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PHYSIOLOGICAL ROLE OF MINERALS IN FEMALE FERTILITY AND THE MENSTRUAL CYCLE

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Minerals are important regulators of female fertility, particularly within the menstrual cycle. Reproductive health is additionally influenced by lifestyle factors such as body weight, stress level, smoking and alcohol consumption. Modern conditions, including changes in eating habits, exposure to environmental pollutants and chronic stress, significantly disrupt the mineral balance of the body. Particularly dangerous is the influence of heavy metals (lead, cadmium), which can reduce the absorption of minerals and negatively affect fertility. While the role of minerals in male reproductive function has been studied quite thoroughly, for women it is considered fragmentarily - mainly in connection with individual pathologies and with an emphasis on vitamin or multivitamin supplements [1].

Human reproduction is controlled by complex hormonal mechanisms that regulate the menstrual cycle from the onset of puberty to ovulation, implantation and pregnancy. At the beginning of the cycle, a decrease in estrogen and progesterone levels causes the endometrium to shed. In the follicular phase, follicle-stimulating hormone stimulates follicle growth and an increase in estrogen levels, which ultimately leads to a peak in luteinizing hormone and ovulation. After that, in the luteal phase, the corpus luteum produces progesterone and estrogen, preparing the endometrium for possible implantation. Minerals play an important role in this process. Iron is necessary

for the normal course of menstruation and regular ovulation, and its deficiency can cause hormonal shifts and anemia. Calcium is involved in hormone regulation, oocyte activation, and endometrial preparation for implantation. Zinc affects the synthesis and action of sex hormones, and together with selenium, protects germ cells from oxidative stress. Magnesium promotes smooth muscle relaxation and can reduce the manifestations of pathological processes associated with the endometrium. Iodine and selenium, by supporting thyroid function, are important for hormonal balance and fertility throughout the cycle [2].

In addition, insulin, traditionally known for its role in glucose metabolism, is also involved in the regulation of reproductive processes. Its excess can cause increased androgen production by the ovaries, which disrupts the action of estrogen and progesterone. This is especially true in polycystic ovary syndrome, which is characterized by ovarian dysfunction, hyperandrogenism and metabolic disorders and has serious consequences for the reproductive and general health of women [3].

Oxidative stress is a critical factor in reproductive dysfunction, determining damage to oocytes, spermatozoa, as well as impaired implantation and embryo development. Increased generation of reactive oxygen species (ROS) correlates with decreased oocyte quality, DNA fragmentation and endometrial dysfunction, which is manifested in reproductive system pathologies such as endometriosis and PCOS. Minerals play a central role in modulating oxidative stress through enzymatic antioxidant mechanisms. Zinc and selenium provide activity, reducing oxidative damage to oocytes and maintaining the stability of the ovulatory cycle. Copper, as a cofactor, modulates antioxidant systems and supports endothelial function, ensuring optimal blood flow in the reproductive organs. Iron, required for oxygen transport and DNA synthesis, in excess promotes the generation of ROS, while deficiency leads to impaired oocyte development. Magnesium and manganese provide coenzymatic support for antioxidant defense enzymes, contributing to the stabilization of oocyte and endometrial function [4, 5].

Iron is critical for maintaining endometrial receptivity. Deficiency of this element correlates with a decrease in the expression of genes and proteins required for blastocyst adhesion. Adequate iron metabolism provides optimal conditions for implantation. Magnesium regulates the tone of the smooth muscle of the fallopian tubes in the endometrium, potentially reducing the risk of retrograde menstruation and the progression of endometriosis. Zinc modulates the proliferation and differentiation of endometrial cells, ensuring cyclic remodeling of the endometrium. Zinc deficiency is associated with a decrease in the concentration in the follicular fluid and impaired gene expression, inhibited after repeated administration of the element, which indicates its potential therapeutic role in endometrial cysts. Calcium is concentrated at the sites of implantation. Ca2+ channels modulate embryo adhesion, ensuring cellular calcium homeostasis and control of inflammatory activity. Iodine affects endometrial receptivity through immunomodulatory effects and optimization of uterine blood

flow. Iodine deficiency is associated with reduced fertility and increased time to pregnancy, while excess can be teratogenic and disrupt embryonic development. Optimal iodine concentrations promote epithelial regeneration and increase the likelihood of successful implantation [6, 7].

Thus, minerals are key regulators of female fertility, influencing hormonal balance, ovulation, endometrial receptivity and embryo implantation. They reduce oxidative stress, protecting oocytes and endometrium. Iron, magnesium, zinc, selenium and calcium support normal cell development, embryo adhesion and stability of the ovulatory cycle. Iodine optimizes uterine blood flow and immune response. Deficiency or excess of any micronutrient can reduce fertility, so maintaining their balance is important for reproductive health.

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