

## Conference Paper

# Influence of the Indicators of Carbohydrate Metabolism on the Elemental Status

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**Abstract**

This study examined the elemental status of the hair and blood biochemistry of young men in the Orenburg region (n=38) with different glucose levels. Estimation of the element status was carried out through the study of the chemical composition of the hair by ICP-AES and ICP-MS. It was found that the studied serum parameters (Ca, Mg, Fe, P cholesterol, thyroxine, TSH and testosterone) were within normal values, and no statistically significant differences were obtained when comparing the groups. The concentration of chemical elements in the hair of the men in each group was in the range of physiologically acceptable values for this region. In the group with elevated glucose levels, there was a tendency for the men to have lower values of Ca and Mg, and higher levels of K, Na, P and a number of toxic elements (Al, Cd, Sn, Hg, Pb).

**Keywords:** elemental status, trace elements, diabetes mellitus, metabolism

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## 1. Introduction

The International Diabetes Federation (IDF) has found that there are 451 million people (between the ages of 18 and 99) with diabetes worldwide. These numbers are expected to increase to 693 million by 2045. About 5 million deaths worldwide are associated with diabetes [1]

Type 2 diabetes is usually preceded by a condition known as prediabetes [2]. This condition is characterized by impaired fasting glucose levels, impaired glucose tolerance, and elevated levels of glycated hemoglobin (HbA1c) [3]. Impaired fasting glucose levels and glucose tolerance are sometimes not sufficient for the diagnosis of diabetes, but indicate the development of insulin resistance [2].

Thus, prediabetes is a complex multifactorial metabolic disorder that goes beyond glucose control [4]. According to numerous studies, 70 % of people with prediabetes

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eventually develop diabetes during their lifetime [5]. In addition, individuals with prediabetes have an increased risk of cardiovascular disease and premature death compared to those with normoglycemia [6]

According to the criteria of the American diabetes Association (ADA), glucose levels from 5.6 to 6.9 mmol/l suggest the presence of a prediabetic condition [7-8]. Achieving glycemic control in patients with prediabetes through lifestyle changes and pharmacological interventions can effectively prevent or delay the development of diabetes and related complications [2,5]. However, an important step is to select patients from the risk group [9-11]

There are a number of studies examining the possibility of using the content of trace elements in various biosubstrates as biomarkers of prediabetes, as well as their use as food additives to correct this condition [12-14]

The results of numerous studies suggest that prediabetes-related disorders may be mediated by changes in the levels of trace elements in the body [15-18]. This is due to the fact that trace elements play an important role in the normal functioning of carbohydrate and lipid metabolism [15, 16].

Fasting glucose variability increases significantly in individuals with prediabetes and is an additional parameter in assessing homeostasis even at the early stages of glucose dysregulation [17]. In this regard, the purpose of this study was to study the biochemistry of blood and the elemental status of hair of students with different glucose levels.

## 2. Methods and Equipment

The study involved young men from 18 to 20 years old, students of Orenburg state University. Groups of 100 students were selected for the study (n=38). The study was conducted in accordance with the Helsinki Declaration and the principles of good laboratory practice. All subjects gave informed consent to be included in the study program. After performing a biochemical blood test, two groups were formed depending on the fasting glucose level: group I (n=25) – glucose value  $\leq 5.5$  mmol/l (normal glucose level) and group II (n=13) – glucose value from 5.6 to 6.9 (prediabetic condition, without a previous history of diabetes). The used interpretation of glucose indicators met the criteria of the American diabetes Association (ADA) [8]

The elemental status was assessed by studying the chemical composition of hair using ICP-AES and ICP-MS methods in the laboratory of the ANCO «Center for Biotic Medicine».

The statistical processing of digital material was carried out using the application «Excel» and «Statistica 6.0». The statistical significance of differences between the groups was assessed using the Mann-Whitney U-test.

### 3. Results

Table 1 shows the blood biochemistry indicators of students with normal glucose levels (group I) and prediabetic status (group II).

TABLE 1: Blood biochemistry indicators, Me (Q25-Q75)

Indicator	Group I (glucose $\leq$ 5.5)	Group II (glucose 5.6-6.9)
Ca	1.94 (1.54–2.05)	1.54 (1.5–1.64)
Mg	0.9 (0.85–0.96)	1.0 (0.9–1.02)
Fe	17.5 (10.4–30.63)	21.1 (10.1–24.2)
P	0.75 (0.62–3.8)	0.69 (0.46–3.4)
Cholesterol	2.9 (1.0–3.5)	2.8 (1.12–3.7)
Thyroxine	17.1 (13.7–18.7)	17.2 (10.6–21.1)
TSH	1.7 (1.0–2.2)	1.6 (0.9–2.6)
Testosterone	16.6 (14.7–20.4)	18.5 (17.2–19.2)

<sup>a</sup> Reliability of differences in performance with group I –  $p < 0.05$ ;

<sup>b</sup> Reliability of differences in performance with group I –  $p < 0.01$ .

In the course of the study, it was found that the studied parameters of the students' blood serum were within normal values. When comparing the groups, no statistically significant changes were obtained.

The results of the study of the elemental status of students' hair are presented in table 2.

The concentration of chemical elements in the hair of the examined young men of both groups was in the range of physiologically acceptable values for this region. When comparing the groups, no statistically significant changes were obtained, but there was a tendency to lower values of Ca, Mg and Zn in group II by 33, 26 and 10 %, respectively. On the other hand, there was a trend towards higher values of K, Na and P by 163, 34 and 10 %, respectively. It is important to note that the level of toxic elements (Al, Cd, Sn, Hg, Pb) was higher in group II relative to group I.

### 4. Discussion

There are a large number of factors that can provoke the development of a prediabetic condition. Microelements are important for the prevention of a number of diseases and

for improving overall health due to their diverse biological role in the body. Even a small number of them interact with macromolecules, including prohormones and biological membranes [28]. In the state of prediabetes, the homeostasis of trace elements in the body can be changed. Impaired absorption and metabolism of trace elements can lead to insulin resistance and the development of a number of diabetic complications. In addition, modern research shows that the level of elements in the human body is correlated with the development of prediabetic condition and, later, with the occurrence of diabetes mellitus [22–25]. For example, it was found that the Cu content in the blood of diabetic patients was significantly higher than in healthy individuals [21]. Excess or deficiency of Fe can lead to obesity, hypoxia, and insulin resistance [22]. It is important to note that, unlike patients with diabetes, those with prediabetes do not yet receive hypoglycemic medications or dietary adjustments, which may provide more accurate conditions for evaluating changes in the metabolism of trace elements [23]. Thus, numerous studies suggest that screening studies of a person's elemental status may reveal a high proportion of people with a prediabetic condition. Hair is often used as a biosubstrate to study the content of elements. This method is characterized by ease of collection of the study sample and non-invasiveness. It is assumed that the content of elements in hair can provide useful diagnostic information about the risk of developing prediabetes [24]

In the course of the study, it was found that the studied blood serum parameters (Ca, Mg, Fe, P cholesterol, thyroxine, TSH and testosterone) in students were within normal values. When comparing the groups, no statistically significant changes were found. This is due to the fact that the blood has a high level of homeostaticity and changes in its composition occur only in serious disorders in the body [25]

The concentration of chemical elements in the hair of the subjects of both groups was in the range of physiologically acceptable values for this region. When comparing the groups, there were also no statistically significant changes. However, there was a trend towards lower levels of Ca, Mg, Zn and higher levels of K, Na, P and a number of toxic elements (Al, Cd, Sn, Hg, Pb). It was found that the level of Zn significantly decreases in blood and hair samples of diabetic patients [25]. Our findings are consistent with other studies confirming that toxic metals may play a role in the development of diabetic conditions. A group of Turkish scientists has shown that the values of lead and aluminum in non-Smoking patients with insulin-dependent diabetes mellitus were significantly higher in relatively healthy individuals, but not higher than toxic levels [26]. In 2008, Afridi et al showed that Pb, Cd, and As levels were significantly higher in hair samples of non-Smoking diabetic patients than in controls [27]

TABLE 2: Blood biochemistry indicators, Me (Q25-Q75)

Element	Group I (glucose $\leq$ 5.5)	Group II (glucose 5.6-6.9)	Regional importance <sup>1</sup>
Macroelements			
Ca	884.3 (657–1 628.8)	586.1 (427.1–1 540.2)	479–2156
K	41.7 (30.3–75.4)	108.5 (52.2–130.2)	25–193
Mg	155.4 (96.6–249.5)	114.6 (64.8–204.2)	65–249
Na	229.7 (178.4–355.8)	307.9 (242.4–472.1)	81–403
P	148.4 (139.1–157.7)	163.0 (142.6–177.7)	122–160
Essential elements			
Co	0.02 (0.019–0.03)	0.02 (0.01–0.024)	0.012–0.03
Cr	0.7 (0.51–0.8)	0.73 (0.68–1.02)	0.32–0.96
Fe	25.3 (19.4–35.1)	24.6 (16.5–34.3)	12.8–29.6
Cu	12.2 (9.8–14.7)	13.9 (10.4–14.4)	9.98–14.4
I	1.1 (0.59–1.91)	1.14 (0.3–1.24)	0.21–1.24
Mn	0.83 (0.63–1.15)	1.0 (0.5–1.8)	0.38–1.3
Se	0.31 (0.21–0.36)	0.32 (0.3–0.39)	0.2–0.42
Zn	209.1 (157.5–243.7)	188.0 (152.5–198.9)	155–199
Conditional essential elements			
Li	0.04 (0.03–0.041)	0.04 (0.03–0.07)	0.016–0.077
Ni	0.25 (0.18–0.32)	0.28 (0.21–0.34)	0.25–0.65
Si	29.0 (24.7–35.8)	31.1 (26.5–34.0)	19.5–58
V	0.16 (0.12–0.21)	0.18 (0.14–0.28)	0.057–0.5
Toxic element			
Al	13.6 (10.8–18.8)	15.2 (11.2–22.6)	4.37–18
Cd	0.02 (0.018–0.06)	0.04 (0.02–0.06)	0.019–0.12
Sn	0.17 (0.13–0.19)	0.23 (0.17–0.28)	0.04–1.5
Hg	0.16 (0.07–0.24)	0.18 (0.13–0.25)	0.17–0.64
Pb	0.36 (0.29–0.78)	0.64 (0.35–0.86)	0.32–1.38

<sup>1</sup> Skalny A.V., 2000;

<sup>a</sup> Reliability of differences in performance with group I –  $p < 0.05$ ;

<sup>b</sup> Reliability of differences in performance with group I –  $p < 0.01$ .

Exposure to heavy metals negatively affects the body's antioxidant status [28]. Available evidence suggests that toxicity caused by such metals can lead to disruption of antioxidant mechanisms in tissues, resulting in the formation of reactive oxygen species (ROS). This antioxidant imbalance can lead to degradation of proteins, nucleic acids, and lipid peroxidation. The oxidative attack of ROS cell components is involved in the pathogenesis of a number of human diseases, including prediabetes and, as a consequence, diabetes mellitus [29]

## 5. Conclusion

The obtained data suggest that, despite the absence of statistically significant results, there was a tendency to an imbalance of elements in the body, which can serve as one of the triggers for the development of pathological disorders responsible for the occurrence of metabolic disorders and associated diseases, in particular prediabetes. There was a tendency to lower levels of Ca, Mg, Zn and higher levels of K, Na, P and a number of toxic elements (Al, Cd, Sn, Hg, Pb) in the hair. The results are consistent with data from other studies confirming that elements can play a significant role in the development of diabetic conditions and the progression of a number of metabolic complications. However, comprehensive studies are required to clarify the clear relationship between glucose metabolism disorders and levels of trace elements

## Conflict of Interest

The authors have no conflict of interest to declare.

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