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Original Article

Serum Biochemical Parameter Levels among Under-Five Children with Nutritional Deficiency Anemia Admitted to Madda Walabu University Goba Referral Hospital: A Comparative Cross Sectional Study

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Abstract

Background: Serum biochemical parameters levels alterations have been one of the medical complications that occur among under-five children with nutritional deficiency anemia (NDA) and these changes may contribute to death if not promptly addressed. These biochemical parameters disturbances occur due to underlying NDA. The aim of this study was to assess the association between alterations in serum biochemical parameters and NDA in under-five children.

Methods: A facility-based comparative cross sectional study design was conducted on under-five children admitted to Madda Walabu University Goba Referral Hospital (MWUGRH) from January 1, 2023 to November 15, 2024. Serum albumin and creatinine levels were measured using a Vitalab Selectra Clinical Chemistry Analyzer, whereas electrolytes (Na+, K+, and Cl-) were assessed with an automated Humalyte Electrolyte Analyzer. The collected data were entered into SPSS version 26 for analysis, curated and analyzed for descriptive, and inferential statistics.

Results: A total of 64 under-five children were included, comprising 32with NDA and 32 without NDA (100% respondent rate). The mean age was 40.47 ±16.6 months, and 53.1% were female. More than half (54.7%) were from rural areas, and 60.9% of mothers had no formal education. Overall, 62.5% of children were malnourished, with a higher proportion among children with NDA (84.4%) than those without (40.6%). Children with NDA had significantly lower mean serum albumin ($P = 0.002$) and sodium ($P = 0.004$), and higher creatinine ($P = 0.009$), potassium ($P = 0.004$), and chloride ($P = 0.009$) levels compared with non-NDA children. Multivariable analysis showed that hypoalbuminemia, elevated creatinine, hyponatremia, hyperkalemia, and hypochloremia were significantly associated with NDA. Malnutrition was a strong predictor of all biochemical abnormalities (AOR: 3.32–5.86, $P < 0.05$). Rural residence, maternal no-formal education, and poor socioeconomic status were also associated with

increased odds of biochemical abnormalities among children with NDA.

Conclusion: This study highlights that major alteration in biochemical parameter levels were associated with pathophysiology of under-five NDA and contributed significantly to its progression. Early recognition and appropriate management should be taken to avoid its adverse effects and improve the treatment outcomes.

Key words: Nutritional deficiency anemia, Under-five children, Serum biochemical parameters

Introduction

Nutritional deficiency anemia (NDA) is a condition in which circulating hemoglobin levels fall below the normal reference value for age and sex due to inadequate nutritional intake, mainly iron and vitamin deficiencies (1-3). The increasing prevalence of NDA among under-five children has also increased disturbances in serum biochemical parameters. Oxygen deprivation and compensatory mechanisms during NDA alter body physiology, acid-base balance, and serum biochemical components, particularly albumin, creatinine, sodium, potassium, and chloride. Studies have shown that children with NDA commonly develop hypoalbuminemia, elevated creatinine, hyponatremia, hyperkalemia, and hyperchloremia, leading to electrolyte imbalance and increased membrane stiffness (4-8).

Hypoalbuminemia mainly results from malnutrition, inadequate protein intake, inflammation, liver dysfunction, excessive milk intake, hemodilution, and increased albumin loss. Excessive milk intake, for instance, may contribute to nutritional imbalance by displacing other protein and iron-rich foods from the diets and may be also associated with protein-losing enteropathy, causing protein loss through the gut and lowering blood protein levels (9-12). Correspondingly, malnutrition reduces albumin synthesis, while inflammation suppresses albumin production in the liver. Additionally, hemodilution, an adaptive response to NDA, dilutes albumin in the blood, even if albumin production is unaffected (13-16). High serum creatinine levels in under-five children with NDA are associated with dehydration, impaired renal function, renal hypoperfusion, erythropoietin deficiency, muscle breakdown, and malnutrition (17-20). It has also been reported that there is a significant association between NDA and elevated creatinine levels (17). Hyponatremia in NDA occurs due to hemodilution, renal water retention, malnutrition, poor dietary intake, medications, and fluid therapy, while hyperkalemia develops from hemolysis, impaired renal function, acid-base imbalance, dietary factors, medications, and transfusions (21-23). Similarly, hyperchloremia in children with NDA is mainly related to hemolysis, inflammation, compensatory mechanisms, and renal adaptations that retain chloride ions to maintain electrolyte balance during anemia (24-26).

In the previous studies, there has been a notable gap on serum biochemical parameters levels alteration in under-five children with NDA. The association between serum albumin, and creatinine disorders with NDA has not been thoroughly studied in previous research (4, 5). Electrolyte imbalances represent another crucial yet understudied aspect of NDA. Therefore, a thorough understanding of these biochemical alterations is essential for improving the diagnosis, treatment, and overall management of NDA (5, 27). Moreover, many existing studies have not to adopted more comprehensive approach to examine how key biochemical parameters, such as serum albumin, creatinine, and electrolytes, interact in the context of NDA (6-8).

In addition, since climatic conditions and nutritional culture of the study area differ considerably from those of the previous studies, this research was conducted to address these gaps. The study was carried out in Bale zone, in Goba town, which lies near Tullu Dimtu, second-highest peak in Ethiopia, with an elevation of 4377 meters above sea level. The climatic conditions in the study area are relatively cold, which may lead to oxygen deprivation. In addition, the nutritional culture of the study population is likely to be poor in iron and vitamin content. Furthermore, this study employed a contemporary laboratory setup to effectively detect biochemical alterations. Therefore, these factors might also affect the study outcomes.

The findings of this study have significant implications for healthcare professionals, policymakers, and stakeholders. Understanding the relationships between NDA and associated biomarkers, such as serum albumin, creatinine, and electrolytes, enables early intervention and targeted treatment strategies. This knowledge can help identify children at risk and highlight potential dietary deficiencies, thereby informing future research and nutrition-focused interventions. In addition, the findings may provide useful preliminary data for healthcare organizations and researchers working in pediatrics nutritional health. Further studies, including interventional and implementation research, are needed to support evidence- based decision-making. Therefore, this study aims to assess the major serum biochemical disorders among children under- five with NDA admitted to the pediatric ward of MWUGRH in Goba, Oromia, Ethiopia.

Methods and materials

Study area

The study was conducted in Goba town, MWUGRH. Goba town, located 460 kilometers from Addis Ababa, has a population of 51,562 with 10,742 households, as reported in 2022. MWUGRH serves as a key healthcare facility for the region, offering a wide range of preventive, curative, and diagnostic services, particularly for pediatric care.

Study design and period

Age- and sex-matched comparative cross sectional study design was conducted from January 1, 2023 to November 15, 2024

Source and study population

The source population included all under-five children admitted to pediatric ward of MWUGRH from January 1, 2023 to November 15, 2024. Children with NDA include all under-five children with NDA, whereas children without NDA were all under-five children without NDA admitted for vaccination services. NDA includes both IDA and VDA.

Eligibility criteria

Children with NDA were all randomly selected children aged less than five years had NDA and attended MWUGRH during the data collection period. The participants NDA history was collected from medical record review. Children without NDA were children under-five without NDA and with parental consent. Children were excluded if they have anemia not related to nutritional deficiency; any concurrent acute illness and chronic disease, bleeding due to trauma or accident; children who were not presented with their family and can't give asked information; a history of surgery within two months; patients already on iron therapy; those unable to respond to the consent interview due to mental problems and auditory impairments.

Sample size determination

The sample size was calculated using a double population proportion formula for comparing

children with NDA and children without NDA with a 1:1 ratio at 95% confidence level and 80% power. Based on expected proportions of 50% among children with NDA and 20% among children without NDA, the final adjusted sample size was 32 children with NDA and 32 children without NDA, making a total of 64 participants.

The proportions of 50% for children with NDA (P_1) and 20% for children without NDA (P_2) were obtained from findings of a previous related study (4, 7), and were used as the estimated prevalence of the outcome in each group. These assumptions reflected the anticipated difference between children with NDA and children without NDA and required to estimate an adequate sample size capable of detecting a statistically significant association with 95% confidence and 80% power.

Sampling procedures

A simple random sampling technique was employed to select children under-five with NDA who were admitted to MWUGRH during the data collection period. Specially, a lottery method was used to randomly select participants' medical record cards.

Variables

Dependent variables: serum biochemical disorders such as albumin, creatinine, sodium, potassium, and chloride levels in under-five patients with NDA.

Independent variables: NDA (IDA and VDA) and associated demographic factors including age, sex, economic status, maternal education, residence, weaning types, vegetables consumption habit, nutritional status, and source of family food.

Data collection tools and procedures

Quantitative data were collected from laboratory examination results whereas qualitative data such as children's biological characteristics were gathered through patient medical records review

Biochemical analysis

Five milliliters of blood were drawn from the children arm (vein puncture) in plain tube (red-top tube) labeled with the child's code in the morning by health professionals. The sample was transported to the laboratory and processed using centrifuge. Blood samples were centrifuged at 3000 rotations per minute for 10 minutes to separate the serum. After processing, the serum samples were stored at -70°C until analysis. Subsequently, the samples were analyzed for various biochemical parameters.

Serum albumin and creatinine levels were determined using the colorimetric method and Jaffe reaction method, respectively. These biochemical parameters were analyzed using the Vitalab Selectra E Clinical Chemistry Analyzer (Vital Scientific, Dieren, Netherlands). Electrolyte concentration, including sodium (Na^+), potassium (K^+), and chloride (Cl^-) level were assessed using ion-selective electrodes principle. The Humalyte Electrolyte Analyzer (Human Diagnostics, Wirsbaden, Germany) was used for electrolytes measurement.

Data quality control

To ensure data quality, the laboratory technicians were informed about the purpose of the study, and a 10% pre-test was conducted prior to the main data collection. Good clinical laboratory practice was strictly followed throughout the laboratory procedures. In addition, all data were carefully checked for completeness and accuracy.

Data entry and analysis

For data analysis, SPSS version 26.0 was used. Continuous variables were presented as means and standard deviations, while categorical data were described using percentages and

frequencies. Statistical significance was determined at a P-value of less than 0.05. Adjusted odds ratios (AOR) with a 95% confidence interval (CI) were used to assess the associations between variables.

Results

Sociodemographic characteristics

Sociodemographic data of participants were collected through a review of medical records from the pediatric ward of MWUGRH. The study included a total of 64 participates, consisting 32 children with NDA and 32 children without NDA. The participants in children without NDA were randomly selected from children attending routine immunization services. The response rate for the study was 100%. Among the total 64 participants, 34 (53.1%) were female and 30 (46.9%) were male. Regarding age distribution, 28 (43.8%) participants were between 0-35 months, while 36 (56.2%) were 36-59 months. The mean age of the participants was 40.47± 16.6 months.

In terms of residence, 35 (54.7%) of study participants were from rural area, with a higher proportion observed among children with NDA 78.1% compared to children without NDA 31.2%.

In contrast, most children without NDA were urban residents 68.8%, while only 21.9% of children with NDA lived in urban. Regarding maternal education status 39 (60.9%) mothers had no formal education. In addition, 34 (53.1%) participants used milk as weaning food. Concerning the breastfeeding practice 27 (42.17%) mothers reported breastfeeding their children. Furthermore, among all study participants, 25 (39.1%) primarily consumed teff (Eragrostis tef/E.tef) and 39 (60.9%) relied on other sources of family food (Table 1).

Table 1: Sociodemographic characteristics of the study participants, MWUGRH, Goba, Oromia, Ethiopia, 2024

Variable	Category	Children with NDA (n=32) n (%)	Children without NDA (n=32) n (%)	Total (n=64) n (%)
Age (months)	0-35	14 (43.8)	14 (4.8)	28 (43.8)
	36-59	18 (56.2)	18 (56.2)	36 (56.2)
	Mean ± SD	40.5 ± 16.6	40.5± 16.6	40.5 ± 16.6
Sex	Male	15(46.9)	15 (46.9)	30 (46.9)
	Female	17(53.1)	17 (53.1)	34 (53.1)
Socioeconomic status	Poor	24 (75.0)	14 (43.8)	38 (59.4)
	Good	8 (25.0)	18 (56.2)	26 (40.6)
Maternal education	Non-formal	25 (78.1)	14 (43.8)	39 (60.9)
	Formal	7 (21.9)	18 (56.2)	25 (39.1)
Residence	Rural	25 (78.1)	10 (31.2)	35 (54.7)
	Urban	7 (21.9)	22 (68.8)	29 (45.3)
Weaning practice	Milk-based	27 (84.4)	7 (21.9)	34 (53.1)
	Family food	5 (15.6)	25 (78.1)	30 (46.9)
Vegetable consumption	Yes	11 (34.4)	17 (53.1)	28 (43.8)
	No	21 (65.6)	15 (46.9)	36 (56.2)
Breastfeeding practice	Yes	11 (34.4)	16 (50.0)	27 (42.2)
	No	21 (65.6)	16 (50.0)	37 (57.8)
Family food source	Teff	8 (25.0)	17 (53.1)	25 (39.1)
	Other	24 (75.0)	15 (46.9)	39 (60.9)

Nutritional status of study participants

Overall, 40 (62.5%) of the children were classified malnourished, while 24 (37.5%) well-nourished. Among the children with NDA, the majority, 27 (84.4%) were malnourished, while only 5 (15.6%) were well-nourished. In contrast, among children without NDA, 19 (59.4%), were well- nourished, while 13 (40.6%) were malnourished (Table 2).

Table 2: Nutritional status of under-five children, MWUGRH, Goba, Oromia, Ethiopia, 2024

Variable	Category	Children with NDA (n=32) n (%)	Children without NDA (n=32) n (%)	Total (n=64) n (%)
Nutritional status	Malnourished	27 (84.4)	13 (40.6)	40 (62.5)
	Well-nourished	5 (15.6)	19 (59.4)	24 (37.5)

Major biochemical parameters among study participants

The major biochemical parameters were summarized using mean and standard deviation. A statistically significant reduction in mean serum albumin level was observed among the children with NDA (2.84 ±1.23 g/dL) relative to the children without NDA (3.84 ±1.43 g/dL) (P = 0.002). Importantly, the mean albumin level in the children with NDA fell below the accepted lower limit of the normal reference interval of 3.50–5 g/dL.

Although mean serum creatinine levels in both groups remained within the normal reference range (0.30–1.00 mg/dL), children with NDA showed a significantly higher mean creatinine level (1.15 ± 0.46 mg/dL) compared with children without NDA at (0.89 ± 0.60 mg/dL) (P = 0.009). Similarly, mean serum sodium levels were significantly lower in children with NDA (128.69 ± 9.20 mEq/L) compared to children without NDA (135.70 ± 11.90 mEq/L) (P = 0.004).

The mean sodium level in the children with NDA was below the normal range of 135–145 mEq/L, indicating hyponatremia. In contrast, mean serum potassium was significantly elevated in the children with NDA (5.93 ± 1.53 mEq/L) relative to children without NDA (4.77 ± 1.67 mEq/L) (P = 0.004). Despite both values were within the normal range (3.5–5.5 mEq/L), the higher level observed among children with NDA suggests a trend toward hyperkalemia.

In addition, mean serum chloride levels were significantly higher in children with NDA (110 ± 10.12 mEq/L) than children without NDA (102.10 ±15.90 mEq/L) (P = 0.009). while both groups remained within the reference range (90–110 mEq/L). The higher value in the children with NDA may indicate a tendency toward hyperchloremia. Table 4 illustrates that the biochemical profiles differed between of children with NDA differed and those without NDA. Low albumin levels were more prevalent among children with NDA 78.1% compared with children without NDA 40.6% (P=0.002). In contrast, higher proportion of children without NDA had normal or higher levels 59.4% than children with NDA 21.9%. Similarly, elevated creatinine levels were more common in children with NDA 78.1% than among children without NDA 46.9% (P= 0.009).

Similarly, low sodium levels were also more frequent in children with NDA 78.1% compared to the children without NDA group 46.9% (P= 0.004). In addition, higher potassium levels were more prevalent among children with NDA 78.1% than among children without NDA 43.8% (P= 0.004). Likewise, increased chloride levels

were observed more frequently in children with NDA 78.1% than in children without NDA 46.9% (P= 0.009). Overall, abnormalities in albumin, creatinine, sodium, potassium, and chloride levels were more common among children with NDA than children without NDA.

Table 3: Major serum biochemical parameters among study participants, MWUGRH, Goba, Oromia, Ethiopia, 2024

Parameter	Statistic	Children with NDA (n=32)	Children without NDA (n=32)	P-value
Serum Albumin level (g/dL)	Mean ± SD	2.84 ± 1.23	3.84 ± 1.43	0.002*
Serum Creatinine level (mg/dL)	Mean ± SD	1.15 ± 0.46	0.89 ± 0.60	0.009*
Sodium level (mEq/L)	Mean ± SD	128.69 ± 9.20	135.70 ± 11.90	0.004*
Potassium level (mEq/L)	Mean ± SD	5.93 ± 1.53	4.77 ± 1.67	0.004*
Chloride level (mEq/L)	Mean ± SD	110.0 ± 10.12	102.10 ± 15.90	0.009*

*Statistically significant at $P < 0.05$

Table 4: Comparison of major biochemical parameters between children with NDA and children without NDA, under-five children attending MWUGRH, Goba, Oromia, Ethiopia, 2024

Parameter	Category	Children with NDA (n=32) n (%)	Children without NDA (n=32) n (%)	*P*-value
Albumin	Low	25 (78.1)	13 (40.6)	0.002*
	Normal/High	7 (21.9)	19 (59.4)	
Creatinine	High	25 (78.1)	15 (46.9)	0.009*
	Normal/ Low	7 (21.9)	17 (53.1)	
Sodium	Low	25 (78.1)	15 (46.9)	0.004*
	Normal/ High	7 (21.9)	17 (53.1)	
Potassium	High	25 (78.1)	14 (43.8)	0.004*
	Normal/Low	7 (21.9)	18 (56.2)	
Chloride	High	25 (78.1)	15 (46.9)	0.009*
	Normal	7 (21.9)	17 (53.1)	

Bivariate logistic regression analysis of serum biochemical abnormalities

The bivariate logistic regression analysis demonstrated that serum biochemical parameters were significantly associated with NDA status among under-five children. Hypoalbuminemia was significantly associated with NDA than children without NDA, with a crude odds ratio (COR) of 5.22 (95% CI: 2.41–11.29) Similarly, elevated creatinine levels were significantly associated with anemia status in the bivariate analysis (COR= 4.05, 95% CI: 1.95–8.40). Hyponatremia was also significantly associated with NDA (COR = 4.05, 95% CI: 1.93–8.47). In addition, hyperkalemia showed a strong

association with NDA (COR = 4.59, 95% CI: 2.10–10.03), while hyperchloremia was similarly associated with NDA (COR = 4.05, 95% CI: 1.92–8.51). Overall, all assessed biochemical abnormalities were significantly associated with NDA status in bivariate analysis, with higher odds observed among children with NDA (Table 5)

Table 5: Bivariate logistic regression analysis of serum biochemicals level among study participants at MWUGRH, Goba, Oromia, Ethiopia, 2024

Parameter	Category	Children with NDA	Children without NDA	Total	COR (95% CI)	*P*-value
Hypoalbuminemia	Yes	25	13	38	5.22* (2.41–11.29)	0.002*
	No	7	19	26	1	
Elevated creatinine	Yes	25	15	40	4.05* (1.95–8.40)	0.009*
	No	7	17	24	1	
Hyponatremia	Yes	25	15	40	4.05* (1.93–8.47)	0.004*
	No	7	17	24	1	
Hyperkalemia	Yes	25	14	39	4.59* (2.10–10.03)	0.004*
	No	7	18	25	1	
Hyperchloremia	Yes	25	15	40	4.05* (1.92–8.51)	0.009*
	No	7	17	24	1	

COR = Crude odds ratio; *Statistically significant at P < 0.05,

Multivariable logistic regression analysis of major serum biochemical abnormalities

Multivariable logistic regression analysis showed that under-five children with NDA had significantly higher odds of several serum biochemical abnormalities. Hypoalbuminemia was significantly associated with NDA, with affected children having higher odds of anemia compared with those normal albumin levels (AOR = 3.80, 95% CI: 1.82–7.91, P = 0.002). Elevated creatinine levels were significantly associated with NDA, with affected children having higher odds of anemia compared with children without NDA (AOR = 3.32, 95% CI: 1.56–7.04, P = 0.009). Similarly, hyponatremia was also significantly associated with NDA, occurring more frequently among children with NDA than children without NDA (AOR = 3.45, 95% CI: 1.67–7.12, P = 0.004). In addition, hyperkalemia showed a strong significant association with NDA, with higher odds observed among affected children (AOR = 4.59, 95% CI: 2.01–10.48, P = 0.004).
Hyperchloremia was significantly associated with NDA, with approximately three times higher odds of anemia among children with NDA compared to children without NDA (AOR = 3.32, 95% CI: 1.49–7.36, P = 0.009) (Table 6). Overall, all assessed biochemical abnormalities remained significantly associated with NDA in the multivariable analysis.

Multivariable logistic regression analysis on hypoalbuminemia, elevated creatinine, and associated demographic factors among under-five children with NDA

The multivariable logistic regression analysis showed that hypoalbuminemia and elevated

Table 6: Multivariable logistic regression analysis of serum biochemicals abnormalities associated with NDA among study participants at MWUGRH, Goba, Oromia, Ethiopia, 2024

Parameter	Category	Children with NDA n (%)	Children without NDA n (%)	Total n (%)	AOR (95% CI)	*P*-value
Hypoalbuminemia	Yes	25 (78.13)	13 (40.63)	38 (59.38)	3.80 (1.82–7.91)	0.002*
	No	7 (21.87)	19 (59.37)	26 (40.63)	1	
Elevated creatinine	Yes	25 (78.13)	15 (46.88)	40 (62.50)	3.32 (1.56–7.04)	0.009*
	No	7 (21.87)	17 (53.12)	24 (37.5)	1	
Hyponatremia	Yes	25 (78.13)	15 (46.88)	40 (62.5)	3.45 (1.67–7.12)	0.004*
	No	7 (21.87)	17 (53.12)	24 (37.5)	1	
Hyperkalemia	Yes	25 (78.13)	14 (43.75)	39 (60.94)	4.59 (2.01–10.48)	0.004*
	No	7 (21.87)	18 (56.25)	25 (39.06)	1	
Hyperchloremia	Yes	25 (78.13)	15 (46.88)	40 (62.5)	3.32 (1.49–7.36)	0.009*
	No	7 (21.87)	17 (53.12)	24 (37.5)	1	

AOR = Adjusted Odds Ratio; *Statistically significant at P < 0.05,

creatinine were significantly associated with several socio-demographic and nutritional factors among under-five children with NDA. For hypoalbuminemia, children aged 0–3 years (toddlers) had approximately four times higher odds of developing hypoalbuminemia compared with children aged 3–5 years (AOR = 4.20, 95% CI: 1.89–9.31; P = 0.001). Children from poor socioeconomic backgrounds were more likely to develop hypoalbuminemia compared with those from better socioeconomic conditions (AOR = 2.71, 95% CI: 1.49–4.96; P = 0.001). Similarly, children whose mothers had non-formal education were more likely to develop hypoalbuminemia than those whose mothers had formal education (AOR = 3.16, 95% CI: 1.71–5.83; P = 0.001). Rural residency was strongly associated with hypoalbuminemia, with rural children having seven times higher odds compared to urban residents (AOR = 7.03, 95% CI: 3.01–16.42; P = 0.001). Milk-based weaning practices were also significantly associated with hypoalbuminemia (AOR = 1.62, 95% CI: 1.10–2.39; P = 0.014). In addition, malnutrition was strongly associated with hypoalbuminemia, with malnourished children having higher odds compared with well-nourished children (AOR = 3.73, 95% CI: 1.98–7.03; P = 0.001).

For elevated creatinine, sex, socioeconomic status, maternal education, residence, and nutritional status were significantly associated. Male children had significantly higher odds of elevated creatinine levels compared with female children (AOR = 2.07, 95% CI: 1.08–3.95; P = 0.028). Children from poor socioeconomic

backgrounds had nearly three times higher odds of elevated creatinine compared with those better socioeconomic conditions (AOR = 2.95, 95% CI: 1.39–6.23; P = 0.005). Likewise, maternal non-formal education was strongly associated with elevated creatinine levels (AOR = 4.33, 95% CI: 2.01–9.34; P = 0.001). Rural residence was also significantly associated with elevated creatinine (AOR = 4.97, 95% CI: 2.27–10.88; P = 0.001). Furthermore, malnutrition was strongly associated with elevated creatinine levels, with malnourished children having five times higher odds compared with well-nourished children (AOR = 5.03, 95% CI: 2.31–10.95; P = 0.001) (Table 7).

Table 7: Multivariable Logistic Regression of hypoalbuminemia, elevated creatinine, and demographic factors in under five children with NDA at MWUGRH, Goba, Oromia, Ethiopia, 2024

Variable	Category	Hypoalbuminemia		Elevated creatinine	
		AOR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
Age	Toddler (0-3 years)	4.20 (1.89–9.31)	0.001	1.25 (0.69–2.30)	0.199
	Children (3-5 years)	1		1	
Sex	Male	1.04 (0.58–1.89)	0.107	2.07 (1.08–3.95)	0.028*
	Female	1		1	
Socioeconomic status	Poor	2.72 (1.49–4.96)	0.001	2.95 (1.39–6.23)	0.005*
	Good	1		1	
Maternal education	Non-formal	3.16 (1.71–5.83)	0.001	4.33 (2.01–9.34)	0.001*
	Formal	1		1	
Residence	Rural	7.03 (3.01–16.42)	0.001	4.97 (2.27–10.88)	0.001*
	Urban	1		1	
Weaning Practice	Milk- based	1.62 (1.10–2.39)	0.014	1.75 (0.99–3.07)	0.053
	Family food	1		1	
Vegetables consumption	Low	0.13 (0.03–0.54)	0.053	0.96 (0.44–2.08)	0.525
	Good	1		1	
Breast feeding	Yes	1.00 (0.51–1.98)	0.850	1.53 (0.96–2.43)	0.070
	No	1		1	
Nutritional status	Malnourished	3.73 (1.98–7.03)	0.001*	5.03 (2.31–10.95)	0.001*
	Normal	1		1	
Family food source	Teff	0.35 (0.12–1.01)	0.666	0.40 (0.14–1.16)	0.398
	Other	1		1	

CI = Confidence Interval; AOR = Adjusted Odds Ratio; ref.= Reference

Multivariable logistic regression analysis of major electrolytes disorder and demographic factors among under-five children with NDA

Multivariant logistic regression analysis showed that electrolyte disorders were significantly associated with several demographic, socio-economic, and nutritional factors among under-five children with NDA. For hyponatremia, children from poor socio-economic backgrounds were significantly more likely to develop hyponatremia compared to those from good socio-economic conditions (AOR = 2.95; 95% CI: 1.28–6.81; P = 0.011). Likewise, children

whose mothers had non-formal education showed significantly higher odds of hyponatremia (AOR = 4.63; 95% CI: 2.03–10.56; P = 0.001). Rural residence was significantly associated with hyponatremia (AOR = 3.81; 95% CI: 1.57–9.22; P = 0.003). Importantly, malnutrition was strongly associated with hyponatremia, with malnourished children having more than five times higher odds compared to children with well-nourished children (AOR = 5.38; 95% CI: 2.36–12.24; P = 0.001). For hypokalemia, children from poor socio-economic backgrounds were significantly more likely to develop hyperkalemia compared than those from good socio-economic conditions (AOR = 3.25; 95% CI: 1.31–8.02; P = 0.011). Likewise, maternal non-formal education was strongly associated with hyperkalemia (AOR = 5.04; 95% CI: 2.18–11.64; P = 0.001). Rural residence was also significantly associated with hyperkalemia (AOR = 3.02; 95% CI: 1.23–7.43; P = 0.016). Furthermore, malnutrition was strongly associated with hyperkalemia, with malnourished children having nearly six times higher odds compared to their well-nourished counterparts (AOR = 5.86; 95% CI: 2.49–13.77; P = 0.001). For hyperchloremia, male children were significantly more likely to develop hyperchloremia compared to females (AOR = 2.21; 95% CI: 1.09–4.48; P = 0.028). Children from poor socio-economic backgrounds had significantly higher odds of hyperchloremia (AOR = 2.95; 95% CI: 1.38–6.31; P = 0.005), while, maternal non-formal education was also strongly associated with hyperchloremia (AOR = 4.63; 95% CI: 2.03–10.56; P = 0.001). Rural residence remained significantly association with hyperchloremia (AOR = 3.81; 95% CI: 1.76–8.23; P = 0.001). Malnutrition was strongly associated with hyperchloremia, with malnourished children having more the five times higher odds compared to well-nourished children (AOR = 5.38; 95% CI: 2.36–12.24; P = 0.001) (Table 8).

Table 8: Multivariable Logistic Regression analysis of electrolyte disorders among under-five NDA at MWUGRH, Goba, Oromia, Ethiopia, 2024

Variable	Category	Hyponatremia		Hyperkalemia		Hyperchloremia	
		AOR (95% CI)	***P*-value**	**AOR (95% CI)**	***P*-value**	**AOR (95% CI)**	***P*-value**
Age	Toddler (0-3 years)	1.34 (0.72–2.51)	0.325	1.44 (0.77–2.69)	0.325	1.34 (0.72–2.51)	0.199
	Children (3-5 years)	1	–	1	–	1	–
Sex	Male	2.21 (0.97–5.01)	0.058	1.76 (0.79–3.95)	0.168	2.21 (1.09–4.48)	0.028*
	Female	1	–	1	–	1	–
Socioeconomic status	Poor	2.95 (1.28–6.81)	0.011*	3.25 (1.31–8.02)	0.011*	2.95 (1.38–6.31)	0.005*
	Good	1	–	1	–	1	–
Maternal education	Non-formal	4.63 (2.03–10.56)	0.001*	5.04 (2.18–11.64)	0.001*	4.63 (2.03–10.56)	0.001*

	Formal	1	–	1	–	1	–
Residence	Rural	3.81 (1.57–9.22)	0.003*	3.02 (1.23–7.43)	0.016*	3.81 (1.76–8.23)	0.001*
	Urban	1	–	1	–	1	–
Weaning practice	Milk-based	1.87 (0.89–3.92)	0.095	2.04 (0.89–4.68)	0.095	1.87 (0.99–3.52)	0.053
	Family food	1	–	1	–	1	–
Vegetable consumption	Low	1.03 (0.49–2.15)	0.717	0.84 (0.39–1.80)	0.717	1.03 (0.49–2.15)	0.525
	Good	1	–	1	–	1	–
Breast feeding	Yes	1.63 (0.86–3.08)	0.133	1.30 (0.76–2.21)	0.133	1.63 (0.96–2.77)	0.070
	No	1	–	1	–	1	–
Nutritional status	Malnourished	5.38 (2.36–12.24)	0.001*	5.86 (2.49–13.77)	0.001*	5.38 (2.36–12.24)	0.001*
	Normal	1	–	1	–	1	–
Family food source	Teff	0.43 (0.15–1.21)	0.247	0.46 (0.17–1.25)	0.247	0.43 (0.15–1.21)	0.398
	Other	1	–	1	–	1	–

CI= Confidence Interval, AOR = Adjusted Odds Ratio, ref.= Reference

Discussion

NDA is a prevalent condition among children under-five of age, arising from inadequate intake or poor absorption of vital nutrients such as iron, folate, and vitamin B12 (4-6). This deficiency is associated with various biochemical disturbances, such as reduced serum albumin, elevated serum creatinine, hyponatremia, hyperkalemia, and hyperchloremia (5, 27-30). These metabolic and electrolyte abnormalities may be more pronounce among young children due to their physiological immaturity and increased nutritional vulnerability.

Accordingly, the findings of the present study are in agreement with the study conducted in Ethiopia by Berhanu et al., which reported that younger children admitted to pediatric intensive care units were more susceptible to hyponatremia and related electrolyte disturbances due to the physiological vulnerability of younger children, including immature kidney function, higher fluid and electrolyte requirements, and increased susceptibility to metabolic and biochemical complications associated with NDA (31).

The present study result is partially consistent with the nationwide study conducted in Ethiopia by Birhanu et al. and Sahiledengle et al., which reported that male children were disproportionately affected by undernutrition compared with female children. The similarity between the findings may be explained by the greater vulnerability of male children to nutritional stress, recurrent infections, and growth-related metabolic demands during early childhood (31, 32).

Similarly, the finding of the present support that study reported by Shimanda et al. in Namibia, which reported that low socioeconomic status as strong predictor of anemia among under-five children. The similarity between the findings

may be explained by limited access to adequate nutrition, poor living conditions, recurrent infections, and reduced healthcare utilization among economically disadvantaged families. These conditions may contribute not only to anemia but also to metabolic and electrolyte disturbances in affected children (33). Furthermore, the findings of this study are in agreement with those reported by Ncogo et al. in Equatorial Guinea, which demonstrated a higher burden of anemia among children living in rural areas compared with urban settings. This similarity may be explained by limited access to healthcare service, poor sanitation, inadequate dietary diversity, recurrent infections, and lower socioeconomic conditions commonly observed in rural communities (34).

The results of the present study are also comparable with those reported by Sunardi et al. in Indonesia, which identified inadequate dietary intake and poor feeding practices were important determinants of anemia among children aged 6–36 months. The similarity between the findings may be explained by insufficient intake of essential nutrients, proteins, and micronutrients required for normal growth, hematologic function, and electrolyte balance. Poor dietary diversity and malnutrition may also impair renal and metabolic functions, contributing to disturbances in creatinine and electrolyte levels (6).

Likewise, the findings of the present study are consistent with the study conducted by Tezol and Mammadova in Türkiye, which emphasized that lower maternal education and poor nutrition literacy were associated with higher risk of anemia in children. The similarity between the findings may be explained by the fact that mothers with limited education are less likely to have adequate knowledge of balanced diets, appropriate child feeding practices, and prevention of micronutrient deficiencies. This can contribute not only to anemia but also to broader metabolic disturbances related to poor nutritional intake (35).

In addition, the finding of the present study is partly consistent with those reported by Monterrosa et al. in Mexico, which reported that predominant breastfeeding during the first six months of life is associated with a reduced risk of gastrointestinal infections but may increase the risk of iron deficiency due to limited dietary iron intake from exclusive breast milk. The similarity between the findings may be explained by the nutritional composition of breast milk, which provides essential nutrients and immunological protection, but contains relatively low iron content beyond early infancy (36).

Moreover, the present findings are further supported by the study conducted by Tezol and Mammadova in Türkiye, which highlighted that inadequate nutrition practices during early childhood, closely linked to low maternal nutrition literacy, are important contributors to the development of anemia in children. The similarity between the findings may be explained by inappropriate complementary feeding practices, where reliance on milk-based diets can limit the intake of iron-rich and diversified foods, thereby increasing vulnerability to anemia and related metabolic disturbances (35).

Regarding serum albumin, similar to the findings of the present study, a study conducted by Özkale and Sipahi reported that children with protein-energy malnutrition commonly developed hematologic abnormalities including anemia together with reduced serum albumin levels (11). Similarly, research conducted in Ethiopia by Gebreweld et al. found that 38.3% of under-five children with NDA had hypoalbuminemia, further emphasizing the interrelationship between these conditions in low-resource settings (30).

In agreement with the present study, Eckart et al. suggested that hypoalbuminemia in

undernourished children may contribute to NDA development rather than being solely a consequence of the condition (37). Likewise, Tiwari et al. reported that anemia resulting from inadequate nutritional intake and chronic illness frequently coexist with low albumin (13).

Despite the fact that these findings indicate a relationship between albumin and malnutrition, Wiedermann et al. proposed that inflammatory responses may contribute to hypoalbuminemia, as cytokines such as IL-6 suppress albumin production, raising questions about whether reduced albumin levels are a cause or a consequence of anemia (10). In addition, Coulthard, and Opoka et al. suggested that albumin levels may be influenced by liver function and hydration status (9, 16).

Furthermore, a previous study reported that, in NDA, the body prioritizes the production of essential proteins such as hemoglobin over albumin, leading to reduced albumin levels, which supports the findings of this study (9-14). The findings of this study suggest a possible association between NDA and impaired kidney function, which is consistent with Patel et al., who examined the relationship between anemia and renal function in children (18). However, Walker et al. cautioned that blood creatinine levels may not be sufficient to detect renal impairment, particularly in children under five years of age, because factors such as muscle mass can significantly influence creatine levels (38).

The findings of the present study are also consistent with those of Shreewastav et al. who observed higher median creatinine levels among children with different forms of anemia, suggesting a potential association between anemia and elevated creatinine levels (39). Nevertheless, Chuang et al. emphasized that median values should be interpreted cautiously because of the possibility of screwed data distribution (20). Furthermore, the present findings were supported by Bishaw et al. reported a high prevalence of anemia among chronic kidney disease patients and identified elevated serum creatinine as a significant predictor of anemia severity. However, Koshy et al. noted that additional factors, such as dietary intake and hydration status, may also have an impact on these outcomes (17, 40).

Regarding the sodium imbalance, the findings of the present study are supported by research conducted by Berhanu et al. and Baez et al., both of demonstrated reduced sodium levels among malnourished children (22, 31). Similarly, Mansoor et al. suggested that nutritional deficiencies may exacerbate electrolyte imbalances by impairing kidney function and impaired sodium retention mechanisms (5).

In contrast, Koumpis et al. reported that not all anemic children develop hyponatremia, as some are able to maintain normal sodium levels due to compensatory physiological mechanisms (21). Furthermore, Zieg et al. proposed that factors such as hydration status, dietary intake, and concurrent infections also contribute to variations in sodium levels independently of NDA. In addition, it was reported that in severe anemia, antidiuretic hormone promotes water reabsorption in kidneys, which may result in dilutional hyponatremia rather than actual sodium loss (41).

With regards to potassium imbalance, the findings of this study are consistent with those reported by Eleftheriadis et al., who suggested that potassium retention is a result of renal impairment brought on by anemia (42). Likewise, Lehnhardt et al. emphasized that metabolic acidosis may further exacerbate potassium abnormalities in anemic people (43). In contrast, Saraf et al. and Yuan et al. proposed that elevated potassium levels may be also result from hemolysis, dehydration, muscle breakdown, and nutritional factors, including dietary potassium intake, thereby complicating

the interpretation of hyperkalemia in NDA patients complex (23, 44).

The pattern observed in the present study also align the findings of Burke et al., who elaborated that metabolic adaptations in anemic children may increase the likelihood of potassium retention (45). Furthermore, Saraf et al. and Burke et al. reported that NDA may lead to hypoxia, which can impair renal potassium and consequently result in potassium accumulation I the blood (23, 45). Conversely, Raza et al. reported that hypokalemia may also occur in under-five with NDA and may present clinically with muscle weakness, hypotonia, apathy, paralytic ileus, and cardiac arrhythmias (28).

Concerning chloride imbalance, the findings of the present study are in line with those reported by Mansoor et al. and Raza et al., who highlighted that renal impairment and chronic inflammation associated with NDA may contribute to increased chloride retention (5, 28). Similarly, Barhight et al. further reported the role of NDA in promoting chloride retention through its association with metabolic acidosis in malnourished children (24). In addition, Stenson et al. noted that elevated chloride levels are commonly observed in under-five children with NDA because of disturbances in fluid homeostasis (26). However, Barhight et al., Mitting et al., and Stenson et al. reported that hyperchloremia associated with dehydration and anemia-induced hypoxia may lead to increased lactic acid production and subsequent metabolic acidosis. To compensate for this acid-base imbalance, the body retains chloride, ultimately resulting in hyperchloremia (24-26).

Moreover, further longitudinal studies are needed to explore long-term impacts of serum biochemical disorders associated with NDA and to support the development of novel and more accurate diagnostic approaches. In addition, the molecular- level effects of NDA and its associated biochemical abnormalities, including potential DNA damage, remain poorly understood and warrant further investigation.

Conclusion

The findings of this study revealed alterations in major biochemical parameters among under-five NDA. These changes were commonly observed in children with NDA and may reflect their underlying nutritional and clinical status. In this study the key biochemical abnormalities identified included hypoalbuminemia, elevated serum creatinine, hyponatremia, hyperkalemia and hyper chloremia. These results highlight the complex relationship between nutritional status, metabolic process, and electrolyte balance in this population.

The findings underscore the close relationship between nutritional status and biochemical imbalance in this population. The observed associations of abnormalities of biochemical parameters with demographic, socioeconomic, and nutritional factors also emphasize the importance of addressing social determinants of health, including improving maternal education, socioeconomic conditions, and dietary diversity, as essential strategies for the prevention and management of biochemical abnormalities among under-five children with NDA.

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Ethical considerations

Ethical clearance was obtained from the ethical approval committee of the Hawassa University

College of medicine and health science on the date of January 22, 2024 (the date is written as 13/5/2016 on the ethical approval letter which is according to the Ethiopian calendar) with approval number IRB/050/16. After ethics approval, permissions were obtained from the MWUGRH. Since the participants were minors, the parents or guardians of the children were informed about the risks and benefits of participation and written informed consent was obtained. The participants were addressed while they were visiting the health facilities for a routine healthcare and hence the data were collected as part of the routine check-up. All the procedures were carried out in accordance with the standard operating procedures of the health facilities and WHO guidelines.

Data availability statement

Data will be available from corresponding author upon request.

Conflicts of interest

The authors hereby declare that they have no conflict of interests regarding this paper.

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References

1. Kotecha PV. Nutritional anemia in young children with focus on Asia and India. Indian J Community Med. 2011;36(1):8-16.
2. Sundararajan S, Rabe H. Prevention of iron deficiency anemia in infants and toddlers. Pediatr Res. 2021;89(1):63-73.
3. Fentaw W, Belachew T, Andargie A. Anemia and associated factors among 6 to 59 months age children attending health facilities in Kombolcha town, Northeast Ethiopia: a facility-based cross-sectional study. BMC Pediatr. 2023;23(1):209.
4. Dosoo DK, Asante KP, Kayan K, Adu-Gyasi D, Osei-Kwakye K, Mahama E, et al. Biochemical and hematologic parameters for children in the middle belt of Ghana. Am J Trop Med Hyg. 2014;90(4):767-73.
5. Mansoor F, Bai P, Kaur N, Sultan S, Sharma S, Dilip A, et al. Evaluation of Serum Electrolyte Levels in Patients With Anemia. Cureus. 2021;13(10):e18417.
6. Sunardi D, Bardosono S, Basrowi RW, Wasito E, Vandenplas Y. Dietary Determinants of Anemia in Children Aged 6-36 Months: A Cross-Sectional Study in Indonesia. Nutrients. 2021;13(7).
7. Zimmermann MB, Hurrell RF. Nutritional iron deficiency. Lancet. 2007;370(9586):511-20.
8. Chouraqui JP. Dietary Approaches to Iron Deficiency Prevention in Childhood-A Critical Public Health Issue. Nutrients. 2022;14(8).
9. Coulthard MG. Oedema in kwashiorkor is caused by hypoalbuminaemia. Paediatr Int Child Health. 2015;35(2):83-9.
10. Wiedermann CJ, Wiedermann W, Joannidis M. Causal relationship between hypoalbuminemia and acute kidney injury. World J Nephrol. 2017;6(4):176-87.
11. Ozkale M, Sipahi T. Hematologic and bone marrow changes in children with protein-energy malnutrition. Pediatr Hematol Oncol. 2014;31(4):349-58.
12. Coutinho GG, Goloni-Bertollo EM, Bertelli EC. Iron deficiency anemia in children: a challenge for public health and for society. Sao Paulo Med J. 2005;123(2):88-92.
13. Tiwari LK, Singhi S, Jayashree M, Baranwal AK, Bansal A. Hypoalbuminemia in critically sick children. Indian J Crit Care Med. 2014;18(9):565-9.

14. Penickova S, Benyaich S, Ambar I, Cotton F. Reliability of albumin bromocresol green colorimetric method and clinical impact. Scand J Clin Lab Invest. 2024;84(7-8):452-8.
15. Braamskamp MJ, Dolman KM, Tabbers MM. Clinical practice. Protein-losing enteropathy in children. Eur J Pediatr. 2010;169(10):1179-85.
16. Opoka RO, Conroy AL, Waiswa A, Wasswa R, Tumwine JK, Karamagi C, John CC. Severe Anemia Is Associated with Systemic Inflammation in Young Children Presenting to a Tertiary Hospital in Uganda. Am J Trop Med Hyg. 2020;103(6):2574-80.
17. Bishaw F, Belay Woldemariam M, Mekonen G, Birhanu B, Abebe A. Prevalence of anemia and its predictors among patients with chronic kidney disease admitted to a teaching hospital in Ethiopia: A hospital-based cross-sectional study. Medicine (Baltimore). 2023;102(6):e31797.
18. Patel SS, Molnar MZ, Tayek JA, Ix JH, Noori N, Benner D, et al. Serum creatinine as a marker of muscle mass in chronic kidney disease: results of a cross-sectional study and review of literature. J Cachexia Sarcopenia Muscle. 2013;4(1):19-29.
19. Nishino T, Endo S, Miyano H, Takemasa Y, Saito M, Umeda C, et al. Reference serum creatinine levels according to sex, age, and height in children with Down syndrome. Eur J Pediatr. 2021;180(9):2977-83.
20. Chuang GT, Tsai IJ, Tsau YK. Serum Creatinine Reference Limits in Pediatric Population-A Single Center Electronic Health Record-Based Database in Taiwan. Front Pediatr. 2021;9:793446.
21. Koumpis E, Florentin M, Hatzimichael E, Liamis G. Hyponatremia in Patients with Hematologic Diseases. J Clin Med. 2020;9(11).
22. Baez G, Chirio M, Pisula P, Seminario E, Carasa N, Philippi R, et al. Hyponatremia and malnutrition: a comprehensive review. Ir J Med Sci. 2024;193(2):1043-6.
23. Saraf SL, Derebail VK, Zhang X, Machado RF, Gordeuk VR, Lash JP, Little J. Hyperkalemia and Metabolic Acidosis Occur at a Higher eGFR in Sickle Cell Disease. Kidney360. 2022;3(4):608-14.
24. Barhight MF, Brinton J, Stidham T, Soranno DE, Faubel S, Griffin BR, et al. Increase in chloride from baseline is independently associated with mortality in critically ill children. Intensive Care Med. 2018;44(12):2183-91.
25. Mitting RB, Ramnarayan P, Inwald DP. Hyperchloremia on Admission to Pediatric Intensive Care in Mechanically Ventilated Children is Associated with Impaired Renal Function. J Pediatr Intensive Care. 2023;12(1):18-23.
26. Stenson EK, Cvijanovich NZ, Anas N, Allen GL, Thomas NJ, Bigham MT, et al. Hyperchloremia Is Associated With Complicated Course and Mortality in Pediatric Patients With Septic Shock. Pediatr Crit Care Med. 2018;19(2):155-60.
27. Schmidt BM, Tameris M, Geldenhuys H, Luabeya A, Bunyasi E, Hawkridge T, et al. Comparison of haematology and biochemistry parameters in healthy South African infants with laboratory reference intervals. Trop Med Int Health. 2018;23(1):63-8.
28. Raza M, Kumar S, Ejaz M, Azim D, Azizullah S, Hussain A. Electrolyte Imbalance in Children With Severe Acute Malnutrition at a Tertiary Care Hospital in Pakistan: A Cross-Sectional Study. Cureus. 2020;12(9):e10541.
29. Lei QL, Dai BT, Xian Y, Yu J. [Risk factors for nutritional iron deficiency anemia in children]. Zhongguo Dang Dai Er Ke Za Zhi. 2014;16(1):16-9.
30. Gebreweld A, Ali N, Ali R, Fisha T. Prevalence of anemia and its associated factors among children under five years of age attending at Guguftu health center, South Wollo, Northeast Ethiopia. PLoS One. 2019;14(7):e0218961.

31. Berhanu Y, Yusuf T, Mohammed A, Meseret F, Demeke Habteyohans B, Alemu A, et al. Hyponatremia and its associated factors in children admitted to the pediatric intensive care unit in eastern Ethiopia: a cross-sectional study. BMC Pediatr. 2023;23(1):310.
32. Sahiledengle B, Mwanri L, Blumenberg C, Agho KE. Gender-specific disaggregated analysis of childhood undernutrition in Ethiopia: evidence from 2000-2016 nationwide survey. BMC Public Health. 2023;23(1):2040.
33. Shimanda PP, Amukugo HJ, Norstrom F. Socioeconomic factors associated with anemia among children aged 6-59 months in Namibia. J Public Health Afr. 2020;11(1):1131.
34. Ncogo P, Romay-Barja M, Benito A, Aparicio P, Nseng G, Berzosa P, et al. Prevalence of anemia and associated factors in children living in urban and rural settings from Bata District, Equatorial Guinea, 2013. PLoS One. 2017;12(5):e0176613.
35. Tezol O, Mammadova S. Mother's Nutrition Literacy and Offspring Anemia: A Comparison Study in a Single Center. Turk Arch Pediatr. 2023;58(6):638-45.
36. Monterrosa EC, Frongillo EA, Vasquez-Garibay EM, Romero-Velarde E, Casey LM, Willows ND. Predominant breast-feeding from birth to six months is associated with fewer gastrointestinal infections and increased risk for iron deficiency among infants. J Nutr. 2008;138(8):1499-504.
37. Eckart A, Struja T, Kutz A, Baumgartner A, Baumgartner T, Zurfluh S, et al. Relationship of Nutritional Status, Inflammation, and Serum Albumin Levels During Acute Illness: A Prospective Study. Am J Med. 2020;133(6):713-22 e7.
38. Walker AM, Schneider G, Yeaw J, Nordstrom B, Robbins S, Pettitt D. Anemia as a predictor of cardiovascular events in patients with elevated serum creatinine. J Am Soc Nephrol. 2006;17(8):2293-8.
39. Shreewastav RK, Joshi BR, Yadav R, Katwal A, Shrestha S. Iron Profile and Status of Anemia with the Associated Factors in Chronic Kidney Disease Patients. J Nepal Health Res Counc. 2023;21(1):129-35.
40. Koshy SM, Geary DF. Anemia in children with chronic kidney disease. Pediatr Nephrol. 2008;23(2):209-19.
41. Zieg J. Pathophysiology of Hyponatremia in Children. Front Pediatr. 2017;5:213.
42. Eleftheriadis T, Leivaditis K, Antoniadi G, Liakopoulos V. Differential diagnosis of hyperkalemia: an update to a complex problem. Hippokratia. 2012;16(4):294-302.
43. Lehnhardt A, Kemper MJ. Pathogenesis, diagnosis and management of hyperkalemia. Pediatr Nephrol. 2011;26(3):377-84.
44. Yuan HC, Jeng MJ, Soong WJ, Chen SJ, Hwang BT. Hyperkalemia during the early postnatal days in premature infants. Acta Paediatr Taiwan. 2003;44(4):208-14.
45. Burke M, Sinha P, Luban NLC, Posnack NG. Transfusion-Associated Hyperkalemic Cardiac Arrest in Neonatal, Infant, and Pediatric Patients. Front Pediatr. 2021;9:765306.