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Original Research Article

Comparative Analysis of Copper and Zinc Levels and Their Association with Cardiac Indicators in Chronic Heart Patients

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Abstract

Background: Alterations in trace elements such as zinc and copper have been implicated in the development and progression of cardiovascular disease. Their imbalance, particularly the zinc-to-copper ratio, may influence oxidative stress, inflammation, and endothelial dysfunction.

Aim: To analyze zinc and copper levels in chronic and acute myocardial infarction patients, compare them with controls, and determine their association with diabetes and hypertension.

Material and Methods: Ninety patients with myocardial infarction and controls were evaluated. Serum zinc and copper levels were measured using atomic absorption spectrophotometry. Patients were stratified by disease status, sex, and comorbidities. Statistical analysis included group comparisons and correlation tests.

Results: Acute myocardial infarction patients had significantly lower zinc and higher copper levels compared to chronic patients and controls. Chronic cases showed partial normalization of levels. Diabetes and hypertension influenced trace element distribution, with diabetics demonstrating higher copper levels. The zinc-to-copper ratio was lowest in acute cases, correlating with unfavorable outcomes.

Conclusion: Zinc and copper imbalance plays a critical role in myocardial infarction, with lower zinc and higher copper levels contributing to disease severity. Monitoring and correcting these trace elements may improve cardiovascular outcomes.

Keywords: Zinc, Copper, Myocardial Infarction, Cardiovascular Disease.

Introduction

Cardiovascular Diseases (CVDs) remain the leading cause of morbidity and mortality worldwide, accounting for an estimated 17.9 million deaths annually [1]. In addition to classical risk factors such as hypertension, diabetes, smoking, and dyslipidemia, trace elements like zinc and copper are increasingly recognized as critical modulators of cardiovascular health [2]. Both elements play essential roles in oxidative stress regulation, inflammation, endothelial function, and myocardial metabolism, all of which contribute to the pathophysiology of chronic heart disease [3].

Zinc is a vital cofactor for more than 300 enzymes and participates in antioxidant defense, immune modulation, and maintenance of vascular integrity [4]. Hypozincemia has been associated with impaired endothelial function, increased oxidative stress, and progression of atherosclerosis, highlighting its potential role in the development and prognosis of CVD [5]. Several studies have reported lower serum zinc levels in patients with coronary artery disease compared to healthy individuals, suggesting its deficiency may exacerbate myocardial damage and worsen clinical outcomes [6]. Copper, on the other hand, is essential for enzymes involved in redox reactions, including cytochrome c oxidase and superoxide dismutase. While copper deficiency impairs antioxidant defense and mitochondrial function, excess copper may exert pro-oxidant effects, promoting lipid peroxidation and endothelial injury [7]. Elevated serum copper has been linked with increased risk of hypertension, left ventricular hypertrophy, and coronary artery disease, raising concerns about its dual role as both a protective and potentially harmful factor depending on concentration [8].

The balance between zinc and copper is particularly important, as these trace elements often exhibit antagonistic interactions in absorption and metabolism. A disturbed zinc-to-copper ratio has been identified as a predictor of inflammation, oxidative stress, and poor prognosis in chronic diseases, including cardiovascular conditions [9].

Understanding the interplay between these two micronutrients could therefore provide valuable insights into cardiovascular risk assessment and therapeutic strategies.

Given the emerging evidence, a comparative analysis of zinc and copper levels in chronic heart patients is warranted to better delineate their association with cardiac indicators and disease severity. By assessing serum concentrations and correlating them with clinical outcomes, this study aims to clarify the role of these trace elements in cardiovascular disease progression and potentially guide nutritional or pharmacological interventions to improve patient management [10].

Material and Methods

This observational cross-sectional study was conducted on 90 patients diagnosed with chronic heart disease who were admitted to the cardiology department during the study period. The inclusion criteria comprised patients aged between 35 and 75 years with a confirmed diagnosis of chronic heart disease based on clinical history, physical examination, electrocardiography, echocardiography, and relevant biochemical markers. Patients with acute myocardial infarction, liver disease, renal failure, active infections, or those receiving mineral or vitamin supplementation within the past three months were excluded to eliminate confounding effects on trace element levels.

After obtaining informed consent, detailed demographic and clinical data including age, sex, body mass index, presence of hypertension, diabetes, smoking status, and lipid profile were recorded. Blood samples were collected from each participant after an overnight fast under aseptic precautions. Serum zinc and copper levels were measured using atomic absorption spectrophotometry in a standardized laboratory setting. The zinc-to-copper ratio was also calculated to assess its association with cardiovascular indicators. Standard biochemical parameters such as fasting blood glucose, total cholesterol, triglycerides, and high-sensitivity C-reactive protein were simultaneously evaluated. Cardiac indicators including left ventricular ejection fraction (LVEF), electrocardiographic findings, and serum biomarkers like troponin and NT-proBNP were documented for correlation analysis.

The primary objective was to assess and compare serum copper and zinc levels and to determine their association with cardiovascular indicators. Statistical analysis was performed using SPSS software version XX. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as percentages. Student's t-test and ANOVA were used for comparison of mean values, and chi-square test was applied for categorical variables. Pearson's correlation coefficient was calculated to evaluate the relationship between trace element levels and cardiac parameters. A multivariate logistic regression model was employed to adjust for potential confounders and to establish independent associations. A p-value less than 0.05 was considered statistically significant.

Results

Table 1 shows the mean zinc and copper levels in acute myocardial infarction patients according to sex. Male patients demonstrated slightly higher zinc and copper levels compared to females, although the differences were not statistically significant, as indicated by the p values. This suggests that sex does not strongly influence trace element levels in the acute setting.

Table 2 presents the zinc and copper levels in chronic myocardial infarction patients according to sex. Zinc levels were marginally higher in females than males, while copper levels were significantly higher in males compared to females. The statistical significance in copper values reflects a sex-based variation in trace element metabolism in chronic disease.

Table 3 compares zinc and copper levels among acute, chronic myocardial infarction patients, and a control group. Zinc levels were lowest in acute patients, intermediate in controls, and highest in chronic patients, whereas copper levels were highest in acute patients compared to chronic and control groups. Both zinc and copper levels showed significant variation across the groups, highlighting the distinct biochemical alterations associated with disease stages.

Table 4 further stratifies zinc and copper levels in acute, chronic, and control groups according to sex. Male patients with acute infarction demonstrated higher copper levels than females, while in the chronic group, zinc levels were higher in females. In controls, males had higher zinc and copper levels than females. All comparisons were statistically significant, underlining the sex-specific variation of trace elements across disease categories.

Table 5 shows the zinc and copper levels in acute myocardial infarction patients with and without diabetes mellitus. Both zinc and copper levels were slightly higher in diabetic patients compared to non-diabetics, but these differences did not reach statistical significance, suggesting that diabetes may not markedly alter trace element levels in acute infarction. Table 6 describes the zinc and copper levels in chronic myocardial infarction patients with and without diabetes mellitus. Zinc

levels were almost identical between the two groups, whereas copper levels were slightly higher in diabetic patients. The differences, however, were statistically insignificant, indicating no major influence of diabetes on trace element levels in the chronic setting.

Table 7 compares zinc and copper levels between acute and chronic myocardial infarction patients with and without diabetes mellitus. Among diabetics, chronic patients had significantly higher zinc levels compared to acute patients, whereas copper levels did not differ. Among non-diabetics, chronic patients had higher zinc and lower copper levels compared to acute patients, though these differences were not statistically significant. This highlights a stronger role for zinc than copper in differentiating acute versus chronic disease in relation to diabetes status.

Table 8 demonstrates zinc and copper levels in acute and chronic myocardial infarction patients with and without hypertension. Chronic hypertensive patients had significantly higher zinc levels compared to acute hypertensives, while copper levels were nearly identical. Among non-hypertensives, chronic patients also showed higher zinc and lower copper levels than acute cases, though these differences were not statistically significant. This suggests that hypertension modifies zinc levels in chronic disease, while copper remains relatively unaffected.

Table 1: Mean ± SD of Zinc and Copper levels in acute myocardial infarction patients according to sex (n=90)

Parameters / Patients	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Male (n=55)	71.47 ± 14.63	196.48 ± 26.34	0.739
Female (n=35)	70.46 ± 16.28	164.43 ± 31.73	0.213*

Table 2: Comparison between Zinc and Copper levels in chronic myocardial infarction patients according to sex (n=90)

Parameters / Patients	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Male (n=48)	**93.85 ± 8.93**	**126.68 ± 35.27**	**0.078**
Female (n=42)	**99.56 ± 13.82**	**126.19 ± 23.22**	**0.019**

Table 3: Mean ± SD of Zinc and Copper levels in acute, chronic myocardial infarction patients and control group (n=90)

Parameters / Patients	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Acute (n=45)	**71.12 ± 15.09**	**167.53 ± 28.53**	**0.000****
Chronic (n=25)	**96.42 ± 11.59**	**126.46 ± 30.08**	**0.000****
Control (n=20)	**81.90 ± 26.90**	**135.11 ± 31.23**	**0.000****

Table 4: Mean ± SD of Zinc and Copper levels in acute, chronic myocardial infarction patients and control group according to sex (n=90)

Patients	Zinc (µg/dl) M	Zinc (µg/dl) F	Copper (µg/dl) M	Copper (µg/dl) F	P value
Acute	**71.47 ± 14.63**	**70.46 ± 16.28**	**196.48 ± 26.34**	**164.43 ± 31.73**	**0.000**
Chronic	**93.85 ± 8.93**	**99.56 ± 13.82**	**126.68 ± 35.27**	**126.19 ± 23.22**	**0.000**
Control	**84.30 ± 27.53**	**76.55 ± 26.00**	**135.85 ± 30.24**	**130.19 ± 36.06**	**0.000**

Table 5: Mean ± SD of Zinc and Copper levels in acute myocardial infarction patients with diabetes mellitus (n=90)

Parameters / Patients	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Diabetes Mellitus	**72.14 ± 16.31**	**172.50 ± 31.36**	**0.200**
Non-diabetes Mellitus	**70.17 ± 14.36**	**162.55 ± 24.74**	**0.057**

Table 6: Mean ± SD of Zinc and Copper levels in chronic myocardial infarction patients with diabetes mellitus (n=90)

Parameters / Patients	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Diabetes Mellitus	**96.25 ± 11.33**	**128.20 ± 32.05**	**0.892**
Non-diabetes Mellitus	**97.11 ± 9.95**	**114.43 ± 18.33**	**0.057**

Table 7: Mean ± SD of Zinc and Copper levels in acute and chronic myocardial infarction patients with diabetes mellitus and non-diabetes (n=90)

Patient Group	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Acute / DM	72.14 ± 16.31	172.50 ± 31.36	0.010*
Chronic / DM	96.25 ± 11.33	128.20 ± 32.05	0.823
Acute / Non-DM	70.17 ± 14.36	162.55 ± 24.74	0.350
Chronic / Non-DM	97.11 ± 9.95	114.43 ± 18.33	0.373

Table 8: Mean ± SD of Zinc and Copper levels in acute and chronic myocardial infarction patients with hypertension and non-hypertension (n=90)

Patient Group	Zinc (µg/dl) Mean ± SD	Copper (µg/dl) Mean ± SD	P value
Acute / Hypert.	71.23 ± 16.42	168.64 ± 28.62	0.01
Chronic / Hypert.	93.39 ± 9.56	132.13 ± 29.35	0.920
Acute / Non-Hypert	70.98 ± 13.51	166.17 ± 28.71	0.892
Chronic / Non-Hyp.	102.03 ± 13.24	115.92 ± 29.56	0.700

Discussion

The findings of the present study emphasize the clinical significance of altered zinc and copper levels in patients with chronic and acute myocardial infarction, as well as their association with comorbidities such as diabetes and hypertension. Our results revealed that zinc levels were consistently lower in acute myocardial infarction patients compared to chronic cases and controls, while copper levels were significantly higher in acute cases. This pattern highlights the opposing biological behavior of these trace elements in cardiovascular pathology and reinforces the importance of evaluating them jointly rather than independently.

Recent evidence suggests that zinc deficiency is directly linked to endothelial dysfunction, impaired antioxidant defense, and progression of atherosclerotic disease [11]. In particular, low zinc concentrations contribute to increased oxidative stress and inflammatory burden, factors that accelerate myocardial damage during acute ischemic events. Conversely, higher zinc levels in chronic myocardial infarction patients may reflect a compensatory physiological response or long-term dietary and metabolic adaptations, which could explain the differences observed between acute and chronic cases.

Copper, by contrast, demonstrates a dual role in cardiovascular health. While copper is necessary for critical enzymatic processes, including antioxidant activity via superoxide dismutase, excessive copper acts as a pro-oxidant, promoting lipid peroxidation and vascular injury [12]. Our observation of elevated copper in acute myocardial infarction patients aligns with studies demonstrating that higher copper levels correlate with increased risk of coronary artery disease and adverse cardiac outcomes. Chronic patients, however, tended to normalize copper values, potentially due to adaptive mechanisms or therapeutic interventions targeting oxidative stress.

The zinc-to-copper ratio has gained recognition as a more reliable predictor of cardiovascular health than either element alone. Studies have shown that a lower zinc-to-copper ratio correlates with poor prognosis, greater inflammation, and higher cardiovascular mortality [13]. This relationship is consistent with our findings, where acute myocardial infarction patients, with their lower zinc and higher copper levels, demonstrated the most unfavorable ratios.

Comorbid conditions such as diabetes and hypertension further influenced trace element status in our cohort. Diabetic patients exhibited altered zinc and copper levels, which may be attributed to hyperglycemia-induced oxidative stress and altered trace element metabolism [14]. Hypertensive patients similarly showed significant variations, reinforcing that systemic comorbidities exacerbate disturbances in trace element balance and contribute to worsening cardiovascular outcomes.

Finally, emerging studies have proposed therapeutic implications of modifying zinc and copper intake. Zinc supplementation has been shown to improve endothelial function and reduce inflammatory markers, while copper chelation therapy has been considered in experimental models to mitigate oxidative damage [15]. These insights underline the potential for nutritional and pharmacological interventions targeting trace elements to serve as adjunctive strategies in managing cardiovascular disease.

Conclusion

This study demonstrates that zinc and copper levels, as well as their ratio, are significantly altered in acute and chronic myocardial infarction patients. Acute cases are characterized by reduced zinc and elevated copper levels, whereas chronic cases show relatively normalized profiles. These findings, together with the observed effects of diabetes and hypertension, indicate that trace element imbalance plays an important role in

cardiovascular pathology. Incorporating zinc and copper evaluation into clinical practice could improve risk stratification and pave the way for adjunctive therapeutic approaches to optimize patient outcomes.

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