International Journal of Advanced Research in Medicine

E-ISSN: 2706-9575
P-ISSN: 2706-9567
IJARM 2024; 6(3): 01-09
Received: 02-05-2024
Accepted: 03-06-2024

Ali H Hanoon
Health and Medical Technical College, Southern Technical University, Basra, Iraq

Alaa K Jassim
Health and Medical Technical College, Southern Technical University, Basra, Iraq

Nidhal A Hashim
Maysan Technical Institute, Southern Technical University, Basra, Iraq

Corresponding Author:
Ali H Hanoon
Health and Medical Technical College, Southern Technical University, Basra, Iraq

Comparative analysis of copper and zinc levels and their association with cardiac indicators in chronic heart patients in Maysan governorate

Ali H Hanoon, Alaa K Jassim and Nidhal A Hashim

DOI: https://doi.org/10.22271/27069567.2024.v6.i3a.561

Abstract
Background: Cardiovascular disease (CVD) kill and hurt more people than any other disease or condition in the world. Dietary input, especially zinc (Zn) and copper (Cu), has a strong link to CVD.
Aims of the study: Knowing the relationship between zinc and copper levels and their effect on cardiovascular diseases.
Methodology: A case-control study conducted at Al-Sadr general hospital and Maysan heart center in Maysan Governorate, Iraq from Augest 2023 to March 2024, included a control group of 60 healthy individuals (40 males and 20 females), a group of 80 individuals diagnosed with acute coronary syndrome (50 males and 30 females), in addition to 40 individuals diagnosed with chronic stable angina (22 males and 18 females). The ages of the participants ranged Between 28 and 67 years old. Individuals with preexisting diseases such as cancer, inflammatory or autoimmune diseases, or receiving immunosuppressive medications or statins were excluded for their potential influence on study variables. 5 milliliters of blood was collected from each participant and the extracted samples were stored after centrifugation at -20 °C for analysis by colorimetric detection of zinc and copper concentrations.
Result: The results did not show statistically significant differences in zinc and copper levels between males and females in cases of acute myocardial infarction, and copper levels were higher in men. While in chronic infarction, the data showed a trend of differences in zinc levels, while copper levels were similar between genders. There were statistically significant differences between the three study groups in the level of these two elements, indicating the presence of differences according to gender in their levels.
Conclusions: The study found that there were no statistically significant differences in zinc and copper levels between men and women who had acute or chronic heart attacks. There were changes in both elements based on gender, and copper levels were only slightly different in chronic heart patients with diabetes.

Keywords: Cardiovascular diseases, cardiac indicators, zinc, copper, chronic myocardial infraction, diabetes mellitus

1. Introduction
A myocardial infarction (MI), which people sometimes call a "heart attack," happens when blood flow to part of the muscle slows down or stops completely. A myocardial infarction could be "silent" and go unnoticed, or it could be a disaster that causes the heart's blood flow to drop and the person to die suddenly [1]. Coronary artery disease, which is the main cause of death in the US, is what leads to most myocardial infarctions. When the coronary artery is blocked, oxygen can't get to the muscle. When the heart doesn't get enough oxygen for a long time, cells can die and necrosis can happen [2]. People may feel pain or pressure in their chest that spreads to their neck, jaw, shoulder, or arm. If you have a history of myocardial ischemia and a physical test, you may also see changes in your ECG and higher levels of biochemical markers like cardiac troponins [3, 4]. Coronary heart disease is the main reason people die and become disabled in the western world and around the world. 2015 death records from the National Health Interview Survey (NHIS-CDC) show that 114,023 people died from MI and 151,863 people died because of MI, which is also known as "MI any-mention mortality [5]. The National Health and Nutrition Examination Survey (NHANES)-CDC data from 2011 to 2014 shows that about 16.5 million Americans older than 20 have coronary heart disease.

Men are more likely than women of all ages to have this condition. According to the NHANES from 2011 to 2014, 3.0% of US people over the age of 20 have had a MI [6]. For good body functions to continue, zinc is an important micronutrient [7]. Inside cells, zinc is stored in organelles and vesicles, which is why blood zinc levels are low, ranging from 10 µmol/L to pmol/L [8]. Zn interacts with cells that are important for the development of atherosclerosis. These cells include immune cells, endothelium, and smooth muscle cells. But the exact part that Zn plays in the development of CAD has not yet been fully figured out [9]. Cu is a tiny element that has a big effect on how our bodies work, like controlling how iron is used, protecting cells from damage, and how blood clots [10]. Disrupted Cu balance was linked to the start of cardiovascular disease (CVD) in a number of different ways. The main way to get copper is to eat food, but the amount of copper absorbed depends a lot on what the food is [11]. Since the absorption of Cu and Zn depends on a lot of things, like gender, age, medicine, and supplement use [12], serum concentration might not be the best way to tell what the elemental status is. Having the right amount of zinc is an important part of peroxisome proliferator-activated receptor signalling in atherosclerosis (ATS). Also, people who have coronary heart disease don't have enough zinc. A lack of zinc can make the walls of blood vessels thicker by increasing their growth and multiplication. People with HF are found to have low amounts of zinc in their blood. While Zn helps with antiapoptotic, anti-inflammatory, and antioxidant actions, it also plays a part in redox signalling pathways. Not having enough zinc can damage important proteins like protein creatine kinase (C kinase), increase the production of inflammatory cytokines and C-reactive proteins, and may trap substances in monocytes and macrophages [13, 14, 15]. People who have left ventricular hypertrophy (LVH) have much lower amounts of zinc in their blood, and there is a strong negative relationship between zinc status and LVH. People who have had an ischemic stroke have lower amounts of zinc in their blood than healthy people. Similarly, people with HF and people whose left ventricle diastoles properly have lower amounts of zinc in their blood. Also, lower amounts of zinc in the blood are linked to less stable blood sugar and insulin resistance. Patients who need coronary angiography are more likely to die if they have a low serum Zn levels. Also, blood Zn levels might be a good way to tell if someone has had an acute MI. According to the meta-analysis data, a lower intake of Zn in the diet is linked to a higher risk of coronary artery disease (CAD), and there is a clear link between Zn status and MI [16, 17]. Hypercholesterolemia can also be caused by not having enough copper. One way this happens is by raising the amounts of hydroxymethylglutaryl-coenzyme A (HMG-CoA) reductase, an important enzyme in the process of making cholesterol. As an example, statin drugs that are used to treat and prevent IHD stop HMG-CoA reductase from working, which lowers cholesterol levels. It was found that rats that didn't get enough copper had more than 50% more total cholesterol and 85% to 288% more HMG-CoA reductase activity [18]. Copper deficiency may lead to a higher total cholesterol level and an increased chance of oxidation of lipoproteins, two major factors in increasing the risk of obstructive heart disease. So, eating copper-rich foods or using copper supplements may help reduce these risk factors without the common side effects of drug therapy. On the other hand, it is possible that high levels of total cholesterol and oxidized lipoproteins in people at risk for chronic hepatitis are merely signs of copper deficiency in the body, which is the real risk factor [19]. It is very important to understand how zinc and copper levels affect cardiovascular disease because this can help in developing effective prevention strategies. A precise understanding of this relationship can help in identifying risk and early intervention. Therefore, the possibility of heart disease can be reduced by monitoring the levels of these minerals.

Methodology

A case-control study conducted at Al-Sadr general hospital and Maysan heart center in Maysan Governorate, Iraq from Augest 2023 to March 2024. A control group consisting of 60 healthy individuals (40 males and 20 females) was selected. This study group included 80 individuals with acute coronary syndrome (50 males and 30 females), as well as a group of 40 individuals with chronic stable angina (22 males and 18 females). Study participants ranged in age from 28 to 67 years. During the specified period, all patients in the study were diagnosed by specialized doctors, with the necessary clinical and laboratory tests performed. Individuals with pre-existing medical conditions such as cancer, autoimmune diseases, infections, immune compromise, or statin use were excluded, given the potential for these conditions to separately influence study outcomes. Five milliliters of blood from each individual, both patients and study controls, was collected, and the samples were transferred into sterile test tubes and left to freeze at room temperature for 30 minutes. Subsequently, the samples underwent centrifuged at a speed of 3000 revolutions per minute for a duration of fifteen minutes. The resulting serum was then extracted and stored at a temperature of -20°C until it was ready for analysis. A colorimetric assay use ti detected the concentration of zinc and copper.

Ethical approval

Before the samples were taken, all of the patients who were going to be part of this study were properly informed and gave their verbal permission. The Committee on Publication Ethics at the Al-Sadr general Hospital in Maysan Governorate, gave its approval to the study.

Statistical analysis

Statistical analysis is often used to analyze quantitative data, and provides methods for data description, simple inference for continuous and categorical data. The procedure involves the collection of data leading to test of the relationship between two statistical data sets. In this study all data are presented as mean ± standard deviation. The statistical analyses were performed using SPSS (version 26) and using using dependent t-test (two-tailed) and independent t-test (two-tailed) for normally distribution variables, whereas the Mann-Whitney *U* and Wilcoxon test used for those variables that were not normally distributed. $P < 0.05$ was considered statistically significant.

Results

Comparison between Zinc, Copper levels in acute myocardial infraction patients according to sex

The results show that the average levels of zinc and copper in acute heart attack patients by gender did not reveal any statistically significant differences, as men recorded an

average zinc level of 71.47±14.63 and an average copper level of 196.48±26.34, while women recorded an average zinc level of 70.46±16.28 and an average copper level. 164.43±31.73. The *P* values for zinc and copper were 0.739 and 0.213, respectively, which means that there are no significant differences between men and women in these variables, but it is noted that the average copper levels are higher in men compared to women.

Table 1: Mean± SD of Zinc and Copper levels in acute myocardial infraction patients according to sex

Parameters / patients	Zinc	copper
Male	71.47±14.63	196.48±26.34
Female	70.46±16.28	164.43±31.73
P Value	0.739	0.213*

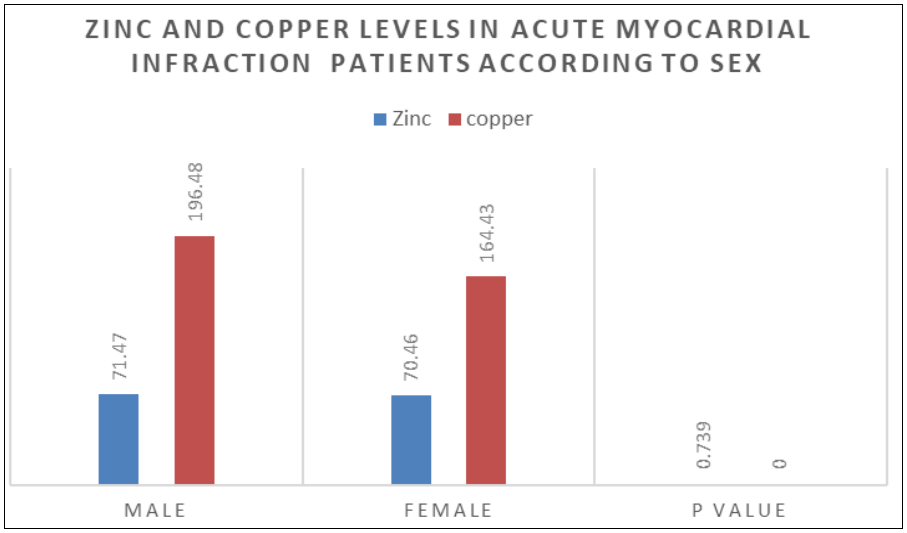

Fig 1: Zinc and Copper levels in AMI patients according to sex

Comparison between Zinc and Copper levels in chronic myocardial infraction patients according to sex

In comparing zinc and copper levels in chronic heart attack patients by gender, the data show differences that indicate a trend towards a difference in zinc levels between men and women, as the average zinc levels in men were 93.85±8.93 compared to 99.56±13.82 in women, with a P value of 0.078. , which reflects a difference that is not strongly statistically significant. As for copper levels, there was a significant convergence on average between men (126.68±35.27) and women (126.19±23.22), with significant statistical significance for this comparison (*P* = 0.019), indicating the presence of statistically significant differences between the sexes. In copper levels among chronic heart attack patients.

Table 2: Comparison between Zinc and Copper levels in chronic myocardial infraction patients according to sex

Parameters / patients	Zinc	Copper
Male	93.85±8.93	126.68±35.27
female	99.56±13.82	126.19±23.22
P Value	0.078	0.019

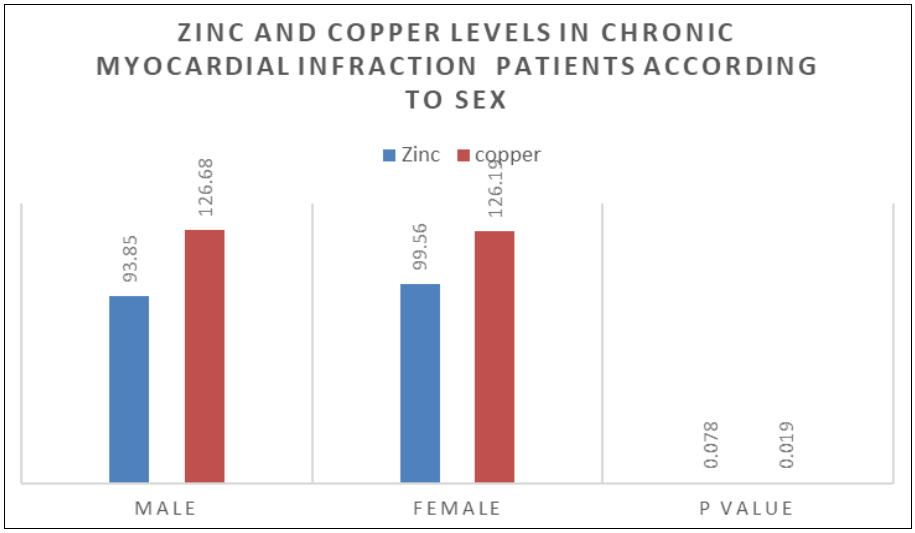

Fig 2: Zinc and Copper levels in CMI patients according to sex

Comparison between Zinc and Copper levels in acute, chronic myocardial infraction patients and control group

The results show differences in zinc and copper levels between acute and chronic heart attack patients and the control group. The average zinc levels in patients with acute condition was 71.12±15.09, while in patients with chronic condition the highest level reached 96.42±11.59, while the

control group recorded average zinc levels estimated at 81.90±26.90. On the other hand, for copper levels, the acute group scored 167.53±28.53 and the chronic group scored 126.46±30.08 compared to the control group, which was 135.11±31.23. The *P* value for both zinc and copper levels was 0.000**, which indicates that there are significant statistical differences in the levels of these two elements between the three study groups.

Table 3: Mean± SD of Zinc and Copper levels in acute, chronic myocardial infraction patients and control group

Parameters / patients	Zinc	Copper
Acute	71.12±15.09	167.53±28.53
Chronic	96.42±11.59	126.46±30.08
control	81.90±26.90	135.11±31.23
P value	0.000**	0.000**

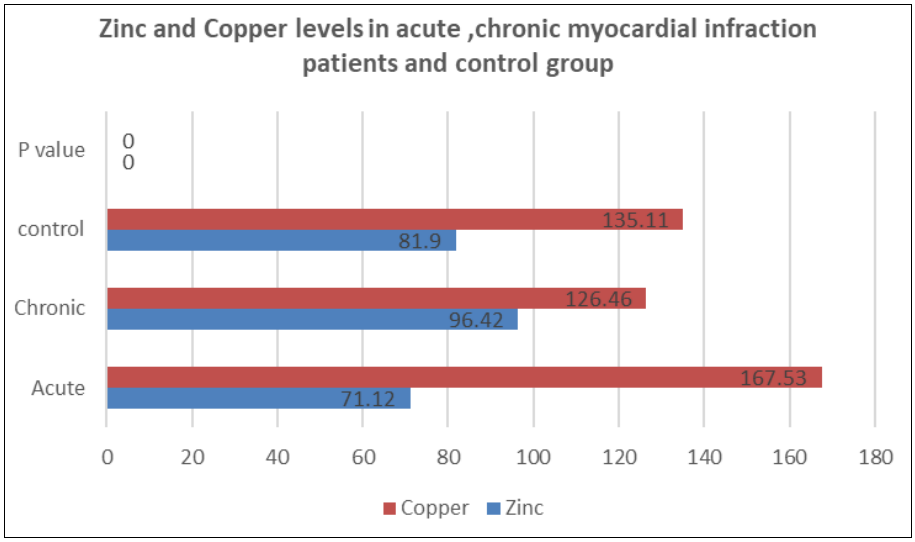

Fig 3: Zinc and Copper levels in acute, chronic myocardial infraction patients and control group

Comparison between Zinc and Copper levels in acute, chronic myocardial infraction patients and control group according to sex

The results indicate a significant difference in zinc and copper levels between acute and chronic heart attack patients and the control group, regardless of gender. In men (M) and women (F) in the acute condition, zinc levels were recorded at 71.47±14.63 for men versus 70.46±16.28 for women, and copper levels were 196.48±26.34 for men versus 164.43±31.73 for women. In chronic cases, zinc levels were 93.85±8.93 for men and 99.56±13.82 for women, while copper levels were 126.68±35.27 for men and 126.19±23.22 for women. The control group recorded zinc levels of 84.30±27.53 for men and 76.55±26.00 for women, and copper levels of 135.85±30.24 for men and 130.19±36.06 for women. The *P* values for both zinc and copper were 0.000 across all groups, indicating a significant statistical difference between groups, with differences according to gender in the levels of both zinc and copper.

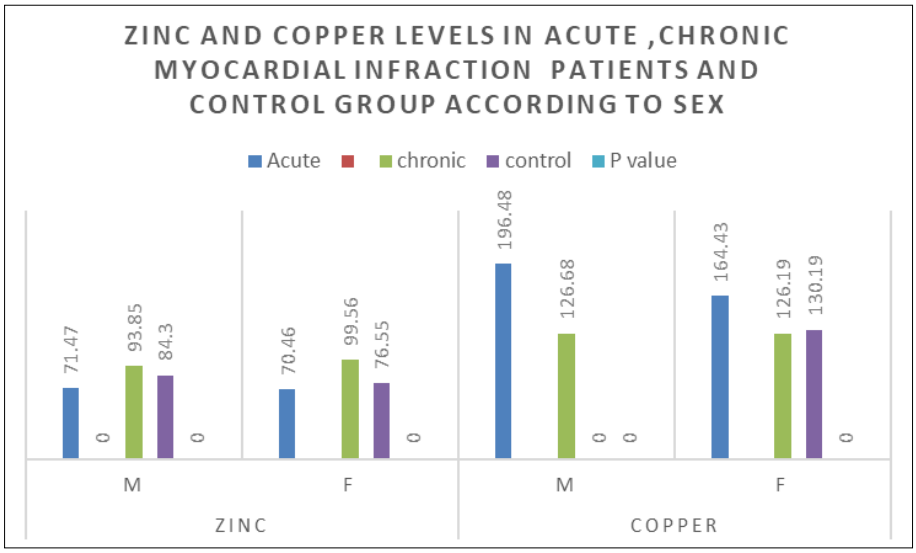

Fig 4: Zinc and Copper levels in acute, Chronic myocardial infraction patients and control group according to sex

Table 4: Mean± SD of Zinc and Copper levels in acute, chronic myocardial infraction patients and control group according to sex

Parameters / patients	Zinc		Copper	
Patients	**M**	**F**	**M**	**F**
Acute	71.47 ± 14.63	70.46 ± 16.28	196.48 ± 26.34	164.43 ± 31.73
chronic	93.85 ± 8.93	99.56 ± 13.82	126.68 ± 35.27	126.19 ± 23.22
control	84.30 ± 27.53	76.55 ± 26.00	135.85 ± 30.24	130.19 ± 36.06
P value	0.000	0.000	0.000	0.000

Comparison between Zinc and Copper levels in acute myocardial infraction patients with diabetes mellitus.

There appear to be differences in zinc and copper levels between acute heart attack patients with diabetes versus those without diabetes. Mean zinc levels in patients with diabetes were 72.14±16.31, compared to 70.17±14.36 in patients without diabetes. As for copper levels, it was recorded at 172.50±31.36 in patients with diabetes, compared to 162.55±24.74 in those who did not suffer from diabetes. Looking at the *P* values, they indicate a value of 0.200 for zinc and 0.057 for copper, which means that the differences observed between the two groups are not strongly statistically significant with regard to zinc and copper levels.

Table 5: Mean± SD of Zinc and Copper levels in acute myocardial infraction patients with diabetes mellitus

Parameters/ patients	Zinc	Copper
Diabetes mellitus	72.14±16.31	172.50±31.36
Non diabetes M.	70.17±14.36	162.55±24.74
P value	0.200	0.057

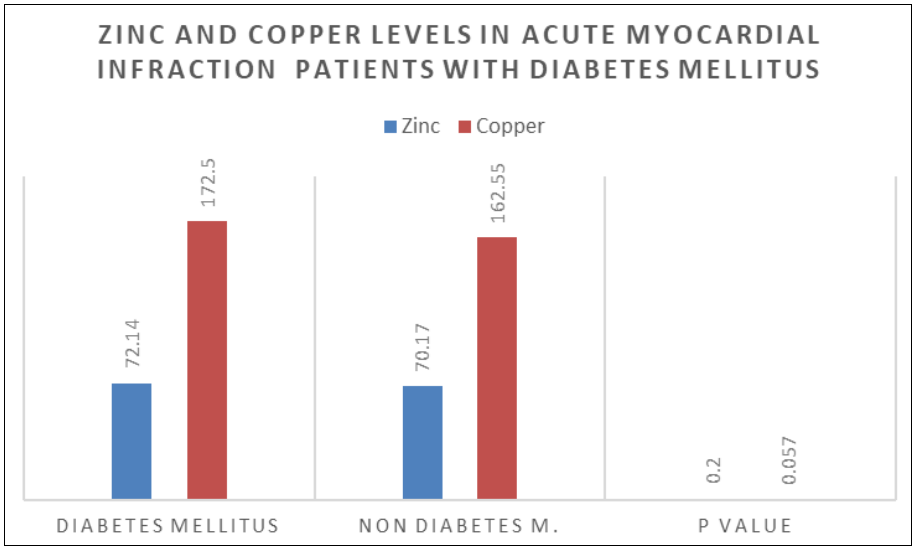

Fig 5: Zinc and Copper levels in acute myocardial infraction patients with diabetes mellitus

Comparison between Zinc and Copper levels in chronic myocardial infraction patients with diabetes mellitus.

Data for zinc and copper levels in chronic heart attack patients with diabetes versus those without diabetes show the following results: Zinc levels in those with diabetes were 96.25±11.33 compared to 97.11±9.95 in those without diabetes. As for copper levels, they appeared at 128.20±32.05 in diabetic patients compared to 114.43±18.33 in non-diabetic patients. The *P* value for zinc levels was 0.892, which indicates that the differences in zinc levels between chronic heart attack patients with and without diabetes are not statistically significant. While the P value for copper levels was 0.057, which somewhat indicates a convergence in marginal statistical significance, but it still lacks strong statistical significance to consider the difference significantly noticeable.

Table 6: Mean± SD of Zinc and Copper levels in chronic myocardial infraction patients with diabetes mellitus

Parameters / Patients	Zinc	Copper
Diabetes mellitus	96.25±11.33	128.20±32.05
Non diabetes M.	97.11±9.95	114.43±18.33
P value	0.892	0.057

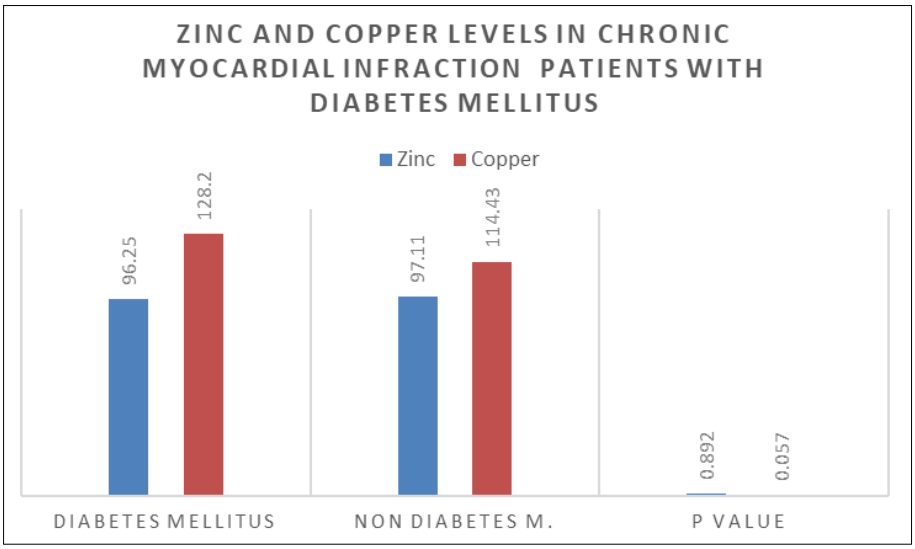

Fig 6: Zinc and Copper levels in chronic myocardial infraction patients with diabetes mellitus

Comparison between Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with diabetes mellitus and Non-diabetes

The table shows the analysis of zinc and copper levels in acute and chronic heart attack patients according to the presence or absence of diabetes. Acute heart attack patients with diabetes recorded a zinc level of 72.14±16.31 and a copper level of 172.50±31.36, while those with a chronic heart attack and diabetes showed higher levels of zinc 96.25±11.33 and lower levels of copper 128.20±32.05. A significant statistical significance was observed in zinc levels between the acute and chronic cases of diabetic patients (*P*=0.010), but no statistical significance appeared for copper levels (P=0.823). In contrast, for people without diabetes, zinc levels in the acute condition were 70.17±14.36 and in the chronic condition 97.11±9.95, and copper levels in the acute condition were 162.55±24.74 and in the chronic condition 114.43±18.33, with no statistical significance for these changes (*P*=0.350 for zinc, *P*= 0.373 for copper).

Table 7: Mean± SD of Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with diabetes mellitus and Non-diabetes

Patient	Zinc	Copper
Acute/DM	72.14±16.31	172.50±31.36
Chronic/DM	96.25±11.33	128.20±32.05
P. Value	0.010*	0.823
Acute /Non-DM	70.17±14.36	162.55±24.74
Chronic /Non-DM	97.11±9.95	114.43±18.33
P value	0.350	0.373

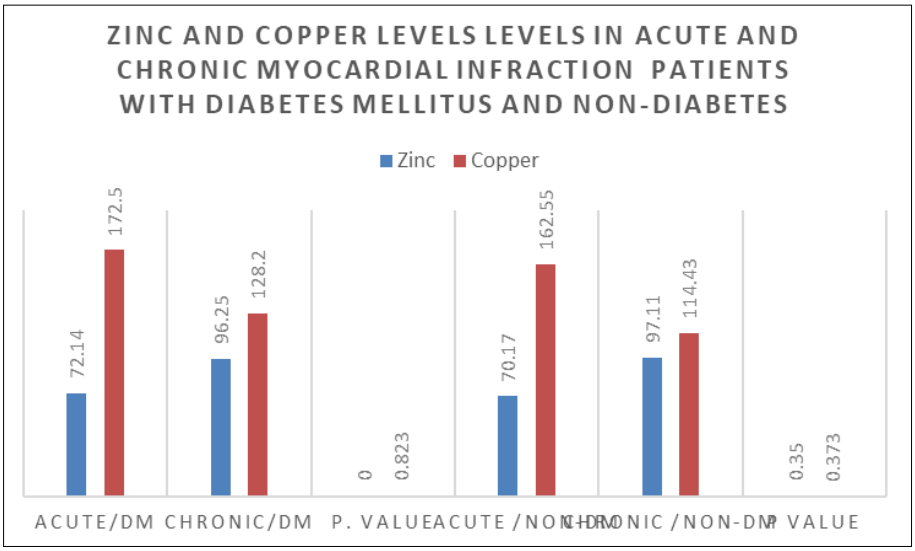

Fig 7: Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with diabetes mellitus and Non-diabetes

Comparison between Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with Hypertension and Non-hypertension.

The table presents the mean and standard deviation of zinc and copper levels in acute and chronic heart attack patients with high blood pressure (hyper) and in patients without high blood pressure (non-hyper). For patients with high blood pressure and acute heart attack, zinc levels were 71.23±16.42 and copper 168.64±28.62, while in chronic cases, zinc levels increased to 93.39±9.56 and copper decreased to 132.13±29.35. There is a statistical significance for the difference in zinc levels between the acute and chronic conditions of patients with high blood pressure (*P*=0.01), while for copper there is no significant

difference (*P*=0.920). For patients without hypertension, zinc levels were 70.98±13.51 in acute and 102.03±13.24 in chronic, and copper levels were 166.17±28.71 in acute and 115.92±29.56 in chronic, without significant statistical significance for zinc (*P*= 0.892) and copper (*P*=0.70).

Table 8: Mean± SD of Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with Hypertension and Non-hypertension.

Patient	Zinc	Copper
Acute/Hyper.	71.23±16.42	168.64±28.62
Chronic/Hyper.	93.39±9.56	132.13±29.35
P. Value	0.01	0.920
Acute /Non-Hyper.	70.98±13.51	166.17±28.71
Chronic /Non-Hyper.	102.03±13.24	115.92±29.56
P value	0.892	0.70

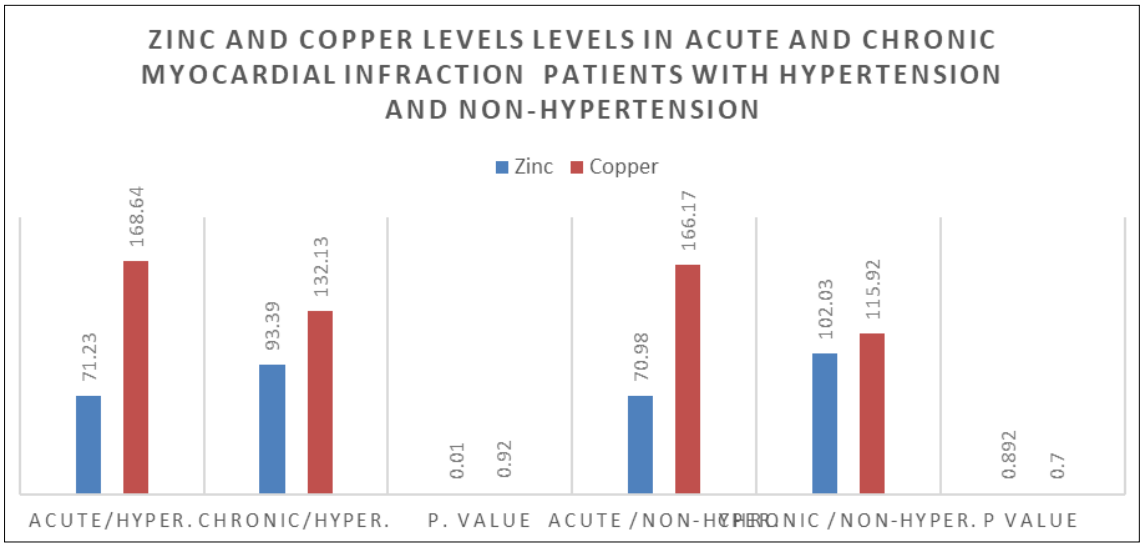

Fig 8: Zinc and Copper levels levels in Acute and chronic myocardial infraction patients with Hypertension and Non-hypertension

Discussion

Zinc, an essential trace element, plays a pivotal role in various physiological processes, including immune function, protein synthesis, wound healing, DNA synthesis, and cell division. The current study found a significant decrease in the levels of zinc in patients with acute coronary syndrome compared to the healthy control. These results agree with Tanita *et al.* 2024, who revealed a decrease in the levels of zinc in acute coronary syndrome [20]. Another study by El-Mahdy *et al.* 2019, on ACS patients revealed that serum zinc levels were significantly decreased compared to healthy controls. This deficiency was strongly associated with the etiopathogenesis of ACS [21]. The study also found that serum zinc levels were particularly lower in patients with ST elevation ACS compared to non-ST elevation ACS, suggesting a potential role of zinc in the severity of the condition Copper shortage can raise total cholesterol and make lipoproteins more likely to oxidise, which are two major factors that raise the risk of IHD. So, eating foods that are high in copper or taking copper supplements may help lower these risk factors without any of the side effects that are common with drug treatment. In a different light, it's possible that the high total cholesterol and oxidised lipoproteins found in people who are more likely to get IHD are just signs of lower copper amounts in the body, which is the real risk factor. It's also found a significant increase in the levels of zinc among patients with chronic CAD compared to healthy group. There is almost no study examining zinc levels in chronic CAD condition, however, the current results are not consistent with Shafqat *et al* 2013, who found non-significant difference in zinc levels between control and stable angina patients [28]. Increased blood levels of urinary tract in patients with chronic CAD or stable angina may be due to a compensatory response to oxidative stress and inflammation alone in these conditions. However, the significance of these findings must remain under investigation, and more research is needed to fully understand the effects. It is considered an essential element and a partial use of copper in various enzymatic processes to maintain human and heart health. This study caused a significant increase in copper levels with a large number of proliferation compared to the control group. These results are consistent with previous research indicating that high levels of copper in the blood pose a risk to the heart [29, 30]. A systematic review and analysis found that increased blood copper levels are associated with an increased risk of adverse cardiovascular events, such as heart attacks and death from cardiovascular disease. These results demonstrate that blood copper levels can be used as an important indicator to measure the risk of cardiovascular disease [31]. Copper is an essential element that plays an important role in many biological processes, however, too much of it can be harmful. Copper is involved in cellular metabolism and is a cofactor in many copper-containing enzymes, which play a role in regulating heart function [32]. The effects that copper has on cardiovascular health are complex. The involvement of copper in low-density lipoprotein (LDL) oxidation is important in the process of atherogenesis. High levels of copper in the blood can lead to an increase in oxidative stress, which can cause damage to

the inner lining of blood vessels and promote the process of atherosclerosis [33]. In addition, copper-related alterations in the DNA genome have been linked to an increased risk of acute coronary syndrome (ACS), highlighting the role of copper in regulating gene expression and its impact in cardiovascular disease [34]. The results detected non-significant changes in blood copper levels between the chronic coronary artery disease (CAD) group and the control group. A study conducted by Lutfi and his team in 2015 showed that there were no significant differences in average zinc and copper levels between patients with coronary artery disease and those with healthy coronary arteries. The lack of differences in copper levels may also indicate that copper is not an important biomarker for these conditions, or that its role in the development of stable angina and chronic coronary artery disease is not significant enough to be reflected in measurable changes in the blood [35]. It is important to realize that the absence of a difference in copper levels does not mean that there are no biochemical or molecular changes between individuals with stable angina or chronic coronary artery disease and healthy subjects in the control group. Biological markers or other physiological data may show differences directly related to the disease process [35]. The aim of the study is to understand the relationship between zinc and copper levels and their effect on cardiovascular diseases.

Conclusion:

The research showed that differences in zinc and copper levels were not statistically significant between males and females in cases of acute myocardial infarction, as copper levels were moderately elevated in men compared to women. In cases of chronic myocardial infarction, the data indicated a trend towards differences in zinc levels between the sexes, while copper levels were similar. Large statistically significant differences were found in the levels of these two elements between the three groups studied, which indicates the presence of sex-related differences in the levels of both zinc and copper. For heart patients with diabetes compared to those without, the results did not show strong statistical differences for copper levels of marginal zinc and copper levels, with significance in chronic heart patients with diabetes. These differences exist because of different biological effects of zinc and copper on body processes, which may be affected by gender differences and diabetes status.

References

1. Thygesen K, Alpert JS, White HD, Jaffe AS, Apple FS, Galvani M, Joint *ESC*/ACCF/AHA/WHF Task Force for the Redefinition of Myocardial Infarction. Universal definition of myocardial infarction. Circulation. 2007;116(22):2634-2653.
2. Reimer KA, Jennings RB, Tatum AH. Pathobiology of acute myocardial ischemia: metabolic, functional and ultrastructural studies. American Journal of Cardiology. 1983;52(2):72A-81A.
3. Apple FS, Sandoval Y, Jaffe AS, Ordonez-Llanos J., IFCC Task Force on Clinical Applications of Cardiac Bio-Markers. Cardiac Troponin Assays: Guide to Understanding Analytical Characteristics and Their Impact on Clinical Care. Clinical Chemistry. 2017;63(1):73-81.
4. Goodman SG, Steg PG, Eagle KA, Fox KA, López-Sendón J, Montalescot G. GRACE Investigators. The diagnostic and prognostic impact of the redefinition of acute myocardial infarction: Lessons from the Global Registry of Acute Coronary Events (GRACE). American Heart Journal. 2006;151(3):654-60.
5. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, Lanas F. INTERHEART Study Investigators. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. The Lancet. 2004;364(9438):937-952.
6. Anand SS, Islam S, Rosengren A, Franzosi MG, Steyn K, Yusufali AH. INTERHEART Investigators. Risk factors for myocardial infarction in women and men: insights from the INTERHEART study. European Heart Journal. 2008;29(7):932-940.
7. Stefanidou M, Maravelias C, Dona A, Spiliopoulou C. Zinc: A multipurpose trace element. Archives of Toxicology; c2006. p. 80, 1–9.
8. Outten CE, O'Halloran TV. Femtomolar sensitivity of metalloregulatory proteins controlling zinc homeostasis. Science. 2001;292:2488–2492.
9. Shen T, Zhao Q, Luo Y, Wang T. Investigating the Role of Zinc in Atherosclerosis: A Review. Biomolecules. 2022;12:1358.
10. Bost M, Houdart S, Oberli M, Kalonji E, Huneau JF, Margaritis I. Dietary copper and human health: Current evidence and unresolved issues. Journal of Trace Elements in Medicine and Biology. 2016;35:107–115.
11. Nakaona L, Maseka KK, Hamilton EM, Watts MJ. Using human hair and nails as biomarkers to assess exposure of potentially harmful elements to populations living near mine waste dumps. Environmental Geochemistry and Health. 2020;42:1197–1209.
12. Chojnacka K, Górecka H, Chojnacki A, Górecki H. Inter-element interactions in human hair. Environmental Toxicology and Pharmacology. 2005;20:368–374.
13. Reiterer G, MacDonald R, Browning JD, Morrow J, Matveev SV, Daugherty A, *et al*. Zinc deficiency increases plasma lipids and atherosclerotic markers in LDL-receptor-deficient mice. Journal of Nutrition. 2005;135:2114–2118. 10.1093/jn/135.9.2114
14. Hashemian M, Poustchi H, Mohammadi-Nasrabadi F, Hekmatdoost A. Systematic review of zinc biochemical indicators and risk of coronary heart disease. ARYA Atherosclerosis. 2015;11:357–365.
15. Bao B, Prasad AS, Beck FW, Fitzgerald JT, Snell D, Bao GW, *et al*. Zinc decreases *C*-reactive protein, lipid peroxidation, and inflammatory cytokines in elderly subjects: a potential implication of zinc as an atheroprotective agent. American Journal of Clinical Nutrition. 2010;91:1634–41. 10.3945/ajcn.2009.28836
16. Giannoglou GD, Konstantinou DM, Kovatsi L, Chatzizisis YS, Mikhailidis DP. Association of reduced zinc status with angiographically severe coronary atherosclerosis: a pilot study. Angiology. 2010;61:449–55. 10.1177/0003319710366702
17. Pilz S, Dobnig H, Winklhofer-Roob BM, Renner W, Seelhorst U, Wellnitz B, *et al*. Low serum zinc concentrations predict mortality in patients referred to coronary angiography. British Journal of Nutrition. 2009101:1534–40. 10.1017/S0007114508084079

18. Kim S, Chao PY, Allen KG. Inhibition of elevated hepatic glutathione abolishes copper deficiency cholesterolemia. FASEB Journal. 1992;6:2467–71.doi:10.1096/fasebj.6.7.1563598
19. Alarcon-Corredor OM, Guerrero Y, Ramirez de Fernandez M, *et al*. [Effect of copper supplementation on lipid profile of Venezuelan hyperlipemic patients]. Archivos Latinoamericanos de Nutrición. 2004;54:413–8.
20. Tanita A, Namiuchi S, Onodera, K. *et al* Serum zinc concentration in patients with myocardial infarction: A retrospective study. BMC Cardiovascular Disorders. 2024;24:107.
21. El-Mahdy RI, Mostafa MM, EL-Deen HS. Serum Zinc Measurement, Total Antioxidant Capacity, and Lipid Peroxide Among Acute Coronary Syndrome Patients With and Without ST Elevation. Applied Biochemistry and Biotechnology. 2019;188:208–224.
22. Meng H, Ruan J, Chen Y, Yan Z, Meng X, Li X. Serum Zinc Ion Concentration Associated with Coronary Heart Disease: A Systematic Review and Meta-Analysis. Cardiology Research and Practice. 2022;2022:4352484
23. Liu B, Cai ZQ, Zhou YM. Deficient zinc levels and myocardial infarction: association between deficient zinc levels and myocardial infarction: A metaanalysis. Biological Trace Element Research. 2015;165:41–50.
24. Choi S, Liu X, Pan Z. Zinc deficiency and cellular oxidative stress: Prognostic implications in cardiovascular diseases. Acta Pharmacologica Sinica. 2018;39:1120–32.
25. Rosenblum H, Wessler JD, Gupta A, Maurer MS, Bikdeli B. Zinc deficiency and heart failure: a systematic review of the current literature. Journal of Cardiac Failure. 2020;26:180–189.
26. Besecker BY, Exline MC, Hollyfield J, Phillips G, Disilvestro RA, Wewers MD, *et al*. A comparison of zinc metabolism, inflammation, and disease severity in critically ill infected and noninfected adults early after intensive care unit admission. American Journal of Clinical Nutrition. 2011;93:1356–64.
27. Lang C, Murgia C, Leong M, Tan LW, Perozzi G, Knight D, *et al*. Anti-inflammatory effects of zinc and alterations in zinc transporter mRNA in mouse models of allergic inflammation. American Journal of Physiology. Lung Cellular and Molecular Physiology; c2007. p. 292–L584.
28. Shafqat N, Ehsan U, Shahadat C. Serum copper levels among patients of ischemic heart disease – an experience from a tertiary care hospital in Bahawalpur, Pakistan. Pakistan Journal of Medical and Health Sciences; c2013, 7(3).
29. Chen A, Li G, Liu Y. Association between copper levels and myocardial infarction: A meta-analysis. Inhalation Toxicology. 2015;27:237-46.
30. Kunutsor SK, Dey RS, Laukkanen JA. Circulating serum copper is associated with atherosclerotic cardiovascular disease, but not venous thromboembolism: A prospective cohort study. Pulse (Basel). 2021;9:109-15.
31. Muñoz-Bravo C, Soler-Iborte E, Lozano-Lorca M, Kouiti M, González-Palacios Torres C, Barrios-Rodríguez R, *et al*. Serum copper levels and risk of major adverse cardiovascular events: A systematic review and meta-analysis. Frontiers in Cardiovascular Medicine. 2023;10:1217748.
32. Dragan PD, Ivan SB, Goran DZ, Maja ND, Nevena LD, Marijana AM, *et al*. The Role of Systemic Oxidative Status in Coronary Arterial and Peripheral Venous Blood of Patients with Unstable Angina Pectoris. Life. 2023, 13(7).
33. Bagheri B, Akbari N, Tabiban S, Habibi V, Mokhberi V. Serum level of copper in patients with coronary artery disease. Nigerian Medical Journal. 2015;56(1):39-42.
34. Long P, Wang Q, Zhang Y, Zhu X, Yu K, Jiang H, *et al*. Profile of copper-associated DNA methylation and its association with incident acute coronary syndrome. Clinical Epigenetics. 2021;13:19.
35. Lutfi MF, Elhakeem RF, Khogaly RS, Abdrabo AA, Ali AB, Gasim GI, *et al*. Zinc and copper levels are not correlated with angiographically-defined coronary artery disease in Sudanese patients. Frontiers in Physiology. 2015;6:191.

How to Cite This Article
Hanoon AH, Jassim AK, Hashim NA. Comparative analysis of copper and zinc levels and their association with cardiac indicators in chronic heart patients in Maysan governorate. International Journal of Advanced Research in Medicine. 2024; 6(3): 01-09.