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Evaluation of the Effect of Computer Load on Metabolic Shifts Using the Method of Laser Correlation Spectroscopy

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Abstract Widespread and constant use of digital devices has become a daily reality of modern life for both adults and children. Computers are mandatorily used in the educational process, even in the elementary school. The spectrum of damaging effects on the health of children and adolescents also increases with increasing the screen time. Functional strain of the body's systems manifested in an impairment of mental and physical performance and an increase in psychological stress, as well as disturbances in the regulation of heart rhythm, peripheral circulation, respiration, and psychomotor and metabolic processes caused by increased computer loads are usually not associated with specific diseases, but accompany the load itself, due to which they are recorded by health services only in case of manifestations of clinical signs of various diseases. Here we use the method of laser correlation spectroscopy/dynamic light scattering to assess the presence and direction of metabolic shifts in elementary school students experiencing different levels of school and out-of-school computer loads. Oropharyngeal washout fluid is used as the material for the study. The results are presented in the form of diagrams of the semiotic classifier. It is found that regular computer loads at school in accordance with hygienic standards significantly increase the percentage of normological shifts and significantly reduce the proportion of allergy-like shifts. In girls, increased out-of-school computer loads enhance the contribution of allergy-like and autoimmune-like shifts. These shifts reflect the predominance of anabolic processes over the catabolic ones. Evaluation of the combined effect of school and out-of-school loads in the elementary school reveals different responses of boys and girls to increased computer screen time. We observe an increase in the relative contribution of catabolic shifts in girls and anabolic shifts in boys. Assessment of the direction of metabolic shifts in screening studies can be useful in the development of preventive methods aimed at minimizing the negative consequences of uncontrolled computer loads.

Keywords Laser Correlation Spectroscopy/Dynamic Light Scattering, Computer Loads, Metabolic Shifts

1. Introduction

The interaction of humans and computer technologies is currently acquiring a symbiotic relationship. Computers, telephones, and TV are inevitable elements in most areas of activity.

Increasing role of computer technologies in everyday life makes it necessary to consider an increase in screen time as a health risk factor. Computerization of the educational environment imposes new requirements to the child's health. In fact, this process is a stress factor that triggers an adaptive response of the body [1], or, when the adaptive resource is exhausted, leads to pathological changes. Complex nature of changes (physical inactivity,

changes in daily routine and eating behavior, effects from the screen light, etc.) suggests shifts in different body systems. With progressive digitalization and computerization of the educational environment, the time spent by children at the computer will only increase, as was seen from the experience of distant learning during the COVID-19 pandemic. And it is important not to cross the line separating a positive adaptive response from the next stage, transition to maladaptation and exhaustion of the functional reserves of the body. This once again emphasizes the importance of multilevel monitoring of children's health aimed at detecting changes in the physiological status at the prenosological level [2].

To make digitalization of education safe, the main attention should be paid to the problems of increasing robustness of the students in the educational environment. The main negative consequence of computer loads is the development of the so-called general fatigue symptoms (reduced mental and physical performance, increased psychological stress, dysregulation of the heart rhythm, peripheral circulation, respiration, and psychomotor and metabolic processes). These functional stresses are usually not associated with specific diseases, but accompany the load itself, due to which they are recorded by health services only in case of manifestations of clinical signs of various diseases. Nevertheless, numerous studies involving large groups of children have demonstrated that lengthening of the screen time is a health risk factor.

The development of the instrumental methods of prenosological diagnostics allows to trace the dynamics of metabolic shifts by analyzing biological fluids obtained by noninvasive methods [3, 4].

Here we use the method of laser correlation spectroscopy to assess the presence and direction of metabolic shifts in elementary school students experiencing different levels of school and out-of-school computer loads. Changes in physiological status of the organism under the effect of environmental factors modulate metabolic processes, which in turn, affect the composition of biological fluids. Laser correlation spectroscopy is used for screening of large groups of conventionally healthy individuals for diagnosis of body functional strain and detection of risk groups [5-7].

2. Materials and Methods

The study included schoolchildren (grades 1-4) of two Moscow schools: School 1 is a school of general education where teaching corresponds to Federal State Educational Standards, which is accepted for most schools in Russia; School 2 implements the Waldorf method focused on artistic and aesthetic education, including painting, handcrafting, gardening, etc. In school 1, 42 girls and 51 boys participated in the study, in school 2 - 41 and 44 respectively. The age of children enrolled in primary school is from 7 to 11 years.

Informed consent for participation in the study was obtained from the parents or legal representatives of children. Compliance with international and Russian legislative acts on the legal and ethical principles of conducting studies involving human subjects is confirmed by the Ethics Committee of the Research Institute of General Pathology and Pathophysiology (Protocol No. 1, January 22, 2019). The study included 178 participants.

The school computer load (SCL) was assessed by teachers on the basis of the hygienic rules and regulations in force during the surveys (SanPiN 2.2.2/2.4.1340-03, http://www.consultant.ru/document/cons_doc_LAW_42836/). Computer load was scored as follows: 0 - no load, 1 - corresponds to SanPiN requirements (15 min per day, during only one lesson), 2 - surpasses the SanPiN requirements by 2 times and more. Out-of-school computer loads (OCL) were also evaluated by teachers on the basis of a questionnaire filled by the parents and scored according to the same principle. The total computer loads (TCL) were calculated as the sum of SCL and OCL and interpreted as minor (total score 0-1), moderate (2-3), and high (4-5).

Oropharyngeal washout fluid (OPW) was used as the biomaterial for the study. The children were asked to gargle with 10 ml saline for 10 sec. The gargle samples were transferred to Eppendorf tubes, frozen, and stored at -24ºC. Prior to assay, the samples were defrosted and centrifuged at 3000 rpm for 20 min to remove debris. The subfraction composition of OPW was studied on an LKS-03-INTOX laser correlation spectrometer, certificate RU.C. 39.003.A N 5381 of the Committee on New Medical Equipment of the Ministry of Health of the Russian Federation for determining the size of microparticles in biological fluids. The method is based on recording dynamic light scattering. The contribution (%) of particles of different sizes into light scatter is determined. The ratio of the contributions of particles of different size ranges characterizes the direction of metabolic shift in the body (Figure 1).

OPW contains protein molecules and their aggregates and represents a multicomponent system. Dynamic light scattering allows measuring the linear dimensions of these molecules. A semiotic classifier was created based on the empirical data on the percentage contribution of particles of different sizes to light scatter in samples collected from patients with documented pathologies [3]. Autoimmune- and allergy-like shifts were characterized by increased contribution of particles >401 nm and corresponded to anabolic processes in the body. Intoxication-, catabolic-, and dystrophic-like shifts were associated with increased contribution of small particles to light scatter. These shifts were associated with enhanced catabolism (Figure 1). The direction of the metabolic shift in OPW was determined for each participant of the study. The data were generalized and the frequency of occurrence of metabolic shifts in the study group was calculated depending on gender and computer load.

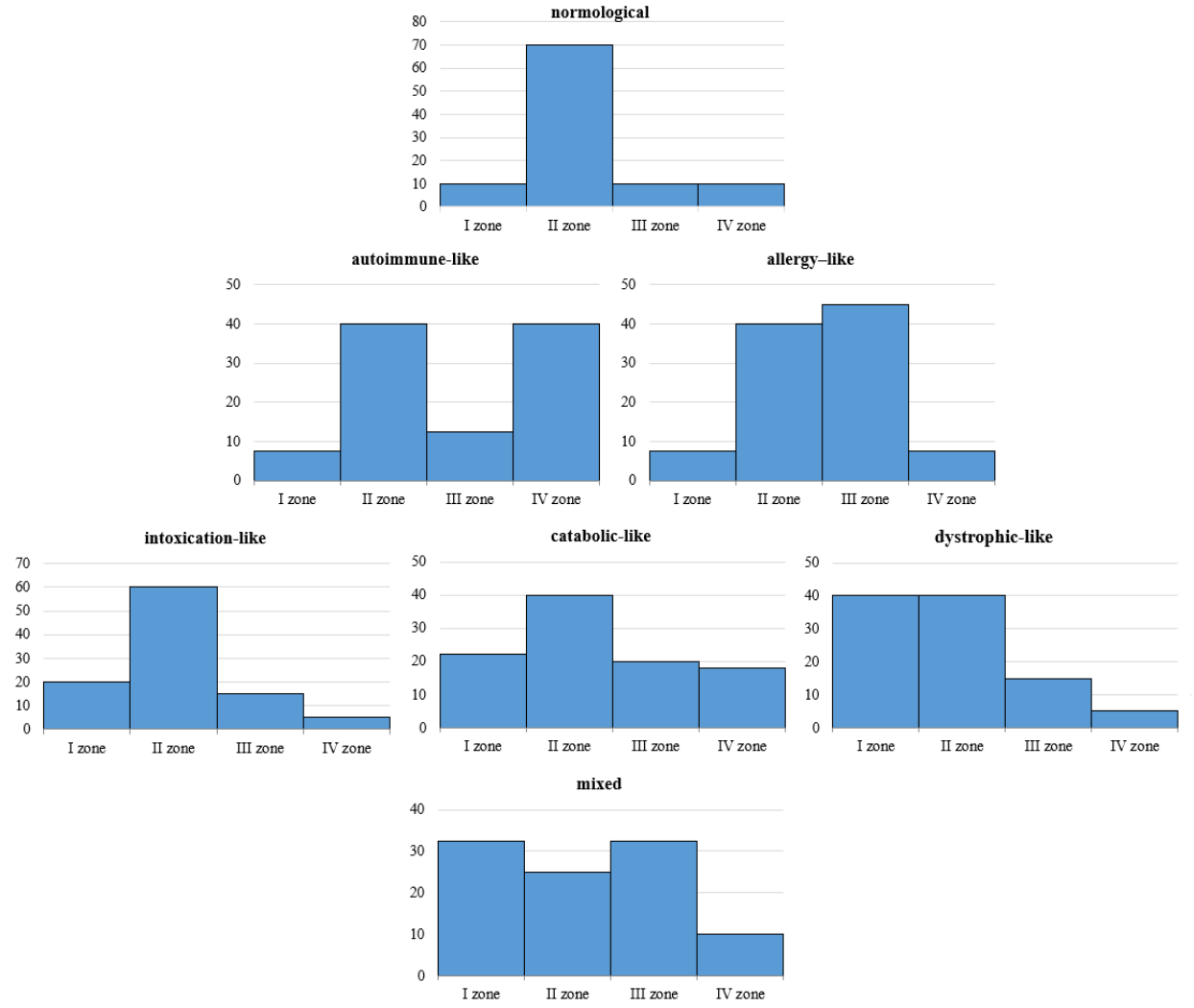

Figure 1. Diagrams of the contributions of particles of different sizes according to the semiotic classifier. The following ranges of particle sizes are distinguished: I - <50 nm; II - 51 - 400 nm; III - 401 - 2000 nm; IV - >2000 nm

The data were processed using Statistica 8.0 software (StatSoft, USA). The frequencies of various metabolic shifts were compared using the exact Fisher test (Φ-test).

3. Results

Integrative assessment of metabolic shifts by the laser correlation spectroscopy of OPW showed that SCL within the limits of hygienic standards in girls did not affect the incidence of normological spectra: they were found in about 40% cases. In the absence of computer loads, greater variability of metabolic shifts was observed in both schools (Figure 2). Computer loads increased the contribution small and medium-sized particles (up to 400 nm) to light scatter (F=0.062, p=0.0003); the autoimmune and catabolic-like shifts were transformed into intoxication-like and dystrophic-like (Figure 1).

In boys, the frequency of normological shifts in the absence of computer loads was significantly lower than that in girls. Interestingly, allergy-like metabolic shifts prevailed in School 1 and intoxication-like shifts prevailed in School 2 (Figure 3).

Regular computer loads in accordance with the SanPiNs significantly increased the percentage of normological shifts (F =0.11, p=0.0005) and significantly reduced the proportion of allergy–like shifts (Figure 3): the differences between the groups at School 1 F=0.053, p=0.002, between the schools - F=0, 043, p = 0.003.

OCL were poorly controlled. In the examined groups, OCL fell on the afternoon and evening time.

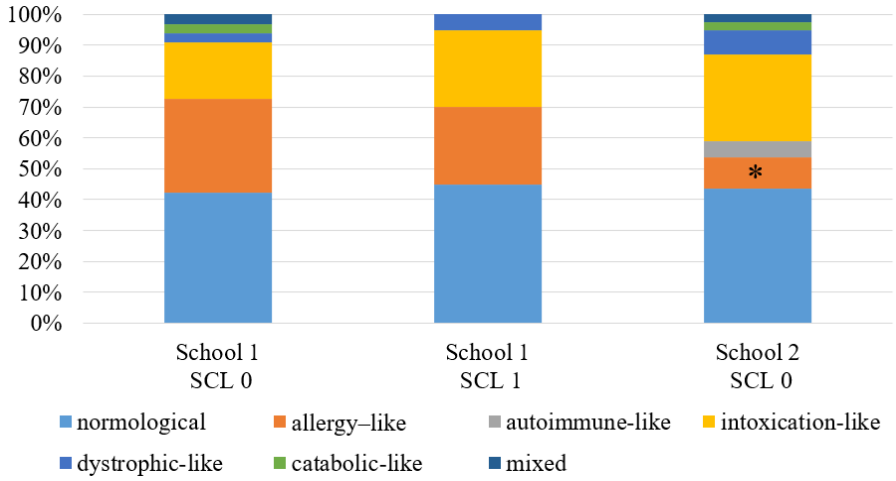

Figure 2. Ratio of metabolic shifts in girls with different SCL scores in different schools, * p<0.05 in comparison with School 1 (exact Fisher test; Φ-criterion). SCL 0 – school computer loads, score 0, SCL 1 – school computer loads, score 1

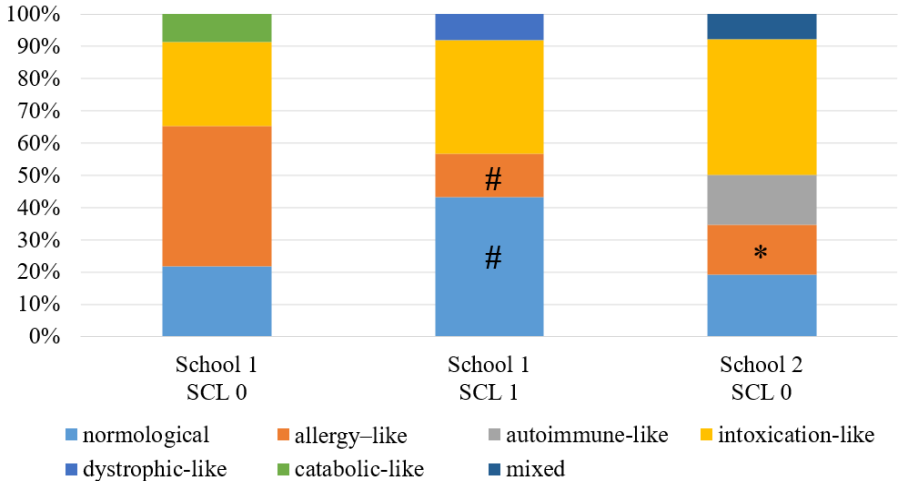

Figure 3. Ratio of metabolic shifts in boys with different SCL scores in different schools, * p<0.05 in comparison with School 1, # p<0.05 in comparison with SCL 0 in School 1, the exact Fisher criterion (Φ-criterion). SCL 0 – school computer loads, score 0, SCL 1 – school computer loads, score 1

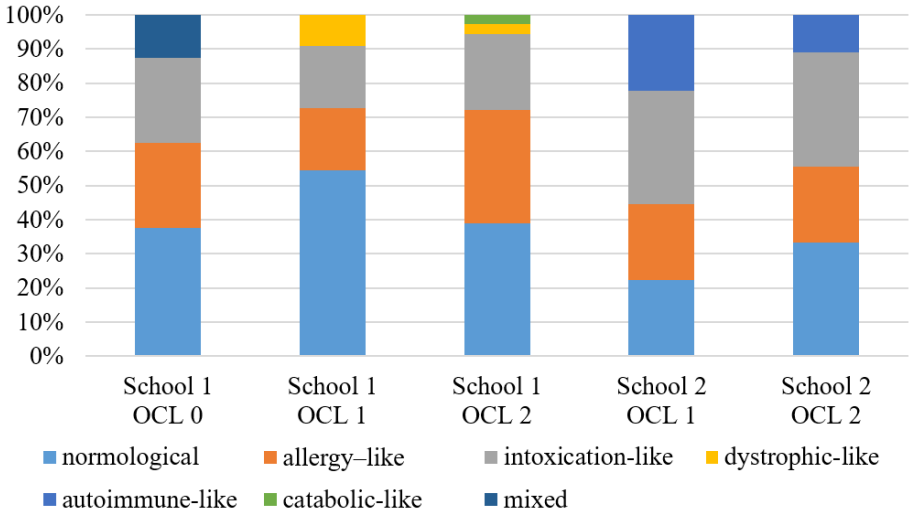

Figure 4. Ratio of metabolic shifts in girls with different OCL scores. OCL 0 – out-of-school computer loads, score 0, OCL 1 – out-of-school computer loads, score 1, OCL 2 – out-of-school computer loads, score 2

In girls, moderate OCL (OCL 1) caused an increase in the percentage of normological shifts, while an increase in OCL led to an increase in the contribution of allergy-like shifts F = 0.02, p=0.01 (Figure 4). In School 2, increased loads were associated with a higher incidence of autoimmune-like shifts.

Both allergy-like and autoimmune-like shifts are associated with increased contribution of large particles (>401 nm) to light scatter and characterize predominance of anabolic processes.

In boys, the increase in OCL did not significantly affect the ratio of metabolic shifts in School 1 and increased the number of normological shifts in School 2 F = 0.14, p=0.0005 (Figure 5).

Evaluation of the combined effect of SCL and OCL in elementary school revealed different responses to increased computer screen time in boys and girls. We observed an increase in the relative contribution of catabolic shifts in girls (F = 0.04, p = 0.001) and anabolic shifts in boys (F = 0.02, p = 0.02) (Figure 6).

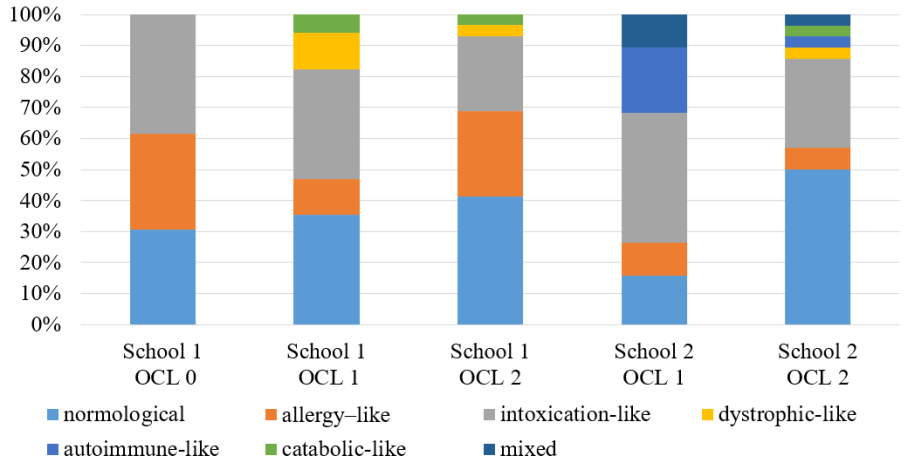

Figure 5. Ratio of metabolic shifts in boys with different OCL scores in different schools. OCL 0 – out-of-school computer loads, score 0, OCL 1 – out-of-school computer loads, score 1, OCL 2 – out-of-school computer loads, score 2

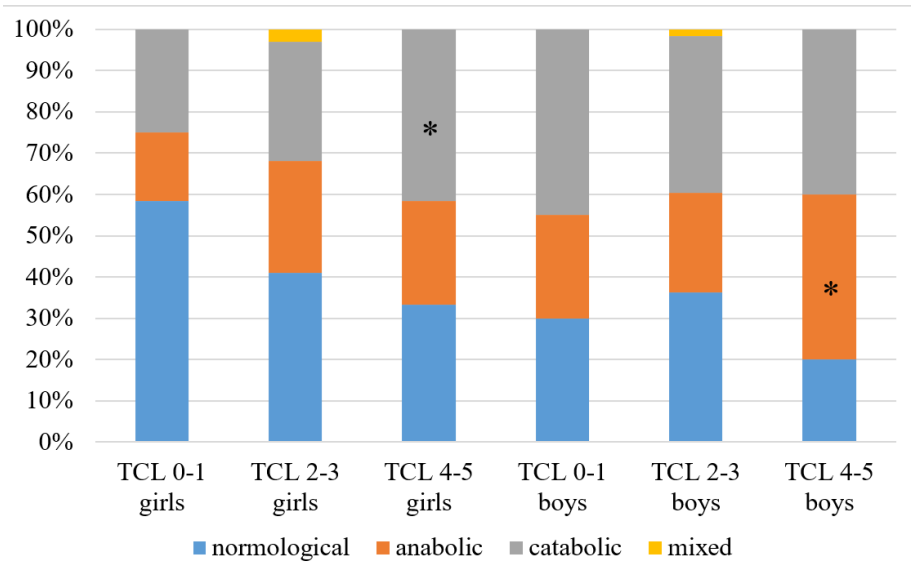

Figure 6. The ratio of the frequency of the predominant direction of metabolic processes in children with total computer loads (TCL score) in different schools. p<0.05 - in comparison with the corresponding TCL 0-1 group, exact Fisher test (Φ-test). TCL 0-1– out-of-school computer loads, score 0-1, TCL 2-3 – out-of-school computer loads, score 2-3, TCL 4-5 – out-of-school computer loads, score 4-5

4. Discussion

The term "screen time" actually includes a whole range of factors that can have a negative impact on the health of children.

Evident consequences of prolonged screen time are behavioral changes, appearance of new habits, including food habits, and a decrease in motor activity. However, the restructuring of metabolic processes towards anabolism is based on a direct change in activity of genes associated with the day-night cycle. Daily use of digital devices during the evening and night time leads to disruption of circadian rhythms and development of desynchronoses.

One of the triggers of sleep disorders is the blue light from fluorescent lamps, screens, and monitors which inhibits the production of melatonin, the main hormone that promotes falling asleep. Population studies have shown that adolescents aged 11-15 years spending more than 3 hours at the computer have sleep problems; reading e-books at night reduces the blood level of melatonin and disrupts 24-hour rhythms [8, 9], and the use of electronic devices by medical students aged 17-22 years increases the body mass index [10].

Cyclic changes in the melatonin concentration at night and during daytime control the expression of circadian clock genes and regulates the rhythm of the synthesis of hormones and enzymes in cells of the pancreas, liver, etc. Circadian clock genes promote gluconeogenesis and glycogenolysis during sleep/fasting and synthesis of glycogen and cholesterol during wakefulness/eating. Proper functioning of circadian clock genes, controlling changes at the periphery of the body, ensures synchronization of the metabolic processes with the environment, which is crucial for health maintenance [11].

Eating disorder is an additional risk factor of desynchronosis development. It is shown that children aged 10-14 years spending 2-3 hours a day in front of the computer consumed more high-calorie snacks. Disparity of the carbohydrate metabolism regulation by circadian clock genes of the brain and activity of bioactive substances in the peripheral organs together with increased amount and calorie value of consumed food creates prerequisites for obesity. Food consumption also increases during watching commercial advertisements, especially commercials embedded in the programs. In addition, reduced time for physical activity and outdoor games is an additional factor for body weight gain [5].

Desynchronoses resulting from increased screen time and exposure to blue light are characterized by changes in the immune status. Some circadian clock genes have a pronounced anti-inflammatory effect (BMAL1, CRY, REV–ERB, and ROR), some stimulate the immune system (CLOCK), and PER proteins can act in both ways. Clock proteins are transcription factors and therefore influence gene transcription directly, as well as by recruiting either activating or repressing enzymes to the promoter region of immune-associated genes [12]. The genes regulating circadian rhythms are expressed in all subgroups of leukocytes, including monocytes, natural killer cells, neutrophils, eosinophils, macrophages, mast cells, etc., and the function and dynamics of these cells strongly depends on the time of day. The genes of circadian rhythms modulate the synthesis of some cytokines with pleiotropic effects (IL6, IL1b, MCP1, MCP2). IL6 and IL1b are also referred to as adipokines, i.e. factors synthesized and released by adipocytes. It was previously considered that the adipose tissue is quite passive and its main role is to store and to release lipids in response to body requirements, but now it is considered a highly active endocrine organ secreting a number of bioactive substances [13]. An increase in the level of MCP1, MCP2 attracts monocytes and macrophages into adipose tissue. The number of macrophages synthesizing cytokines increases with increasing body weight [14].

It is well known that obesity is associated with a chronic systemic inflammatory status [15-17], which leads to temporary neutrophil infiltration of the abdominal adipose tissue. Obesity is an energy imbalance that leads to hypertrophy and hyperplasia of adipocytes and chronic inflammation in the adipose tissue of varying severity that causes certain chronic disorders due to enhanced cytokine production by macrophages and preadipocytes [18]. Thus, the adipose tissue not only initiates systemic inflammation, metaflammation, but also plays a role in its long-term maintenance [19]. Obesity has a lifelong effect on the metabolism and activation of the immune system, and this effect can have several starting points from the prenatal period to adolescence. There are data that manifestations and consequences of metaflammation that appears in the childhood can persist during the adulthood. Our previous studies have revealed a correlation between the level of OCL and body mass index (BMI) in elementary school students. However, there is no correlation between the level of SCL and BMI. The more pronounced response to increased OCL is found in boys. It consists in an increase in BMI and changes in its seasonal variability (from an increase during winter to considerable increase during summer) [20]. Uncontrolled computer use after school promotes anabolic shifts, which can potentially lead to the development of obesity.

Considerably increased screen time is the cause of a pathophysiological "vicious circle". An imbalance in the genes of circadian rhythms shifts the balance between lipogenesis and lipolysis and leads to cytokine imbalance. Metaflammation develops under the influence of constant increasing effect of factors of physiological imbalance and leads to obesity [21].

Prenosological monitoring of changes in the metabolism and measures on body weight control in children can normalize markers of inflammation, which gives us hope that the process can be reversed and its consequences can be eliminated [22]. Studies aimed at detection of early signs of metaimflammation can help in the development of preventive methods for correcting the consequences of negative external influences.

5. Conclusions

Laser correlation spectroscopy of biological fluids is a technique that allows detecting pathological shifts in screening studies at an early stage. In this study, it is possible to identify shifts in the metabolism of students under the influence of digital learning technologies. This integral assessment of shifts is in accordance with the previously obtained data on the increase in body mass index and the development of inflammation in hypodynamia due to an increase in screen time [20]. With the development of instrumental systems of multifunctional monitoring, it becomes possible to differentiate physiological states directly in the dynamics of the educational process. Moreover, even with an unfavorable variant, objectively installed with the help of the attached software and hardware, it is possible to determine exactly in which specific control function the tension is detected [23]. This provides the basis for the use of addressable methods of correction of physiological balance.

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