22, 1.44±0.63 ,6.89±0.81, 4.13±0.76, 15.36±1.3) was highly decreased when compared to reference value (p value= 0.001 ,0.01, 0.044 ,0.01, 0.033, 0.01), presented in (Table 2). Serum levels of Zn, Cu, Mg and Ca in male malnourished children was (65.12±11.23, 45.62±13.42,1.47±0.37, 6.89±.86) and in females' group was (63.40±11.63 ,45.81±13.17, 1.41±0.35, 6.89±.76), respectively, p - values=0.454 ,0.945, 0.497, 0.944). Also, serum


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albumin level was not different in the two group (4.12±0.75, 4.14±0.75) p - value =0.867 (Table 3). The mean serum levels of Zn, Cu, Mg, Ca and albumin in malnourished children of mothers BMI category (<18.5 and >18.5) were (61.18±14.36, 43.04±16.21, 1.47±0.37, 7.01±0.82, 4.06±0.84) and (65.09±10.39 ,46.47±12.27, 1.43±0.36 ,6.86±0.80, 4.15±0.73), respectively and (p.value =0.157, 0.335, 0.691, 0.354, 0.645) was (>0.05) for all, presented in Table 4.
The comparison of means of serum trace elements zinc, copper, magnesium, calcium, and albumin in malnourished children with Malaria (63.20±11.20, 45.45±12.11, 1.44 ± 0.63, 6.83±0.770. 4.11±0.83) and malnourished children without Malaria showed no difference. (64.92±11.61, 45.89±14.02. 47±0.35, 6.94±0.84, 4.14±0.71), respectively, presented in Table 5. Correlation between the serum (Zinc, Cu) and BMI of malnourished children showed positive correlation R.value = 0.641, 0.621, p value=0.000, 0.000, presented in (Figure 3, 4), while correlation between the serum (Mg, Calcium, albumin) and BMI of malnourished children was also found significantly positive correlation, R = (0.863, 0.856, 0.468)(p value=0.000, 0.000, 0.007), respectively, (Figure 5, 6, 7).

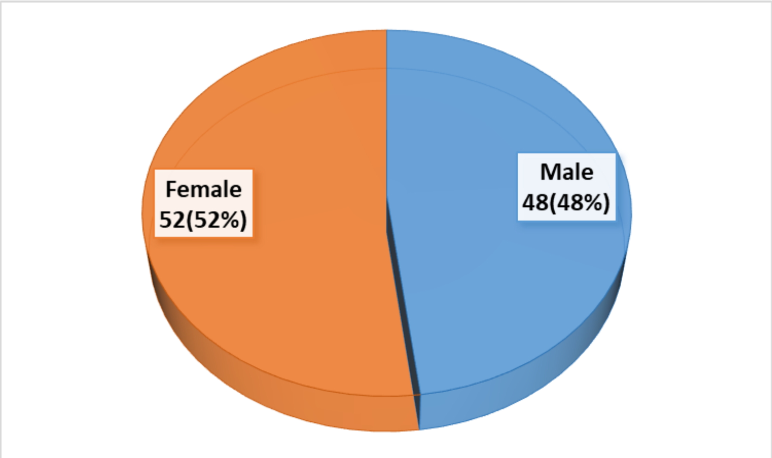


***Figure 1. Frequency of study malnourished children according to gender***

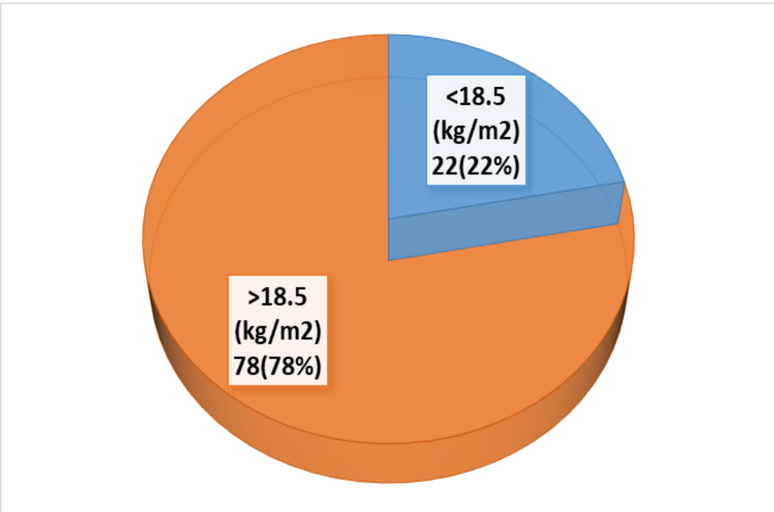


***Figure 2. Illustrate percentage of mother's nutritional of malnourished children according to WHO classification.***

***Table 2. Comparison of means of serum trace elements, albumin and BMI in malnourished children with the mean of reference values***

| Parameters | Mean ± SD | Mean (R.V) | *P-value* |
|---|---|---|---|
| Zn (µgm/dl) | 64.23±11.42 | 90 (60- 120) | 0.001 |
| Cu (µgm/dl) | 45.72±13.22 | 107(70-145) | 0.001 |
| Mg (mg/dl) | 1.44 ± 0.63 | 1.7 (1.4-2) | 0.044 |
| Ca (mg/dl) | 6.89 ± 0.81 | 9.9 (8.6-11.2) | 0.001 |
| Albumin (g/dl) | 4.13 ± 0.76 | 4.5 (3.5-5.5) | 0.033 |
| BMI kg/m$^2$ | 15.36 ± 1.3 | 18.5 – 24.9 | 0.001 |


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*Table 3. Comparison of serum trace elements among malnourished children (male, female)*

| Parameters | Male No= 48 | Female No= 52 | *P-value* |
|---|---|---|---|
| Zn (µgm/dl) | 65.12±11.23 | 63.40±11.63 | 0.454 |
| Cu (µgm/dl) | 45.62±13.42 | 45.81±13.17 | 0.945 |
| Magnesium (mg/dl) | 1.47±0.37 | 1.41±0.35 | 0.497 |
| Calcium (mg/dl) | 6.90±0.86 | 6.89±0.76 | 0.944 |
| Albumin (g/dl) | 4.12±0.75 | 4.14±0.75 | 0.867 |

**Table 4. Serum trace elements of malnourished children according to Mothers BMI/kg/m2.**

| Parameters | <18.5 kg/m$^2$ No= 22 | >18.5 kg/m$^2$ No= 78 | *P-value* |
|---|---|---|---|
| Zn (µgm/dl) | 61.18 ± 14.36 | 65.09 ± 10.39 | 0.157 |
| Cu (µgm/dl) | 43.04 ± 16.21 | 46.47±12.27 | 0.335 |
| Magnesium (mg/dl) | 1.47 ± 0.37 | 1.43 ± 0.36 | 0.691 |
| Calcium (mg/dl) | 7.01 ± 0.82 | 6.86 ± 0.80 | 0.354 |
| Albumin (g/dl) | 4.06 ± 0.84 | 4.15 ± 0.73 | 0.645 |

*Table 5. Trace elements among malnourished children with and without Malaria.*

| Parameters | With malaria | No malaria | *P-value* |
|---|---|---|---|
| Zn (µgm/dl) | 63.20±11.20 | 64.92±11.61 | 0.464 |
| Cu (µgm/dl) | 45.45±12.11 | 45.89±14.02 | 0.869 |
| Magnesium (mg/dl) | 1.40±0.36 | 1.47±0.35 | 0.385 |
| Calcium (mg/dl) | 6.83±0.77 | 6.94±0.84 | 0.505 |
| Albumin (g/dl) | 4.11±0.83 | 4.14±0.71 | 0.831 |
| BMI kg/m2 | 15.7±2.7 | 15.4±1.3 | 0.469 |

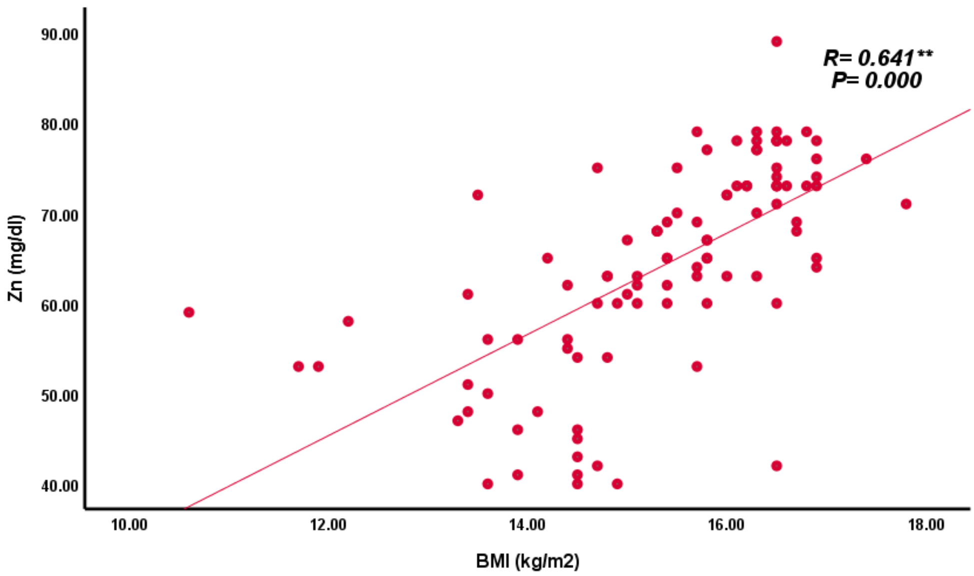


*Figure 3. Correlation between the serum Zinc and BMI of malnourished children*


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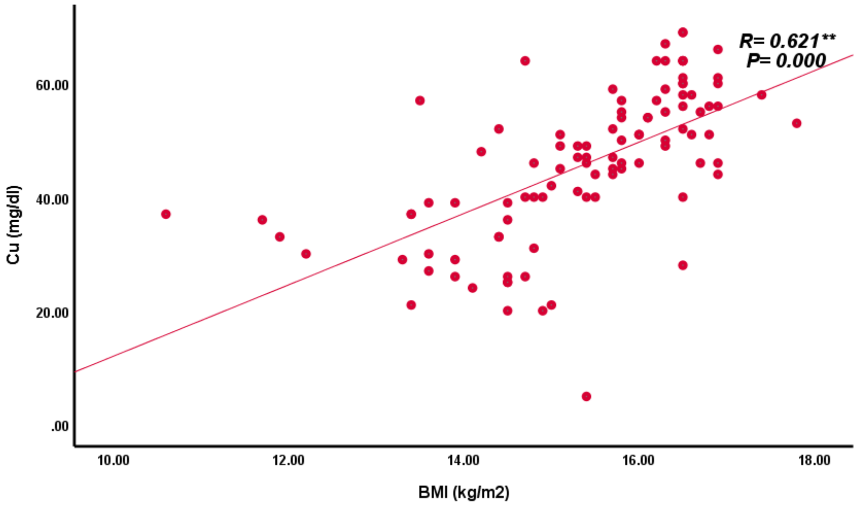


***Figure 4. Illustrate correlation between serum copper and BMI of the patients.***

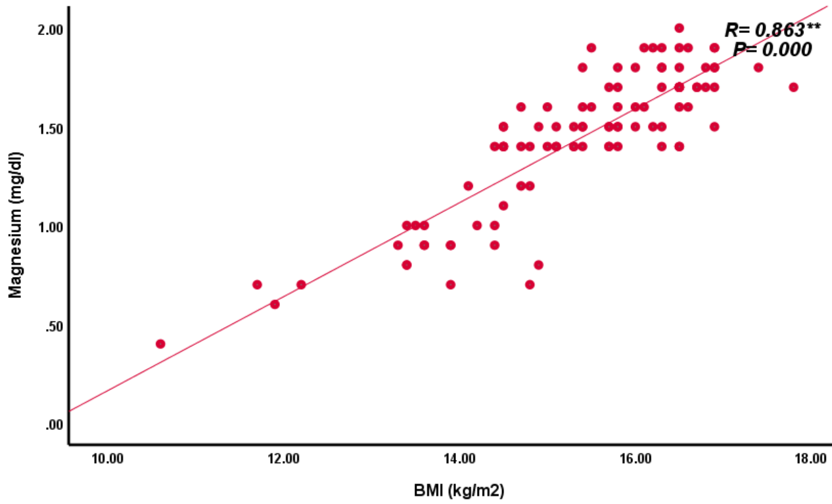


***Figure 5. Illustrates correlation between the serum Magnesium and BMI of patients***

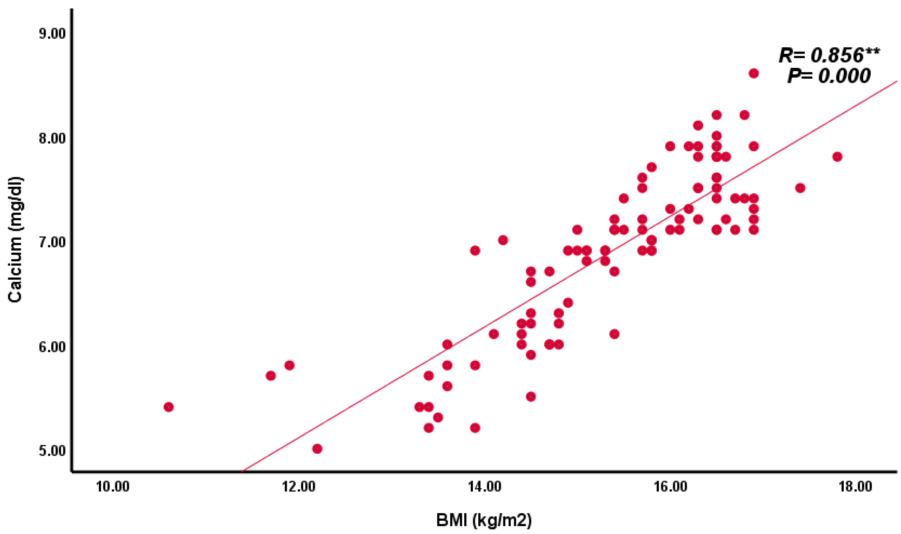


***Figure 6. Correlation between the serum Calcium and BMI of the patients.***


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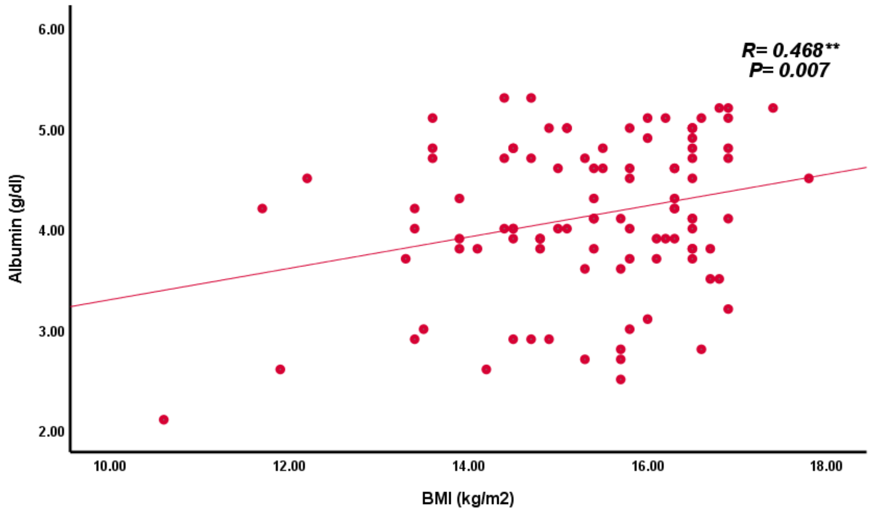


***Figure 7. Correlation between serum albumin and BMI of malnourished children*.**

## Discussion

Globally, child malnutrition is a public health problem with major consequences for survival, damaging cognitive and physical development of children [15]. Malnutrition cases were reported to affect 19 million children worldwide in 2013, and an estimated 2.9 million children under five were admitted globally for treatment of Malnutrition [16]. Patients with Malnutrition often have multiple nutritional deficiencies, anemia, and multiple comorbidities, and account for the most cases of child mortality worldwide. Trace elements are essential for human beings as they are required for the functional activity of several enzyme systems. Trace element deficiencies are common in children with malnutrition [17]. So, this study was carried out to evaluate serum trace elements (zinc, copper, magnesium, calcium and albumin) levels among malnourished children.

Hundred Sudanese children diagnosed as malnutrition and the female gender of malnourished children was slightly higher (52%) and other (48%) were males, so our result was consistent with previous studies D'Souza*, et al* 1980 [18] and Mitra, *et al*1996 [19] who reported that female children were more likely to be severely malnourished than male moreover [20, 21], reported higher female childhood mortality than males in Bangladesh. Inconsistent with these findings was reported by a group of older and recent studies done by (kaneta, et al, 2000, [22], Ahmed et al, 2016 [23], Shazia F, et al, 2017 [24], Khansa, et al 2020, [9], who mentioned that malnutrition most abundant in males than females. In this study our results found the frequency of normal or overweight BMI > 18.5 of malnourished mothers about 78% while only 22% were underweight < 18.5 BMI indicating no association between maternal BMI and nutritional status of their children, while significant such associations between maternal BMI and children nutritional status were noted by past Ray, et al 2004 and Ajslev, *et al 2014* [25,26].

Furthermore, Bouzitou, et al [27] observed that there were significant associations between maternal BMI and children's weight and height. Our study findings were different from previous; this may be due to the small sample size or other factors related to mothers. Our study results revealed significantly lower, serums trace elements when compared with established reference values. In the present study the serum zinc and copper were significantly lower in the malnourished than the mean of the reference value, which is in accord with (Ugwugja, et al 2007) [28]. Zinc and copper deficiencies is a part of micronutrient deficiencies has been attributed to increase losses as in catabolic states, protein-losing enteropathies mainly copper and zinc, inadequate intake and/or poor bioavailability [28]. Moreover, copper deficiency has been found in children receiving long-term parenteral nutrition [29], also in population with high intake of cereals, which contain phytate that may be responsible for copper and zinc deficiency as a result of poor availability. The noticeably common dietary meals are cereals may incriminated in zinc and copper deficiency because it constitute the most important source of nutrients of children in Darfur, additionally may be due to inadequately dietary intake per low absorbability of elements especially of zinc and copper elements, also children at this age usually complains from Intestinal infections (bacteria, protozoa, helminthes) that causes malabsorption disturbances.

Previously Faroug et al 2016 [30] mentioned that Poor nourishment results from an improper diet or from a defect in metabolism that prevents the body from using its food properly, or this could be attributed to an increase in food consumption and dietary deficiency in relation to low family income. These findings agree with Mahaman et al.2017 [31] had reported that the occurrence of reduced levels of these nutrients (Ca, Mg) among malnourished children was due to dietary deficiency or infection owing to increased metabolic losses. The dietary deficiency of calcium could be as a result of intake of a calcium-free diet such as gruel, which is often prepared from phytate-containing cereals Irena, et al [32]. Henry et al [33] and Anne-Louise et al [34] found a decrease in calcium levels in malnourished children. Moreover, the deficiency of calcium and magnesium may be due to educational level which may rely on good cooking and healthy meal preparation.


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Nutritionally, the demands and availability of trace elements is in multiple diversity diets source, noteworthy, may attributed to unaffordable of the families being able to consume one to two meals/per day, and they may depend on market purchasing as their main source. Moreover, the minimal income levels may threaten the families to food access resilience. Collectively, these issues are incorporated as depravities causes of trace element deficiency. In this study, there was no significantly different in trace elements regarding children infected with malaria and other not infected group, this may be due to immune protection or newly onset infection. Concerning correlation, this study revealed a highly significant positive correlation between study variables (Zn, Cu, Mg, Ca, Albumin) and BMI, R = (0.641, 0.621, 0.863, 0.856, 0.468), respectively. In other circumstances (Khansaa et al 2020 and Freedman et al 2008) [9,35] their study research revealed calcium and BMI, but not parallel to our findings of magnesium and BMI.

***Study strengths***

The main strength is the study of a bundle of parametric blood-measured variables in malnourished children, and the incorporation of their mothers, arises focus to diagnose health challenges associated with micronutrient deficiency in the targeted geographical area.

***Study Limitations***

This study did not include a healthy control group; therefore, comparisons were applied against paediatric reference ranges. However, the study provides only cross-sectional outcomes with limited parametric interpretation at a single center study in an enclosed geographical area of Nyala City, and a small sample size with residual confounding factors.

**Conclusion** This study concluded that serum trace elements (zinc, copper, magnesium, calcium, and albumin) in malnourished children were compared to normal values. No statistically significant differences were observed according to gender, age category, mothers weight (BMI <18.5 kg/m2, BMI > 18.5 kg/m2), or malaria status in this sample. A positive correlation was obtained between trace elements and BMI of malnourished children. To solve challenges of malnutrition among the community, interventions are needed to improve healthcare accessibility and strengthen nutrition programs and outcomes of child health in such communities.

***Recommendations***

The study recommended that routine investigations of trace elements for malnourished children as a routine follow-up should be carried out for their benefit and to assist in compensatory therapy. For effective management of protein-energy malnutrition, trace elements supplementation should be part of the nutritional rehabilitation balance and treatment regimen, in order to prevent their deficiency and its health implications in pre-school age children, as well as food fortification should be promoted. Practical strategic studies are needed to address the dietary inadequacies, phytate content in cereals in relation to deficiency of zinc, and copper elements and malnutrition among children of the region, Southern Darfur.

***Conflicts of interest***

The authors declare that they have no conflicts of interest.

***Acknowledgments***

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***Author contributions***

S.A.E. K.SM. S.B.M, A.M.A and G.M conceptualized the study and drafted the manuscript. S.A.E. and H.A.O were responsible for the data collection and study design. S.A.E, A.A.A. S.G.M and AEA. supervised statistical analyses. All authors have read, edited, and revised the manuscript accordingly.

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