

SLEEP DISORDERS, METABOLIC SYNDROME, AND COGNITIVE ABILITIES IN ADOLESCENTS: CLINICAL AND PATHOPHYSIOLOGICAL RELATIONSHIPS

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Abstract: The article presents a comprehensive analysis of the relationships between sleep disorders, metabolic syndrome, and cognitive functions in adolescents. Epidemiological data indicate a steady increase in the prevalence of both sleep disorders and metabolic syndrome in the pediatric population, which is accompanied by a significant decrease in cognitive abilities and academic performance. The pathophysiological mechanisms underlying these relationships are examined, including changes in neuroendocrine regulation, circadian rhythms, leptin and ghrelin levels, insulin resistance, oxidative stress, and neuroinflammation. It has been demonstrated that insufficient duration and quality of sleep contribute to the development of components of metabolic syndrome, while metabolic disorders, in turn, exacerbate sleep disorders and negatively affect cognitive functions. Special attention is paid to critical periods of neuroplasticity in adolescence and the impact of these disorders on the formation of neural networks responsible for executive functions, working memory, and attention. Modern diagnostic criteria and therapeutic strategies based on an interdisciplinary approach are presented, including lifestyle modification, sleep hygiene, dietary recommendations, and psychological support. The necessity of early diagnosis and timely correction of sleep disorders and metabolic disorders in adolescents is emphasized to prevent long-term negative consequences for cognitive functioning and psychosocial adaptation.

Key words: sleep disorders, metabolic syndrome, cognitive functions, adolescents, insomnia, obesity, insulin resistance, circadian rhythms, neuroplasticity, neuroendocrine relationships, sleep hygiene, executive functions, working memory, neuroinflammation, psychosocial adaptation

Introduction. According to recent studies, insomnia occurs in 25-90% of people and typically leads to cognitive and behavioral disorders. Literature sources more often present sleep disorders in the form of specific symptoms of change, for example, profanation of cycle organization, disruption of the sleep structure itself (poor falling asleep, frequent awakening, sleep inefficiency, etc.) (1, 3, 7). Moreover, while in the adult population this problem may occur episodically, in childhood, especially with a deep factor of disturbance, the process progresses. Such factors have common pathophysiological mechanisms, including organic brain damage, neurotransmitter deficiency, hormonal imbalance, psycho-emotional dysfunction, social adaptation or lack of normative social conditions, and in recent years, scientific interest has focused on upper airway dysfunction syndrome during sleep or (nocturnal) apnea. Scientists present research that indicates cognitive dysfunction in people with sleep disorders (2, 4, 8). The formation of speech skills and motor speech in children occurs at the age of 1.5-3 years; accordingly, if during this period children have difficulties and risk factors, they negatively affect the

development of cognitive abilities (5, 6). Since the state of sleep and daytime activity (requiring increased attention) are different in functional nature of brain actions but mutually balancing consignators, sleep disorders and behavioral disorders in children are a very relevant, although not fully investigated topic.

Aim of the study: to study and conduct a correlation analysis of clinical and diagnostic studies in adolescents with sleep disorders.

Material and methods of research. The research material consisted of adolescents aged 16 to 18 years, totaling 47, with 29 boys and 18 girls. The study was conducted in several stages. In the first stage, where it was necessary to gather patients according to selection criteria, staff conducting the research surveyed children among secondary school students (9-10th grade of an urban school - 12); a similar survey was conducted in the outpatient clinic conditions of MC SamSMU (adolescents who visited neurologists, pediatricians, endocrinologists, psychologists). At this stage, a group of 74 adolescents was formed. The main criteria for the first stage were: adolescents with excess body weight (obesity grade 2-3, sleep disorders, decreased academic performance, emotional instability (all these symptoms are described and formed in an arbitrarily compiled questionnaire (approved by the problem commission for December 2024))). In the second stage, patients underwent a full functional examination by specialists (to whom were added: ophthalmologists, otolaryngologists, psychiatrists from those listed above); examination of standard laboratory research methods (blood, urine, feces); additional research methods: ECG, polysomnography. At this stage, out of 74 adolescents, only 47 continued the study (with written permission from parents). It should be noted that at these stages, as a comparison, a group of healthy adolescents consisting of 31 volunteers was determined with the consent of parents. The current study was further conducted in the Department of Pediatric Neurology of SamSMU from September 2024 to April 2025. During the study, the main group of 47 adolescents was divided into three subgroups, which were identically comparable in age and gender but differed in body mass index and related comorbidities. Thus, subgroup 1 (15) included adolescents assessed as having first-degree obesity; subgroup 2 (18) included patients with second-degree obesity, in addition, these adolescents showed a mild degree of OSA (obstructive sleep apnea) syndrome; the third subgroup (14) included patients with third-degree obesity and severe OSA. The exclusion criteria included adolescents with organic CNS damage, patients taking any medications to improve sleep or psychoactive drugs, patients with chronic lung and bronchial diseases, with chronic heart failure. The formed group of 47 patients underwent further research: scales-questionnaires (Epworth scale, determining daytime sleepiness and the likelihood of sleep apnea, where up to 15 points is mild and above 16 points is severe apnea); Patients underwent polysomnography at the private clinic "Innova" using a sonoscreen plus RC combi 39, with apnea events being recorded if there was a decrease in respiratory amplitude to 90% (limit 10 sec), a low indicator was in the range of 35-40%. Cognitive functions in patients were assessed by the method of neuropsychological testing: MOCA scale (a score of more than 26 is considered normative); a preliminary survey of patients revealed aspects of anxiety-depressive situations, in accordance with this, it was appropriate to conduct testing for the level of depression, for which the Beck scale was used, adapted for our patients (the threshold for transition to severe depression is up to 30 points). To obtain a complete picture of the brain structure, patients underwent brain neuroimaging, with a correlational comparison of bioelectric brain activity. MRI studies were conducted in T1, T2 mode for the brain (2021 GE SIGNA Explorer manufactured in the United States of America). Statistical analysis was carried out on a personal computer using standard software packages with Student's criteria.

Results of the study. Among the examined adolescents of the main group, as noted, concomitant symptoms of metabolic disorder were identified, including excessive body weight, hyperlipidemia in 13 adolescents (27.6%); cardiogram revealed ventricular hypertrophy in 22 patients (46.8%); non-alcoholic steatohepatitis in 7 patients (14.9%). Important symptoms that were noted as criteria for including patients in the main group: snoring/apnea (resulting in awakening) (in 100% of cases); sleep disorder (resulting in morning drowsiness) (97.3%); headache after waking up (morning) (81.5%); lethargy and daytime sleepiness (especially during the first lessons) (69.7%).

Cognitive dissonance in patients revealed certain characteristics. Thus, using the scale (MoCA), we obtained a statistically significant difference in the values of the main and control groups, where $P < 0.001$. If we consider the main group in detail, changes were noted in the following parameters: attention (59.9%), concentration of attention (98.5%), working activity (perception in class) (84.4%). Moreover, in the third subgroup, these signs were more pronounced. Assessment of the research results on the Beck depression scale showed a statistically significant change between the main and control groups ($P < 0.05$), but no deviations were noted between the three subgroups of the main contingent of adolescents.

The Epworth scale in the study determined a fairly high risk of changes compared to the control group. Thus, the average score value was in the range from 15.5 points in the first subgroup, that is, a relatively mild change in obstructive apnea; in the second subgroup, the limit figures had a value of 16.3 points (moderate change); and in the third subgroup a severe degree, with average values of 18 points; which indicates a statistically significant difference between subgroups in the severity of obstructive apnea detection and pronounced sleepiness. In addition, analysis of the result of the correlation comparison of the Epworth scale with the body mass index level in patients determined a positive assessment, where $P < 0.001$. The index of the average component of obstructive apnea (OAI) in the main group (47 patients) was in the range of 33.3 ± 10.9 , compared with the control group, in which this indicator was 1.9 ± 0.9 , where $P < 0.001$. In addition, the OAI values in the subgroups differed; thus, in the first subgroup, the figures were 19.0 ± 2.5 ; in the second subgroup, the range of values varied within 23.7 ± 1.9 ; and in the third subgroup, the indicator corresponded to 30.6 ± 3.4 , which shows a statistically significant difference between the main group and the control group, a significant difference between the subgroups, with high negative values in the third subgroup. Neuroimaging was performed on all examined patients in the main group and adolescents in the control group (5 adolescents refused the procedure due to signs of claustrophobia). According to the results of the analysis of MRI images of the brain, variations of structural elements of disturbance and the influence of hypoxic factors of various degrees were revealed. These accounted for 62% in the total sample of the main group, whereas in the control group, only one patient showed changes (when clarifying the anamnesis, the mother of this adolescent had a difficult birth leading to hypoxia, which was not clinically manifested later). When considering individual subgroups, it was noted that the distribution of structural units of disturbance among them can be presented in the following percentages: in the first subgroup, only two children (4.3%); in the second subgroup, eight adolescents (17.0%); and in the third subgroup, 9 adolescents (19.1%), that is, in the second and third subgroups, the changes in the number of patients are almost similar. The picture of structural changes is presented in the form of lighter areas of white matter; periventricular leukomalacia; lesions in the basal ganglia; at the same time, there is a difference, as periventricular changes in the subcortical nuclei show a greater difference between the first and third subgroups. When decoding MRI images, slight deviations in the brain structure by areas were noted, where most of the changes were concentrated in the parietal-temporal and frontal regions. Correlation analysis of cognitive functions, in accordance with the indicators of the MOCA scale and neuroimaging results of MRI, revealed a correspondence of scale scores and structural components of brain disturbance, which is statistically significantly higher in the main group compared to the control group, where $P < 0.001$. However, if cognitive symptoms had more attention disorders, then on MRI, a higher percentage of lesions was noted in the frontal area.

The result of the analysis of polysomnographic study indicators of adolescents in the main and control groups showed a decrease in the duration of the REM sleep phase in the average range from 35 to 50 minutes in the main group, whereas in the control group, these indicators varied on average up to 90 minutes, where $P < 0.05$. An important task of studies using polysomnography is to identify sleep quality; for this purpose, based on the obtained indicators, the sleep quality and efficiency index (SEGI) was determined. It was found that in adolescents in the main group, the index has a lower level of magnitude compared to the control group of healthy adolescents, so in the main group - 79.3 ± 5.0 , and 90.3 ± 5.0 respectively in the control group, where $P < 0.05$. As can be seen from the results obtained, several parameters accumulated in the main group, each important in its own way: increased

body mass index, high obstructive apnea index, cognitive deficit, structural changes presented on MRI neuroimaging, polysomnography indicators with the identification of sleep quality and efficiency index; therefore, it is necessary to conduct a mathematical analysis of the average criterion that combines sleep disorder, factors, and consequences. In a situation of multifaceted indicators and a relatively small sample of patients, the Kruskal-Wallis H-test is convenient for such a criterion. According to the H-test, the relationship of sleep in adolescents of the main group with obstructive apnea has an average value of 23, where $P < 0.05$, statistically significant compared to the control group, which proves the peculiarity of the development of sleep disorders, with a reduction in the slow-wave sleep phase.

Conclusion:

Thus, the study investigated the relationship between sleep disorders and the level of cognitive imbalance in adolescents. The research was conducted in several stages, where an important aspect was the selection of patients according to inclusion criteria: adolescent age from 14 to 18 years, increased body mass index, poor school performance, impaired sociability and attention, sleep disorders with daytime sleepiness, snoring during sleep, and obstructive apnea. The results of the evaluation of the obtained data presented peculiarities according to the MOCA scale indicators, with a statistically significant difference detected between adolescents in the main and control groups, with correlation of neuroimaging indicators of structural changes, where in the main group there was periventricular leukomalacia with greater intensity in the frontal regions and significant differences in the subcortical nuclei and corpus callosum. In addition, in the subgroups divided by the level of body mass index difference, signs of dependence between sleep disorders and cognitive insufficiency were revealed, where in cases of greater obesity, the correlation indicators were statistically significant.

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