Research and Development of Trace Elements Related with Human Health and Longevity

Fang Liu (Zhuoyi Liu) [1], Qi Xiao[2], Huaijie Zhu[1,3]

[1]Henan Zhuoyi Culture Communication Co., Ltd.186-3978-8010, Zhengzhou City，Henan, China; 1650451367@qq.com ；
[2]China Musicians' Association, Zhejiang Province Musicians Association, China。First-level composer
[1,3]Department of Pathology and Cell Biology, Columbia University, New York, USA. Jacksun Easy Biotech Inc. New York，USA； Corresponding by Huaijie Zhu，917-635-2608， jacksun689@gmail.com

Abstract: With societal development and the accelerating aging of the population, healthy longevity has become a major global public health goal and a research hotspot. Besides genetics, lifestyle, and macronutrients, micronutrients are playing an increasingly crucial role in maintaining human physiological functions, delaying aging, and preventing age-related diseases. This article systematically reviews the research on the correlation between essential trace elements such as zinc, selenium, iron, copper, manganese, and chromium and human health and longevity, and explores the reasons and mechanisms by which they affect the aging process through molecular mechanisms such as anti-oxidation, immune regulation, metabolic stabilization, and telomere maintenance. Meanwhile, this article also analyzes the challenges currently faced by trace element research in terms of detection methods, individual differences, and the establishment of causal relationships. It also provides an outlook on future research directions, including precision nutrition, multi-omics integration, and the development of novel functional foods. The aim is to provide theoretical basis and practical guidance for intervention to achieve healthy aging through methods and measures to regulate and supplement trace elements.
[Fang Liu (Zhuoyi Liu), Qi Xiao, Huaijie Zhu. **Research and Development of Trace Elements Related with Human Health and Longevity.** *Life Sci J* 2025;22(11):171-173]. ISSN 1097-8135 (print); ISSN 2372-613X (online)**.** http://www.lifesciencesite.com**.** 05. doi:10.7537/marslsj221125.05

Keywords: Trace elements; healthy longevity; healthy 120 years old; anti-aging; antioxidant; oxidative stress; minerals

1. Introduction：

As we all know, the desire for health and longevity is a goal pursued and strived for by every living person. Extending lifespan without sacrificing quality of life is a perpetual human endeavor. Aging is a complex biological process influenced by multiple factors, including genetics, environment, nutrition, and psychology. In the field of nutrition, trace elements (minerals present in the human body at levels below 0.01% of body weight), though required in minute quantities, are core components of enzymes, hormones, and vitamins, participating in all life activities. In recent years, numerous epidemiological and basic studies have confirmed that the homeostasis of trace elements is closely related to the rate of aging, the probability of longevity, and the risk of common age-related diseases (such as cardiovascular disease, neurodegenerative diseases, diabetes, and cancer). Therefore, in-depth exploration of the mechanisms of action of trace elements in healthy longevity and promoting the translational application of related research have extremely important scientific and social value.

2. Research on the correlation between major trace elements in the human body and health and longevity

2.1 Zinc (Zn)：

Zinc is a cofactor for more than 300 enzymes in the body and is widely involved in DNA synthesis, cell division, immune function, and antioxidant defense. Studies have shown that mild zinc deficiency is common among the elderly, which is closely related to immunosenescence, increased risk of infection, cognitive decline, and muscle loss.

2.2 Selenium (Se)：

Selenium's core function is to exert a powerful antioxidant effect through selenoproteins (such as glutathione peroxidase GPx), protecting cells from lipid peroxidation damage. In addition, selenium is involved in thyroid hormone metabolism and immune regulation. The renowned Ethiopian Study found that low selenium levels are associated with increased cancer mortality. Adequate selenium intake plays a

protective role in maintaining cardiovascular health and cognitive function. However, it is worth noting that selenium intake exhibits a U-shaped relationship; excessive selenium can also be toxic and harmful to health.

2.3 Iron (Fe)：
Iron is a key component of hemoglobin and cytochrome, responsible for oxygen transport and energy metabolism. However, iron is also a double-edged sword. Excess iron in the body generates a large number of hydroxyl radicals through the Fenton reaction, exacerbating oxidative damage and directly related to Alzheimer's disease, Parkinson's disease, and cardiovascular aging. Therefore, maintaining iron homeostasis, rather than simply supplementing iron, is crucial for healthy longevity. Studies suggest that long-lived individuals often exhibit superior iron metabolism regulation capabilities.

2.4 Copper (Cu), Manganese (Mn), Chromium (Cr)：
2.4.1. Copper: As a component of Cu/Zn-SOD and cytochrome C oxidase, copper is essential for antioxidant activity and energy metabolism. However, excessive copper can also promote oxidative stress and is associated with β-amyloid deposition in Alzheimer's disease.
2.4.2. Manganese: It is the core of manganese superoxide dismutase (Mn-SOD), which is specifically responsible for clearing superoxide anions in mitochondria and is crucial for protecting the function of the "cell's energy power plant".
2.4.3. Chromium: As a component of glucose tolerance factor, it can enhance insulin sensitivity and play a special role and function in maintaining glycated hemoglobin and blood glucose homeostasis and preventing type 2 diabetes. Blood glucose stability is an important indicator of health and longevity.

3. Molecular mechanisms by which trace elements affect health and longevity:

3.1 Promoting Antioxidant and Anti-inflammatory Mechanisms:
The free radical theory of aging posits that the accumulation of reactive oxygen species (ROS) is a core driver of aging. Antioxidant enzyme systems centered on selenium, zinc, manganese, and copper (such as GPx and SOD) constitute the body's endogenous antioxidant defense network, playing a crucial role in synergistically scavenging ROS, mitigating oxidative damage, and protecting the integrity of biological macromolecules (DNA, proteins, and lipids).

3.2 Enhancing and Promoting Immune Regulation Mechanisms:
Trace elements are the cornerstone of maintaining and stabilizing normal immune function in the human body. Zinc deficiency can lead to impaired T lymphocyte function and thymus atrophy; selenium can enhance the activity of natural killer cells (NK cells) and their antiviral capabilities. By maintaining immune homeostasis, trace elements help the body effectively resist infection and eliminate cancerous cells, thereby extending healthy lifespan.

3.3 Stabilizing Metabolism and Endocrine Regulation:
Zinc and chromium play important roles in insulin signaling, delaying the onset of diabetes and its complications by maintaining stable glycated hemoglobin and blood glucose levels.Iodine and selenium work together to regulate and maintain the secretion and function of thyroid hormones, stabilizing and influencing the body's basal metabolic rate. The stability and balance of these metabolic pathways are essential for ensuring the body's energy balance and the normal functioning of organs.

3.4 Stabilizing and maintaining telomere length:
Telomeres are protective caps at the ends of chromosomes, and their length is considered a "biological clock" for cellular aging. Preliminary studies suggest that trace elements such as zinc and selenium may slow down the rate of telomere shortening by reducing oxidative stress and maintaining telomerase activity, providing cutting-edge molecular biological evidence for the intervention of trace elements in aging.

4. Exploring the impact of trace elements on human health, longevity, and future development:

4.1 Challenges Faced:
4.1.1. Challenges in Detection and Evaluation: The levels of trace elements in serum/plasma may not accurately reflect the true storage and bioavailability within tissues. This is a pressing issue that needs to be addressed in current research on the application of trace elements to human health and longevity.
4.1.2. Significant Individual Variations: Factors such as age, sex, genetic background (e.g., polymorphisms in metal metabolism-related genes), and gut microbiota composition can all affect an individual's need for and response to trace element
4.1.3. Synergistic and antagonistic effects: There are complex interactions among trace elements (such as zinc-copper antagonism), and the value of studying a single element in isolation is limited.

4.1.4. Establishment of causal relationship: Most observational studies are difficult to eliminate confounding factors and establish a direct causal relationship between trace elements and longevity.

4.2 Future Development Direction：

4.2.1. Practice of precision nutrition: Combining genomics, metabolomics and microbiome to develop personalized micronutrient supplementation plans to achieve precise intervention with "one plan for one person".

4.2.2. Multi-omics integrated research: Using systems biology methods, comprehensively analyze the overall pathways by which trace elements affect the aging network.

4.2.3. Development of novel functional foods and formulations: Research and develop trace element carriers with high bioavailability and strong targeting (such as nano-selenium and organic zinc), and explore their application in functional foods and special medical foods.

4.2.4. Conduct large-scale prospective intervention trials: Design rigorous randomized controlled trials for specific elderly populations to determine the effect of supplementing specific trace elements on extending healthy lifespan.

5. Conclusion；

Trace elements, as indispensable "spark plugs" and "stabilizers" in life activities, play a vital role in regulating the aging process and promoting healthy longevity. Current research has moved beyond simple deficiency-supplementation relationships to explore molecular mechanisms and maintain homeostasis. In the future, research and development in this field will inevitably place greater emphasis on systematic, individualized, and precise approaches. Through multidisciplinary collaboration and in-depth exploration of the intrinsic link between trace elements and healthy longevity, a solid scientific foundation will be laid for developing effective nutritional intervention strategies and promoting healthy aging globally.

11/16/2025

References：

1.Łukasz Bryli nski and Jacek Baj : Effects of Trace Elements on Endocrine Function and Pathogenesis of Thyroid Diseases—A Literature Review, Nutrients, 2025, 17(3980):1-54.

2. AnnaDługosz, Marcin Wróblewski, Błazej Błaszak andJoannaSzulc: The Role of Nutrition, Oxidative Stress, and Trace Elements in the Pathophysiology of Autism Spectrum Disorders, Int.J.Mel.Sci.2025, 26(808):1-34.

3. Tara Rolić1,Mazyar Yazdani, Sanja Mandić1, Sonia Distante: Iron Metabolism, Calcium, Magnesium and Trace Elements: A Review, Biological Trace Element Research (2025) 203:2216–2225.

4. Mariam Aslam1, Anuradha Kulasekaran, Giovanna Maraula , Graça Coutinho, Lucas Jacobs , Krathish Bopanna：The key role of vitamin C and zinc in throat health and the benefits of regular fortified lozenge use in counteracting discomfort，International Journal of Medical and Health Research，2023，9（1）：58-67.

5. Robert S. Houk, Velmer A. Fassel, Gerald D. Flesch, and Harry J. Svec: Inductively Coupled Argon Plasma as an Ion Source for Mass Spectrometric Determination of Trace Elements, Analytical Chemistry,1980,52(14):2283-2289. 6. Stephanie Strachan：Trace elements，Current Anaesthesia & Critical Care，2010，21（1）：44-48.7. Mocchegiani, E., et al. Zinc, metallothioneins, and longevity. Interdisciplinary Topics in Gerontology, 2013, 29：111-131.

7. Rayman, M. P.：Selenium and human health. The Lancet, 2012，379(9822):1256-1268.

8. Ames, B. N. (2018). Prolonging healthy aging: Longevity vitamins and proteins. Proceedings of the National Academy of Sciences, 2018, 115(43):10836-10844.

9. Prasad, A. S.Zinc: an antioxidant and anti-inflammatory agent. Current Opinion in Clinical Nutrition and Metabolic Care,2013，16(6), 675－679.