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BEYOND BEAUTY: A REVIEW OF MICRONUTRIENTS SUCH AS COPPER, ZINC AND IRON'S INFLUENCE ON HEALTH, TEXTURE AND VISUAL APPEAL OF HAIR AMONG YOUNG ADULT FEMALES.

Biochemistry

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ABSTRACT

Micronutrient deficiencies are a significant public health issue affecting billions of people worldwide, with young women being a particularly vulnerable demographic. Micronutrient deficiencies raise the overall risk of contracting an infectious disease and of passing away from pneumonia, measles, malaria, and diarrhea. (1) The role of nutrition and diet in treating hair loss represents a dynamic and growing area of inquiry (2).The health, texture and appearance of hair are influenced by a complex interplay of genetics, hormonal balance, styling practices and critically-nutritional status(3).Many Analysis revealed a significant association between low serum iron profile and lower zinc levels and there was no significant correlation was found between serum copper levels among young adult females. However, some studies shows a significant inverse relationship between copper levels among young adult females between 18-30 years. Copper, Zinc and Iron status significantly impacts hair health and texture in young adult females, influencing factors like brittleness, thickness, and density (4).

KEYWORDS

Iron, Zinc, Copper, Young Adult Females, Healthy Hair.

BACKGROUND

In the last 20 years, the shortage of micronutrients in the human body continues to increase. Micronutrients such as zinc, copper and iron deficiencies can disrupt the hair growth cycle and compromise the physical and aesthetic qualities of hair in young adult females.

Iron: The Crucial Energy Booster

Iron is vital mineral for producing protein called hemoglobin present in red blood cells that carries oxygen throughout the body(5). Iron is also necessary for physical growth, neurological development, cellular functioning, and the synthesis of some hormones (6,7) Iron levels significantly influencing the body, impacting almost every organ and system. For young adult females, iron's influence on hair is profound.Iron deficiency can disrupt the growth cycle,leading to premature shift of more hair follicles into the resting phase. This causes shedding to accelerate while the growth of new hair stalls, creating an imbalance that leads to thinning. Inadequate iron and ferritin (iron storage protein) levels can result in the hair follicles not receiving enough nourishment.Iron is a crucial element of hemoglobin, the protein found in red blood cells responsible for transporting oxygen from the lungs to other parts of the body. Hair follicles, especially the swiftly dividing cells within the hair matrix, possess a high metabolic rate and demand a consistent oxygen supply for proper growth.When iron reserves are diminished, hemoglobin synthesis diminishes, leading to reduced oxygen supply to non-vital tissues such as hair follicles.

Regulation of the Hair Growth Cycle

Hair development happens in three stages (i) Anagen (growth) phase: This phase is when hair follicles are at their most active. For this phase to persist for its complete duration, optimal delivery of oxygen and nutrients, which relies significantly on iron, is essential. (ii) Telogen (resting) phase: In this phase, the follicle remains inactive and the hair strand falls out. (iii) Disruption due to lack of iron: A common trigger for telogen effluvium is iron deficiency, which occurs when a greater-than-normal number of hair follicles are unexpectedly pushed into the telogen (resting) phase.

Energy Production and Cellular Processes

Cellular processes and energy production, In addition to supplying oxygen, iron plays an essential role as a cofactor in numerous cellular processes important for hair growth. Iron plays a role in DNA synthesis, a crucial process for the swift cell division that takes place in the hair follicle. Iron is essential for the creation of keratin,and also essential for cellular respiration, the mechanism through which cells produce energy (ATP). Mitochondria in hair follicle cells need energy to facilitate growth and repair.

Counteracting the Impact of Low Iron on Hair

The main approach centers on addressing the iron deficiency through supplements and a diet abundant in iron-rich items like red meat, lentils, and leafy greens (8,9). The richest sources of heme iron in the diet include lean meat and seafood(10).The assessment of iron status depends almost entirely on hematological indicators (11). Iron deficiency progresses from the depletion of iron stores (mild iron deficiency), to iron-deficiency erythropoiesis (erythrocyte production), and finally to iron deficiency anemia (IDA) (12,13). With iron-deficiency erythropoiesis (also known as marginal iron deficiency), iron stores are depleted and transferrin saturation declines, but hemoglobin levels are usually within the normal range. IDA is characterized by low hemoglobin concentrations and decreases in hematocrit (the proportion of red blood cells in blood by volume) and mean corpuscular volume (a measure of erythrocyte size) (8,14)

Serum ferritin concentration, a measure of the body's iron stores, is currently the most efficient and cost-effective test for diagnosing iron deficiency (15-17) Because serum ferritin concentration decreases during the first stage of iron depletion, it can be used to identify low iron status before the onset of IDA (11,13,18). A serum ferritin concentration that is lower than 30 micrograms/liter (mcg/L) suggests iron deficiency, and a value lower than 10 mcg/L suggests IDA (19). However, it should be noted that inflammation (e.g., in those with infectious diseases) can elevate serum ferritin concentrations (20).

Hemoglobin and hematocrit tests are the most commonly used measures to screen patients for iron deficiency, even though they are neither sensitive nor specific (9,11,21). Often, hemoglobin concentrations are combined with serum ferritin measurements to identify IDA (11). Hemoglobin concentrations lower than 11 g/deciliter (dL) in children under 10 years of age, or lower than 12 g/dL in individuals age 10 years or older, suggest IDA (12). Normal hematocrit values are approximately 41% to 50% in males and 36% to 44% in females.

Copper

Copper has a dual effect on hair health, texture, and appearance based on whether it is absorbed externally via environmental exposure or internally through nutrition. copper in the body is necessary for good hair, external exposure to copper from tap water can seriously harm hair. Many studies revealed the role of exogenous copper in increasing UV damage both in terms of total protein degradation and also increased formation of the marker fragment and proposed a mechanism of action. (22).

Internal Copper: The Dietary Necessity

Hair health is greatly influenced by appropriate internal copper levels, which can be maintained through diet or supplementation. Production of melanin: The pigment that gives hair its color, melanin, requires copper to be produced. Premature graying may result from a decrease in melanin caused by low copper levels. It has also been hypothesized that the premature graying is associated with osteopenia indicating a probable role for vitamin D3 and calcium (24).Copper serves as a cofactor for the antioxidant enzymes such as superoxide dismutase (SOD), which shields hair follicles from free radical damage and oxidative stress. Oxidative stress related to mitochondrial DNA damage has been found to be high in gray hair follicles. Gray hair melanocytes with more vacuoles also support the role of oxidative stress with accumulation of reactive oxygen species in gray hair

follicles. The relationship between oxidative stress and psychological disorders (emotional stress, anxiety, and depression), alcohol intake, and atherosclerosis has been reported (25). The copper peptides increase blood flow to the scalp, which guarantees that hair follicles have enough oxygen and nourishment to thrive. By extending the hair cycle's development phase and possibly enlarging hair follicles, copper peptides may also aid in encouraging hair growth (23). Adequate copper strengthens the hair shaft by promoting collagen and keratin cross-linking. copper intake is essential for preserving bright, natural hair color since copper is necessary for the manufacture of melanin, a shortage is linked to early graying.

External Copper: A danger to the Environment

When hair is exposed to sunlight, the copper that is deposited on it serves as a catalyst for chemical reactions that result in the production of free radicals. High copper levels in hair can react with the oxidants in hair colors, resulting in a chemical reaction that may cause breakage.

Zinc

Zinc is a vital cofactor for the enzymes involved in the synthesis of keratin, the fundamental protein of hair. Zinc deficiency can lead to numerous hair issues, while adequate levels are essential for strong, vibrant hair. By aiding in the synthesis of DNA and RNA, zinc facilitates the rapid cell division required for healthy hair follicle growth. This helps sustain the anagen (growth) phase of the hair cycle. Some studies reported that zinc is a potent dose-dependent immunomodulator of hair follicles(27).

Zinc helps to protect hair follicles from oxidative stress caused by free radicals. Zinc is involved in the regulation of the sebaceous glands, which generate the sebum, or natural oils, that hydrate hair. Enough zinc fortifies hair strands from the inside out by aiding in the creation of keratin and collagen, which increases their elastic and resistant properties(26).

Many Studies have shown a strong link between low zinc levels and conditions like alopecia areata (patchy hair loss) and telogen effluvium (excessive hair shedding), which are prevalent among young women. Thus zinc deficiency has been associated with changes in hair color. Young adult females, particularly those with restrictive diets or certain medical conditions, may be at higher risk for zinc deficiency.

Assessing Hair health Clinical examination and medical history: A healthcare provider, such as a dermatologist or trichologist, performs a thorough examination of the scalp and hair. The Pull test done gently by a doctor. If more than a certain number of strands (often more than 10%) come out, it may indicate excessive shedding. Followed by that, Blood tests was done to screen for nutritional deficiencies (e.g., iron, ferritin, zinc, vitamin D) and hormonal imbalances (e.g., thyroid hormones, sex hormones) that can impact hair health. In cases of severe or undiagnosed hair loss, a small piece of scalp skin is removed and examined under a microscope to identify underlying skin conditions or disease (Scalp biopsy test) (i)Trichoscopy/ Videodermoscopy: A magnifying camera (dermatoscope or trichoscope) is used to examine the hair and scalp without plucking. It can reveal follicular health, hair shaft diversity, density, and signs of inflammation. (ii)Phototrichogram/TrichoScan: A highly accurate, non-invasive method that combines imaging with automated analysis. It measures hair density, thickness, and growth rate by evaluating a small, shaved section of the scalp over a short period. (iii)Hair mineral analysis: Laboratory testing of hair strands can reveal information about mineral levels and heavy metal exposure over a period of several months (28-30).

Hair texture, Physical and microscopic assessment: The thickness of a single hair strand can be measured in a lab with a microscope or at home by comparing a strand to a piece of sewing thread.(i) Hair porosity test: This can be done at home by dropping a clean strand of hair into a glass of water. How quickly the hair sinks indicates its porosity (ability to absorb moisture), which influences its texture. (ii)Scanning Electron Microscopy (SEM): In a lab setting, SEM provides highly magnified images of the hair shaft's surface, revealing damage to the cuticle, which influences hair texture and shine. (iii) Consumer assessment Tactile evaluation: Participants can use a finger-and-thumb test to feel if hair strands are fine, medium, or coarse. This is a common method in product testing. (iv)Expert panel ratings: Trained evaluators assess hair texture properties, such as smoothness, frizz, and volume, using a standardized rating scale.

Assessing visual appeal (i) Global photography: A standardized setup with fixed head positioning, lighting, and camera distance ensures consistent images. (ii)Visual Analog Scale (VAS): Visual scales can be developed to quantify subjective aspects.

Subjective Questionnaires and Self-reporting

Some studies have used computer-generated images of virtual hair with varying diameters and densities to analyze perceptions of hair health and attractiveness among observers.

CONCLUSION

The metabolism of iron, copper, and zinc may be changed in young adult females. These changes in metabolism could impact their nutritional condition. Prompt evaluation based on changes in their hair growth, color, and texture may aid in the early treatment of these conditions, improving their overall health.

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