

Changes in biological rhythms under conditions of mismatch between administrative time and natural time

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ABSTRACT

It is well established that adequate and proper sleep is essential for the health of children and adolescents. This study examined the effect of a 1.5–2-hour difference between administrative and natural time in Kazakhstan on adolescents (n = 120). In particular, adolescents in Atyrau, where administrative time is ahead of natural time, experienced chronic desynchronization. Consequently, this situation led to lowered sleep duration and quality, impaired cognitive performance, increased emotional instability, and compromised immune function. The predominance of “owl” and “dove” chronotypes among adolescents indicates a misalignment between their natural biological rhythms and school schedules. As a result, scores for memory, attention, and visual-motor reaction were below average. This decline in cognitive performance, particularly in the morning, negatively affected academic achievement. Notably, in the 9th grade, when classes started earlier, grades dropped across all subjects, demonstrating the direct impact of desynchrony on learning efficiency. Physiological compensatory responses were observed in the respiratory system, including increased vital capacity of lungs and related indicators, and the cardiovascular system was also investigated. Additionally, a marked rise in disease incidence was noted among girls. These findings suggest that prolonged desynchronization has a significant impact on adolescent health.

Keywords: Adolescent health, Desynchronosis, Biological rhythm, Time zone, Administrative time, Natural time.

Article type: Research Article.

INTRODUCTION

Most tormenting of all was to be woken up in the morning right after I had finally dozed off. This was what made me despise kindergarden, and then school. True, I did get assigned to the afternoon shift two years in a row. For those two years, I was nearly an A student. After that, I was never an exemplary student, - Max Frei (Max Fry 1996). Today, the problem faced by the book's character can be said to affect many children and adolescents in countries where administrative time is not used appropriately. In other words, this results from applying administrative time ahead of natural geographic time. In the Republic of Kazakhstan, the use of administrative time zones has changed several times in its history. For the first time, in 1930 during the Soviet period, the clock was moved forward by one hour and “decree time” was used; most recently, in March 2024, a unified administrative time of UTC+5 was established across the country (Resolution 2024). Geographically, the Republic of Kazakhstan spans four natural time zones: UTC+3, UTC+4, UTC+5, and UTC+6 (Fig. 1). Specifically, the UTC+3 zone covers parts of the West Kazakhstan, Atyrau, and Mangystau regions, amounting to roughly 10–12% of the country's territory. A portion of East Kazakhstan lies in UTC+6, about 10.4% of the area. The remaining regions of the country (around 80%) are located within the UTC+4 and UTC+5 geographic time zones.



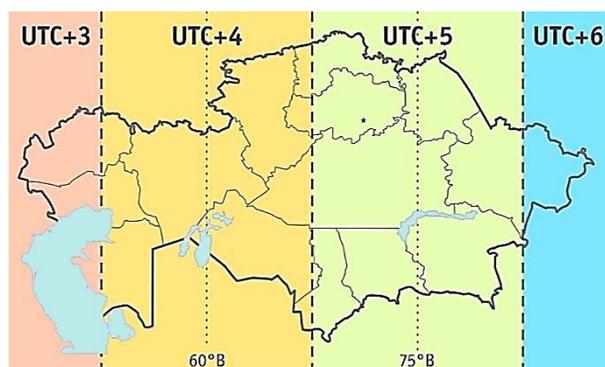


Fig. 1. Division of the Republic of Kazakhstan into geographic time zones (<https://www.google.com/>).

As shown in Fig. 2, the images compare sunrise at 08:00 administrative time in Astana and in Atyrau. At this time, classes begin in all schools across both regions. While Astana's geographic time aligns with administrative time (UTC+5), Atyrau lies within the UTC+3/UTC+4 geographic time zone. Therefore, administrative time (UTC+5) in Atyrau runs 1.5–2 hours ahead of local solar time. As a result, school students in the region effectively have to be seated in class at what is 06:00–06:30 natural time. Firstly, this chronically deprives students of sleep; secondly, it impairs their ability to adequately absorb learning material during lessons (Atyrau Press 2023). According to global scientific data, inappropriate application of administrative time has a marked negative effect on the body. The earliest and main changes that manifest are disruptions to biological rhythms and sleep. Circadian rhythms orient our internal biological clock toward the sleep–wake cycle and help us adapt to a particular routine. If a person works at night or frequently changes their work schedule (e.g., night shifts), this disrupts circadian rhythms and leads to insomnia, fatigue, and cognitive decline. Sleep disturbance reduces restorative capacity and can impair memory, attention, and emotional state. Over time, it can disrupt glucose and lipid metabolism, decrease insulin sensitivity and melatonin secretion, and increase the risk of obesity, diabetes, and neurological disorders (Wang 2025).



Fig. 2. Sunrise in Astana (A) and Atyrau (B) relative to natural time zones (08:00 administrative time, 04 Dec 2024).

For children and adolescents, psychological and emotional health are key indicators. Frequent changes to schedules or misalignment of rest and activity times raise stress and anxiety levels. Combined with regular disruptions to the daily sleep schedule, this leads to heightened anxiety and persistent fatigue. In Atyrau, late sunsets and late sunrises cause students to go to bed late and wake up early. This, in turn, can provoke irritability and depression. It is well known that people have difficulty adapting to time used “ahead” of natural light. For example, a cohort study of adolescents ($n = 65$) found marked social jet lag in 71% of participants, especially in evening chronotypes. Adolescents with pronounced social jet lag had higher scores on anxiety (GAD-7), depression (BDI-II), and insomnia (ISI; Solveig Magnúsdóttir *et al.* 2024). Chronic sleep schedule disruption, along with anxiety and depressive states, also weakens the immune system. In adolescents, desynchronization (including that related to school schedules) increases the incidence of common colds and diminishes immune responses (e.g., reduced IgA levels and T-cell activity; Borrmann *et al.* 2024; McHill *et al.* 2025). Sleep disturbance and desynchronization reduce the activity of natural killer (NK) cells, hampering the body's ability to fight viruses and tumors. They also decrease secretion of key pro-inflammatory cytokines such as interleukin-1 (IL-1) and interleukin-6 (IL-6; Besedovsky 2012). A reduction in the adaptive immune response manifests as impaired development of T- and B-lymphocytes and slower responses to antigens. Evidence shows that

vaccination under chronic sleep deprivation provokes a weaker immune reaction. Chronic sleep disturbance and desynchronization also contribute to elevated cortisol levels, which, over the long term, suppress immunity and induce chronic inflammation—factors that can drive cardiovascular and autoimmune diseases (Irwin, 2019). Chronic sleep disruption adversely affects cognitive functions as well. It reduces overall performance, memory, attentional focus, and the ability to make decisions and solve complex problems (Alhola & Polo-Kantola 2007). When prolonged, this can cause “brain fog,” impairing mental activity and, in some cases, may even be associated with suicidal behavior (Porrás-Sieck *et al.* 2019). Researchers report a link between sleep disturbance and suicide risk, including meaningful associations between cognitive dysfunctions (e.g., impulsivity and emotional dysregulation) and heightened risks of suicidal thoughts and actions. Insufficient sleep increases the likelihood of errors at work, raising the risk of occupational injuries and accidents. A meta-analysis found that workers with sleep problems had a 1.62-fold higher risk of injury compared to those without such problems, implying that about 13% of workplace injuries can be attributed to sleep disturbance (Uehli 2014). These results are relevant both to researchers of sleep and to occupational health specialists. When discussing school students’ learning capacity and the errors that may occur in the learning process, these are measured by their ability to master the learning process. That is, beginning with chronotypes formed on the basis of biological rhythms, factors such as self-assessment, memory for different kinds of material, indicators of physical growth and development, the functions of the respiratory and cardiovascular systems, and the activity of the autonomic nervous system all play an important role. In our research, we conducted comprehensive studies of these indicators and identified their interrelationships. As noted above, although Atyrau Region is geographically located in the UTC+3 and UTC+4 time zones, it currently lives by UTC+5 administrative time. Studies show that using time “ahead” of natural light has a negative effect on the organism, including that of children and adolescents. Therefore, within the project AP23483545, “A comparative study of administrative time and social factors influences on the psychophysiology and level of academic performance of schoolchildren,” the aim of the study was to examine the psychophysiological indicators of adolescents studying in secondary schools in Atyrau City, Kazakhstan.

MATERIALS AND METHODS

Object and methods of the study

The research was carried out by scientists from the Kazakh National Women’s Teacher Training University (NJC) and the Institute of Genetics and Physiology of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The chief consideration was to avoid negative impacts on students’ psychological state; therefore, only non-invasive methods were used. In addition, informed consent for participation was obtained from adolescents and their legal guardians. Psychophysiological diagnostics were conducted to assess the development and functional characteristics of the nervous system in children and adolescents. Using a dedicated block of methods from the “NS-Psychotest” system, general psychological indicators were measured. Cognitive and neural processes such as memory, attention, and visuomotor reactions were assessed in children and adolescents.

Heart rate variability (HRV) analysis method. For all participants, HRV was recorded in the supine or seated position using the “VNS-Spektr” device (NeuroSoft LTD) according to the standard protocol. HRV indices obtained from short-term recordings are considered sensitive to various external influences, such as psycho-emotional load, physical strain, changes in body position, etc. Real-time preliminary protocols were recorded and processed in specially equipped, completely quiet rooms. By computerized spirometry (SpiroSpectrum software), we measured vital capacity, forced ventilation indices, and other parameters to determine adolescents’ functional respiratory capacity. Body composition (water, muscle, fat, bone fractions) was measured using a Tanita (Japan) device. Anthropometric indicators were measured; blood pressure and heart rate were recorded. Functional and physical performance levels were evaluated. Martinet–Kushelevsky test — 20 sit-to-stands in 30 seconds (pulse measured before the load in a sitting position, immediately after the load while standing, and again after 1 minute while seated). Orthostatic and clinorthostatic tests were performed. Forearm strength was measured with a hand dynamometer. In addition, students’ academic performance during first-shift and second-shift schooling was compared.

RESULTS

Modern urbanization and administrative decisions about time zones have resulted in official (administrative) time being ahead of natural geographical time, causing chronic circadian misalignment and social jetlag (Roenneberg 2016). Changes in administrative time, such as shifts in time zones or adjustments to clock settings, can lead to a

chronic mismatch between external (social) and internal (circadian) clocks. This desynchronization is associated with alterations in cardiovascular regulation, which can be objectively measured using heart rate variability (HRV) parameters. These changes may include a decrease in total power (TP), an increase in sympathetic activity [indicated by low-frequency (LF), LF normalized units (LFnu), and LF to high-frequency (HF) ratios], or, in some individuals, vagal responses. Additionally, there may be a decrease in RMSSD/pNN50, reflecting reduced parasympathetic activity, and variations in SDNN, which represents total variability. The HRV study aims to provide a scientifically valid interpretation of all the key indicators based on the protocols used and to connect the observed patterns to the potential effects of administrative time changes. Social jet lag is linked to poorer sleep quality, increased activation of the sympathetic nervous system in the morning, changes in hormonal levels such as cortisol and melatonin, decreased overall heart rate variability (HRV), a higher stress index (SI), and a greater risk of developing metabolic or cardiovascular disorders. Heart rate variability (HRV) provides insight into the influence of circadian rhythms on the autonomic nervous system. The indices HF, RMSSD, and pNN50 measure parasympathetic activity, while LF, LFnorm, and LF/HF reflect sympathetic regulation. The VLF index relates to humoral-metabolic pathways, and SDNN and TP measure the overall regulatory power of the system.

It is particularly informative to examine morning baseline indicators and responses to the orthostatic test, as the effects of circadian misalignment are most pronounced in the morning hours. This study examines morning data from patients (14-16 years old) to assess how early 'administrative morning' influences heart rate regulation.

The sample was randomly selected and included HRV analysis from 96 volunteers, consisting of 49 boys and 47 girls. Background HRV recording was conducted in the supine position, followed by an orthostatic test that involves transitioning to a vertical position. The analysis includes RR intervals and assessments of time, spectral, and integral parameters. Interpretation based on the guidelines provided by the European and American Cardiological Associations (Task Force 1996). The analysis of heart rate regulation in school-aged adolescents focused on background and orthostatic responses. The findings revealed that most participants exhibited signs of circadian desynchrony. This desynchrony was characterized by a reduction in total heart rate variability (HRV) power, increased sympathetic activation in the morning (as indicated by the LF/HF ratio), decreased vagal modulation (measured by HF), and heightened reactivity during orthostatic testing. These results support the social jet lag model and confirm that shifts in official time can have a significant impact on autonomic regulatory mechanisms (Table 1).

Table 1. Summary table of key HRV indicators for adolescents.

Indicator	Boys (n = 49)		Girls (n = 47)	
	Background	Orthostatic	Background	Orthostatic
HR, beats (min)	79.5 ± 7.8	102.4 ± 9.5*	82.3 ± 8.1	109.7 ± 10.2*
SDNN (ms)	63.20 ± 10.5	36.20 ± 6.8*	66.35 ± 11.0	40.78 ± 7.1*
RMSSD (ms)	58.70 ± 12.0	43.40 ± 9.2*	69.00 ± 14.3	50.55 ± 11.2*
pNN50 (%)	116.0 ± 22.5	90.5 ± 18.1*	137.5 ± 26.0	100.25 ± 21.4*
TP (ms ²)	2757.5 ± 530.3	2441 ± 480.5*	2374.5 ± 460.3	2094.3 ± 412.5*
LF (ms ²)	831.7 ± 170.1	945 ± 190.5*	1015 ± 213.7	1098.8 ± 231.2*
HF (ms ²)	988.4 ± 210.6	1426.5 ± 261.7*	1324 ± 274.5	1707 ± 314.6*
LFnorm (%)	47.63 ± 8.1	29.08 ± 6.5*	45.44 ± 7.5	16.61 ± 5.1*
HFnorm (%)	52.37 ± 8.4	31.63 ± 6.8*	54.56 ± 7.9	17.42 ± 5.4*

* Reliability (p < 0.001).

Table 1 shows that heart rate (HR) values are higher than expected for adolescents, whose normal resting HR typically ranges from 70 to 75 beats per minute. During orthostatic testing, HR increases substantially, reaching 102–110 beats per minute. Such elevated values indicate a state of chronic sleep deprivation. When adolescents experience a shift in their sleep schedule, they are effectively forced to wake during their biological “night,” which has adverse effects on physiological regulation. In addition, a decrease of more than 35–40% in SDNN and RMSSD, two key indicators of heart rate variability during orthostasis, reflects sympathetic activation, reduced vagal tone, and growing fatigue. Due to the shift in sleep timing, adolescents tend to go to sleep late and wake up earlier than their biological rhythm allows, resulting in a marked decline in vagal HRV parameters. High HF and RMSSD values at rest, especially in girls, indicate a strong parasympathetic reserve. However, when switching to the orthostatic position, these values drop sharply. This pattern suggests reduced adaptive capacity, meaning the body experiences stress when changing posture. In this context, social jet lag contributes to unstable autonomic regulation: parasympathetic activity appears high at rest but decreases abruptly under physiological load. The study results show a decrease in LFnorm and an increase in HFnorm during orthostasis. In healthy adolescents, the typical response to standing is the opposite: LFnorm should increase, while HFnorm should decrease. In our

data, however, LFnorm decreases from 47% to 29% in boys and from 45% to 16% in girls. This atypical pattern indicates a dysregulated autonomic response, characterized by vagotonic autonomic dysfunction and overload of the regulatory systems. HRV findings reveal that chronic sleep deprivation leads to circadian desynchrony (social jet lag), less efficient heart rate regulation, heightened sympathetic activity during the day, and inadequate nighttime recovery. Administrative time advancement forces adolescents to live "out of sync with solar time." They fall asleep late but must wake before their circadian rhythms permit. Consequently, they show higher stress indices and heart rates, along with poorer adaptability to physiological stressors, such as orthostatic vagal decline. In summary, administrative time shifts misalign circadian rhythms and impair adaptive mechanisms. To illustrate, three adolescents (A, B, and C) were studied. Their HRV profiles exhibited increased sympathetic tone, reduced vagal modulation during orthostasis, and signs of hyperreactivity. Although some measurements were better balanced, all three demonstrated a significant rise in LF during standing, denoting autonomic imbalance (Table 2).

Table 2. Results of HRV indicators of adolescents A, B, C in the background and orthostatic position.

Indicator	A		B		C	
	background	orthostatic	background	orthostatic	background	orthostatic
HR, beats (min)	78.6	120.8	76.2	83.9	77.3	96.7
SDNN (ms)	42	21	34	60	33	40
RMSSD (ms)	37	17	55	24	38	26
pNN50 (%)	16.1	0.0	46.9	4.1	17.4	5.2
TP (ms ²)	2215	331	689	4106	1035	1586
VLF (ms ²)	407	66	199	3271	256	401
LF (ms ²)	1287	235	79	698	304	860
HF (ms ²)	521	30	412	136	475	325
Lfnorm (%)	71.2	88.5	16.1	83.7	39.1	72.6
Hfnorm (%)	28.8	11.5	83.9	16.3	60.9	27.4
LF/HF	2.47	7.72	0.19	5.12	0.64	2.65

Key Observations (Patient Summary).

Patient A: Baseline: Heart Rate (HR) \approx 78.6 bpm; SDNN 42 ms; RMSSD 37 ms; pNN50 16.1%; Total Power (TP) = 2215 ms²; Low Frequency (LF) = 1287 ms²; High Frequency (HF) = 521 ms²; LFnorm = 71.2%, HFnorm = 28.8%; LF/HF ratio = 2.47.

Orthostasis: Severe tachycardia with HR of 120.8 bpm, a sharp decrease in RR metrics, and HF power (HF = 30 ms²). LFnorm = 88.5%, LF/HF ratio = 7.72. Stress indicators and indices (SI, etc.) are significantly elevated during orthostasis (Fig. 3). Interpretation: At rest, there is moderate relative sympathicotonia (LF predominates), but overall regulatory activity (TP) is below average. The reactivity during orthostatic loading shows a hypersympathetic response (a sharp increase in LF relative to HF), indicating a strong compensatory sympathetic response and limited parasympathetic reserve. This pattern is typical for individuals experiencing chronic partial desynchronosis or those with nocturnal sleep deprivation and morning stress.

Assessment of patient A's regulatory mechanisms according to the protocol

Overall activity of regulatory mechanisms (TP): below average.

Activity of humoral-metabolic/central regulatory mechanisms (VLF): low.

Activity of the sympathetic nervous system (LF): average.

Activity of the parasympathetic nervous system (HF): low.

Description of the relationship between regulatory mechanisms

Relative contribution of humoral-metabolic/central regulatory mechanisms within physiological limits.

Balance of the autonomic nervous system: relative sympathicotonia.

Regulatory system tension (according to R.M. Baevsky's method): average tension.

Assessment of regulatory system reactivity

Reactivity of the parasympathetic nervous system: low.

Reactivity of the sympathetic nervous system: below average.

Patient B: Baseline: HR 76.2 bpm; SDNN 34 ms; RMSSD 55 ms; pNN50 46.9%; TP 689 ms² (low overall activity); LF 79, HF 412 ms²; LFnorm 16.1%, HFnorm 83.9%; LF/HF = 0.19 (marked vagotonia at rest).

Orthostatic: TP increases to 4106 ms², with sharp increases in LF and VLF (LF = 698, VLF = 3.271), LFnorm

rises to 83.7%, while HFnorm drops to 16.3%; LF/HF=5.12; 30/15 ratio = 1.46 — indicating high sympathetic reactivity (Fig. 4).

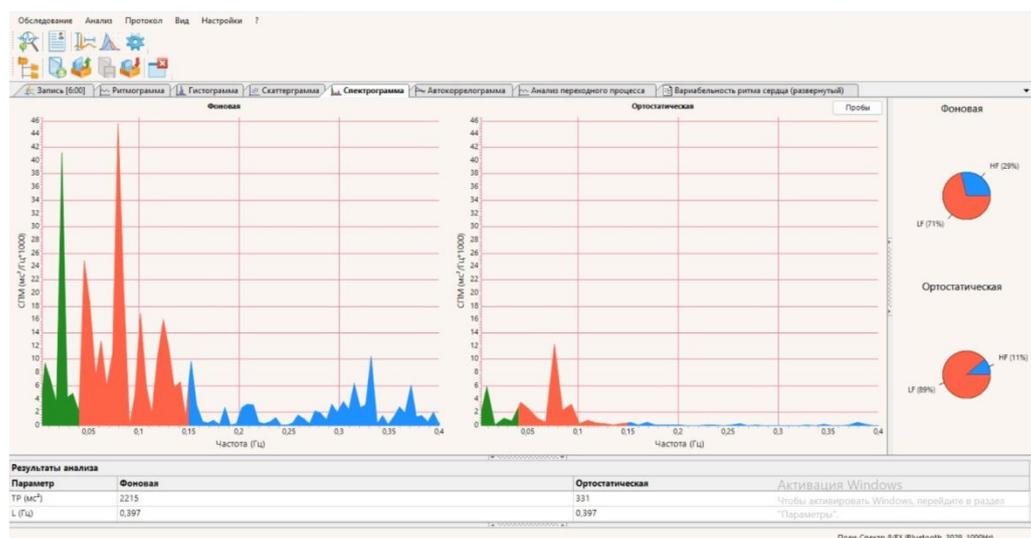


Fig. 3. Spectrogram of teenager A.

Interpretation: This subject displayed predominantly parasympathetic tone at rest, as indicated by high RMSSD and pNN50 values. However, during orthostasis, the data show a strongly reactive sympathetic response, characterized by a sharp increase in total power and VLF. This pattern reflects a “high-tension” state of the regulatory systems, likely associated with pronounced morning compensation (a rapid activation of sympathetic activity upon standing). Such a contrast typically indicates good adaptive flexibility. However, under conditions of chronic circadian desynchrony, this pattern may also signal the potential for regulatory fatigue and an increased risk of autonomic imbalance when exposed to repeated stressors.

Assessment of patient B's regulatory mechanisms according to the protocol

Overall activity of regulatory mechanisms (TP): low.

Activity of humoral-metabolic/central regulatory mechanisms (VLF): low.

Activity of the sympathetic nervous system (LF): low.

Activity of the parasympathetic nervous system (HF): low.

Description of the relationship between regulatory mechanisms

Relative contribution of humoral-metabolic/central regulatory mechanisms within physiological limits.

Balance of the autonomic nervous system: relative vagotonia.

Regulatory system tension (according to R.M. Baevsky's method): high tension.

Assessment of regulatory system reactivity

Reactivity of the parasympathetic nervous system: above average.

Reactivity of the sympathetic nervous system: high.

Patient C: Background: HR 77.3 bpm; SDNN 33 ms; RMSSD 38 ms; pNN50 17.4%; TP = 1035 ms²; LF 304, HF 475 ms²; LFnorm 39.1%, HFnorm 60.9%; LF/HF = 0.64 — vagal component dominance at rest. Orthostatic: increase in LF (860 ms²), decrease in HF (325 ms²), LFnorm 72.6%, LF/HF = 2.65; reactivity — average.

Interpretation: The profile is similar to the adaptive vagotonic type at rest, with adequate sympathetic mobilization during orthostasis. Overall regulatory activity is low, which may indicate submaximal reserves (TP below average), potentially associated with chronic mild sleep retardation or decreased sleep quality (Fig. 5).

Regulatory mechanism activity assessment

Total regulatory mechanism activity (TP): low.

Humoral-metabolic/Central regulatory mechanism activity (VLF): low.

Sympathetic nervous system activity (LF): low.

Parasympathetic nervous system activity (HF): low.

Description of regulatory mechanism relationships

Relative contribution of humoral-metabolic/central regulatory mechanisms within physiological values.

Balance of autonomic nervous system divisions: relative vagotonia.

Regulatory system stress (according to R.M. Baevsky's method): high stress.

Assessment of regulatory system reactivity

Parasympathetic nervous system reactivity: medium.

Sympathetic nervous system reactivity: medium.

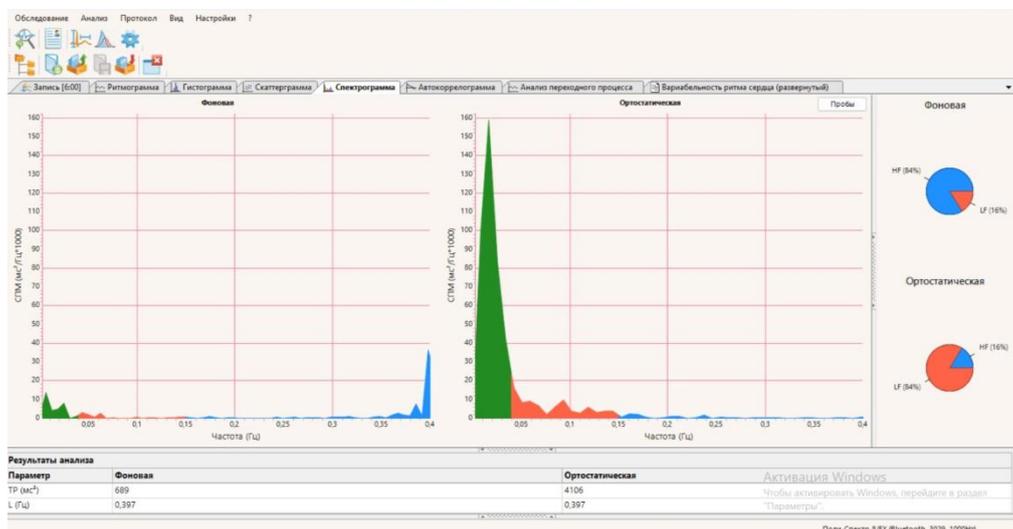


Fig. 4. Spectrogram of teenager B.

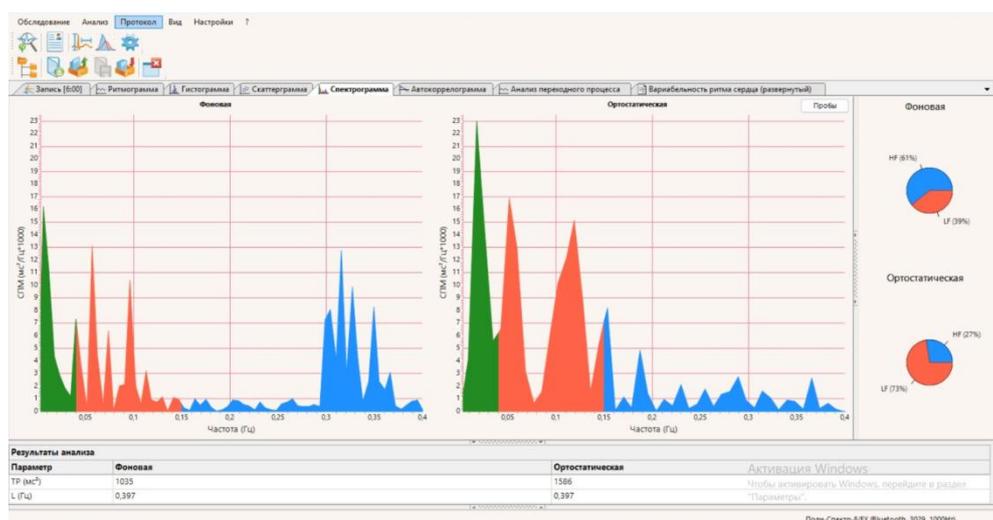


Fig. 5. Spectrogram of teenager C.

Chronic desynchrony and variability of responses were observed in two of the three subjects, A and C. Subject A exhibited relative sympathicotonia, while subject C displayed vagotonia with low overall activity at rest. When the administrative time was advanced (for example, through forced awakenings in the morning before the biological morning), a reduction in total power (TP), indicating decreased overall variability, was noted in some individuals due to insufficient recovery during the night. This was evident in subjects A and B, with TP measurements of 2215 ms² and 1035 ms², respectively, both below the optimal levels for young adults. Additionally, there was a pronounced decrease in high-frequency power (HF), which represents parasympathetic activity, during the morning hours and during orthostasis. In subject A, HF dropped significantly from 521 ms² to 30 ms². This decrease correlates with impaired nocturnal recovery and an increased sympathetic response in the morning. Increased sympathetic reactivity during orthostasis was observed in all three subjects, particularly in Subjects B and A. Their orthostatic recordings show a pronounced rise in LFnorm and LF/HF ratios, indicating strong sympathetic mobilization upon standing. Such an imbalanced response is characteristic of both chronobiological desynchrony and social jet lag, where a “forced” early-morning awakening triggers excessive sympathetic activation as a compensatory mechanism. Stress indices (SI, AMo, Mo) are key markers of

“regulatory system tension”. Significant changes in these indicators during orthostasis reflect increased physiological stress. Such shifts may be associated with repeated early-morning awakenings, accumulated sleep debt, or disturbances in circadian rhythms. Chronic systematic shifting of wake/sleep timing results in reduced nocturnal recovery (lower TP and HF), increased morning sympathetic reactivity, and the potential for cardiovascular risk with long-term exposure. Analysis of HRV recordings indicates that advancing administrative time is typically associated with decreased total regulatory system power (TP) in some subjects, reduced morning parasympathetic activity (HF), and heightened sympathetic reactivity during orthostatic tests. These physiological changes align with models of chronic circadian desynchrony elevate cardioautonomic stress. Individualized approaches involving customized sleep schedules, light therapy, and lifestyle modifications are needed. Additional research with larger samples and chronotype controls is necessary to assess risk and inform population-level guidelines. Desynchronosis arising from disrupted sleep schedules, improper use of the time zone, or prolonged night-time gadget use can also negatively affect adolescents’ respiratory systems. Circadian rhythms regulate not only sleep but also respiratory rate, ventilation, and gas exchange (Jones *et al.* 2024). Under desynchronosis, fluctuations in breathing rate and reduced stability are observed.

Table 3. Effects of desynchronosis on the respiratory system.

Indicator	Change during desynchronosis	Main reasons for the change
VC (Vital capacity of the lungs)	Slightly increased (sometimes within the norm)	Hyperventilation and deep breathing as a reaction to stress or mild hypoxia
FVC (Forced vital capacity)	Mostly increased	Activation of the sympathetic nervous system, rapid breathing, functional increase in effort during expiration
FEV ₁ (Forced expiratory volume in 1 second)	Often no marked change, or only slightly increased	More intensive breathing work, but no improvement in bronchial conductance
Ratios: FEV ₁ /VC and FEV ₁ /FVC	No clear change	No bronchial pathology; changes are functional
Respiratory rhythm (respiratory rate)	Increased	Sympathetic activation, stress, insomnia
Gas exchange (O ₂ , CO ₂)	Hypocapnia (↓CO ₂) only during hyperventilation; with sleep insufficiency, moderate hypoxia may be observed	Over-ventilation of the lungs or dysregulation of the respiratory control center
Overall condition of the respiratory system	Functional changes; no structural alterations	The body’s attempt to compensate for circadian rhythm disruption and stressful influences

In our study, we measured adolescents’ VC (vital capacity of the lungs) and FVC (forced vital capacity). When analyzing the sample by sex (boys and girls), the majority showed elevated VC and FVC values (Table 5).

Table 4. Respiratory system capacity in adolescents.

Respondents	FVC (L)	Reference value (L)	Percentage of deviation from reference (%)	VC (L)	Reference value (L)	Percentage of deviation from reference (%)
Boys (n = 50)	3.20 ± 1.37	1.76 ± 0.09	181.54 ± 79.07	4.08 ± 1.57	1.76 ± 0.09	231.48 ± 88.05
Significance of change			$p \leq 0.05$			$p < 0.0001$
Girls (n = 50)	2.34 ± 0.86	1.55 ± 0.06	147.54 ± 58.87	3.07 ± 1.02	1.55 ± 0.06	198.48 ± 65.70
Significance of change			$p \leq 0.05$			$p < 0.001$

Based on the data obtained—taking into account the state of desynchronosis (administrative time being ahead of natural time) and drawing on scientific sources—the following interpretation can be offered. The increases in VC (vital capacity) and FVC (forced vital capacity) values (on average by 147–231% of the reference values) can be regarded as compensatory reactions of the respiratory system to the chronic effects of desynchronosis. In other words, the 1.5–2-hour advance of administrative time over natural time in Atyrau leads to a systematic shift in adolescents’ circadian rhythms, causing later bedtimes and earlier wake-ups and thus shortening sleep duration. As a result, there is an increase in morning respiratory rate and a compensatory rise in pulmonary ventilation. Compared to boys, girls generally show lower mean VC and FVC values, which corresponds to typical sex differences. However, the excess over the expected (reference) values indicates desynchronosis as a pronounced stress factor. A number of studies show that girls more often suffer from sleep disturbances and circadian phase

shifts (Troekel & Manber 2022). Given this, fluctuations in hormonal processes in girls can also lead to impairments in the function of the reproductive organs. Disruption of the body's biorhythms leads to chronic fatigue, "social jet lag," decreased sleep quality, and changes in adolescents' breathing patterns (Wittmann *et al.* 2006; Touitou & Smolensky 2019). In response to morning sleepiness and hypoxia arising from insufficient sleep and a shifted wakefulness period, increased lung ventilation and higher VC are observed (Martinez-Nicolas *et al.* 2020). Chronic desynchronosis is associated with altered autonomic regulation of breathing and changes in respiratory rate—findings that are confirmed by data on adolescents living in regions where administrative time does not coincide with natural time (Magnusdottir *et al.* 2024). The data for adolescents in Atyrau may therefore reflect the chronic effects of desynchronosis, showing substantial deviations from reference values. The persistent mismatch between biological and social time leads to remodeling of the respiratory system, increased ventilation, and instability of the breathing rhythm, which may have long-term adverse health effects. High VC and FVC values under desynchronosis are not indicative of improved respiratory function; rather, they may be observed for several reasons linked to the body's functional adaptive responses. The first is hyperventilation. As a result of desynchronosis (shifted biorhythms, sleep disruption), anxiety and stress levels rise, respiratory rate increases, and the volumes of inhalation and exhalation become larger. Chronic insomnia and changes in biological rhythm cause tissue hypoxia (reduced oxygenation of tissues). The body attempts to compensate for this through deeper breathing and expansion of lung volume—i.e., through the compensatory function of the respiratory system. Elevated VC and FVC can also be explained by activation of the sympathetic nervous system due to desynchronosis—higher cortisol and adrenaline levels enhance the work of the respiratory muscles and raise these indicators in functional tests. Since breathing patterns are unstable, adolescents may breathe more rapidly and deeply before measurements are taken, which increases volumetric indicators but does not reflect the lungs' true steady-state function. Over the long term, desynchronosis typically reduces overall respiratory efficiency; without training or hyperventilation, persistently high VC and FVC are most often a functional phenomenon associated with stress-induced remodeling of respiration. In studying the physiological, anthropometric, and metabolic indicators of Atyrau school students—and their annual morbidity—we observed several deviations from average values (Tables 5-6).

Table 5. Comparison of adolescents' physiological and anthropometric indicators with normative values.

Indicator	Girls (n = 50)			Interpretation
	Mean ± SD	Norm (WHO, NHANES)	p	
Morbidity frequency (per year)	3.21 ± 0.87	1–1.5	<0.001	Significantly higher
Hand-grip strength (kg)	19.51 ± 2.69	20–25	0.04	Below norm
Height (cm)	162.17 ± 4.37	160–165	0.88	Within norm
SpO ₂ (%)	99.25 ± 0.46	97–100	0.07	Within norm
Pulse (beats min ⁻¹)	87.42 ± 10.44	70–80	<0.01	Significantly above norm
Systolic BP (mmHg)	113.4 ± 7.23	110–120	0.42	Within norm
Diastolic BP (mmHg)	76.6 ± 7.09	70–80	0.36	Within norm

Indicator	Boys (n = 50)			Interpretation
	Mean ± SD	Norm (WHO, NHANES)	p	
Morbidity frequency (per year)	1.02 ± 1.05	1–1.5	0.09	Normal (tendency to be lower)
Hand-grip strength (kg)	33.16 ± 5.23	35–45	<0.001	Considerably below norm
Height (cm)	174.32 ± 4.91	172–178	0.62	Within norm
SpO ₂ (%)	98.31 ± 0.71	97–100	0.27	Within norm
Pulse (beats min ⁻¹)	82.38 ± 12.86	70–80	0.08	Within norm (tendency upward)
Systolic BP (mmHg)	117 ± 8.71	110–120	0.38	Within norm
Diastolic BP (mmHg)	76 ± 6.93	70–80	0.45	Within norm

As for morbidity frequency, girls showed a significantly higher annual incidence of illness (3.21 ± 0.87) compared to boys (1.02 ± 1.05). Given that 1–1.5 acute illnesses per year is regarded as the norm for adolescents, the values found in girls can be viewed as a significant deviation. The increase in illness can be explained by chronic sleep deprivation and reduced immune resistance against the background of desynchronosis. This is consistent with reports on the adverse effects of shifted sleep schedules on the immune system (Smolensky *et al.* 2017).

Muscle strength. Although adolescents' hand-grip strength indicators were within age norms, the mean value for girls was close to the lower bound of the physiological norm. Given that muscle strength is closely tied to

restorative processes during sleep and to growth-hormone secretion, we consider this reduction to be the result of chronic effects caused by shifts in sleep and wake times.

Height. The average height for girls was 162.17 ± 4.37 cm and for boys 174.32 ± 4.91 cm, corresponding to age norms. No marked differences attributable to desynchronization were identified in this group. However, studies show that chronic sleep deprivation may, in the long term, slow growth and disrupt physical development (James & Hale 2016).

Cardiovascular indicators. For SpO₂, no significant differences related to desynchronization were found. Regarding heart rate, girls had a higher resting rate than boys (87.42 ± 10.44 beats min⁻¹ vs. 82.38 ± 12.86 beats/min). Since the normal range for adolescents is 70–80 beats min⁻¹, we can say girls show a tendency toward tachycardia. This may reflect morning sleep insufficiency and increased sympathetic nervous-system activity typical of desynchronization, especially among respondents with an “owl” chronotype.

Blood pressure. Mean blood pressure in girls was $113.4/76.6 \pm 7.23/7.09$ mmHg and in boys $117/76 \pm 8.71/6.93$ mmHg; overall, these values are within age norms (110–120 / 70–80 mmHg). Only a few girls showed a slight increase in diastolic pressure, which may be associated with the morning stress component of cardiovascular activation when sleep and wake phases are misaligned.

Thus, the dataset indicates the presence of signs of desynchronization in adolescents, more frequently in girls. If prolonged, it increases the risk of chronic fatigue, reduced cognitive performance, and susceptibility to infections. This is reflected in higher morbidity, a tendency to tachycardia and elevated diastolic pressure, as well as decreased muscle strength. In boys these changes were not pronounced, which is consistent with the hypothesis that males have greater physiological tolerance to shifts in biorhythms. In analyzing metabolic-level indicators in adolescents in Atyrau, we obtained the following results (Table 6). Among girls, body weight and overall body-composition measures corresponded to normative values, but a subset of respondents showed a tendency toward a higher percentage of adipose tissue. Psychophysiological fatigue, reduced physical activity, chronic sleep insufficiency, and morning sleepiness lower activity and energy expenditure in adolescents and promote fat accumulation. In addition, hormonal changes, specifically reduced melatonin secretion, disturb the balance of leptin and ghrelin. As a result, adolescents, particularly in the evening, overeat relative to the norm, leading to an increase in fat mass. Chronic desynchronization worsens glucose tolerance, which in turn activates lipogenesis (fat storage). In boys, there was a statistically significant decrease in the percentage of adipose tissue and an elevation in the proportion of muscle mass compared to the norm ($p < 0.01$). Such changes can be regarded as adaptive reactions, but under chronic desynchronization they may also be accompanied by accelerated expenditure of energy resources. In both groups, basal metabolic rate remained within normal limits, indicating preservation of the body’s overall energy balance. At the same time, girls showed a somewhat higher percentage of adipose tissue, while boys displayed a clear predominance of muscle mass: sex-specific differences in adaptation to desynchronization. Thus, the 1.5–2-hour advance of administrative time over natural time creates a chronic state of desynchronization that promotes changes in adolescents’ bodies, revealing differences in the physiological adaptive capacities of boys and girls. To prevent potential metabolic disturbances, the school schedule in the western regions of Kazakhstan should be optimized with adolescents’ chronotypes and the administrative-time regime in mind.

Table 6. Indicators of metabolic level in adolescents.

Indicator	Norm	Girls (n = 50)	Boys (n = 50)	p (deviation from norm)
Weight (kg)	F: 50–55; M: 55–65	55.2 ± 7.94	62.19 ± 9.5	< 0.05 (girls above norm; boys within norm)
Body fat (%)	F: 20–25; M: 10–15	20.45 ± 6.40	8.99 ± 4.18	Girls within norm; boys below norm ($p < 0.01$)
Muscle mass (%)	F: 36–40; M: 45–52	40.81 ± 2.61	53.13 ± 5.57	Girls within norm; boys above norm ($p < 0.01$)
Total body water (%)	F: 52–56; M: 60–65	55.51 ± 3.97	66.28 ± 4.56	Within norm
Bone mass (kg)	F: ~2.2; M: ~2.8	2.19 ± 0.14	2.81 ± 0.26	Within norm
Basal metabolism (kcal)	F: 1300–1400; M: 1600–1700	1351.76 ± 88.73	1677.71 ± 177.39	Within norm

Alongside psychophysiological indicators, we collected information on students’ academic performance in relation to the administrative time zone. Specifically, we analyzed the achievement of participating students in

humanities and in natural sciences when they studied in the afternoon and before noon—i.e., in Grades 8 and 9, respectively. Delayed sleep phase syndrome or disruption of circadian rhythms in adolescents leads to a significant decline in academic performance. Studies report that adolescents with such disturbances show lower average grades, partial absenteeism, daytime sleepiness, and insufficient sleep (Hysinget *et al.* 2016).

In our dataset, students studied in the afternoon in Grade 8 and before noon in Grade 9. Comparing their cumulative grades in each subject across Grades 8 and 9 yielded the following results (Tables 7 and 8).

Table 7. Students' average score in general humanities subjects (n = 112).

Grade	Kazakh language	History of Kazakhstan	English	Russian language & literature	Kazakh literature	Overall (general humanities subjects)
Grade 8	3.62	3.78	3.72	3.79	3.61	3.70 ± 0.071
Grade 9	3.49	3.64	3.69	3.7	3.51	3.61 ± 0.084
Decrease in performance, %	-3.6	-3.7	-0.8	-2.4	-2.8	-2.6
Statistical significance						p<0.001

Table 8. Students' average score in mathematics & natural-science subjects (n = 112).

Grade	Algebra	Physics	Chemistry	Biology	Overall (mathematics & natural-science subjects)
Grade 8	3.58	3.79	3.65	3.7	3.68 ± 0.065
Grade 9	3.52	3.61	3.48	3.62	3.55 ± 0.057
Decrease in performance (%)	-1.7	-4.7	-4.7	-2.2	-3.3
Statistical significance					p < 0.001

Changes in academic performance between the periods when Atyrau students studied in the afternoon and when they studied before noon showed declines in several individual subjects. From a chronobiological perspective, adolescents are generally closer to the “owl” type. Accordingly, their circadian rhythms are shifted later, and their peak cognitive activity typically falls around midday or in the afternoon. When the respondents in our study attended classes in the afternoon in Grade 8, the start of lessons coincided with their period of higher alertness, and their productivity was correspondingly higher. In Grade 9, however, lessons began in the morning, and since administrative time in Atyrau Region is 1.5–2 hours ahead of geographic time—students were not able to wake naturally. As a result, brain activity was lower, and especially among adolescents there was a decline in cognitive level due to sleep insufficiency. As noted above, this can be corroborated by the decrease in memory for images and for numbers. Consequently, a decline in performance was observed across all subjects. Humanities fell by an average of –2.6%, slightly less than mathematics and natural sciences (–3.3%). Lower productivity in math and science is explained by the need for maximal concentration to process logically demanding material and by the fact that early morning hours under “ahead” administrative time are particularly difficult for adolescents. This is also supported by our finding of reduced numerical memory in the adolescents studied. It should also be noted that in humanities subjects, a slight reduction in attention may cause the loss of some details but does not completely distort comprehension or outcomes. Group discussions, oral answers, and extensive text work in humanities classes stimulate the nervous system and help students “wake up.” By contrast, in mathematics and physics a single error in a logical chain leads to an incorrect answer. Work in mathematics and the natural sciences is often individual and highly attention-dependent, usually conducted in quiet settings where decreased concentration is amplified. During the morning “cognitive fog,” this occurs frequently and grades decline markedly. Improper application of the school schedule to administrative time creates a mismatch between adolescents' biological clocks and natural time. This results in reduced sleep duration and quality, slower cognitive processing, diminished long-term memory, and an increased number of errors—effects that are confirmed by our cognitive findings. Here we see a classic sequence: early start of classes → sleep insufficiency and morning cognitive “inhibition” → decreased academic performance.

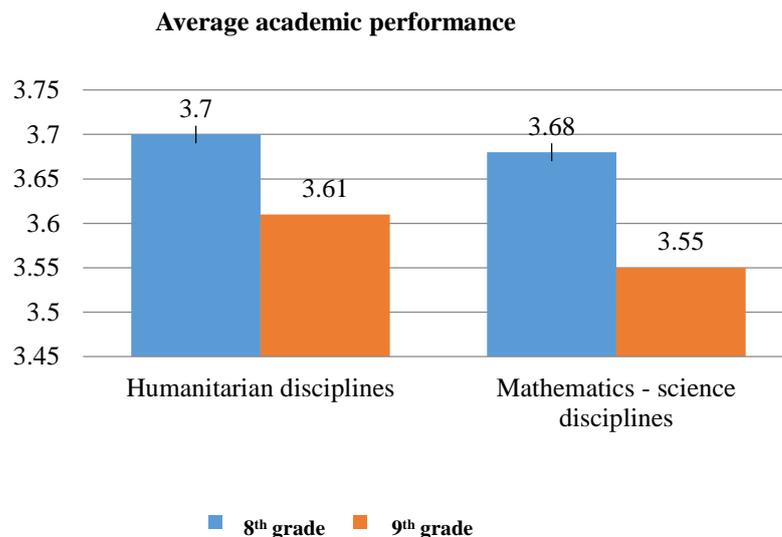


Fig. 6. Indicators in general humanities and mathematics and natural sciences disciplines.

The academic-performance results show that the natural-science and mathematics subjects are particularly sensitive to desynchronization caused by the advance use of administrative time. We believe the main reason is that these subjects require a high level of abstract thinking and sustained attention. The more pronounced decline in the science–mathematics cycle under desynchronization is consistent with the scientific literature. Even a small percentage drop in grades can, over the long term, accumulate into learning gaps and reduce motivation.

DISCUSSION

Among adolescents in Atyrau, it was established that using administrative time 1.5–2 hours ahead of natural time—and, accordingly, starting school earlier—leads to social jet lag and chronic desynchronization. Under the current schedule, which corresponds to about 6:00 a.m. natural time, the vast majority of students with “owl” and “pigeon” chronotypes (96.2%) begin studying before their natural wake-up period. This becomes a persistent factor that, on school days, causes chronic sleep deprivation, disrupts hormonal regulation (cortisol, and melatonin), lowers morning cognitive productivity, and weakens immune defenses. Adolescents experience a significant reduction in sleep on school days and pronounced social jetlag. Teenagers with an evening chronotype show even more pronounced sleep problems and psycho-emotional symptoms (Solveig Magnúsdóttir *et al.* 2024). Considering the desynchronization in adolescents of the Atyrau region, caused by a 1.5–2-hour difference in administrative time, this highlights the importance of addressing adolescents’ mental health. According to the results of the study, schoolchildren in Atyrau showed changes in metabolic processes under the influence of desynchronization. This is also supported by literature, where fluctuations in the circadian system during desynchronization lead to metabolic disturbances, particularly impairments in carbohydrate and lipid regulation (Roenneberg *et al.* 2012; Wang 2025). As our results show, administrative time being ahead of natural time leads to instability in productivity and a general decrease in cognitive efficiency among Atyrau students. The impact of sleep duration and sleep quality on psycho-emotional well-being, attention, and memory plays a significant role. According to the literature, the association between sleep duration and well-being is nonlinear (U-shaped): both very short and very long sleep are associated with higher levels of behavioral problems and poorer physical health compared to average sleep duration (James & Hale 2017). The findings also indicate the presence of desynchronization in adolescents, especially among girls and respondents with an “owl” chronotype. This is manifested in increased illness frequency, tachycardia, a mild elevation of diastolic pressure, and reduced muscle strength. The results confirm the need to account for chronobiological factors when coordinating school timetables and organizing preventive measures to protect adolescents’ health. The authors (Cespedes Feliciano 2019) conclude that circadian rhythm synchronization and healthy sleep regularity are critically important for maintaining adolescents’ mental well-being. Disruptions in these processes are often reflected in increased anxiety, depression, emotional difficulties, and other mental health problems. Effective strategies should take into account both the biological characteristics of adolescent sleep and the influence of social factors (school schedules, technology use, etc.) in order to improve sleep quality and reduce the risk of mental disorders. In this context, for

school students living in areas of Atyrau Region where administrative time is misaligned with natural time (used “ahead”), we consider it necessary to provide psychological-pedagogical support; to monitor sleep using questionnaires and objective methods (e.g., actigraphy); to promote adherence to sleep hygiene; and to revisit the timing of school schedules. The results of the study showed that the use of administrative time 1.5–2 hours ahead of natural time in Atyrau adolescents led to persistent desynchrony. This condition contributed to a decrease in the duration and quality of sleep, a decrease in cognitive performance, psychoemotional instability, and a weakening of the immune system. The predominance of the “owl” and “pigeon” chronotypes among adolescents indicated that their natural biological rhythms did not correspond to the school schedule. As a result, the indicators of memory, attention, and visual-motor reactions were below average. The decrease in cognitive abilities, especially in the morning hours, was reflected in the level of student performance. In the 9th grade (when classes began in the morning), a decrease in grades was recorded in all subjects, which proves the direct impact of desynchrony on academic performance. The study demonstrates a clear and independent association between sleep problems and poor academic performance in adolescents. The authors emphasize the importance of assessing and intervening in sleep patterns when adolescents experience difficulties with school performance (Hysing *et al.* 2016). In our case, changes are required in the school schedules of the Atyrau region. Physiologically, compensatory reactions in the respiratory system, increased heart rate, and a significant increase in the incidence of diseases in girls were detected. These data indicate that chronic desynchrony leaves a clear mark on the health of adolescents. Based on these results, we recommend shifting the start time of classes for schoolchildren in regions where administrative time is far from natural time to 8:30–9:00, maintaining sleep hygiene, psychological and pedagogical support, and strengthening preventive measures. The educational process, organized taking into account chronobiological features, allows preserving the psychophysiological health of adolescents and improving the quality of education.

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REFERENCES

- Alhola, P & Polo-Kantola, P 2007, Sleep deprivation: Impact on cognitive performance. *Neuropsychiatric Disease and Treatment*, 3 (5): 553-567.
- Atyrau Press 2023, Atyrau ranks last in terms of the quality of education in the Republic. <https://atpress.kz/ru/news/obrazovanie/atyrau-na-poslednem-meste-po-kachestvu-obrazovaniya-po-respublike>.
- Beal, SJ, Grimm, KJ, Dorn, LD & Susman, EJ 2016, Morningness/eveningness and physical activity in adolescent girls: Variation across puberty and associations with depressive symptoms. *Journal of Youth and Adolescence*, 45: 232-245, <https://doi.org/10.1007/s10964-015-0292-5>.
- Borrmann, H, Lange, T & Born, J 2024, Circadian disruption impairs innate and adaptive immune responses: A systematic review. *Sleep Medicine Reviews*, 73: 101789, DOI:10.1016/j.smrv.2024.101789.
- Besedovsky, L, Lange, T, & Born, J 2012, Sleep and immune function. *Pflügers Archiv-European Journal of Physiology*, 463(1): 121-137, DOI: 10.1007/s00424-011-1044-0.
- Cespedes Feliciano, EM 2019, Sleep and circadian rhythm disruptions in adolescence and their effects on mental health: A review. *Journal of Clinical Sleep Medicine*, 15(7): 957-964, DOI: 10.5664/jcsm.7804.
- Cooper, R, Creswell, C & Daws, RE 2023, Development of morning–eveningness in adolescence: Implications for brain development and psychopathology. *Journal of Child Psychology and Psychiatry*, 64(1): 4-18, <https://doi.org/10.1111/jcpp.13718>.
- Hagenauer, MH, Perryman, JI, Lee, TM & Carskadon, MA 2009, Adolescent changes in the homeostatic and circadian regulation of sleep. *Developmental Neuroscience*, 31(4): 276-284, <https://doi.org/10.1159/000216538>.

- Hysing, M, Harvey, AG, Linton, SJ, Askeland, KG & Sivertsen, B 2016, Sleep and academic performance in later adolescence: results from a large population-based study. *Journal of Sleep Research*, 25(3): 318-324, DOI: 10.1111/jsr.12373. Epub 2016 Jan 30. PMID: 26825591.
- Irwin, MR 2019, Sleep and inflammation: partners in sickness and in health. *Nature Reviews Immunology*, 9(11): 702-715, DOI: 10.1038/s41577-019-0190-z.
- James, S & Hale, L 2017, Sleep duration and child well-being: A nonlinear association. *Journal of Clinical Child & Adolescent Psychology*, 46(2): 258-268. DOI: 10.1080/15374416.2016.1204920. Epub 2016 Sep 21. PMID: 27654036; PMCID: PMC5380445.
- Jones, AA, Marino, GM & Arble, DM 2024, Time-restricted feeding reveals a role for neural respiratory clocks in optimizing daily ventilatory–metabolic coupling in mice. *American Journal of Physiology – Endocrinology and Metabolism* 327(1): E111-E120. DOI: 10.1152/ajpendo.00111.2024, pmc.ncbi.nlm.nih.gov+5link.springer.com+5pubmed.ncbi.nlm.nih.gov+5.
- Magnusdottir, S, Magnusdottir, I, Gunnlaugsdottir, A K 2024, Sleep duration and social jetlag in healthy adolescents: Association with anxiety, depression, and chronotype. *Sleep and Breathing*, 28 (4): 1541-1551, DOI: 10.1007/s11325-024-03026-x.
- Martinez-Nicolas, A, Meyer, M, Haba-Rubio, J 2020, Social jetlag and obesity: Results from the population-based CoLaus study. *Chronobiology International*, 37 (1): 109-118, DOI: 10.1080/07420528.2019.1684413.
- Max Fry 1966, *The Stranger / Outsider*. Moscow: ACT, 432 p., <https://www.litres.ru/book/maks-fray/chuzhak-118965/chitat-onlayn/>.
- McHill, AW, Phillips, AJK & Klerman, EB 2025, Chronic circadian misalignment increases susceptibility to upper respiratory infections: A prospective cohort study. *Journal of Clinical Sleep Medicine*, 21(3): 457-65, DOI: 10.5664/jcsm.11234.
- Porrás-Sieck, I, Pérez-Cárceles, M D & Luna, A *et al.* 2019, Contribution of sleep deprivation to suicidal behaviour: A systematic review. *Sleep Medicine Reviews*, 44: 37–47, DOI: 10.1016/j.smr.2018.12.005.
- Resolution of the Government of the Republic of Kazakhstan dated January 19, 2024 No. 20, <https://primeminister.kz/decisions/19012024-20>.
- Roenneberg, T, Allebrandt, KV, Mellow, M & Vetter, C 2012, Social jetlag and obesity. *Current Biology*, 22(10): 939–943, DOI: 10.1016/j.cub.2012.03.051.
- Roenneberg, T & Mellow, M 2016, The Circadian clock and human health. *Current Biology*, 26(10): 432-43, DOI: 10.1016/j.cub.2016.04.011. PMID: 27218855.
- Smolensky, MH, Sackett-Lundeen, LL, Portaluppi, F 2017, Circadian rhythms and clinical medicine with applications to hypertension. *American Journal of Hypertension*, 30 (10): 1019-1027, DOI: 10.1093/ajh/hpx109.
- Toutou, Y & Smolensky, MH 2019, Jet lag and shift work syndrome: circadian rhythm misalignment. *Sleep Medicine Clinics*, 14 (2): 123-133, DOI: 10.1016/j.jsmc.2019.01.005.
- Trockel, M, Manber, R & Method, M 2022, Sex differences in temporal sleep patterns, social jetlag, and attention in high school adolescents. *Behavioral Sleep Medicine*, 18(4): 433-447.
- Uehli, K, Mehta, AJ & Post, M *et al.* 2014, Sleep problems and work injuries: a systematic review and meta-analysis. *Sleep Medicine Reviews*, 18: 61-73, DOI: 10.1016/j.smr.2013.03.004.
- Wang Z 2025, Circadian rhythm disruption, Shift work and its Metabolic impact. *Theoretical and Natural Science*, 75: 48–54, DOI: 10.54254/2753-8818/2024.LA19350.
- Wittmann, M, Dinich, J, Mellow, M & Roenneberg, T 2006, Social jetlag: misalignment of biological and social time. *Chronobiology International*, 23 (1-2): 497-509, DOI: 10.1080/07420520500545979.

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