Summary. This literature review describes the role of the different trace elements in the development, progression and prevention of diabetes mellitus and its complications. The results of the studies of microelements in blood, urine and hair are presented.

Key words: diabetes mellitus, trace elements, insulin, chromium, copper, iodine, selenium, manganese, molybdenum, vanadium, zinc.

Diabetes mellitus (DM) is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces [1]. DM leads to high morbidity and mortality throughout the world [2]. The prevalence of DM in the age groups between 20 to 70 years worldwide was estimated to be 8.3 % in 2013 and 10.1 % in 2035. The total number of adult with DM is projected to rise from 382 million in 2013 to 592 million in 2035. In 2013, an estimated 5.1 million people died from consequences of hyperglycemia. Type 2 diabetes mellitus (T2DM) can be prevented or delayed through healthy diet, regular physical activity, maintaining a normal body weight, and avoiding smoking [3].

T2DM is the most common form of DM and individuals are characterized by disorders of insulin action and secretion, either of which may be the predominant feature [4]. Direct associations of trace elements with diabetes mellitus have been observed in many research studies. Insulin action on reducing blood glucose was reported to be potentiated by some trace elements as chromium, vanadium zinc, manganese, molybdenum, and selenium [4].

Trace elements constitute a minute part of the living tissues and have various metabolic characteristics and functions. Trace elements participate in tissue and cellular and subcellular functions; these include immune regulation by humoral and cellular mechanisms, nerve conduction, muscle contractions, membrane potential regulations, and mitochondrial activity and enzyme reactions [4].

The trace element is a dietary mineral that is needed for the proper growth, development, and physiology of the organism. Alterations in the status of trace elements could stem from chronic uncontrolled hyperglycemia. Trace elements include the transition metals vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), copper (Cu), zinc (Zn), and molybdenum (Mo) and the nonmetals selenium (Se), fluorine (F), and iodine (I). All of these belong to the category of micronutrients, which are needed by the human body in very small quantities (generally less than 100 mg/day) [5].

Chromium is required for normal carbohydrate metabolism and as a critical cofactor for insulin action and is a component of the glucose tolerance factor, which plays a role in glucose homeostasis [4]. Chromium concentrations were significantly reduced in blood of T2DM patients as compared to control subjects of both genders but urinary levels of these elements were found to be higher in the diabetic patients than in the age-matched healthy controls [6].

Copper is considered as both a powerful enzyme catalyst and a dangerous reactant that generates hydroxyl radical. A deficiency of copper results in glucose intolerance, decreased insulin response, and increased glucose response. It is associated with hypercholesterolemia and atherosclerosis [4].

Iodine is absolutely vital for proper thyroid function. The iodine deficiency is the most common cause of hypothyroidism worldwide. The iodine deficiency will cause mental retardation and cretinism and it is the most devastating in all trace elements [4]. Thyroid hormone controls insulin secretion. In hypothyroidism, there is a reduction in glucose-induced insulin secretion by β cells, and the response of β cells to glucose or catecholamine is increased in hyperthyroidism due to increased β-cell mass. Moreover, insulin clearance is increased in thyrotoxicosis [7]. Insulin resistance and β-cell function are inversely correlated with thyroid stimulating hormone (TSH) which may be explained by insulin-antagonistic effects of thyroid hormones along with an increase in TSH. The higher serum TSH usually corresponds to lower thyroid hormones via negative feedback mechanism. As TSH increased, thyroid hormones decreased and insulin antagonistic effects are weakened. These
observations demonstrate that insulin imbalance is closely associated with thyroid dysfunction and the phenomenon is mediated via β-cell dysfunction [8]. The significantly lower level of iodine was reported in the urine of T2DM than in that of healthy control subjects [9].

Selenium, a trace element, is involved in the complex system of defense against oxidative stress through selenium-dependent glutathione peroxidases and other selenoproteins [4]. Due to its antioxidant properties, selenium might be preventing the development of diabetes. In addition, selenate, an inorganic form of selenium, mimics insulin activity in experimental models [4]. Selenium is incorporated into selenoproteins [10, 11] that have a wide range of pleiotropic effects, ranging from antioxidant and anti-inflammatory effects to the production of active thyroid hormone. In the past 10 years, the discovery of disease-associated polymorphisms in selenoprotein genes has drawn attention to the relevance of selenoproteins to health. Low selenium status has been associated with increased risk of mortality, poor immune function, and cognitive decline. Higher selenium status or selenium supplementation has antiviral effects, is essential for successful male and female reproduction, and reduces the risk of autoimmune thyroid disease [10]. This antioxidant property of selenium prevents the development of complications in diabetic patients [4]. Conflicting evidence linking selenium to glucose metabolism has been reported. For instance, high selenium status was associated with reduced diabetes prevalence in several prospective cohort and case-control studies [12].

Manganese plays an important role in a number of physiologic processes as a constituent of some enzymes such as pyruvate carboxylase and arginase and an activator of different enzymes such as phosphoenolpyruvate carboxykinase and glutamine synthetase. These manganese activated enzymes play important roles in the metabolism of carbohydrates, aminoacids, and cholesterol. Manganese helps in glucose metabolism and it is required for normal synthesis and secretion of insulin. The level of manganese is lower in T2DM subjects as compared to control subjects [4]. In an another study, the mean manganese was significantly low in blood and scalp-hair samples of diabetic patients as compared to control and both genders [13].

There is accumulating evidence that molybdenum plays an important role in insulin action as it has been suggested to be able to bind the insulin receptor and to be involved in the activation of glucose metabolism enzymes [11]. Therefore, molybdenum complexes have been proposed as possible adjunct in the treatment of DM [11, 14].

In addition to reproductive problems and skeletal abnormalities observed in case of deficiency, vanadium is likely to have a significant role in thyroid, iron, glucose and lipid metabolism [15]. The potential use of vanadium in the treatment of diabetic complications including cardiomyopathy has been assessed and indeed its hypoglycemic effect along with reversal of functional abnormalities has been clearly demonstrated by several studies [2, 16, 17].

Zinc plays an important role in glucose metabolism. It helps in the utilization of glucose by muscle and fat cells. It is required as a cofactor for the function of intracellular enzymes that may be involved in protein, lipid, and glucose metabolism. Zinc may be involved in the regulation of insulin receptor-initiated signal transduction mechanism and insulin receptor synthesis [18]. Zinc is a structural part of key antioxidant enzymes such as superoxide dismutase, and zinc deficiency impairs their synthesis, leading to increased oxidative stress. Low zinc has also been seen to lead to poor or slowed wound healing, which is common in diabetic patients. Oxidative stress plays an important role in the pathogenesis of diabetes and its complications. Clinical studies reported that serum levels of zinc are usually found low in T2DM patients compared to nondiabetic due to the impaired intestinal reabsorption of endogenous zinc and the increase in excretion of zinc into the intestine during the digestive process may lead to this low serum zinc level [4].

Zinc supplementation can be effective for preventing or ameliorating of DM. Zinc transporter (ZnT–8) is a crucial protein for the regulation of insulin secretion in pancreatic β-cells [19]. Several studies have reported that diabetics had lower serum/plasma zinc levels [20, 21]. Increased urinary excretion of zinc suggests a deficiency in blood zinc and further dysregulation of insulin secretion [11].

Nutrition management aims to improve health quality maintaining blood glucose levels in normal range so as to reduce the risk for diabetes complications. A well-balanced diet will maintain the impairment of essential macro- and micronutrients in patient with DM. 

Список литературы / References


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САХАРНИЙ ДИАБЕТ И НЕКОТОРЫЕ МИКРОЭЛЕМЕНТЫ

Резюме. В обзоре литературы описана роль разных микроэлементов в развитии, прогрессировании и профилактике сахарного диабета и его осложнений. Приведены результаты исследований микроэлементов в крови, моче, волосах.

Ключевые слова: сахарный диабет, микроэлементы, инсулин, хром, медь, йод, селен, марганец, молибден, внадий, цинк.