

ELECTROLYTE DYNAMICS IN COVID-19: UNRAVELING BIOCHEMICAL CHANGES IN KHARTOUM STATE

¹Sarah Ahmed Abdelrahman, ²Mohamed Ali Elhassan and ³Hala Mohammed Mustafa

¹University of AlZaeim Al Azhari Faculty of Medical Laboratory Sciences, Department of Clinical Chemistry

²University of Elimam Elmahdi Department of Medical Laboratory Sciences

³College of Medical Laboratory Sciences. Department of Clinical Chemistry. The National Ribat University, Khartoum, Sudan.

Abstract Coronaviruses, named for their distinctive halo or crown-like appearance, are a family of enveloped, positive-sense single-stranded RNA viruses with zoonotic origins. This study delves into the unique characteristics of coronaviruses, focusing on COVID-19, their zoonotic nature, and the associated implications for transmission and quarantine measures. Additionally, it explores the intricate relationship between coronavirus infection and electrolyte imbalances, particularly hyponatremia and hypernatremia, emphasizing their neurological manifestations and the underlying physiological mechanisms.

The emergence of COVID-19 in Wuhan, China, initially linked to a seafood market, underscores the zoonotic potential of coronaviruses. Infection spreads primarily through respiratory droplets and close personal contact, prompting global health responses, including quarantine measures for exposed individuals. Understanding the modes of transmission is vital for effective public health strategies.

Electrolytes, crucial for homeostasis, conduct electrical currents in body fluids. Hyponatremia, marked by low serum sodium levels, presents with neurological symptoms such as headaches and confusion. Conversely, hypernatremia, characterized by elevated serum sodium levels, manifests through signs like tachypnea and agitation. The study explores the neurological implications of these electrolyte imbalances in the context of coronavirus infections.

The virus's impact on the renin-angiotensin-aldosterone system further complicates the electrolyte balance. COVID-19's entry into cells reduces ACE2, leading to increased aldosterone production and potassium loss through urine. This mechanistic insight sheds light on the multifaceted consequences of coronavirus infections on physiological processes, particularly electrolyte regulation.

This comprehensive exploration contributes to a deeper understanding of the complex interactions between coronaviruses and host physiology. Recognizing and addressing the neurological manifestations of electrolyte imbalances in COVID-19 patients is imperative for optimizing clinical management. The findings presented here bridge virology and clinical care, providing valuable insights for healthcare professionals grappling with the intricate nuances of coronavirus infections.

Keywords: Coronavirus, COVID-19, Zoonotic Infections, Electrolyte Imbalances, Neurological Manifestations.

Introduction:

The term "coronavirus" means "halo" or "crown." Coronaviruses are enveloped, positive-sense singlestranded RNA viruses with a genome size range of 26 and 32 kbs (1,2). Coronaviruses are zoonotic infections that originate in animals and can be transmitted directly from one person to another. The seafood market in Wuhan, China, where

COVID-19 is said to have first appeared, was later closed down by Chinese authorities (3). Infection is primarily spread from person to person through respiratory droplets, close personal contact, like touching or shaking hands, and fecaloral routes are rarely used. Therefore, it has been advised to place persons who have been exposed to infection under quarantine for 14 days (4,5). Electrolytes are compounds that dissolve in body fluids and can conduct an electrical current. The extracellular fluid and intracellular fluid include these substances, therefore electrolytes are essential for regulating homeostasis (6). Neurological symptoms of hyponatremia, one of the electrolyte diseases, are present. Headaches, disorientation, confusion, and nausea are common patient complaints. When the serum sodium levels are higher than 145 mmol/L, hyponatremia manifests. Tachypnea, trouble falling asleep, and agitation are all signs of hyponatremia (7). The virus's entry reduces ACE2 and stops angiotensin II from degrading, which leads to an increase in the production of aldosterone and potassium loss from urine (8,9).

Despite the rarity of reports of hypocalcemia during COVID-19 infection, we should therefore pay greater attention to changes in calcium/phosphorus metabolism in COVID-19 patients and closely monitor calcium levels, especially in those with a history of hypocalcemia, to prevent the condition from getting worse and to start the right treatment as soon as possible. (6,8,9). In the pathophysiology of COVID-19, trace elements play a significant role. Recent assessments have noted that amounts of zinc are necessary for both the innate and adaptive immune systems (10).

For instance, low levels of zinc impair the activity of natural killer (NK) cells, which are essential for maintaining the immune response against viruses and tumors (11). Zinc must be in balance with copper in order to neutralize any negative impacts that copper may have. Additionally, copper is an essential trace element for both humans and pathogens (12). No matter the causative agent (virus, bacterium, or fungus), a steady rise in serum copper is a characteristic of infection (13–15). However, there is no data on copper levels in people who have COVID-19 infection. One of the significant ions needed as a cofactor for the ATP enzyme, which is involved in numerous crucial enzymatic activities, is magnesium. By controlling the active sites of particular kinases, Mg^{2+} has also been shown to play a crucial immunological function in CD8⁺ T cell activation in infection [16]. Understanding the potential connection between magnesium and pulmonary outcomes of COVID-19 disease depends on the finding from a recent study that serum magnesium levels may have a protective impact against lung function loss in asthma-chronic obstructive pulmonary disease [17].

Material and Methods

Study Group

A cross-sectional study was conducted during the period from December 2020 to April 2021 in Khartoum State. Sudanese patients with COVID-19 and patients who were diagnosed with COVID-19 during the study period were enrolled to participate in this study. The confirmation of COVID-19 will be based on a CT scan and/or RT-PCR. The total study group was 100, 50 patients with COVID-19 as a case study, and 50 healthy individuals were enrolled as a control group.

Criteria for Inclusion and Exclusion

Patients with any chronic disease that may have an impact on serum electrolytes calcium phosphate magnesium zinc and copper levels will be excluded.

Ethical considerations:

The study was revised and ethically approved by the ethical and scientific committee of the Faculty of Medical Laboratory Sciences, University of Alzaiem Alazhari. Samples were taken with verbal consent from patients or their relatives.

Data collection:

A direct interview questionnaire was used to collect data. Medical information was collected from the patient's file with the help of the treating physician.

Collection of specimens:

Venous blood samples were collected by using sterile, dry, plastic syringes and a tourniquet to make the veins more prominent. The puncture sites are cleaned with 70% ethanol and 5 mL of blood is collected in lithium heparin containers. The lithium heparin blood sample was centrifuged at 4000 rpm to obtain the plasma and then stored at (-4 c) until the analysis.

Measurement of biochemical parameters:

The serum electrolytes Sodium potassium is measured by EasyLyte analyzer ion selective electrode technology, the flow-through sodium electrode uses a selective membrane that is specially formulated to be sensitive to sodium ions, and the potassium electrode employs a similar design with the appropriate selective membrane material. Each electrode's potential is measured in relation to a fixed and stable voltage set by the double-junction silver silver chloride reference electrode. An ion-selective electrode develops a voltage that varies with the concentration of the ion to which it responds.

(18)

The colorimetric method is used for measuring zinc and copper by a single reagent colorimetric test with dibromo-PAESA). The assay principle consists of dissociating copper from ceruloplasmin and other copper-containing proteins, by a denaturalizing agent in acidic conditions. free and the portion associated with copper will form the copper-3-5DiBr-PAESA complex. which is detected by absorbance at 580nm. (19). Zinc forms a red chelate complex with 2-(5-Bromo-2pyridylase)-5-(N-propyl-N-sulfopropylamino)-phenol in a single reagent calorimetric test with 5-Bromo-PAPS. (20) Calcium, phosphate, and magnesium blood levels were measured by the Cobas 6000 fully automated analyzer (Roche-Germany). **Data examination**

The statistical analysis of the results was performed by using the Statistical Package for Social Sciences (SPSS) version 15.0 for Windows version 10 using a T-test for testing difference significance and a Pearson correlation test (rvalue as the coefficient). A P value of 0.05 was considered statistically significant.

Results

This study described 50 adult patients (21–81 years old) who were hospitalized with COVID-19 in an isolation center in Sudan. The study aimed to determine the serum levels of sodium, potassium, calcium, phosphate, magnesium, copper, and zinc in COVID-19 patients and compare the results with a control group. The COVID-19 patients are classified into mild (n = 19), moderate (n = 9) and severe (n = 22) according to disease severity in figure (1).

In the present study, the majority of COVID-19 cases were males (52%), which demonstrated that the incidence of COVID-19 is higher in males than in females. Abnormal laboratory parameters were more frequently observed in confirmed COVID19 patients, particularly in mild, moderate and severe or critical patients, as shown in Tables (1,2) and figures (2,3,4,5).

Table (1) showed hyponatremia and hypokalemia that there was a significant decrease in the mean level of sodium, potassium, and calcium in COVID-19 patients when compared with the control group (p-value = 0.000). Insignificant differences were found in the levels of phosphorus and magnesium among COVID-19 patients. There was no significant difference in the levels of phosphorus and magnesium when compared with the control group. This study showed that there was a significant decrease in the mean level of zinc and an increase in the mean level of copper in COVID-19 patients when compared to the control group (p-value = 0.000), table

1.

Pearson correlation investigates the relationship between COVID-19 disease stages and biochemical changes in plasma parameters in table (2) and figures (2, 3, 4,) and (5) .

Negative correlation between sodium levels and disease severity stages, $R = -0.75$, $P = .000$; negative correlation between serum potassium levels and disease stages, $R = -0.74$, $P = 0.000$.

Negative correlation between Plasma Zinc level and stages of the disease, $R = -0.8$

P . value = 0.000, Positive correlation between Plasma copper and stages of COVID-19 disease, $R = 0.7$, P . value = 0.000,

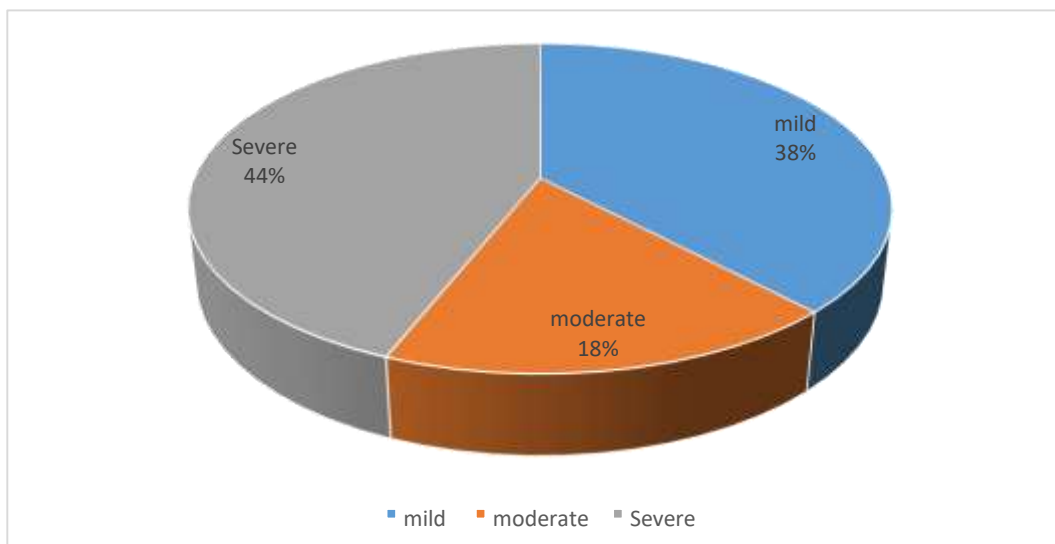


Figure (1) Distribution of stages of the disease in the case study

Table (1) Comparison of biochemical parameters means and Sd. among of the study groups

Test	Cases (Covid19 patients)	Control (Healthy)	P value
Sodium (Na mmol\L)	132 ±4.3	139±2.9	0.000
Potassium (K mmol\L)	3.2±.40	4.3±.46	0.000
Calcium (Ca mg\dL)	7.8±.98	9.2±.60	0.000
Phosphate (Ph mg\dL)	4.5±2.2	3. 9±.024	0.15
Magnesium (Mg mg/dL)	2.2 ±0.5	2.2±0.2	0.8
Zinc (Zn µg/dL)	60±26.8	85±23.4	0.000
Copper (Cu µg/dL)	219 ±89	93 ±23	0.000

Table (2) Correlation between the stages of the disease and biochemical changes in the plasma parameters

Test	Correlation(R-+)	P.value
Na mmol\L	-.753**	.000
K mmol\L	-.736**	.000
Zn µg \dL	-.819**	.000
Cu µg \dL	+.700*	.000

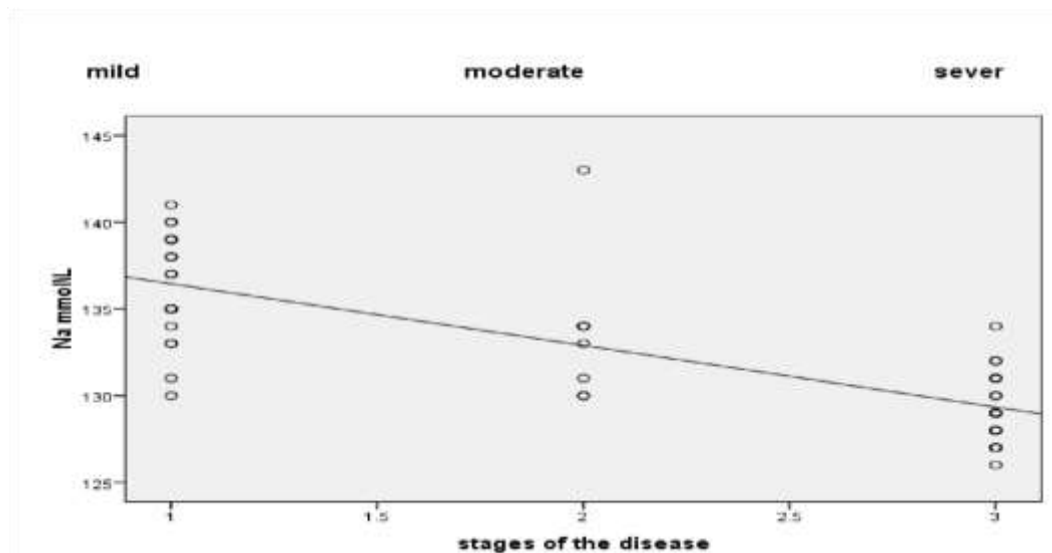


Figure (2)

Correlation between Plasma Sodium (Na) level and stages of COVID 19 disease, R= -0.75 , P.value =.000

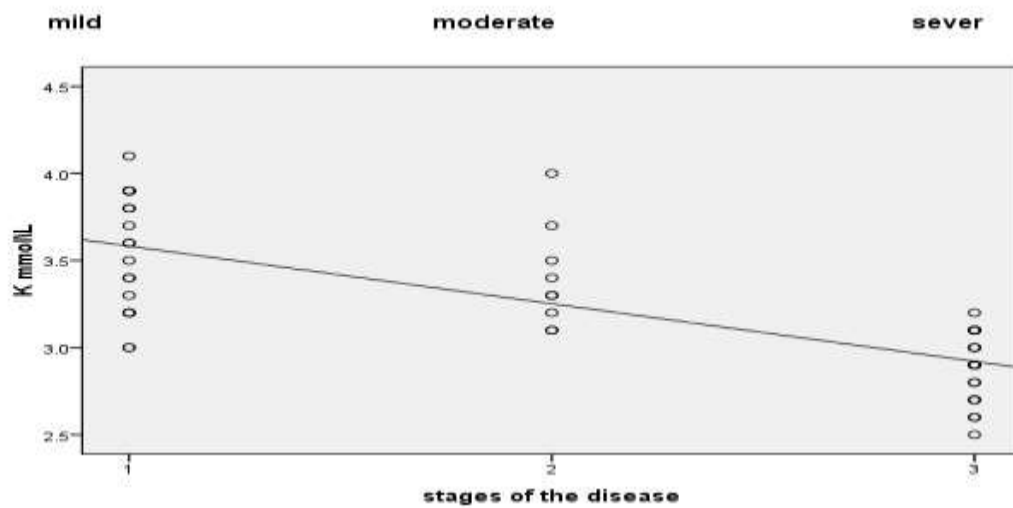


Figure (3) Correlation between Plasma level of Potassium (K) and stages of COVID 19 disease, $R = -0.74$ P.value = 0.000

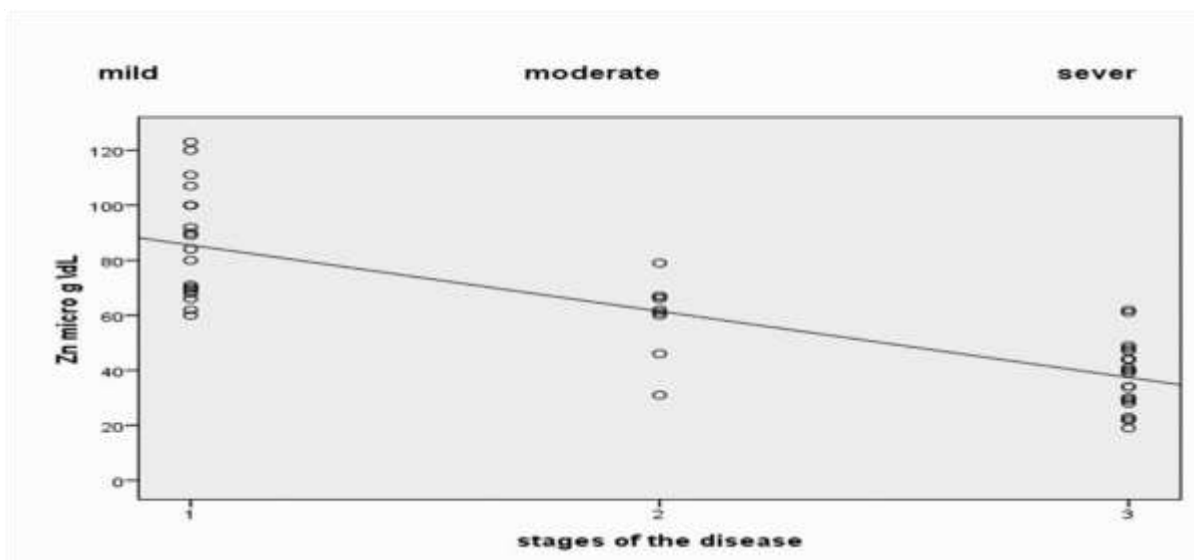


Figure (4) Correlation between Plasma Zinc (Zn) level and stages of COVID 19 disease, $R = -0.8$ P.value = 0.000

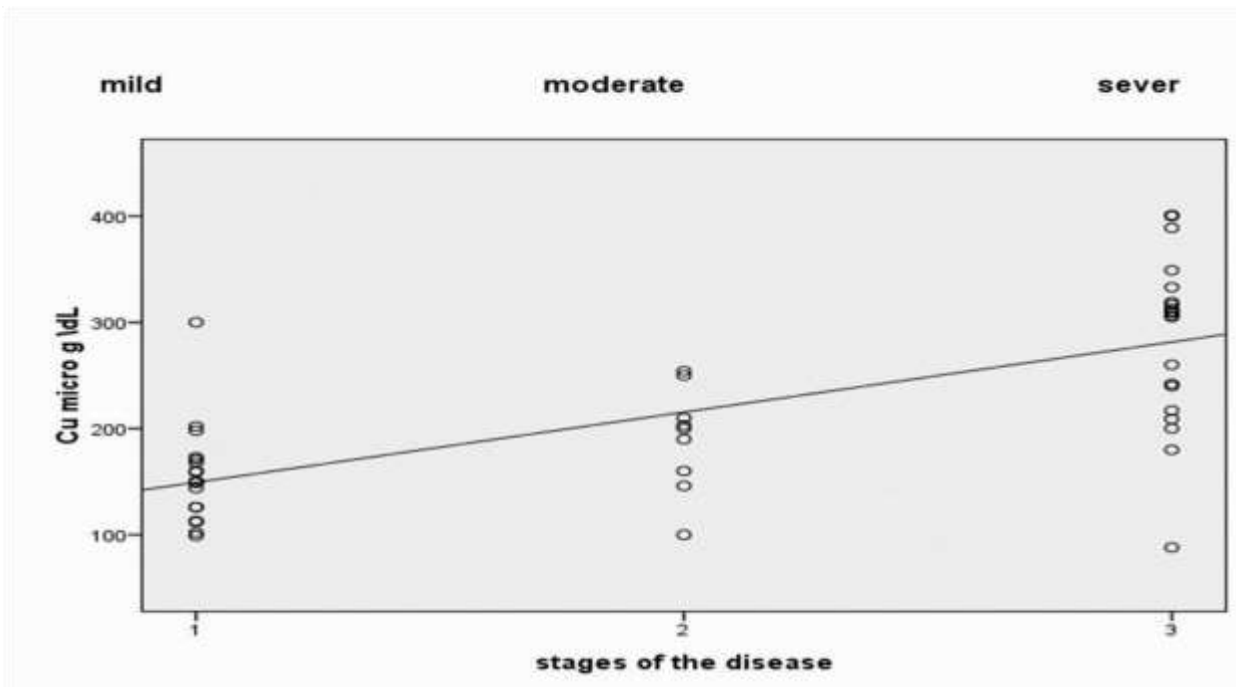


Figure (5) Correlation between Plasma Copper (Cu) and stages of COVID 19 disease, $R = 0.7$ $P\text{-value} = 0.000$

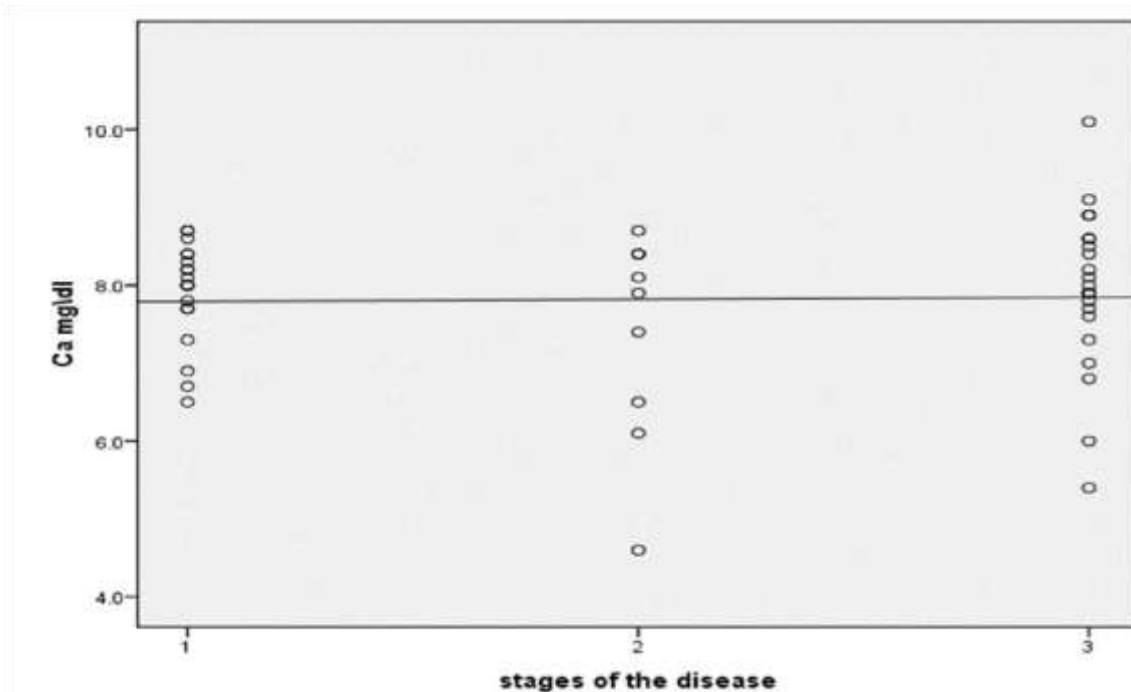


Figure (6) Correlation between serum Calcium (Ca) level and stages of COVID 19 disease $R = 0.02$ and $P\text{-value} = 0.8$.

Discussion

A new coronavirus known as COVID-19 was discovered in Wuhan, China, at the end of 2019. It caused havoc there, with an overall case-fatality rate (CFR) of 2.3% (4512 deaths among 68151 confirmed cases (21) found to

spread from person to person like droplet infections (22) and was highly contagious, leading to a city lockdown to stop the spread of the illness (23) It began to spread over the world, and in March 2020 it reached Sudan (24).

COVID-19 is a huge global health problem due to its high rate of transmission and its high morbidity and mortality rates. Among the numerous pathophysiological effects associated with the virus, endocrine and metabolic disorders stand out. However, the particular consequences on the electrolytes, Calcium, Phosphorus, and trace elements metabolism system are still not fully understood., electrolyte and trace elements disturbances are commonly observed in patients with coronavirus disease 2019 (COVID-19) and associated with outcomes in these patients. Our study was designed to examine whether abnormal levels of electrolyte and trace elements are associated with mortality in COVID-19 patients.

Serum levels of electrolytes essential and trace elements are necessary for the well-functioning and maintenance of the immune system during any infection. In this present study, we measured serum levels of electrolytes and trace elements and their association with the severity of COVID-19 patients. The results indicate that these metal levels are altered in a severity-dependent manner.

This study described adult patients who were hospitalized with COVID-19 in an isolation center in Sudan. In the present study, the majority of COVID-19 cases were males (52%), which agrees with the study of Team TNCPERE (25) which demonstrated that the incidence of COVID-19 is higher in males than in females. This is due to dissimilar innate immunity, steroid hormones, and factors related to sex chromosomes.

The findings of this study, there was a significantly lower mean sodium and potassium levels in COVID-19 patients when compared to the control group , these results corroborated those of Carvalho et al. (26) who found that hyponatremia and hypokalemia were different associations with COVID-19 in comparison to controls. The enhanced production of antidiuretic hormone (ADH) in response to volume depletion after gastrointestinal fluid losses is thought to be responsible for these outcomes , severe illnesses have been linked to hyponatremia, hypokalemia, and hypocalcemia [27].

Some theories have developed, despite the fact that the pathophysiological mechanisms behind such alterations are still not completely known. SARS-interaction of Cov-2's with the ACE2 receptor may result in decreased ACE2 expression and increased angiotensin II, which stimulates potassium excretion and causes hypokalemia [28]. Additionally, diarrhea brought on by gastrointestinal dysfunction may be a cause in electrolyte imbalance (28). The kidneys and GI tract are key players in various processes that regulate fluid and electrolyte balance. Because of this, damage to them usually throws off the balance of fluid and electrolytes [29]. Electrolyte changes in patients, including sodium, potassium, chlorine, and calcium imbalances, are confirmed by similar studies of COVID-19 [30, 31].

Hyponatremia is one of the most frequent electrolyte abnormalities and is associated with a higher mortality risk in hospitalized patients [32].

Patients with COVID-19 who take RAS-inhibiting medications experience decreased aldosterone production, which can result in fluid and electrolyte imbalances. The central nervous system (CNS), the heart, the kidneys, and other GI tracts like the colon all express the mineralocorticoid receptor (MR), also known as the aldosterone receptor. Changes in ion concentration occur as a result of MR activation (such as sodium and potassium). These adjustments are required to keep the body's fluid and electrolyte equilibrium. In spite of this, MR is present in the large intestine [33–35]. Fluid and electrolyte imbalances result from a disruption of the aldosterone pathway, which also affects the absorption and secretion of ions in the colon. Electrolyte abnormalities, such as hyponatremia,

hypokalemia, and hypochloremia, were more prevalent in COVID-19 patients than in controls, according to a case study [36]. A COVID-19 consequence called hypokalemia can increase acute respiratory distress syndrome (ARDS) and put patients at risk for cardiac damage [37]. In patients with acute COVID-19, hyponatremia is rather prevalent. Patients with hyponatremia have spent more time in intensive care and are at greater risk of passing away. As a result, in COVID-19 patients, the level of ions, especially sodium and potassium, is an important signal [38].

According to this study, there was a significantly lower mean calcium level in COVID-19 patients than in the control group, these findings supported by Yang's (39) finding that COVID-19 was independently related with hypocalcemia more so than the control group. Increased neuromuscular irritability, which is characterized by muscle spasms, tingling in the limbs, and perioral numbness, was found to be the most frequent side effect of hypocalcemia in a prior study. A rare complication of hypocalcemia is reversible cardiomyopathy [40]. The findings of the current study are similar with those of Ramesh (41) who found that COVID-19 was significantly associated with hypocalcemia more so than among controls.

When compared to the control group in this investigation, COVID-19 patients had normal levels of phosphate see table (1). Disagree with previous studies findings that hypophosphatemia was more significantly linked with COVID-19 than the control group (39, 41). Nutritional phosphate intake, intracellular to extracellular phosphate transfer, renal glomerular function, and tubular phosphate reabsorption all affect serum phosphate levels. Diets and environmental changes are likely to be responsible for the discrepancy. Other earlier studies discovered that the link between hypophosphatemia and poor outcomes was likely mediated by the risk factors for hypophosphatemia, which are excessive energy consumption and catabolism as well as inadequate nutritional intake. Individuals with COVID-19 frequently suffered from malnutrition, which has been linked to a poor outcome for these patients. (42-47).

Additionally, the regular operation of immune cells may be impacted by cellular ATP depletion, which may be indicated by the low serum phosphorus level, which could affect the immune system's capacity to defend against viral infection. (42-47).

The current study shows the case study's normal serum magnesium level. Low of magnesium makes endothelium cells more susceptible to oxidative stress and encourages endothelial dysfunction. Low intracellular magnesium increases platelet-dependent thrombosis, and low serum magnesium is linked to increased thrombotic risk and slower fibrinolysis (48,49,50,51). Additionally, magnesium decreases mortality in vivo trials of induced pulmonary thrombosis and has antithrombotic properties (52). All of these shows that diffuse intravascular coagulopathy is more likely in COVID-19 individuals who are magnesium deficiency. Rare clinical data available on the serum Cu status of COVID-19 patients. The severity of the condition was positively correlated with higher serum copper levels among COVID-19 patients in this study table (1). Similar findings from previous studies have also shown that copper increased concentrations, with small deviations only in comparison to the healthy control group [53].

Additionally, a study conducted in Wuhan, China, found that patients with more severe diseases had generally higher Cu statuses, without finding a difference in full blood Cu between survivors and non-survivors [54].

Zinc is transiently transferred from the serum to the organs during infection and inflammation, resulting in momentarily low serum zinc levels, which return to normal as the inflammatory response decreases (55,56).

When fighting infections, a normal zinc level is essential, by controlling the pro-inflammatory response, zinc signals have an anti-inflammatory effect during infection. (57)

Higher IL-6 responses have been linked to zinc deficiency. When COVID-19 causes severe lung injury, IL-6 is essential. When compared to mild, moderate, and controls in this study, it was found that the severe stage had significantly lower serum zinc levels see figure (4).

Similar findings were reported by Jothimani et al., who found that patients with decreased zinc levels had more serious problems and required longer hospitalizations in hospitals [29]. Numerous other studies [58, 59] reported reduced zinc levels in COVID-19-infected women, including pregnant women. Muhammad et al. [60] reported similar outcomes in the Nigerian population. In several studies, zinc supplements were also initiated as part of the standard treatment to confirm the role of zinc in the progression of the disease; the groups who were not given any supplements had higher mortality than the population taking zinc supplements [61]. Other findings for zinc and trace elements evaluated in severe COVID-19 patients are similar with those from earlier studies. When compared to mild-to-moderate COVID-19 infection, serum Zn levels have been reported to be reduced [62]. Skalny and others, 2021 (63). Additionally, it was found that as compared to controls, increasing COVID-19 severity is linked to a large, steady decline in serum zinc levels as well as declines in serum calcium, iron, and selenium levels. However, there are higher levels of serum Cu and, in particularly, the Cu Zn ratio [63]. Additionally, according to the study, there is no obvious gender difference in the mean levels of sodium and potassium in COVID-19 patients (p-value 0.05). This result is in contrast a study by Vahidy et al. (64) who found that male patients hospitalized for COVID-19 had a larger proportion of abnormal laboratory values than female patients. The short sample size and environmental changes can be used as an explanation for this difference. Potassium and sodium have a high negative significant link ($r = -.736$, $p = .000$) according to the correlation study. This is similar to Zhou et al. (65), which discovered a high correlation between the severity of the disease and decreasing blood levels of sodium and potassium. The correlation study revealed a weak relationship between calcium and phosphate ($r = 0.02$, $p = 0.8$ and $r = -0.02$, $p = 0.9$, respectively). This is in contrast to Yang's study, which found a significantly positive link between the severity of the disease and reduced blood levels of phosphate and calcium. Acute complications caused on by the virus can include acute kidney damage (AKI) and digestive issues for the patient. Fluid and electrolyte abnormalities are one of the side effects of kidney and GI involvement in COVID-19. The most prevalent of these conditions are hyponatremia, hypernatremia, hypokalemia, hypocalcemia, hypochloremia, hypervolemia, and hypovolemia. If untreated, these conditions can lead to a variety of complications for patients and even increase mortality (66). Additionally, changes in fluid, electrolyte, and trace element levels can be a good indicator of disease progression, this is due to the risk of fluid, electrolyte, and trace element disturbance complications requires special attention from clinicians in order to manage patients' fluid and electrolyte status, in addition to trace element supplements.

Conclusion

In conclusion, based on our results there was a significant decrease in serum levels of Sodium, Potassium, and Calcium in covid-19 patients when compared with the control group. In addition, there was a significantly strong negative correlation between serum levels of Sodium, Potassium, Calcium, and severity of patients of COVID-19. No biochemical change in Serum level of phosphate and magnesium among patients of COVID-19. Serum level of zinc decrease and serum copper levels increase when compared to mild, moderate and sever ill patients of COVID-19. According to our findings, serum levels of calcium were slightly lower in COVID-19 patients.

Acknowledgment

We would like to thank the biomedical scientist who collected samples during the period of research and the staff of the Therapeutic Hospital for Patients of COVID-19 in Khartoum state(nursing, doctors, and medical laboratory specialists) for providing facilities for this work.

References

- Wang, L.-F.; Shi, Z.; Zhang, S.; Field, H.; Daszak, P.; Eaton, B.T. Review of bats and SARS. *Emerg. Infect. Dis.*, 2006 ; 12: 1834–1840.
- Ashikujaman S. Coronavirus: A Mini-Review. *Int. J. Curr. Res. Med. Sci.* 202; **6**(1): 8-10.
- Huang, C., Wang, Y., Li, X., et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *The Lancet*, (2020). 395(10223), pp.497-506.
- Carlos WG, Dela Cruz CS, Cao B, Pasnick S, Jamil S. Novel Wuhan (2019-nCoV) coronavirus. *Am J Respir Crit Care Med.* (2020) ; 201:P7–8.
- Holshue, M., DeBolt, C., Lindquist, S et al . First Case of 2019 Novel Coronavirus in the United States. *New England Journal of Medicine*, 2020; 382(10), pp.929-936.
- Terry J. the major electrolytes: sodium, potassium, and chloride. *J Intraven Nurs.* (2018) 17(5):240-7. PMID: 7965369.
- Shrimanker I, Bhattarai S. Electrolytes. . In *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan–. PMID: (2020) 31082167.
- Lippi G, South AM, Henry BM Electrolyte imbalances in patients with severe coronavirus disease 2019 (COVID-19). *Ann Clin Biochem* (2020) 57(3):262–265.
- 9..Berni A, Malandrino D, Parenti G, Maggi M, Poggesi L, Peri A Hyponatremia, IL-6, and SARS-CoV-2 (COVID-19). (2020).
- 10-Rink L, Gabriel P. Zinc and the immune system. *Proc Nutr Soc.* (2000);59:541–52.doi: 10.1017/S0029665100000781
- Allen JI, Perri RT, McClain CJ, Kay NE. Alterations in human natural killer cell activity and monocyte cytotoxicity induced by zinc deficiency. *J Lab Clin Med.* (1983) 102:577–89.
- Kardos J, Héja L, Simon Á, Jablonkai I, Kovács R, Jemnitz K . Copper signaling: causes and consequences. *CCS* 2018 ;16(1):1–22
- Ilbäck N-G, Frisk P, Tallkvist J, Gadhasson I-L, Blomberg J, Friman G . Gastrointestinal uptake of trace elements are changed during a common human viral (Coxsackievirus B3) infection in mice. *J Trace Elem Med Biol* 2008 ;22(2):120–130

- Cernat R, Mihaescu T, Vornicu M, Vione D, Olariu R, Arsene C . Serum trace metal and ceruloplasmin variability in individuals treated for pulmonary tuberculosis. *Int J Tuberc Lung Dis* 2011; 15(9):1239– 1245
- Besold AN, Culbertson EM, Culotta VC .The Yin and Yang of copper during infection. *J Biol Inorg Chem* 2016; 21(2):137–144
- Kanellopoulou C, George AB, Masutani E, Cannons JL, Ravell JC, Yamamoto TN, SmelkinsonMG, Jiang PD, Matsuda-Lennikov M, Reilley J . Mg²⁺ regulation of kinase signaling and immune function. *J Exp Med* 2019; 216(8):1828–1842
- Ye M, Li Q, Xiao L, Zheng Z . Serum magnesium and fractional exhaled nitric oxide about the severity in asthma chronic obstructive pulmonary disease overlap. *Biol Trace Elem Res.*2020 <https://doi.org/10.1007/s12011-020-02314-5>
- 18-69-Tietz, N.W. (ed) *Fundamentals of clinical chemistry*,2008; 6th ed. P.836-8719-Sergey Makarychev - Mikhailov, Alexey Shvarev, Eric Bakker New trend in iron selective electrode, Electrochemical Sensor, Biosensor and their applications 2008;71 -114
- D J Johnson, YY Djuh, J Bruton, HL Williams, improved colorimetric determination of Serum Zinc *Clinical Chemistry* 1977; 23, 1321 - 1323
- Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID19) outbreak in China: summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention. *J Am Med Assoc*; (2020); 323(13): 1239-42.
- Chan JFW, Yuan S, Kok KH, To KK, Chu H, Yang J. a familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet*. (2020) ; 140-6736(20): 30154-59.
- Phan LT, Nguyen TV, Luong QC, Nguyen TV, Nguyen HT, Le HQ, et al Importation and Human-to-Human Transmission of a Novel Coronavirus in Vietnam. *N Engl J Med* 2020, 382(9): 87274.
- HCT & UNCT. Sudan- Coronavirus- COVID-19 Country preparedness and response plan [Internet]. (2020)
- Team TNCPERE. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China. *Chin J Epidemiol*. 2020(8),113-122.
- Carvalho Hugo De, Marie Caroline Richard, Tahar Chouihed, Nicolas Goffinet and Quentin Le Bastard et al. Electrolyte imbalance in COVID-19 patients admitted to the Emergency Department: a case-control study. *Internal and Emergency Medicine*.2021; 1-6.
- Lippi G, South AM, Henry BM. Annals express electrolyte imbalances in patients with severe coronavirus disease 2019(COVID-19). *Ann Clin Biochem* 2020 ; 57(3) : 262 – 265.

- <https://doi.org/10.1177/000456322092225528> . Dong Chen Jr , Xiaokuni Li et al. Hypokalemia and clinical implications in patients with coronavirus disease 2019 (COVID- 19).WHO,(18, 593 medRxiv) , 2020; P 1-10.
- medRxiv 2020. <https://doi.org/10.1101/2020.02.27.2002853029>.A.H.ChowdhuryandD.N.Lobo, "Fluidsandgastrointestinal function," Current Opinion in Clinical Nutrition and Metabolic Care, 2011; vol. 14, no. 5, pp. 469–476.
- 30.-C. Huang, Y. Wang, X. Li et al., “Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China,” The Lancet,2020; vol. 395, no. 10223, pp. 497–506.
- W. Guan, Z. Ni, Y. Hu et al., “Clinical characteristics of coronavirus disease 2019 in China,” The New England Journal of Medicine, 2020 ; vol. 382, no. 18, pp. 1708–1720
- G. Corona, C.Giuliani, G. Parenti, et al., "Moderate hyponatremia is associated with increased risk of mortality: evidence from a meta-analysis, " PLoS One 2013; vol. 8, no. 12, p. e80451,
- 33-Z. Belden, J. A. Deiuliis, M. Dobre, and S. Rajagopalan, “The role of the mineralocorticoid receptor in inflammation: focus on kidney and vasculature,” American Journal of Nephrology, 2017; vol. 46, no. 4, pp. 298–314.
- Y.-S. Fan, R. L. Eddy, M. G. Byers, et al., "The human mineral –corticoid, receptor gene (MLR) islocatedonchromosome4at 4 BioMed Research International q31. 2," Cytogenetic and Genome Research,1989; vol. 52, no. 1–2, pp. 83-84.
- P. J. Fuller and M. J. Young, "Mechanisms of mineralocorticoid action, "Hypertension, 2005; vol.46, no.6, pp. 1227–1235.
- H.De Carvalho,M.C.Richard,T.Chouihedetal., "Electrolyte imbalance in COVID-19 patients admitted to the emergency department: a case-control study," Internal and Emergency Medicine, 2021; vol. 23, pp. 1–6.
- 37.G. Lippi, A. M. South, and B. M. Henry, “Electrolyte imbalances in patients with severe coronavirus disease 2019 (COVID-19),” Annals of Clinical Biochemistry, 2020; vol. 57, no. 3, pp. 262–265.
- M. A. Zimmer, A. K. Zink, C. W. Weißer et al., “Hypernatremia—a manifestation of COVID-19: a case series,” A&a Practice, 2020 ;vol. 14, no. 9, p. e01295.
- YongkangDong, Li Dong Novel Coronavirus Epidemic Prevention and Control Research Project of Shanxi Province, Grant/Award Numbers The Research Project of Shanxi Health Commission . : 202003D31002/GZ, 202003D31005/GZ.
- E. Bove-Fenderson and M. Mannstadt, “Hypocalcemic disorders,” Best Practice & Research. Clinical Endocrinology & Metabolism,2018; vol. 32, no. 5, pp. 639–656.

- 16..Pal R, Ram S, Zohmangaihi D Biswas I, Suri V, Yaddanapudi LN, Malhotra P, Soni SL, Puri GD, Bhalla A and Bhadada SK . High Prevalence of Hypocalcemia in Non-severe COVID-19 Patients: A Retrospective Case-Control Study. *Front. Med* 2021; 7:590805.DOI: 10.3389/fmed.2020.590805.
- Li T, Zhang Y, Gong C, et al. Prevalence of malnutrition and analysis of related factors in elderly patients with COVID-19 in Wuhan, China. *Eur J Clin Nutr.* 2020;74(6):871–875. doi:10.1038/s41430- 0200642-3
- Di Filippo L, De Lorenzo R, D'Amico M, et al. COVID-19 is associated with clinically significant weight loss and risk of malnutrition, independent of hospitalization: a posthoc analysis of a prospective cohort study. *Clin Nutr.* 2021;40(4):2420–2426. doi:10.1016/j.clnu.2020.10.043
- Yu Y, Ye J, Chen M, et al. Malnutrition prolongs the hospitalization of patients with COVID-19 infection: a clinical epidemiological analysis. *J Nutr Health Aging.* 2021;25(3):369–373. doi:10.1007/ s12603-0201541-y
- Liu A, Cong J, Wang Q, et al. Risk of malnutrition is common in patients with Coronavirus Disease 2019 (COVID-19) in Wuhan, China: a Cross-sectional Study. *J Nutr.* 2021;151(6):1591–1596.
- Wei C, Liu Y, Li Y, Zhang Y, Zhong M, Meng X. Evaluation of the nutritional status in patients with COVID-19. *J Clin Biochem Nutr.* 2020;67(2):116–121. doi:10.3164/jcbrn.20-91
- Zhou J, Ma Y, Liu Y, et al. A correlation analysis between the nutritional status and prognosis of COVID-19 patients. *J Nutr Health Aging.* 2021;25(1):84–93. doi:10.1007/s12603-020-1457-6
- Sobczak AIS, Phoenix FA, Pitt SJ, et al. Reduced Plasma Magnesium Levels in Type-1 Diabetes Associate with Prothrombotic Changes in Fibrin Clotting and Fibrinolysis. *Thrombosis and haemostasis.* 2020; 120:243–52. [PMC free article] [PubMed] [Google Scholar]
- Gromova OA, Torshin IY, Kobalava ZD, et al. Deficit of Magnesium and States of Hyper coagulation: Intellectual Analysis of Data Obtained From a Sample of Patients Aged 18–50 years From Medical and Preventive Facilities in Russia. *Kardiologiia.* 2018; 58:22–35. [PubMed] [Google Scholar]
- Çiçek G, Açıkgöz SK, Yayla Ç, et al. Magnesium as a predictor of acute stent thrombosis in patients with ST-segment elevation myocardial infarction who underwent primary angioplasty. *Coron Artery Dis.* 2016; 27:47–51. [PubMed] [Google Scholar]
- Shechter M, Merz CN, Rude RK, et al. Low intracellular magnesium levels promote platelet-dependent thrombosis in patients with coronary artery disease. *American heart journal.* 2000; 140:212–8. [PubMed] [Google Scholar]
- Sheu JR, Hsiao G, Shen MY, et al. Antithrombotic effects of magnesium sulfate in vivo experiments. *Int J Hematol.* 2003; 77:414–9. [PubMed] [Google Scholar]
- Anuk A.T., Polat N., Akdas S., Erol S.A., Tanacan A., Biriken D., Keskin H.L., Tekin O.M., Yazihan N., Sahin D. The Relation Between Trace Element Status (Zinc, Copper, Magnesium) and Clinical Outcomes in COVID-

19 Infection During Pregnancy. *Biol. Trace Elem. Res.* 2020;1–10:54. Zeng H.L., Yang Q., Yuan P., Wang X., Cheng L. Associations of essential and toxic metals/metalloids in whole blood with both disease severity and mortality in patients with COVID-19. *FASEB J.* 2021; 35:e21392. DOI: 10.1096/fj.202002346RR. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Wessels I, Maywald M, Rink L. Zinc as a gatekeeper of immune function. *Nutrients.* (2017) ; 9:1286. DOI: 10.3390/nu9121286

Maywald M, Wessels I, Rink L. Zinc signals and immunity. *Int J Mol Sci.* (2017); 18:2222. DOI: 10.3390/ijms18102222

57 . Wessels I, Cousins RJ. Zinc dyshomeostasis during polymicrobial sepsis in mice involves zinc transporter Zip14 and can be overcome by zinc supplementation. *Am J Physiol Gastrointest Liver Physiol.* (2015); 309:G768–78. DOI: 10.1152/ajpgi.00179.2015

Arrieta F, Martinez-Vaello V, Bengoa N, et al . Serum zinc and copper in people with COVID-19 and zinc supplementation in parenteral nutrition. *Nutrition* 2021; 91–92:111467. [https:// doi. org/ 10. 1016/j. nut. 2021. 111467](https://doi.org/10.1016/j.nut.2021.111467)

Anuk AT, Polat N, Akdas S et al . The relation between trace element status (zinc, copper, magnesium) and clinical outcomes in COVID-19 infection during pregnancy. *Biol Trace Elem Res* 2021; 199:3608–3617. [https:// doi. org/ 10. 1007/ s12011- 020- 02496-y](https://doi.org/10.1007/s12011-020-02496-y)

Muhammad Y, Kani YA, Iliya S, et al (2021) Deficiency of antioxidants and increased oxidative stress in COVID-19 patients: a cross-sectional comparative study in Jigawa, Northwestern Nigeria. *SAGE Open Med* 9:2050312121991246. [https:// doi. org/ 10. 1177/ 20503 12121 991246](https://doi.org/10.1177/2050312121991246)

Carlucci PM, Ahuja T, Petrilli C, et al . Zinc sulfate in combination with a zinc ionophore may improve outcomes in hospitalized COVID-19 patients. *J Med Microbiol* 2020; 69:1228–1234. [https:// doi. org/ 10. 1099/ jmm.0. 001250](https://doi.org/10.1099/jmm.0.001250)

Ishida T . Antiviral activities of Cu²⁺ ions in viral prevention, replication, RNA degradation, and for antiviral efficacies of the lytic virus, ROS-mediated virus, copper chelation. *World Sci News* 2018; 99:148–168

te Velthuis AJW, van den Worm SHE, Sims AC et al (2010) Zn (2+) inhibits coronavirus and arterivirus RNA polymerase activity in vitro and zinc ionophores block the replication of these viruses in cell culture. *PLoS Pathog* 6:e1001176. [https:// doi. org/ 10. 1371/ journal. pp t. 10011 76](https://doi.org/10.1371/journal.ppat.1001176)

Vahidy FS, Pan AP, Ahnstedt H, Munshi Y, Choi HA, TirunehY, et al Sex differences in susceptibility, severity, and outcomes of coronavirus disease 2019: *PLoS ONE journal.* pone 2021; 16(1): e0245556. [https://doi.org/10.1371/journal. pone.0245556](https://doi.org/10.1371/journal.pone.0245556).(2021)

Zhang W, Du RH, Li B. correlation between hyponatremia and severity of coronavirus disease 2019. *Emerg Microbes Infect* 2020; 9:386–9.

Mohammad Pourfridoni, Seyede Mahsa Abbasnia, Fateme Shafaei, Javad Razaviyan, and Reza HeidariSoureshjani,
Fluid and electrolyte disturbances in COVID-19 and Their Complications Hindawi BioMed Research
International Volume 2021,Article ID 6667047, 5 pages