

Mineral Status of Blood in Patients with Computer Visual Syndrome Depending on Their Severity

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Abstract The article presents an assessment of the state of blood mineral status and an analysis of its relationship with the severity of computer vision syndrome (CVS) in computer users. 160 patients with clinical manifestations of CVS and 40 healthy individuals from the control group were examined. Depending on the severity of the syndrome, patients were divided into subclinical, mild, moderate, and severe CVS groups. The severity of symptoms was assessed using the author's questionnaire CVS-44, comprehensive ophthalmological examination, and the author's clinical and functional classification of COPS. The concentrations of zinc, selenium, copper, iron, magnesium, calcium, and phosphorus were determined in blood serum. It has been established that the progression of CVS is accompanied by a dose-dependent decrease in the levels of zinc, selenium, iron, magnesium, and calcium against a background of a relative increase in copper and phosphorus. In moderate and severe CVS, a number of indicators reached threshold or subnormal values. Significant correlations have been identified between the severity of CVS and blood mineral status indicators, which confirms their pathogenetic significance and the expediency of considering them in the diagnosis and prevention of CVS.

Keywords Computer vision syndrome, Mineral status, Micro and macro elements, Computer users

1. Introduction

In the context of global digitalization and the widespread introduction of information technologies, computer vision syndrome (CVS) is considered one of the most common forms of functional visual pathology in people of working age. According to epidemiological studies, CVS symptoms are detected in 60-90% of digital device users, while the severity of clinical manifestations directly correlates with the duration and intensity of visual load [1,5].

According to modern concepts, CVS is a multifactorial condition, the pathogenesis of which includes accommodation disorders, tear film instability, decreased blinking frequency, development of asthenopic disorders, and autonomic nervous system dysfunction [3]. In recent years, special attention has been paid to the role of systemic metabolic mechanisms capable of reducing the adaptive capabilities of the visual analyzer during chronic visual strain [4].

Microelements play a key role in ensuring antioxidant protection, energy metabolism, neuromuscular transmission, and the regulation of vascular tone. Zinc and selenium participate in the functioning of antioxidant system enzymes, magnesium and calcium in the regulation of neuromuscular

excitability and accommodation processes, iron in tissue respiration, and copper in oxidative stress and inflammation reactions [2]. Disruption of microelement homeostasis can contribute to increased oxidative stress, vegetative dysfunctions, and functional decompensation of the visual system.

Despite the existence of studies dedicated to the role of microelements in various ophthalmological and neurosensory disorders, data on the nature of changes in the blood's microelement status in patients with CVS, depending on the severity of the disease, remain limited and contradictory [6]. The lack of systematized information on this issue makes it difficult to develop differentiated diagnostic and preventive approaches.

In this regard, studying the microelement status of the blood in patients with computer vision syndrome, taking into account the severity of clinical manifestations, is a pressing scientific and practical task aimed at deepening understanding of the pathogenesis of computer vision syndrome and substantiating comprehensive therapeutic and preventive measures.

Purpose of the study:

The purpose of this study was to assess the state of blood microelement status and to identify its relationship with the severity of computer vision syndrome in computer users.

2. Material and Methods

The object of the study was 160 computer users with clinical signs of computer vision syndrome. The control group consisted of 40 healthy individuals comparable in gender and age, regularly using computers, but without clinical manifestations of CVS.

The research protocol was in accordance with the principles of the Helsinki Declaration, and all the examined individuals signed informed voluntary consent to participate in the study.

The severity of computer vision syndrome symptoms was assessed using the author's COVS-44 questionnaire, the results of which, in combination with ophthalmological examination data, were used to distribute patients according to the degrees of CVS according to the developed author's clinical and functional classification.

Depending on the severity of CVS, the examined patients were divided into four clinical groups (each with 40 people): subclinical CVS, mild, moderate, and severe CVS.

Ophthalmological examination included visometry, refractometry, biomicroscopy of the anterior segment of the eye, ophthalmoscopy, as well as assessment of accommodative and binocular functions, the state of tear production, and the stability of the tear film.

To assess the microelement status, a biochemical study of blood serum was conducted to determine the concentrations of zinc, selenium, copper, iron, magnesium, calcium, and phosphorus. Venous blood collection was performed in the morning on an empty stomach. The analyses were conducted using standard certified laboratory methods.

Statistical processing of the data was carried out using methods of variation statistics. The results are presented as the mean and the error of the mean ($M \pm m$). For intergroup comparisons, Student's criterion was used for independent samples, and correlation analysis was performed using Pearson and Spearman coefficients. Differences at $p < 0.05$ were considered statistically significant.

3. The Results and Discussion

Analysis of mineral element concentrations in blood serum revealed a clear correlation between impaired mineral

homeostasis and an increase in the severity of computer vision syndrome (CVS). In the control group, all the studied indicators were within the reference values. As CVS progressed from the subclinical form to the severe stage, statistically significant and unidirectional changes in most of the studied elements were noted (Table 1).

Zinc concentration demonstrated a progressive and statistically significant decrease as CVS progressed.

If in the control group the indicator was $13.2 \pm 0.09 \mu\text{mol/l}$, then already at the subclinical stage of CVS, a tendency towards a decrease ($12.93 \pm 0.12 \mu\text{mol/l}$) was noted, which intensified at mild ($11.98 \pm 0.10 \mu\text{mol/l}$) and moderate ($10.83 \pm 0.11 \mu\text{mol/l}$) stages, reaching minimal values at the severe form of CVS ($10.35 \pm 0.08 \mu\text{mol/l}$).

The identified dynamics indicate an increasing zinc deficiency, which may be associated with its active consumption under conditions of chronic visual strain, oxidative stress, and disorders of accommodative-neurovegetative regulation.

The selenium content was also characterized by a pronounced downward trend, reflecting the depletion of the body's antioxidant potential.

In the control group, the Se level was $90.7 \pm 0.10 \mu\text{g/l}$, decreasing to $88.73 \pm 0.19 \mu\text{g/l}$ in subclinical CVS and $83.78 \pm 0.37 \mu\text{g/l}$ in mild CLS. In moderate CVS, the concentration decreased to $76.65 \pm 0.31 \mu\text{g/l}$, and in severe CVS, it decreased to $69.73 \pm 0.14 \mu\text{g/l}$.

This dynamic confirms the role of selenium deficiency in the formation of oxidative imbalance and inflammatory changes in the progression of CVS.

Unlike Zn and Se, the copper concentration showed a moderate, but stable increase with increasing CVS severity.

The indicator increased from $17.93 \pm 0.13 \mu\text{mol/l}$ in the control group to $18.68 \pm 0.08 \mu\text{mol/l}$ in severe CVS.

This increase can be considered as a compensatory reaction, as well as a reflection of prooxidative and inflammatory processes that intensify with chronic visual strain.

Iron levels were characterized by a gradual decrease as the syndrome progressed.

From a value of $17.35 \pm 0.17 \mu\text{mol/l}$ in the control group, the indicator decreased to $16.6 \pm 0.18 \mu\text{mol/l}$ in subclinical CLS and to $16.1 \pm 0.23 \mu\text{mol/l}$ in the mild degree. In moderate and severe forms of CVS, the concentration decreased to 15.63 ± 0.28 and $14.85 \pm 0.41 \mu\text{mol/l}$, respectively.

Table 1. Systemic mineral status in computer users depending on the severity of computer visual syndrome ($M \pm m$)

Micro element	Control (n=40)	Subclinical CVS (n=40)	Mild degree of CVS (n=40)	Average degree of CVS (n=40)	Severe CVS (n=40)
Zinc, $\mu\text{mol/l}$	$13,2 \pm 0,09$	$12,93 \pm 0,12$	$11,98 \pm 0,10$	$10,83 \pm 0,11$	$10,35 \pm 0,08$
Selen, $\mu\text{g/l}$	$90,7 \pm 0,10$	$88,73 \pm 0,19$	$83,78 \pm 0,37$	$76,65 \pm 0,31$	$69,73 \pm 0,14$
Copper, $\mu\text{mol/l}$	$17,93 \pm 0,13$	$18,4 \pm 0,08$	$18,53 \pm 0,09$	$18,63 \pm 0,08$	$18,68 \pm 0,08$
Iron, $\mu\text{mol/l}$	$17,35 \pm 0,17$	$16,6 \pm 0,18$	$16,1 \pm 0,23$	$15,63 \pm 0,28$	$14,85 \pm 0,41$
Magnesium, mmol/l	$0,88 \pm 0,01$	$0,81 \pm 0,01$	$0,79 \pm 0,01$	$0,73 \pm 0,01$	$0,71 \pm 0,01$
Calcium, mmol/l	$2,37 \pm 0,02$	$2,33 \pm 0,02$	$2,28 \pm 0,02$	$2,25 \pm 0,02$	$2,21 \pm 0,02$
Phosphorus, mmol/l	$0,89 \pm 0,02$	$0,91 \pm 0,02$	$1,02 \pm 0,02$	$1,04 \pm 0,02$	$1,06 \pm 0,02$

The obtained data may indicate impaired tissue metabolism and energy supply to the visual system.

Magnesium content decreased monotonously and statistically significantly as the CVS severity increased.

If in the control group the Mg level was 0.88 ± 0.01 mmol/l, then in the severe degree of CVS it decreased to 0.71 ± 0.01 mmol/l.

Magnesium deficiency can contribute to neuromuscular transmission dysregulation, accommodation disorders, and vegetative instability characteristic of CVS.

Calcium concentration also demonstrated a gradual decrease from 2.37 ± 0.02 mmol/l in the control group to 2.21 ± 0.02 mmol/l in severe CVS.

The identified changes reflect impairments in calcium-dependent regulatory mechanisms, including neuronal transmission and ciliary muscle tone.

Unlike most microelements, phosphorus levels were characterized by an increasing trend.

The indicator increased from 0.89 ± 0.02 mmol/l in the control group to 1.06 ± 0.02 mmol/l in severe CVS.

The increase in phosphorus concentration may be associated with changes in energy metabolism, increased catabolism, and calcium-phosphorus imbalance during chronic visual overload.

The obtained results indicate that computer vision syndrome is accompanied by systemic disorders of mineral homeostasis, the severity of which increases parallel to the progression of clinical manifestations of the disease. The identified changes affect both micro- and macroelements and are of a regular, stage-dependent nature, which confirms the metabolic involvement of the CVS and goes beyond the scope of exclusively local ophthalmological disorders.

The most pronounced changes were noted in essential trace elements with antioxidant and neurotropic properties. The sequential decrease in the concentration of zinc and selenium as the CVS severity increases indicates the depletion of antioxidant protection and an increase in the vulnerability of eye tissues to chronic oxidative stress, which develops under conditions of prolonged visual and cognitive stress. It is known that Zn deficiency is accompanied by retinal dysfunction, slowing of reparative processes, and decreased stability of the accommodation apparatus, while a decrease in the level of Se is associated with a weakening of the glutathione peroxidase system activity and an increase in inflammatory reactions. Thus, the detected decrease in the concentration of these elements can be considered as one of the pathogenetic factors in the progression of CVS.

Simultaneously, a moderate, but persistent increase in copper levels was observed as the degree of the syndrome increased. This dynamic likely reflects compensatory-desadaptive shifts in the microelement balance system. On the one hand, copper is a cofactor of antioxidant enzymes, on the other hand, its excessive accumulation can enhance prooxidant reactions and the inflammatory response. In this context, the imbalance of the Cu/Zn ratio can be considered a marker of metabolic stress and chronic stress exposure in CVS.

A decrease in iron concentration, detected in moderate and severe forms of CVS, may indicate impaired energy metabolism and tissue hypoxia, potentially exacerbating functional insufficiency of the visual analyzer. Considering the key role of iron in mitochondrial respiration processes, its deficiency can contribute to a decrease in visual endurance and accelerated development of visual fatigue.

Analysis of the macroelemental composition of the blood revealed no less significant changes. The progressive decrease in magnesium and calcium levels indicates a dysregulation of neuromuscular and autonomic regulation, which has direct relevance to the pathogenesis of accommodation disorders and autonomic symptoms characteristic of CVS. In particular, magnesium deficiency is associated with increased neuromuscular excitability, decreased adaptive reserves, and increased subjective manifestations of visual discomfort.

Unlike most of the elements studied, phosphorus levels demonstrated an increasing trend as the syndrome worsened. The increase in phosphorus concentration likely reflects shifts in energy and phosphorus-calcium metabolism associated with increased catabolic processes and disruption of mineral balance regulation during chronic visual overload. This fact emphasizes the systemic nature of the identified metabolic changes.

In summary, the obtained data confirm that computer vision syndrome is accompanied by the formation of a complex mineral imbalance, including a decrease in the levels of essential micro- and macroelements against a background of a relative increase in copper and phosphorus. These changes can play an important role in maintaining the chronic course of CVS, contributing to the progression of functional and neurovegetative disorders. The identified patterns justify the feasibility of including mineral status assessment in the comprehensive diagnosis of CVS and open up prospects for pathogenetically oriented correction of the identified disorders.

4. Conclusions

The conducted research showed that in computer vision syndrome, changes occur in the mineral composition of the blood, the severity of which increases with the severity of the disease. Even in the early stages of CVS, deviations from the control values are noted, and in moderate and severe cases, they become most pronounced.

For zinc, selenium, magnesium, iron, and calcium, a gradual decrease in concentrations is characteristic, while the levels of copper and phosphorus, on the contrary, increase. The most noticeable changes were identified for selenium and zinc, which allows us to consider them as the most sensitive indicators related to the degree of CVS.

Overall, computer vision syndrome is accompanied by the formation of a systemic mineral imbalance, which confirms the presence of a metabolic component in the development and progression of the disease. Considering the mineral status of the blood can supplement the clinical assessment of the severity of computer vision syndrome.

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