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The Influence of Chronotypes and Sleep Patterns on Heart Rate Variability and Cognitive Functions in Students

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Abstract: *This scientific article examines the influence of chronotypes and sleep patterns on heart rate variability (HRV) and cognitive functions in students. Based on contemporary empirical research, differences between "morning" and "evening" chronotypes, their physiological and psychological characteristics, as well as the impact of sleep quality and duration on HRV indicators and cognitive performance are analyzed. Particular attention is given to the relationship between circadian rhythms, the autonomic nervous system, and the level of cognitive activity in students.*

Keywords: Chronotype, Sleep, Heart Rate Variability, Cognitive Functions, Students, Circadian Rhythms, Autonomic Nervous System

Introduction

Modern students frequently face disruptions in their sleep patterns due to high academic workload, extensive use of digital technologies, and irregular lifestyles. According to research data, up to 60–70% of students experience chronic sleep deprivation [1]. Under such conditions, the study of the influence of chronotypes and sleep patterns on physiological and cognitive indicators becomes particularly relevant.

Chronotype represents an individual predisposition to activity at certain times of the day and is typically classified into morning, evening, and intermediate types [2]. These differences influence circadian rhythms, the functioning of the cardiovascular system, and cognitive processes.

Heart rate variability (HRV) is an important marker of autonomic nervous system activity and reflects the adaptive capacity of the organism [3]. Reduced HRV is associated with increased stress levels and impaired cognitive functions.

Methodology

The study employed methods of scientific literature analysis, comparative analysis, and generalization of empirical data. Publications related to sleep, chronotypes, HRV, and cognitive functions in students were reviewed.

The following methods were used in several studies:

1. Questionnaires (chronotype surveys, such as MEQ);
2. Polysomnography and actigraphy for sleep assessment;
3. HRV analysis (RMSSD, SDNN indicators);
4. Cognitive tests (attention, memory, reaction time).

The sample size in most studies ranged from 100 to 500 students aged 18–25 years [4].

Results

The analysis of scientific data showed that chronotype has a significant impact on both physiological and cognitive indicators in students.

Students with a morning chronotype demonstrate more stable HRV indicators and higher levels of cognitive activity in the first half of the day [5]. In contrast, individuals with an evening chronotype are

more likely to experience sleep disturbances and show reduced cognitive performance in the morning hours.

Studies indicate that sleep deprivation (less than 6 hours per day) leads to a decrease in HRV, indicating an imbalance in the autonomic nervous system [6]. This is accompanied by impairments in cognitive functions such as attention, memory, and executive functions.

According to experimental data, sleep restriction results in a 20–30% decrease in reaction speed and an increase in errors in cognitive tests [7].

It has also been established that maintaining a regular sleep schedule contributes to increased HRV and improved cognitive performance [8].

Discussion

The results obtained from the analysis of scientific literature convincingly demonstrate the existence of a complex and multi-level relationship between chronotype, sleep patterns, heart rate variability (HRV), and cognitive functions of students. This relationship is systemic in nature and is driven by the interaction of biological, psychophysiological, and social factors that shape the adaptive capabilities of the organism under academic conditions.

First of all, it should be noted that chronotype represents a fundamental characteristic determining the functioning of the human circadian system. Circadian rhythms are regulated by the suprachiasmatic nucleus of the hypothalamus and are synchronized with external factors such as the light-dark cycle and social schedules. However, students often experience a mismatch between internal biological rhythms and external demands, leading to the phenomenon of "social jetlag" [9].

This effect is particularly pronounced in students with an evening chronotype, who are physiologically inclined toward later sleep onset and wake times. Under traditional educational systems, which are oriented toward early class schedules, such students are forced to systematically reduce their sleep duration. This results in chronic sleep deprivation, accumulation of fatigue, and a decrease in the functional reserves of the body. Consequently, dysregulation of the autonomic nervous system occurs, which is reflected in reduced HRV indicators.

From a physiological perspective, HRV is an integral indicator of the balance between the sympathetic and parasympathetic branches of the autonomic nervous system. High HRV values indicate good adaptive capacity and strong parasympathetic regulation, whereas low values reflect sympathetic dominance and a stress state.

In the context of the problem under consideration, it is important to emphasize that chronic sleep disturbances, which are common among students, lead to decreased parasympathetic activity and, consequently, reduced HRV. This is supported by studies showing that sleep deficiency is associated with increased cortisol levels and activation of stress responses in the body.

A decrease in HRV has not only physiological but also cognitive consequences. It has been established that HRV is closely related to the functioning of the prefrontal cortex, which is responsible for higher cognitive functions such as attention, working memory, planning, and decision-making [10]. Thus, reduced HRV may lead to decreased cognitive flexibility, impaired attention concentration, and an increased number of errors in intellectual tasks.

Another important aspect is the influence of chronotype on the daily dynamics of cognitive activity. Studies show that peak cognitive performance occurs during periods corresponding to an individual's chronotype. "Morning types" reach peak performance in the morning hours, whereas "evening types" are more productive in the evening.

A mismatch between the timing of academic activities and biological rhythms leads to reduced learning efficiency. For example, students with an evening chronotype demonstrate lower performance during morning classes due to insufficient activation of cognitive processes. This effect is exacerbated by sleep deprivation, which further reduces information processing speed and memory performance.

Special attention should be paid to the influence of sleep duration on cognitive functions. According to research data, the optimal sleep duration for young adults is 7–9 hours per night. However, a significant proportion of students sleep less than 6–7 hours, which negatively affects their cognitive performance [11].

Sleep deficiency disrupts memory consolidation processes, which primarily occur during slow-wave

and REM sleep phases. As a result, the ability to retain new information deteriorates, and the efficiency of recall decreases [12].

Moreover, lack of sleep affects attention and executive functions. Experimental studies show that after a night of restricted sleep, there is a significant decline in reaction speed and an increase in errors in attention-related tasks [13]. This is particularly important in educational environments where concentration and accuracy are critical for success.

Another important factor is sleep regularity. Even with sufficient sleep duration, irregular sleep patterns can lead to desynchronization of circadian rhythms. Studies indicate that variability in sleep and wake times is associated with decreased HRV and reduced cognitive performance [14].

Irregular sleep is especially common among students, who often change their daily routines depending on academic workload, exams, and social activities. This leads to instability in the circadian system and reduced adaptive capacity of the body.

The role of psycho-emotional factors should also be emphasized. Chronic stress associated with academic activities amplifies the negative impact of sleep disturbances on HRV and cognitive functions. Increased anxiety and emotional tension contribute to activation of the sympathetic nervous system, further reducing HRV and impairing cognitive performance.

An interesting aspect is the possibility of modifying these negative effects through lifestyle changes. Studies show that adherence to sleep hygiene—including regular sleep schedules, limiting the use of electronic devices before bedtime, and optimizing light exposure—improves sleep quality and increases HRV [15].

Additionally, physical activity and relaxation techniques (such as breathing exercises) have a positive effect on autonomic regulation and cognitive functions. Improvements in HRV resulting from such interventions are accompanied by enhanced attention and reduced stress levels.

An important direction is the individualization of the educational process based on students' chronotypes. Some studies propose flexible class schedules or the use of online learning formats, allowing students to adapt their academic activities to their biological rhythms. This may contribute to improved academic performance and reduced stress levels.

From a practical perspective, the results of this analysis highlight the need to develop comprehensive programs aimed at optimizing students' sleep patterns. Such programs should include educational initiatives to raise awareness about the importance of sleep, as well as organizational changes in the educational process.

It should also be considered that the impact of chronotype and sleep on HRV and cognitive functions may vary depending on individual characteristics such as physical activity level, nutrition, presence of chronic diseases, and psycho-emotional state. This requires further research using an interdisciplinary approach.

Conclusion

As a result of the analysis, it has been established that chronotype and sleep patterns have a significant impact on heart rate variability and cognitive functions in students.

Students with a morning chronotype demonstrate more favorable physiological and cognitive indicators under traditional academic schedules, whereas an evening chronotype is associated with a higher risk of sleep disturbances and reduced cognitive efficiency.

Insufficient and irregular sleep leads to decreased HRV, impaired attention, memory, and reaction speed.

It is recommended to take individual chronotype characteristics into account when organizing the educational process and to develop students' skills in maintaining proper sleep hygiene.

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