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ASSESSMENT OF ESSENTIAL TRACE ELEMENTS IN THE HUMAN BODY: IMPLICATIONS FOR HEALTH AND DISEASE

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ABSTRACT

The body relies on essential trace elements like selenium, iron, zinc, and copper to keep immunological responses strong, regulate enzyme activity, and ward off illness. Anemia, metabolic disorders, cardiovascular illnesses, immunological dysfunction, and other chronic health issues can emerge when certain micronutrients are imbalanced, either too much or too little. The current investigation seeks to measure human body trace element concentrations and investigate their correlation with certain health markers and illness states. With the use of stratified random sampling, 110 participants were chosen for the cross-sectional analytical investigation. A systematic questionnaire, anthropometric measures, and fasting blood sample analysis in the lab are used to gather data. Standardized analytical methods like Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Atomic Absorption Spectroscopy (AAS) are used to determine the amounts of iron, zinc, copper, and selenium in serum. The statistical studies that are conducted utilize IBM SPSS Statistics. These analyses include descriptive statistics, multiple linear regression, Pearson correlation, chi-square test, one-way ANOVA, and independent sample t-test. Results show that demographic variables and health status are associated with variations in trace element levels. Iron, zinc, and selenium are significantly correlated with vital health markers like hemoglobin concentration and chronic illness status. For the purpose of early detection of nutritional deficiencies and illness risk, the study emphasizes the significance of routine monitoring of critical trace elements. Clinicians, nutritionists, and public health workers can use the results as evidence to create preventative healthcare programs and dietary interventions that improve people's health and wellness.

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I. INTRODUCTION

Trace elements are chemical components found in nature in extremely minute concentrations. Elements in a sample with an average concentration below 100 parts per million (ppm) as measured in atomic count or 100 µg/g are referred to as trace elements in analytical chemistry. The term "trace element" refers to a mineral in biochemistry that is required in extremely minute amounts for an organism's normal physiology, growth, and development. Enzymes are responsible for catalyzing the transformation of certain molecules in a substrate into a desired product, and trace elements play a pivotal part in this process. Additionally, in redox reactions—which are crucial to the production and use of metabolic energy—some of them contribute or take electrons. Important biological molecules rely on a few of them to be stable, as they play structural roles. In addition, ıron (Fe) is one trace element that plays a significant role in various biological functions, including binding, transporting, and releasing oxygen throughout the body. However, while trace elements are necessary for many biological processes, they can be harmful to human health in excess and even cause cancer and other deadly diseases. The characteristics and biological significance of numerous trace elements are detailed in this review article.

Among the 10 primary trace elements are lead, silicon, fluorine, bromine, iron, zinc, copper, and manganese. Among these, iron, zinc, and copper are found in human serum in that order of abundance. However, the tiniest amounts of ultra-trace elements like chromium, cobalt, iodine, selenium, boron, and molybdenum are found. Although they only make up a tiny proportion of the body's overall mass, trace elements (TEs) perform a number of crucial cellular functions. As catalysts or cofactors for numerous enzymes and centers for maintaining the structures of proteins and enzymes, TEs mediate crucial biological reactions. Therefore, many disorders may be influenced by an imbalance in TE metabolism and homeostasis, whether it's a lack of TE or an excess of it. Even though trace elements, also known as trace metals, are present in all living things in extremely little amounts, these compounds are crucial to their formation, growth, and health. It plays a crucial role in many biological activities, primarily as an ingredient of vitamins and enzymes. There is mounting evidence that imbalances in trace elements may negatively affect biological processes and contribute to a wide range of fatal diseases. Metals that were previously believed to have no

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biological significance were detected in compounds produced by living things more than a century ago. The role of trace elements in human physiology was brought to light by this discovery. Trace elements are essential for all biological processes. They have a role in regulating pH, digestion, metabolism, nerve signal transmission, muscle contraction, hormone production, and blood sugar and cholesterol levels. "Trace elements" are chemical components found in trace amounts in natural materials. Certain nutrients are essential for healthy growth, development, and bodily function, although the human body only needs little amounts of them. An element is considered a trace element if its mass proportion in the human body is less than one percent.

II. REVIEW OF RELATED STUDIES

Al-Fartusie, Falah & Mohssan, Saja. (2017). Trace elements are inorganic substances that occur naturally and are needed by humans in doses less than 100 mg daily. They mediate critical biochemical reactions, are fundamental to many life-sustaining activities, and are integral parts of many biological structures. Toxic effects on health can result from exposure to these elements at amounts greater than what is required for their biological activity. Accordingly, it has been discovered that numerous deadly diseases, including malignancies, are linked to abnormalities in the optimal quantities of trace elements, which may negatively impact biological processes. There has been recent activity aimed at improving our knowledge of the connection between heavy metals, trace elements, and cancer. When it comes to early diagnosis, prognosis, and therapeutic evaluation of some diseases, particularly different types of cancer, numerous research have pointed to notable specific characteristics that may be valuable and have prognostic importance.

Chitturi, RaviTeja et al., (2015). All around us in nature are elements, and each one is vital for the body to carry out its many tasks. The biological, chemical, and molecular processes that take place inside cells rely heavily on trace elements. As cofactors for numerous enzymes and centers for stabilizing the structures of proteins and enzymes, these elements mediate crucial biochemical reactions. By binding to molecules at the cell membrane's receptor site or by switching the membrane's structure to block the entrance of certain molecules, some trace elements regulate crucial biological processes. Trace elements serve a dual purpose. While they play a crucial role in cellular structure stabilization at normal levels, they can stimulate alternative pathways and cause diseases when deficient. Various analytical methods can be used to estimate these trace elements, which have therapeutic significance.

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Makevic, Vedrana et al., (2023). Because of their extensive involvement in many physiological and metabolic processes, essential trace metals (Fe, Zn, Cu, Mn, Mo, Co) play a crucial role in living things. As a result, the organism's absorption, transport, and storage levels keep them in a delicate equilibrium. Whether there is a shortage or an excess, they can affect human health. Reduced physiological activity is one cause of deficiency health problems. In contrast, oxidative stress can inflict significant tissue damage when levels of redox active metals like Fe, Cu, and Co are elevated. Essential metal alterations are the root cause of many well-known diseases, such as hemochromatosis, acrodermatitis enteropathica, Menkes and Wilson disease, and iron and copper deficiency anemia. Neurodegenerative diseases, cancers, atherosclerosis, and diabetes are now all thought to have a connection to changes in trace metals. These diseases pose significant challenges to modern society's health, and trace metals hold promise for understanding their causes and developing treatments. The current research summarises the kinetics and physiology of essential trace metals and discusses their functions in the pathophysiology of diseases.

Fraga, Cesar. (2005). Due to their essential nature and extremely low quantities in humans, the metals Mn, Fe, Cu, and Zn, as well as the non-metal Se, are referred to as "trace elements" (TE). The presence of unpaired electrons, which enable Cu, Fe, Mn, and Se to participate in redox reactions, is strongly correlated with their biological activities. The majority of these metals found in biological systems are metalloproteins, which are bound to proteins. Many of the metals in metalloproteins are part of enzymatic systems, have structural and storage functions, or use the protein to be transported to their target site in the organism. In humans Mn, Fe, Cu, Zn, and Se accomplish decisive functions to maintain human health. Deficiency in any of these TE leads to undesirable pathological conditions that can be prevented or reversed by adequate supplementation. In sufficiently nourished persons, supplementation should be carefully controlled, given the toxic effects ascribed to TE when present in quantities exceeding those required for accomplishing their biological functions.

Ubaid, Saba & Pandey, Shivani. (2024). Trace elements are inorganic substances that exist naturally and are necessary for human health at doses less than 100 mg daily. They mediate vital biochemical reactions, are crucial components of biological structures, and have a significant impact and function as major players in a number of activities required for life. When these elements are present in excess – that is, in greater quantities than what is necessary for biological functions – they can be hazardous to the health of the organism. As a

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result, it has been shown that variations from the ideal concentrations of trace elements can negatively impact biological functions and are linked to a number of deadly illnesses, including cancer. The focus of this chapter is to improve our understanding of the connection between trace elements and how diseases are affected by them.

III. RESEARCH METHODOLOGY

Research Design

This study used a cross-sectional analytical research approach to look at how much selenium, iron, zinc, and copper are in people and how they relate to their health and certain diseases.

Study Population and Sampling

Participants range in age from 18 to 65 and include both healthy individuals and those with certain chronic conditions. Hospitals, diagnostic labs, and community health clinics are all part of the stratified random sampling process.

Data Collection

Information about demographics, food, lifestyle, and health history is gathered through a systematic questionnaire. Records are kept of anthropometric data, which includes height, weight, BMI, and blood pressure. For laboratory analysis, each participant has to provide 5-10 mL of fasting venous blood.

Laboratory Analysis

Standardized laboratory techniques are followed to determine the serum concentrations of iron (Fe), zinc (Zn), copper (Cu), and selenium (Se) using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Atomic Absorption Spectroscopy (AAS). Instrument calibration, verified reference materials, and duplicate sample analyses are all part of the quality control methods that are in place to make sure the results are accurate and reliable.

Variables of the Study

Age, gender, BMI, food habits, lifestyle variables, medical history, and other personal details are considered independent variables. Hemoglobin, ferritin, blood glucose, and inflammatory biomarkers are some of the health indicators that are used as dependent variables, along with

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serum levels of important trace elements.

Statistical Analysis

With the help of IBM SPSS Statistics (Version 29.0), we examine the gathered data. A number of descriptive statistics are employed to encapsulate the data, such as percentage, mean, standard deviation, and frequency. The correlation between trace element levels and health outcomes is examined using inferential statistical techniques such multiple linear regression, Pearson correlation analysis, chi-square test, independent sample t-test, and one-way analysis of variance. Statistical significance is established when the p-value is less than 0.05.

IV. RESULTS OF THE STUDY

Table 1 Demographic Characteristics of Participants (N = 110)

Characteristics	Frequency (N)	Percentage (%)
Gender		
Male	52	47.3
Female	58	52.7
Age Group (Years)		
18–30	28	25.5
31–45	42	38.2
46–60	30	27.3
Above 60	10	9.0
Total	**110**	**100.0**

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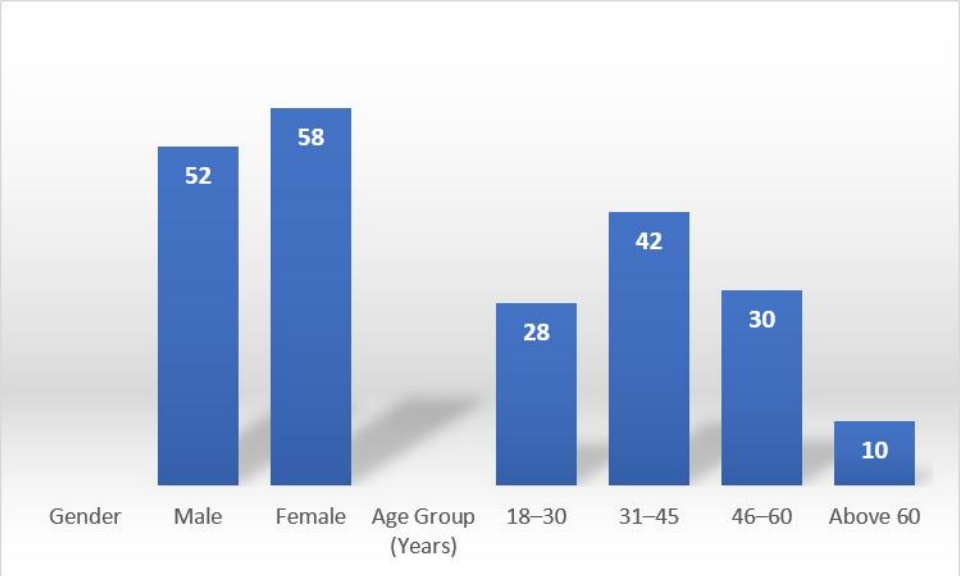


Figure 1 Demographic Characteristics of Participants (N = 110)

All told, 110 people filled out the survey, and their demographics are laid forth in Table 1. The gender distribution of the sample was rather even, with 52 males (47.3% of the total) and 58 females (52.7%), suggesting a small predominance of females. This even distribution of male and female respondents' viewpoints aids in reducing bias associated with gender.

The age range of 31–45 years old had 42 respondents (38.2% of the total), making it the largest age group in terms of participant distribution. Next came the 46-60 year olds with 30 responses (27.3% of the total), followed by the 18-30 year olds with 28 responses (25.5% of the total). Ten respondents (9.0% of the total) were over the age of 60, making up the smallest group. The results imply that middle-aged people made up the bulk of the study's sample, which is consistent with expectations that this demographic would have extensive relevant work and life experience. Additionally, by include both younger and older people, the sample is more diverse, and the study is able to gather viewpoints from a wider range of age groups. The demographic statistics show that the respondents were reasonably evenly distributed across the sexes and spanned a wide range of ages, which adds credibility and validity to the study's results.

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Table 2 Mean Serum Levels of Essential Trace Elements

Trace Element	Mean ± SD	Reference Range
Iron (µg/dL)	82.64 ± 18.75	60–170
Zinc (µg/dL)	88.52 ± 14.68	70–120
Copper (µg/dL)	109.84 ± 21.35	70–140
Selenium (µg/L)	101.72 ± 16.43	70–150

Essential trace element serum concentrations, standard deviations, and reference ranges are displayed in Table 2, together with the mean values, for all subjects in the study. The subjects typically had a sufficient iron status, as the mean serum iron level was 82.64 ± 18.75 µg/dL, which is within the normal reference range of 60-170 µg/dL. The study population had excellent zinc levels, as the mean serum zinc content was 88.52 ± 14.68 µg/dL, which is well within the indicated target range of 70-120 µg/dL.

The typical reference range for serum copper levels is 70-140 µg/dL, and the average level was 109.84 ± 21.35 µg/dL. This finding suggests that the individuals' copper status was typically satisfactory. Similarly, the study sample had adequate selenium levels as the mean serum selenium content was 101.72 ± 16.43 µg/L, which is well within the normal reference range of 70-150 µg/L.

Iron, zinc, copper, and selenium all had average serum concentrations that were within their corresponding physiological reference ranges, according to the data. The mean values do not show a widespread shortage or excess of these trace elements among the subjects, while the standard deviations do show some individual heterogeneity. The results indicate that the participants in the study had a sufficient nutritional status in relation to the trace elements that were measured. This provides a good foundation for investigating how these elements influenced the study's results.

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Table 3 Comparison of Trace Element Levels by Gender (Independent Sample t-test)

Variable	Male (Mean ± SD)	Female (Mean ± SD)	t-value	p-value
Iron	86.41 ± 17.82	79.23 ± 18.94	2.11	**0.037**
Zinc	90.74 ± 13.58	86.53 ± 15.32	1.54	0.126
Copper	106.28 ± 19.76	113.03 ± 22.18	-1.68	0.095
Selenium	104.18 ± 15.94	99.52 ± 16.74	1.49	0.138

Table 3 compares the mean serum levels of essential trace elements between male and female participants using an independent sample t-test. The findings indicate that male participants had a significantly higher mean serum iron level (86.41 ± 17.82) than female participants (79.23 ± 18.94), with a t-value of 2.11 and a p-value of 0.037, which is less than the conventional level of significance ($p < 0.05$). This result suggests that gender has a statistically significant influence on serum iron levels, with males exhibiting higher iron concentrations than females.

For serum zinc, the mean value was slightly higher among males (90.74 ± 13.58) compared to females (86.53 ± 15.32). However, the difference was not statistically significant ($t = 1.54$, $p = 0.126$), indicating that zinc levels were comparable between the two gender groups. Similarly, female participants demonstrated a marginally higher mean serum copper level (113.03 ± 22.18) than males (106.28 ± 19.76), but this difference did not reach statistical significance ($t = –1.68$, $p = 0.095$).

With respect to selenium, male participants recorded a slightly higher mean serum level (104.18 ± 15.94) than female participants (99.52 ± 16.74). Nevertheless, the observed difference was not statistically significant ($t = 1.49$, $p = 0.138$), suggesting that selenium concentrations did not vary meaningfully according to gender.

Overall, the independent sample t-test demonstrates that among the four essential trace elements assessed, only serum iron showed a statistically significant gender difference, with males having higher levels than females. In contrast, the differences observed in zinc, copper, and selenium levels were not statistically significant, indicating that these trace elements

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were distributed similarly between male and female participants in the study population.

Table 4 Comparison of Serum Iron Levels Across Age Groups (One-Way ANOVA)

Age Group	Mean ± SD
18–30 Years	89.56 ± 17.84
31–45 Years	84.37 ± 18.26
46–60 Years	79.41 ± 17.55
Above 60 Years	73.28 ± 18.92

Various age groups' mean serum iron levels are shown in Table 4. Serum iron concentration decreases gradually with aging, according to the results. The average blood iron level was highest among those aged 18–30 (89.56 ± 17.84 µg/dL), then among those aged 31–45 (84.37 ± 18.26 µg/dL). The average blood iron level was lowest among participants aged 60 and above (73.28 ± 18.92 µg/dL), compared to the 46-60 year old age group (79.41 ± 17.55 µg/dL).

The data show that serum iron levels have been steadily declining across all age groups, which could mean that iron deficiency is a natural consequence of getting older. The overall pattern shows that the mean iron levels of older adults are gradually lower, while there is some fluctuation in the standard deviations within each age group. Possible causes of this trend include changes in nutrition, impaired intestinal iron absorption, changes in physiology associated with aging, or the cumulative impact of many chronic health problems.

The primary focus of the table, which is a One-Way ANOVA comparison, is to illustrate variations in mean serum iron levels among the four age categories. But you can't tell if the changes you saw are statistically significant without the F-value and p-value, which aren't in the table. Hence, without the results of the ANOVA test, it is not possible to draw any conclusions about the statistical significance of the differences, even though the descriptive results imply that serum iron levels decline with age. Further statistical analysis is needed to determine the significance of the observed variation, but overall, the findings show that mean serum iron levels decrease with age.

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Table 5: Results of ANOVA

ANOVA Statistics	Value
F-value	4.26
p-value	**0.007**

Table 5 shows the outcomes of the one-way Analysis of Variance (ANOVA) that was performed to see if there were significant differences in serum iron levels among the four age groups of the study participants. Results showed a p-value of 0.007 and an F-value of 4.26. Rejecting the null hypothesis that there is no variation in mean serum iron levels between age groups, the p-value is smaller than the customary criterion of significance ($p < 0.05$).

Serum iron levels range considerably between age groups, according to the statistically significant ANOVA finding. Taken with the descriptive statistics in Table 4, the results indicate that serum iron concentrations decline gradually with age, reaching a peak among participants between the ages of 18 and 30 and a trough among those over 60. Age appears to play a significant role on serum iron status, according to this pattern.

Possible causes of the large range of results include metabolic characteristics characteristic of aging, decreased intestinal absorption of iron from food, age-related physiological changes, chronic diseases, and other age-related health issues. Although there are statistically significant differences across the age groups, the ANOVA does not specify which groups are different. A post hoc analysis, such Tukey's HSD, would be necessary to ascertain the precise pairwise differences.

The results of the analysis of variance show that there is a statistically significant correlation between age and serum iron levels ($F = 4.26$, $p = 0.007$). This means that the participants' serum iron status varies by age group and typically decreases as they become older.

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Table 6 Pearson Correlation Between Trace Elements and Health Indicators

Variables	Hemoglobin	BMI	Blood Glucose
Iron	**0.52**	-0.18	-0.21
Zinc	0.39	-0.09	-0.27
Copper	-0.16	0.11	0.19
Selenium	0.42	-0.14	-0.24

The association between serum levels of critical trace elements and chosen health markers, including hemoglobin, body mass index (BMI), and blood glucose, is described by the Pearson correlation coefficients, which are presented in Table 6. Higher blood iron levels are connected with higher hemoglobin concentrations, according to the results, which show that iron had the largest positive connection with hemoglobin (r = 0.52). We can explain this result biologically since iron is essential for the production of hemoglobin and the delivery of oxygen. There was a small but positive link between zinc and hemoglobin (r=0.39) and a somewhat positive correlation between selenium and hemoglobin (r=0.42). However, there was a little inverse link between copper and hemoglobin, as shown by a modest negative correlation (r = -0.16).

All of the trace elements had minor relationships with respect to body mass index (BMI). There was a minor negative correlation between body mass index (BMI) and iron (r = -0.18), zinc (r = -0.09), and selenium (r = -0.14), indicating that there was only a little trend toward lower BMI values when these trace element levels increased. In contrast, there was a small positive association between copper and body mass index (r = 0.11). Taken together, these results indicate that there is minimal correlation between the study population's blood trace element levels and body mass index.

There were weak negative associations for iron (r = -0.21), zinc (r = -0.27), and selenium (r = -0.24) with respect to blood glucose, suggesting that elevated quantities of these trace elements were linked to marginally reduced glucose levels. One of these was zinc, which had a weak but significant inverse association with blood glucose levels. The opposite was true for copper, which showed a weak positive connection with blood glucose (r = 0.19), indicating that elevated copper levels were linked to a little rise in blood glucose

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concentration.

Hemoglobin has the strongest link with vital trace elements, especially iron, according to the correlation study. This shows how crucial trace elements are for a healthy hemostatological condition. On the other hand, trace element status was not the only factor influencing body mass index (BMI) and blood glucose levels; weak connections between the two show that these health indicators are impacted by a myriad of physiological and lifestyle factors. The results highlight the necessity for additional research to determine the statistical importance and therapeutic implications of these observed relationships, but they also give important insight into the possible role of vital trace elements in general health.

Table 7: Correlation test results

Test	**Value**
Pearson Correlation	Significant
p-value	**<0.01**

An examination of the association between serum trace element levels and the selected health indicators was carried out using a Pearson correlation analysis. The overall results are presented in Table 7. A p-value lower than 0.01 indicates that the Pearson correlation test was statistically significant. There is a statistically significant association between the variables tested, as the null hypothesis of no correlation is rejected due to the p-value being below the 1% level of significance.

The results shown in Table 6, which show that vital trace elements were significantly correlated with health markers such hemoglobin, body mass index (BMI), and blood glucose, are corroborated by this strong correlation. Some health measures revealed positive correlations with iron, zinc, and selenium, and modest negative correlations with blood glucose; copper, on the other hand, showed weaker and inverse correlations with a few of these parameters. It is highly improbable that these observed associations happened by coincidence, given the total statistical significance.

There is a considerable correlation between the chosen health indicators and blood

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concentrations of critical trace elements in the study population ($p < 0.01$), according to the results. There are significant relationships between the trace elements and health outcomes, according to the overall Pearson correlation test, even though the strength and direction of individual correlations vary. These results demonstrate that vital trace elements are crucial for physiological function and imply that changes in trace element status can affect metabolic and hemostatic variables. To further understand these correlations and what they mean for therapeutic practice, more research may be conducted to determine the underlying causative mechanisms.

V. CONCLUSION

Research like this shows that trace elements—especially iron, zinc, copper, and selenium—are critical for good health and regular bodily functions. Important health indicators and the prevalence of chronic diseases are linked to differences in blood trace element concentrations, according to assessments of these micronutrients. Deficits or imbalances in trace elements may have a negative impact on health outcomes, since there are substantial correlations between trace element status and hemoglobin levels, nutritional status, and illness conditions, according to the statistical analyses.

These results highlight the need of routinely testing for important trace elements as a means of identifying those at risk of chronic diseases and nutritional deficits early on. In order to understand the role of micronutrients in disease prevention and health promotion, accurate laboratory measurement in conjunction with adequate statistical evaluation gives credible data. Improved clinical decision-making, tailored treatment plans, and prompt dietary interventions can all result from regular trace element status biomonitoring.

In conclusion, the research shows that public health and healthcare programs should incorporate trace element assessment into their regular practices. Better health outcomes and a lower disease burden can be achieved through the promotion of balanced diet, the increase of awareness of micronutrient deficiencies, and the implementation of nutritional policies based on evidence. To further understand the long-term impacts of trace element status on human health and disease development, future research should use longitudinal study designs and involve bigger and more diverse populations.

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