POLISH HYPERBARIC RESEARCH 2(83)2023
Journal of Polish Hyperbaric Medicine and Technology Society

THE EFFECT OF COOPER, ZINC AND SELENIUM ON SKIN CONDITION

Anna Kulik

J. Piłsudski Academy of Physical Education in Warsaw Branch in Biała Podlaska, Poland

ABSTRACT

Trace elements are essential for the maintenance of the homeostasis of the body, and condition the proper functioning of the human organism. Micronutrients influence a number of metabolic processes in the dermis and epidermis. An excess or deficiency of trace elements may represent a potential threat to human health with implications for skin condition. This study reviews the literature on the effects of copper, zinc and selenium on skin condition.
Keywords: Copper, Zinc, Selenium, skin, skin health, physiology.

ARTICLE INFO

PolHypRes 2023 Vol. 83 Issue 2 pp. 23 – 30
ISSN: 1734-7009 **eISSN:** 2084-0535
DOI: 10.2478/phr-2023-0009
Pages: 8, figures: 0, tables: 0
page www of the periodical: www.phr.net.pl

Publisher
Polish Hyperbaric Medicine and Technology Society

Rewiev article

Submission date: 09.10.2022 r.
Acceptance for print: 10.12.2022 r.

INTRODUCTION

Copper (Cu), Zinc (Zn) and Selenium (Se) are micronutrients that are vital for the body's metabolic processes. They are present in the human body in trace amounts with the demand being disproportionately lower compared to the macronutrients. Deficiency symptoms of these elements typically develop slowly along with the utilisation of the body's resources. Micronutrients play an important role in skin physiology and in maintaining skin in a healthy condition [1].

The skin is the body's main protective barrier. States of deficiency or excess of specific trace elements disrupt the physiological balance of the skin and can lead to a number of dermatological conditions[2,3]. During the ageing process, the body experiences a decrease in immunity and a dynamic modulation of the redox state, which significantly worsens the condition of the skin [4,5,6]. The significant role of micronutrients in skin regeneration has been documented [7,8].

METHODS

The aim of this study was to review the literature from PubMed, Google Scholar and Scopus databases on the effects of Copper, Zinc and Selenium on physiological processes and skin condition and to highlight the effects of deficiency and excess of these elements. Analysis of the data obtained may allow the development of a prevention plan for a number of dermatological conditions and the identification of principles for micronutrient supplementation.

COPPER (CU)

Copper is a heavy metal and at the same time a micronutrient essential for the body's metabolism. The body of an adult contains approximately 100-150 mg of this element. The greatest amount of Cu is found in the liver, which is due to the storage functions of this organ and the fact that the liver is the only site for the synthesis and release of ceruloplasmin, the protein with the highest Cu content. The organ with the second highest copper content is the brain. In the blood, Cu occurs in a labile form, bound to amino acids and albumin, and in a stable form, bound to ceruloplasmin [9,10]. Due to its ability to receive and release electrons, this element is incorporated into the active centre of many enzymes involved in basic metabolic reactions [11,12]. Cu ions are part of approximately 30 enzymatic and non-enzymatic proteins. These proteins are referred to as metalloproteins and among them are: proteins with enzymatic activity such as ceruloplasmin, superoxide dismutase (SOD), an endogenous antioxidant enzyme, cytochrome c oxidase and amine oxidase, tyrosinase, n-dopamine hydroxylase. A metalloprotein that does not exhibit enzymatic properties is metallothionein [13,14,15]. Cu plays an important role in lipid and carbohydrate metabolism [16]. Deficiency of this element decreases copper-dependent enzymes, resulting in skin depigmentation, anaemia, neurological disorders, ataxia, and muscle weakness. Low Cu levels are a feature in prion diseases and Parkinson's disease [17,18,19]. Excess Cu is toxic to cells. One of the main consequences of disruption of Cu homeostasis in the body is the formation of reactive oxygen species, which trigger the development of oxidative stress [20,21]. In cells, this process can lead to damage to proteins and lipids and thus damage to cell structures and genetic material [15]. Cu conditions the normal functioning of the nervous system. It plays a role in bone formation, iron metabolism and heme synthesis. It participates in the maintenance of keratin structure and in melanin synthesis. In the skin, Cu is involved in the formation of the extracellular matrix, synthesis and stabilisation of skin proteins and angiogenesis. Clinical studies have shown that this element helps improve skin elasticity, wound healing and reduces fine lines and wrinkles [22]. With Cu deficiency, the activity of lysyl oxidases, enzymes necessary for the formation of cross-links in collagen and elastin that initiate their cross-linking, decreases [23].

The main source of Cu for an adult is food. Food products of animal origin are a better source of this element compared to plant products owing to differences in bioavailability. Large amounts of Cu are found in oysters, baker's yeast, sesame seeds and cocoa. Also rich in copper are squid, lobster, chocolate, sunflower seeds, sun-dried tomatoes, pumpkin and soya beans, flaxseed, wheat bran, dried plums and peppers [9,24].

The requirement for Cu is approximately 1-2 mg per day. This element is absorbed from food in the small intestine (approximately 15%), particularly in its initial section, from where it enters the bloodstream, the remainder being removed in the faeces [25]. Abnormalities in copper metabolism, especially those leading to an excess of copper in the body, result in disturbances in the metabolism of other trace elements. It has been shown that excess Cu in the body leads to zinc deficiency [26].

ZINCK (ZN)

It is found in all human tissues and body fluids. Tissues such as muscle, skin, bones, liver, pancreas, spleen, kidneys, and brain contain particularly high amounts of Zn. It is estimated that 60% of this element is found in bones, 30% in muscles. The skin contains about 6% Zn, which is found primarily in the epidermis, in its stratum spinosum. In the dermis, the highest levels are found in the upper parts of the skin [27,28].

Zn is an essential element for the proliferation and differentiation of epidermal keratinocytes, as demonstrated, inter alia, by Bauer et al. in a study of increased dietary zinc-rich amino acids [29,30]. Excess Zn can be detrimental to the human body, and a deficiency of this micronutrient can result in a decrease in immunity and inflammation of the skin and the entire body [28].

The daily requirement for Zn depends on a number of factors, including gender and age. The average daily zinc requirement for an adult is around 15 mg. The main sources of this element are animal products such as meat, eggs, fish and oysters. Slightly less Zn is provided by products of plant origin, including sunflower seeds, pumpkin seeds, wheat germ, wheat bran, garlic and onions [24].

Zn in the human body has catalytic, regulatory and structural functions. It is an essential substrate for the division and differentiation of new cells. It plays an important role in apoptosis and skin ageing. In addition, this element influences the structure and proper functioning of mucous membranes [31]. Zn stabilises skin cell membranes and participates in the division of basal

Zn reduces the risk of skin cancer, through its ultraviolet-protective properties. When used in cosmetic preparations, it helps to improve skin condition [33,34]. Zn plays an antioxidant role, protecting sulfhydryl groups from oxidation and preventing the production of superoxide and hydroxyl free radicals by prooxidant metals, including Cu and Fe. Zn deficiency can exacerbate oxidative stress-induced tissue damage. The antioxidant properties of this element help to scavenge the resulting free radicals. This effect of Zn results from its chemical properties, such as its lack of free radical-forming capacity due to its lack of oxidation-reduction activity, its ability to replace the harmful metal ions of copper and zinc, which cause the formation of free radicals in the oxidation-reduction process, the presence as a component of metallothionein and superoxide dismutase, which exhibit strong antioxidant activity [34,35]. Zinc oxide is an ingredient in radiation-protective preparations. An alternative to zinc oxide is the zinc-glycine complex, which has the ability to induce MT (metallothionein), thus enhancing resistance to UV-induced oxidative stress and reducing the risk of hyperpigmentation [34].

Zn exhibits anti-inflammatory effects. The action of Zn ions is to reduce the production of reactive oxygen species (ROS) by nicotinamide adenine dinucleotide phosphate (NADPH) [32]. Zn inhibits the formation of inflammatory mediators. Zinc oxide and zinc carbonate have soothing properties and are therefore used in the treatment of dermatological conditions with pruritic skin conditions. Zinc intake reduces the levels of pro-inflammatory cytokines and biomarkers of oxidative stress, C-reactive protein [32,36]. Zn compounds are used in the topical treatment of a number of inflammatory dermatological conditions such as acne, rosacea, seborrhoeic dermatitis, eczema, erosive pustular dermatosis, wounds of various aetiologies [32]. Zn deficiency leads to impaired wound healing. When used in monotherapy as well as in combination therapy, it exhibits anti-inflammatory and bacteriostatic activity. It inhibits the proliferation of Propionibacterium acnes and inhibits the amount of lipases and free fatty acids secreted by this microorganism, which exacerbate inflammation. Moreover, due to its anti-androgenic effect, Zn reduces the secretion of sebum [37].

Of the known zinc compounds, the zinc-glycine complex possesses the greatest antipigmentation potential due to its antioxidant and UV-protective properties. It is a metallothionein inducer, thus activating c-glutamylcysteine synthetase (c-GCS). It demonstrates the ability to reduce oxidative stress by inhibiting the formation of free radicals inside the cell. This affects the condition of the skin and slows down the ageing process. Zinc oxide is used in the manufacture of preparations for the sun protection of the skin [36]. Zn compounds significantly reduce the severity of inflammation. Additionally, they inhibit excessive sebum secretion. In the treatment of inflammatory dermatological conditions, these compounds can be used externally and in oral preparations [38]. The most commonly used compound in cosmetic preparations is zinc oxide and zinc 2-pyrrolidone 5-carboxylate (Zn PCA - Zinc Pyrrolidine Carboxylate). Zn acts on the hair matrix cells, activates enzymes responsible for protein metabolism and participates in the formation of keratins. Zn deficiency has been associated with abnormal and delayed healing of skin wounds [39]. A rare inborn metabolic error that leads to severe Zn deficiency is acrodermatitis enteropathica [40,41]. Zinc sulphate and zinc gluconate supplementation is used in acne therapies. It has been shown that patients receiving Zn supplementation have decreased inflammatory cytokines in the body and increased antioxidant capacity [42]. Zn is also a component of botulinum toxin, used in cosmetic procedures to remove facial wrinkles [43].

Excess Zn resulting from excessive chronic supplementation of this element can lead to impaired absorption of copper and molybdenum, leading to symptoms of deficiency of these elements [44].

SELENIUM (SE)

Selenium is another mineral that is important for proper skin condition. Se is present in the human body in amounts of approximately 10-30 mg. It is a cofactor for many enzymes, including oxidoreducing enzymes, glutathione peroxidase and cytochrome. It influences the proper functioning of the immune system and the synthesis of nucleic acids. In synergy with vitamin E, it delays the skin ageing process and accelerates cell regeneration by, inter alia, protecting against damage to nucleic acids, neutralising the negative effect of sunlight on the skin, and protecting cells against the destructive effect of free radicals. [45,46].

Sn has been shown to play an important role in the prevention of skin cancer. It protects the skin from damage caused by excessive UV radiation [47,48]. Selenium's potential anticancer properties stem from its pro-oxidant properties [49]. Se has a soothing effect on the skin, showing anti-allergic properties. Due to its regulation of sebum secretion, it is often used in people with acne and dandruff, especially in combination with vitamin E and zinc. Se deficiency enhances skin ageing, causes deterioration of skin appendages, and may be responsible for the development of dandruff. Lack of Se in the diet impairs the UV-B-induced antioxidant capacity of the skin, making it more sensitive to UV-induced oxidative stress [50]. Se-enriched proteins are essential for keratinocyte development and function [51]. Se is a component of about 20 enzymes. In the body, it is mostly found in amino acids such as selenomethionine and selenocysteine [52].

Selenium supplementation may reduce the incidence of acute and/or chronic skin diseases [53]. The body's supply of this element may affect skin condition and skin type, defined as dry, oily, combination skin. A diet deficient in selenium is likely to be one of the main factors in the pathogenesis and course of psoriasis [54]. Se inhibits melanoma proliferation [49]. Se together with vitamin E delays the ageing process, and accelerates cell regeneration [55]. It reduces the toxic effects of other elements, such as mercury, lead, cadmium or arsenic, and can prevent skin diseases caused by these elements. The greatest quantities of Se are found in nuts, mainly Brazil nuts, fish (mainly tuna and salmon), poultry meat, wheat, mushrooms and chicken eggs. Selenium is an element that is fairly well absorbed by the body, and protein and vitamins A, E and C further facilitate its absorption [56].

Both excess and deficiency of Se is harmful to the human body. Poisoning can occur by consuming excess amounts of supplements containing this element [57,58,59,60]. Excess Se in the diet can induce oxidative stress and lead to selenosis, a disease that manifests itself

by loss of nails, hair, sometimes heart muscle disease and even blindness [61]. Se deficiency can lead to Keshan disease and Kashin-Beck disease, which are well known in Se-deficient areas of China [62].

CONCLUSION

Analysis of the literature review from selected articles showed that there is a correlation between deficiency and excess of Cu, Zn and Se and skin health. The antioxidant properties of the above trace elements, which reduce free radicals, are highly valued. Due to their anti-inflammatory effects, they have found applications in dermatology, cosmetology, dietetics and in the treatment of certain inflammatory diseases. Both deficiency and excess of Cu, Zn and Se are dangerous to health, thus it is important to monitor their levels in the body and establish indications and a plan for supplementation of these elements.

A number of issues concerning the metabolism of micronutrients in the human body and their effects on the state and condition of the skin and the integumentary system still remain unexplained, confirming the need for further research.

REFERENCES

1. Bjørklund G., Shanaida M., Lysiuk R., Butnariu M., Peana M., Sarac I., Strus O., Smetanina K., Chirumbolo S. 2022. Natural Compounds and Products from an Anti-Aging Perspective. Molecules,27(20):7084. doi: 10.3390/molecules27207084.
2. Pourzand C., Albieri-Borges A., Raczek N.N. 2022. Shedding a New Light on Skin Aging, Iron- and Redox-Homeostasis and Emerging Natural Antioxidants. Antioxidants (Basel),11(3):471. doi: 10.3390/antiox11030471.
3. Khmaladze I., Leonardi M., Fabre S., Messaraa C., Mavon A.2020. The Skin Interactome: A Holistic "Genome-Microbiome-Exposome" Approach to Understand and Modulate Skin Health and Aging. Clin Cosmet Investig Dermatol.,13:1021-1040.doi:10.2147/CCID.S239367.
4. Ratanapokasatit Y., Laisuan W., Rattananukrom T., Petchlorlian A., Thaipisuttikul I., Sompornrattanaphan M.2022. How Microbiomes Affect Skin Aging: The Updated Evidence and Current Perspectives. Life (Basel),12(7):936. doi: 10.3390/life12070936.
5. Cao C., Xiao Z., Wu Y., Ge C.2020.Diet and Skin Aging-From the Perspective of Food Nutrition. Nutrients,12(3):870. doi: 10.3390/nu12030870.
6. Baudry J., Kopp J.F., Boeing H., Kipp A.P., Schwerdtle T., Schulze M.B.2020. Changes of trace element status during aging: results of the EPIC-Potsdam cohort study. Eur J Nutr.,59(7):3045-3058. doi: 10.1007/s00394-019-02143-w.
7. Torres A., Rego L., Martins M.S., Ferreira M.S., Cruz M.T., Sousa E., Almeida I.F.2023. How to Promote Skin Repair? In-Depth Look at Pharmaceutical and Cosmetic Strategies. Pharmaceuticals (Basel), 11;16(4):573. doi: 10.3390/ph16040573.
8. Koptyug A., Sukhovei Y., Kostolomova E., Unger I., Kozlov V.2023.Novel Strategy in Searching for Natural Compounds with Anti-Aging and Rejuvenating Potential. Int J Mol Sci.,24(9):8020. doi: 10.3390/ijms24098020.
9. Brzezińska J., Grembecka M.2021. Dietary supplements - a specific food. Advances in Hygiene and Experimental Medicine, vol.75,655-673. doi: 10.2478/ahem-2021-0011.
10. 10.Romanowicz G.E., Terhune A.H., Bielajew B.J., Sexton B., Lynch M., Mandair G.S., McNerny E.M.B., Kohn D.H. 2022. Collagen cross-link profiles and mineral are different between the mandible and femur with site specific response to perturbed collagen. Bone Reports, 17:101629. doi:10.1016/j.bonr.2022.101629.
11. McCann C.J., Hasan N.M., Padilla-Benavides T., Roy S., Lutsenko S. 2022. Heterogeneous nuclear ribonucleoprotein hnRNPA2/B1 regulates the abundance of the copper-transporter ATP7A in an isoform-dependent manner. Front. Mol. Biosci., 9:1067490, doi: 10.3389/fmolb.2022.1067490 0592-7.
12. Whitlow T.J., Zhang Y., Ferguson N., Perez A.M., Patel H., Link-Kemp J.A., Larson E.M., Mezzell A.T., Shanbhag V.C., Petris M.J., Vest K.E.2023. Regulation of Atp7a RNA contributes to differentiation-dependent Cu redistribution in skeletal muscle cells. Metallomics. 15(7):mfad042. doi: 10.1093/mtomcs/mfad042.
13. Dobrowolski, M., Cave, C., Levy-Myers, R., Lee, C. H., Park, S., Choi, B. R., et al.2020. GDE3 regulates oligodendrocyte precursor proliferation via release of soluble CNTFRα. Development, 147:dev180695. doi: 10.1242/dev.180695.
14. McKean M., Napoli F.R., Hasan T., Joseph T., Wheeler A., Beebe K., Soriano-Cruz S., Kawano M., Cave C. 2023.GDE6 promotes progenitor identity in the vertebrate neural tube. Front Neurosci.,17,1047767. doi: 10.3389/fnins.2023.1047767.
15. Marsico T.V., Silva M.V., Valente R.S., Annes K., Rissi V.B., Glanzner W.G., Sudano M.J.2023. Unraveling the Consequences of Oxygen Imbalance on Early Embryo Development: Exploring Mitigation Strategies. Animals (Basel),13(13):2171. doi: 10.3390/ani13132171.
16. OliverGerman C., Martinez G. 2022. Accumulation dynamics of ARGONAUTE proteins during meiosis in Arabidopsis. Plant Reproduction, vol.35,153-160.doi: 10.1007/s00497-021-00434-z.
17. An Y., Li S., Huang X., Chen X., Shan H., Zhang M.2022. The Role of Copper Homeostasis in Brain Disease. Int J Mol Sci.,23(22):13850. doi: 10.3390/ijms232213850.
18. Chen Q.Y., Wu P., Wen T., Qin X., Zhang R., Jia R., Jin J., Hu F., Xie X., Dang J.2022. Association of cerebral spinal fluid copper imbalance in amyotrophic lateral sclerosis. Front Aging Neurosci., 14:970711. doi: 10.3389/fnagi.2022.970711.
19. Jenkins J.A., Musgrove M., White S.J.O.2023. Outlining Potential Biomarkers of Exposure and Effect to Critical Minerals: Nutritionally Essential Trace Elements and the Rare Earth Elements. Toxics,11(2):188. doi: 10.3390/toxics11020188.
20. Carreon-Gonzalez M., Alvarez-Idaboy J.R.2023. The Synergy between Glutathione and Phenols-Phenolic Antioxidants Repair Glutathione: Closing the Virtuous Circle-A Theoretical Insight. Antioxidants (Basel),12(5):1125. doi: 10.3390/antiox12051125.
21. Javali P.S., Sekar M., Kumar A., Thirumurugan K.2023. Limited Expression of *Nrf2* in Neurons Across the Central Nervous System. Biogerontology, May 17, doi:10.1007/s10522-023-10040-3.
22. Melamed E., Rovitsky A., Roth T., Borkow G. 2022. Anterior Ankle Full Thickness Skin Necrosis Treated with Copper Oxide Dressings without Debridement and Skin Grafting -A Case Report. Arch Clin Med Case Rep.,6 (3): 501-510. doi:10.26502/acmcr.96550504.
23. Javali P.S., Sekar M., Kumar A., Thirumurugan K.2023. Dynamics of redox signaling in aging via autophagy, inflammation, and senescence. Biogerontology, May 17. PMID: 37195483, doi: 10.1007/s10522-023-10040-3.
24. Jarosz M., Rychlik E., Stoś K., Charzewska J. (red.), 2020. Nutrition standards for the Polish population and their application. Narodowy Instytut Zdrowia Publicznego – PZH, Warszawa.

25. Therstappen, Eichner, Wohlrab J.2023. [Practical problems with the use of topicals in geriatric dermatology]. Dermatologie (Heidelb), Jul 26. doi: 10.1007/s00105-023-05187-6.
26. Hibi H., Tokoro M., Sugie M., Ohori T., Sonohara M., Fukunaga N., Asada Y. 2022.Evaluation of the serum zinc concentration in male infertility patients: an analysis of 2010 cases. Nagoya J Med Sci.,84(4):839-847. doi: 10.18999/nagjms.84.4.839.
27. Kręcisz B., Michalak M., Pierzak M., Suliga E.2021.Bioactive Compounds for Skin Health: A Review. Nutrients,13(1):203. doi:10.3390/nu13010203.
28. Ośko J., Pierlejewska W., Grembecka M. 2023. Comparison of the Potential Relative Bioaccessibility of Zinc Supplements-In Vitro Studies. Nutrients, 15(12):2813, doi:10.3390/nu15122813.
29. Yang Y., Wang P., Gong Y., Yu Z., Gan Y., Li P., Liu W., Wang X. 2023. Curcumin-zinc framework encapsulated microneedle patch for promoting hair growth. Theranostics,13(11):3675-3688. doi: 10.7150/thno.84118.
30. Maares M.,Haase H.A. 2020.Guide to human zinc absorption: General overview and recent advances of in vitro intestinal models.Nutrients,12, 762. doi: 10.3390/nu12030762.
31. Liang Y., Su W., Wang F. 2023. Skin Ageing: A Progressive, Multi-Factorial Condition Demanding an Integrated, Multilayer-Targeted Remedy. Clinical Cosmetic and Investigational Dermatology, 16:1215-1229. doi:10.2147/CCID.S408765.
32. Chruściel P., Kubasińska-Sajnóg A. 2021. Characteristics and applications of zinc in cosmetology and dietetics. Aesth Cosmetol Med.,10(4):189-193, doi: 10.52336/acm.2021.10.4.03.
33. Wang B., Fang T., Chen H.2023. Zinc and Central Nervous System Disorders. Nutrients, 15(9):2140. doi: 10.3390/nu15092140.
34. Salesa B.,Serra, R.S., Serrano-Aroca A. 2021. Zinc Chloride: Time-Dependent Cytotoxicity, Proliferation and Promotion of Glycoprotein Synthesis and Antioxidant Gene Expression in Human Keratinocytes. Biology, 10, 1072. https://doi.org/10.3390/ biology10111072.
35. Suvarna C., Chaitanya N.C., Ameer S., Mannava H., Bontala P., Alyami J.S., et al.2020. A comparative evaluation on the effect of oral zinc 50 mg with or without 0.1% triamcinolone orabase on oral lichen planus. Int J Appl Basic Med Res.,10,54–8. doi: 10.4103/ijabmr.IJABMR_138_19.
36. Di Altobrando A., Tabanelli M.2022. Topical zinc oxide: breaking the vicious cycle of erosive pustular dermatosis of the scalp. Int J Dermatol.,61:e216-7. doi: 10.1111/ijd.15867.
37. Zou P., Du Y., Yang Ch., Cao Y. 2023.Trace element zinc and skin disorders. Front. Med. 9:1093868. doi: 10.3389/fmed.2022.1093868.
38. Khalid H.N., Mostafa M.I., Attia N.S., Bazid H.2022. Serum level of selenium, zinc, and vitamin C and their relation to the clinical spectrum of leprosy. J Infect Dev Ctries.,16,491–9, doi: 10.3855/jidc.14832.
39. Mutlu N., Liverani L., Kurtuldu F., Galusek D., Boccaccini A.R.2022. Zinc improves antibacterial, anti-inflammatory and cell motility activity of chitosan for wound healing applications. Int J Biol Macromol.,213:845–57. doi: 10.1016/j.ijbiomac.2022.05.199.
40. Hara T., Yoshigai E., Ohashi T., Fukada T. 2022. Zinc transporters as potential therapeutic targets: an updated review. J Pharmacol Sci.,148:221–8. doi: 10.1016/j.jphs.2021.11.007.
41. Raszewska-Famielec M., Flieger J.2022.Nanoparticles for Topical Application in the Treatment of Skin Dysfunctions-An Overview of Dermo-Cosmetic and Dermatological Products. Int J Mol Sci., 23(24):15980. doi: 10.3390/ijms232415980.
42. Cervantes J., Eber A.E., Perper M., et al. 2018.The role of zinc in the treatment of acne: A review of the literature. Dermatol Ther.,31(1).doi: 10.1111/dth.12576.
43. Abadie Al. M., Sharara Z., Abadie Al. M., Ball A.P., Morrissey H.2022. Possible relationship between poor skin disorders prognosis and serum zinc level: A narrative review. Dermatology Reports, vol.14:9512.doi:10.4081/dr.2022.9512.
44. Chruściel P., Kubasińska-Sajnóg A. 2021. This person is not on ResearchGate, or hasn't claimed this research yet. Characterisation and application of zinc in cosmetology and dietetics. Aesth Cosmetol Med.,10(4):189-193.doi:10.52336/acm.2021.10.4.03.
45. Michalak M., Pierzak M., Kręcisz B., Suliga E.2021. Bioactive Compounds for Skin Health: A Review. Nutrients,13(1):203. doi: 10.3390/nu13010203.
46. Boo Y.C. 2020.Natural NRF2 modulators for skin protection. Antioxidants,9:812. doi: 10.3390/antiox9090812.11112270.
47. Garbo S., Di Giacomo S., Łażewska D., Honkisz-Orzechowska E., Di Sotto A., Fioravanti R,. Zwergel C., Battistelli C. 2022. Selenium-Containing Agents Acting on Cancer-A New Hope?. Pharmaceutics, Dec 28;15(1):104. doi: 10.3390/pharmaceutics15010104.
48. An J.K., Chung A.S., Churchill D.G. 2023. Nontoxic Levels of Se-Containing Compounds Increase Survival by Blocking Oxidative and Inflammatory Stresses via Signal Pathways Whereas High Levels of Se Induce Apoptosis. Molecules, Jul 5;28(13):5234. doi: 10.3390/molecules28135234.
49. Sandsveden M., Nilsson E.,Borgquist S., Rosendahl H.A., Manjer J.2020.Prediagnostic serum selenium levels in relation to breast cancer survival and tumor characteristics. Int J Cancer, 147(9):2424-2436. doi: 10.1002/ijc.33031.
50. Zhu Q., Yao Y., Ning C.X., Zhao Y.L.2019. Trace Element Levels in the Elders over 80 from the Hainan Province of China. J Nutr Health Aging.,23(9):883-889, doi: 10.1007/s12603-019-1239-1.
51. Natarelli N., Gahoonia N., Sivamani R.K.2023. Integrative and Mechanistic Approach to the Hair Growth Cycle and Hair Loss. J Clin Med.,12(3):893. doi: 10.3390/jcm12030893.
52. Pincemail J., Meziane S.2022. On the Potential Role of the Antioxidant Couple Vitamin E/Selenium Taken by the Oral Route in Skin and Hair Health. Antioxidants (Basel), 11(11):2270. doi: 10.3390/antiox11112270.
53. Dall'Oglio F., Nasca R.M., Fiorentini F., Micali G. 2021. Diet and acne: review of the evidence from 2009 to 2020.International Journal of Dermatology, Volume 60, Issue 6, 651-780, doi:10.1111/ijd.15390.
54. Dobrzyńska M., Drzymała-Czyż S., Woźniak D., Drzymała S., Przysławski J.2023.Natural Sources of Selenium as Functional Food Products for Chemoprevention. Foods., 12(6):1247. doi: 10.3390/foods12061247.
55. Pincemail J., Meziane S.2022. On the Potential Role of the Antioxidant Couple Vitamin E/Selenium Taken by the Oral Route in Skin and Hair Health. Antioxidants (Basel),11(11):2270. doi: 10.3390/antiox11112270.
56. Genchi G., Lauria G., Catalano A., Sinicropi M.S., Carocci A.2023. Biological Activity of Selenium and Its Impact on Human Health. Int J Mol Sci.,24(3):2633, doi: 10.3390/ijms24032633.
57. Hisbiyah Y., Endaryanto A., Setyoboedi B., Rochmah N., Faizi M., Fedora K. 2023. Selenium level correlates negatively with antibodies but positively with thyroid function in children with down syndrome: an Indonesian study. Front Endocrinol (Lausanne),14:1177373, doi: 10.3389/fendo.2023.1177373.
58. Pierzak M.,Kubala-Kukuś A., Banaś D.,Stabrawa I., Wudarczyk-Moćko J., Głuszek S.2020.Study of chromium, selenium and bromine concentrations in blood serum of patients with parenteral nutrition treatment using total reflection X-ray fluorescence analysis. PLoS ONE, 15(12):e0243492. doi:10.1371/journal.pone.0243492.
59. Matthews N.H., Fitch K., Li W.Q., Morris J.S., Christiani D.C., Qureshi A.A., Cho E. 2019. Exposure to Trace Elements and Risk of Skin Cancer: A Systematic Review of Epidemiologic Studies. Cancer Epidemiol Biomarkers Prev.,28(1):3-21. doi: 10.1158/1055-9965.EPI-18-0286.
60. Torres A., Rego L., Martins M.S., Ferreira M.S., Cruz M.T., Sousa E., Almeida I.F.2023. How to Promote Skin Repair? In-Depth Look at Pharmaceutical and Cosmetic Strategies. Pharmaceuticals (Basel), Apr 11;16(4):573. doi: 10.3390/ph16040573.
61. Zhang T., Qi M., Wu Q., Xiang P., Tang D., Li Q.2023.Recent research progress on the synthesis and biological effects of selenium nanoparticles. Front Nutr., 10:1183487, doi: 10.3389/fnut.2023.1183487.
62. Iddir M., Brito A., Dingeo G. et al.2020. Strengthening the Immune System and Reducing Inflammation and Oxidative Stress through Diet and Nutrition: Considerations during the COVID-19 Crisis. Nutrients,12(6),1562.doi:10.3390/nu12061562.

Anna Kulik
Akademia Wychowania Fizycznego im J. Piłsudskiego w Warszawie
Filia w Białej Podlaskiej
Akademicka 2
21-500 Biała Podlaska