HEALTH RISK MANAGEMENT IN OCCUPATIONAL MEDICINE

UDC 616-053-2-036:12-02.613.865
DOI: 10.21668/health.risk/2018.1.08.eng

FATIGUE RISK ASSESSMENT FOR WORKERS WITH NEURO-ENMOTIONAL LABOR

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The papers dwells on the results obtained during fatigue risk assessment as per subjective and objective parameters in civil aviation crew members.

Our research goal was to assess fatigue and overfatigue risks as per subjective and objective cardiovascular system parameters and central nervous system parameters in workers with morning and evening biorhythms under neuro-emotional workloads and shift work performed by planes crew members, air traffic controllers, and operators. Our examined workers were mostly people aged 35–45 with working period equal to 5–15 years.

Fatigue which occurred during flights was assessed subjectively by crew members questioning as per Epworth Sleep Scale, Karolinska Sleepiness Scale, and crew state control as per Samn-Perelli. Working efficiency was studied via PVT test (psychomotor vigilance test), sleep monitoring, and actigraphy. Circadian rhythms dynamics was examined as per changes in minimal body temperature which aircrew members had. We applied Ostberg's questionnaires to assess biorhythmologic activity type. Workers' functional reserves were assessed via stress testing. We calculated functional changes index to assess functional abilities of the circulatory system and adaptation state during a working shift in workers with various biorhythmologic types.

The paper outlines the examination results for physiological reactions appearing in the cardiovascular system and central nervous system of workers with morning and evening biorhythms. We revealed that functional state peculiarities in operators when they performed their work tasks in a shift regime were closely connected with their biorhythmologic activity type. "Early risers" had more adverse physiological reactions during their work activities. We developed ways to lower risks related to fatigue and overfatigue caused by shift work. It was shown that regulatory mechanisms stress occurring in the circulatory system, lower labor motivation, and poorer health in people with the morning biorhythmologic type made it necessary to correct the body functional state during shift work, especially when labor was very intense.

Key words: *neuro-emotional labor, shift work, physiological reaction, fatigue risk, biorhythmologic activity type, regulatory mechanism.*

Fatigue or fatigability risk assessment is a vital problem nowadays; as a rule, it involves hazardous factors detection, risk assessment and risk lowering [1, 2–4]. "Fatigability" concept is widely used in publications issued by International Civil Aviation Organization, or ICAO [5], however, the authors prefer to apply such conventional concepts as

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fatigue and over-fatigue in this work. As per ICAO definition, fatigue an aircraft crew member has is a physiological state when mental or physical capacity goes down due to sleeplessness or long-term wakefulness, a daily rhythm phase and/or workload (mental or physical one) which can reduce a crew member's activity and ability to manage an aircraft or perform his or her job responsibilities.

Two knowledge spheres, namely hypnology and chronobiology, are the leading sciences which concentrate on fatigue experienced by civil aviation crew members [6]. Research on the brains activity which takes place during sleep gave ground for working out practical recommendations on sleep inertia reduction and sleep deficiency compensation, as well as ways to make disturbances during sleep as minimal as possible and to organize work and rest regimes most rationally. The same problem related to work and rest regime organization and keeping to it exists for car drivers and maintrack locomotive drivers [18]. Generally, sleep deficiency to a greater extent exerts its influence on complicated mental activities, such as decision-making, than on performing relatively simple tasks. It can take more than two nights of recovery sleep for the central nervous system functions to come to their normal state after a period when sleep was limited.

Research performed on 67 Boeing 747-400 crews revealed that lack of sleep led to an increase in number of errors made by crew members [2]. Aircraft commanders often faced situations when detected inaccuracies were not eliminated. As for decision-making, crew tended to choose less risky actions which could lead to a certain decrease in potential fatigue risk.

According to chronobiology, circadian rhythms disorders in civil aviation personnel are likely to occur during night cargo flights on internal lines or when they pass through several time zones and are exposed to drastic changes in "day-night" cycle. It was shown that civil aviation personnel made mistakes more frequently during a certain period of time, so called minimal circadian activity window (MCAW) and this fact was taken into account when aviation accidents were investigated.

Time zones change syndrome (desynchronization) was given special attention; researchers here concentrated on a number of time zones which crew members passed through and a flight direction. Body functions adapted faster when a flight was from east to west. A separate resynchronization was detected as per research results when one rhythms had their phase shifted towards advance, and others, on the contrary, towards a delay.

Shift work is a working regime which requires a crew wakefulness during such hours in their biological cycle which correspond to night hours, that is, sleep time [8, 9]. Crew members who had night cargo flights suffered from incomplete adaptation of their circadian rhythms to a night work regime. In some cases they had to perform their flight when sleepiness reached its peak, or during so called MCAW. And only one thing saved them from necessity to adequately react to non-standard situations: their tasks were rather routine.

Literature data tell that ability to work in a shift regime is extremely individual. 20% of all shift workers are thought to adapt fully to work in a multi-shift regime. Another 20% can't adapt to such working activities and, as a result, suffer from physical and mental overloads [10–13]. Research on workers' biorhythmologic activity helped to create a "human circadian system". According to it, heart rate is at its maximum at 3-4 p.m.; systolic blood pressure, stroke and minute blood volume, at noon-4 p.m. [14,15]. A standard daily rhythm curve is a curve with its peak in the middle of a day or in its second half. There was also research on daily changes in body functional state of healthy people who had to work in shifts [16–18].

Adaptation to work in a shift regime depends on working activities and a biorhythmologic activity type [10]. Nowadays some attempts are being made to spot out people with a morning and an evening biorhythmologic type; these types are usually called "early risers" and "late risers" in literature. Besides, some authors [19] describe the third biorhythmologic type, which is called "arrhythmics". There are tests which can help to assess people's biorhythmologic activity; however, there have been practically no examinations dedicated to peculiarities of workers' functional state depending on their biorhythmologic type. But shift schedules are widely used in various mental activities, including, for example, operators or traffic controllers, and it calls for such research.

Literature analysis revealed that an issue of studying functional state, stages in physiological processes related to fatigue transferring into overfatigue, or physiological criteria which specific stages have is a central one in occupational physiology and is not only of theoretical interest but also has considerable practical value [12, 20]. However, "physiological costs" of activities performed by people with different biorhythmologic types (a morning or an evening one) depending on labor intensity have not been studied enough and it doesn't allow to give grounds for practical measures aimed at achieving maximum personnel efficiency in such occupations with great responsibilities as civil aviations crew members or operators and traffic controllers working in shifts.

Our basic task was to assess fatigue and overfatigue risk as per subjective and objective parameters of the cardiovascular and central nervous system in workers with the morning and evening biorhythms types under work with neuro-emotional loads and shifts (civil aviation crew members, operators, and air traffic controllers).

Data and methods. Fatigue during flights was assessed subjectively via crew members questioning as per Epworth Sleep Scale, Karolinska Sleepiness Scale, and crew state control as per Samn-Perelli. They working capacity was assessed objectively as per PVT test (psychomotor vigilance test), sleep monitoring with use of diaries, and actigraphy (movement registration and detecting wakefulness and drowsiness periods). Circadian rhythms dynamics was examined as per changes in crew members minimal body temperature.

Workers from four occupational groups were examined in their actual working conditions. The first group was made up of cigarrettes-making lines operators employed at "Dukat" factory; the second group included robot-handled technological stations (RTS) operators; the third one were air traffic controllers working at one of Moscow airports; group four included PC operators. Most examined were 35-45 years old with their working period being 5-15 years.

We applied Ostberg's questionnaires to assess biorhythmologic activity types [10,15], trying to examine workers with polar biorhythmologic types, "early risers" and "late risers". Job analysis with labor intensity determination was performed in conformity with P 2.2.2006-05 Guide [21]; correction sample with Landolt's rings was applied to assess attention concentration (a perceived information volume, PIV, was calculated); we applied "numerical memory" test to assess short-term memory, and chronoreflexometry, to assess perception speed and speed of visual and audio signals processing [22]. We assessed the cardiovascular system state as per heart rate, systolic and diastolic blood pressure, which helped us to calculated pulse and average dynamic blood pressure, stroke blood volume, minute blood volume, and peripheral resistance [23, 24]. We also calculated proper parameters of the general hemodynamics (proper minute volume or PMV, proper peripheral resistance or PPR). We determined circulation types (hyperkinetic, eukinetic, or hypokinetic) on the basis of comparing actual data with proper cardiovascular system parameters [25].

Functional reserves which workers' bodies had were assessed via stress tests. We applied a cycle ergometer (load capacity 100 Wt, 1.5 minute duration) to perform a sample with a dosed physical load. All the circulatory system parameters were registered before the load, during its performance, and when its consequences occurred during the first 5 minutes after it was over.

To assess circulatory system functional abilities and adaptation in workers with different biorhythmologic types in a shift dynamic, we calculated functional changes index in accordance with methodical guidelines issued by the RSFSR public health ministry [20].

Examinations were performed 3-5 times during a morning, an evening, and a night 8-hour shift on RTS operators; a day and a night 12-hour shift on cigarettes-making lines operators and air traffic controllers. As a results we obtained daily activity curves for all the examined parameters depending on a worker's biorhythmologic type (1 group were "morning" people, 2 group were "evening" ones).

Results and discussion. Job analysis of activities performed by civil aviation crew members revealed emotional loads prevalence was caused by each error being greatly significant, responsibility for other people's lives being too high, personnel's own lives being at risk, and conflict situations being quite possible. Intellectual loads were related to an individual leadership in difficult situations, work under time deficiency, and perception of signals when all the parameters were to be assessed as a complex. All the above-mentioned, plus high sensory loads and unfavorable work regime, allowed us to rank civil aviation crew members labor as having 3.3 hazard degree in terms of labor intensity [21].

We examined the structure of activities performed by robot-handled technological stations operators and found out that their labor intensity was determined by sensory loads level including apparently long periods of concentrated observation, perception of data coming from robot-handlers control consoles as well as from displays which showed machines functioning. Working regime was organized in three 8-hour shifts.

Cigarettes-making lines operators work in 12-hour shifts. Their job responsibilities involve control and monitoring over NC machine tools displays, correcting disorders in automated systems, and constant quality control under a strict time regime as per their job description. Overall assessment of RTS operators and cigarettes-making lines operators labor allowed us to rank it as having the 2nd permissible category in terms of labor intensity according to the Guide P 2.2.2006-05 [21].

Neuro-emotional loads which air traffic controllers had to undergo were determined by highly dense visual signals including data coming from VDUs, audio signals and messages per a time unit, long-term periods of concentrated attention, work under time deficiency, complicated job tasks, high responsibility for other people's lives, and any error being greatly significant. Air traffic controllers' job peculiarities rank their labor as 3.2 hazard category in terms of labor intensity; and PC operators labor, as applied to flight labor, as 3.1 hazard category.

Circadian biological rhythms of crews who had long-distance flights didn't manage to adapt to any of time zones at their destination points. NASA research performed on a 3-member crew (aircraft commander, co-pilot, and flight engineer) revealed that they didn't return to their home time zone to spend any long period of time there when they performed trans-Pacific flights [26, 27]. A shift in internal biological rhythms cycle was observed in crew members as per time periods during which their body temperature reached its minimal value. It took them several additional days off to normalize their psychophysiological state after they returned home.

A more favorable situation was observed when crew members periodically stayed in their home time zone during breaks in flights. Daily biological rhythms were able to synchronize with local time existing in a home time zone. Sometimes circadian biorhythms adapted to a time zone at a destination point when crews stayed there and performed local flights in that zone for several days.

Results of research performed on aircraft crew members activities detected their peculiarities related to various flight types [28]. Crews consisting of two members and performing short-distance flights had the longest working hours a day and the shortest rest periods. Fatigue here was thought to be caused by limited sleep due to short rest periods, early wakening and early working day beginning, as well as high workloads.

Crews consisting of two pilots and a flight engineer and performing night cargo flights had rest periods during daytime and they had to work at night. Examinations conducted on temperature changes rhythms allowed to detect absence of circadian biorhythms adaptation to such working schedule.

Long working hours and long wakefulness period (20.6 hours) determined by absence of places where crew members could get some rest were basic reasons which caused fatigue in crew members performing long-distance flights (Table 1). In some cases crew members had to fly their aircraft during an unfavorable period in their circadian rhythm when they had to make additional efforts to maintain their working capacity in spite of their fatigue and feeling not quite well. Sleep divided into short periods during breaks between flights also caused greater fatigue.

Research revealed that sleep loss consequences accumulated in crew members and fatigue accumulation rate depended on sleep deficiency growth. Sleep in places aimed for crew members rest on an aircraft is less deep and qualitative while homeostatic process determines a body demand for slow-wave sleep. Sleep at night turns out to be more preferable. Sleepiness peaks were detected due to research results; the first appeared during early morning hours or so called minimal circadian activity window (MCAW) from 3 a.m. to 6 a.m.; a middle-day peak (day drowsiness window) appeared during a period from 3 p.m. to 5 p.m. Time frames of sleepiness peaks differ in people with morning biological activity type ("early rises") and evening biological activity type ("late risers").

Research results revealed that mental working activities involved stable levels formation for basic central nervous system (CNS) functions which were determined as per three components: efficiency, stability, and reliability. Thus, short memory efficiency (quantity of numbers remembered) measured before a working shift started amounted to 6.40± 0.21 among cigarettes-making lines operators from the first group (early risers), and to 6.51±0.14, among late risers; at the end of a working shift it was equal to 6.56±0.15 and 6.43±0.22 correspondingly, discrepancies between groups being insignificant. Functions stability varied within 3.2%. Levels of such short memory parameter as reliability were quite stable. The same data were obtained for such functions as attention and simple information perception.

When labor intensity was high (3.2 hazard category), a decrease in CNS functions activity was detected by the end of a working shift. CNS parameters didn't reach high functional level. There was a 15.3% decrease in attention concentration over a shift dynamics in air traffic controllers who were early risers, and a 13.4% decrease in those who were late risers, after 12 hours of work; it was higher than physiological

Table 1

Job-related reasons for fatigue in aircraft crew members

Factors related to fatigue	Flight type		
	Short-distance flights	Night cargo flights	Long-distance flights
Limited sleep due to short rest periods	+		
Limited sleep due to necessity to come to a work place at early hours	+		
Multiple periods of high workloads during a flight shift	+		
Flying through a lot of sectors	+	+	
Flying under intense air traffic.	+		
Long working hours a day	+		+
Long wakefulness periods during a working day			+
High workload during periods of low circadian activity		+	+
Short sleep periods not conforming to body circadian rhythms		+	+
Circadian rhythms disorder caused by night work		+	+
Sleep divided into short periods during breaks between flights		+	+
Circadian rhythms disorder caused by passing through multiple time zones			+
Phase shift in circadian biological rhythms caused by longer work and rest sequence cycle			+

standards for body strain and indicated that mental working capacity went down significantly and fatigue occurred.

Analysis performed on daily curves showing CNS parameters revealed lower short memory efficiency during evening hours than during night and morning ones. At the same time attention function, visual and audio information perception were quite stable and didn't differ in the afternoon and at night. In other words, we detected that daily curves showing basic CNS parameters flattened regardless of a biorhythmologic group. It is seemingly caused by requirements set forth for operators' activities and it eliminated reduction in working capacity thus forming additional body strain.

Physiological research performed on the cardiovascular system revealed that daily periods for heart rate didn't change in RTS operators with the evening biorhythmologic type when their labor wasn't significantly intense (the 2nd permissible category). It was also proved by lower statistically authentic heart rate parameters detected in late risers during a night shift against their counterparts with the morning biorhythmologic type which on average amounted to 69.90±1.17 and 74.22±1.40 strokes/minute, correspondingly ($p<0.05$), during a shift. Heart rate parameters in morning type operators (early risers) didn't have any discrepancies during a night shift (74.27±1.04 strokes/minute) and a morning one (72.0±1.95 strokes/minute). It showed that heart rate remained the same in late risers, that is, people with the evening biorhythmologic type. Heart rate disorders in "early risers" (people with a morning biorhythmologic type) can lead to additional strain in cardiovascular system regulation related to work in shifts.

When we compared blood pressure parameters in people with insignificantly intense labor (corresponding to the 2nd permissible category), we didn't reveal any statistically significant changes in blood pressure parameters during a day in people with the morning and evening biorhythmologic type. Thus, average systolic blood pressure level during a shift amounted to 118.43±1.07 mmHg in people from the 1st group, and to 116.84±0.97 mmHg, in people from the 2nd one; against a morning shift, correspondingly: 112.29±0.75; 110.84±1.27; and a night shift: 114.84±2.30: 111.87±2.36 mmHg. Diastolic blood pressure remained at almost the same level during morning and evening research periods.

The same data were obtained when the research was performed on cigarettes-making lines operators whose labor could also be ranked as having the 2nd permissible category in terms of its intensity. These workers' work activities differed from the previous occupational group ones as their working day was longer and lasted 12 hours.

Blood pressure examinations during stress tests showed that systolic blood pressure reached its peak when namely early risers had to undergo physical loads. By the end of an evening shift it amounted to 150.0±3.20 mmHg; to 140.0±1.91 mmHg, when a night shift began; and to 144.09±3.80 mmHg, by the end of a night shift. The same parameters were lower in late risers: 146.11±3.61; 135.83±3.59; 140.62±3.33 mmHg. Systolic blood pressure as a reaction to loads, as a rule, grew most considerably by the end of a working shift and varied within 24.5–26.4%. Besides, we detected slower blood pressure recovery to its standard levels in people with the morning biorhythmologic type. Systolic blood pressure parameters in workers with the evening biorhythmologic type recovered by the 4th minute while it took longer in workers with the morning one, especially at the end of a night shift, and their blood pressure reached standard values only when 5 minutes after a shift passed. Individual parameters analysis revealed even later recovery in some cases which proved there was a hazardous response from the cardiovascular system related to work strain accumulation.

The calculated values for stroke blood volume (SBV), minute blood volume (MBV), and peripheral resistance (PR) revealed that all the detected levels fully corresponded to age standards. There were no dynamic changes in these parameters caused by work. To determine circulation types peculiarities, we compared the obtained minute blood volume and peripheral resistance values to proper ones. Our determination of a circulation type as per average groups comparison of actual MBV and PR values with their proper ones allowed us to detect that hyperkinetic and eukinetic circulation types prevailed both in "early risers" and in "late risers", and it could be considered a favorable results as their bodies seemed to adapt to work loads.

We performed a comparative analysis of research results for workers with different biorhythmologic types whose labor was highly intense (3.2 hazard category) and revealed statistically significant discrepancies in blood pressure, both at the beginning of a shift, and over a shift dynamics. Systolic blood pressure in air traffic controllers with the morning biorhythmologic type ("early risers") amounted to 134.28 ± 2.29 at the beginning of a shift, and to 140.91±1.28 mmHg by the end of it; diastolic blood pressure, to 82.16±2.13 and 84.22±1.46 mmHg correspondingly. Initial systolic blood pressure in air traffic controllers with the evening biorhythmologic activity type amounted to 127.51±2.64 mmHg at the beginning of a shift, and to 126.0±1.78 mmHg by the end of it. Discrepancies between groups were statistically significant ($p<0.05$).

Blood pressure examinations performed on workers with different biorhythms showed that systolic and diastolic blood pressure tended to be higher in "early risers" than in "late risers". Parameters were higher than physiological standards set forth for workers with mental activity type. We also detected high average dynamic blood pressure levels at the beginning of a shift (99.53±1.45 mmHg) and during a whole shift (from 101.71±1.24 to 103.12±1.16 mmHg). It proved the circulation system in workers with the morning biorhythmologic type was under strain. But when it comes to "late risers", we should note that blood pressure parameters in them corresponded to physiological standards.

As we analyzed these data, we saw that there were no authentic discrepancies between blood pressure during day and night shifts. "Early risers" didn't have statistically significant discrepancies in average shift systolic blood pressure during day and night working hours (138.39±1.45 and 139.03±1.48 mmHg, correspondingly, $p>0.05$), as well as in diastolic one (83.45 ± 0.48 and 83.82±0.42 mmHg). The same data were obtained among "late risers" as per systolic blood pressure parameters (126.82±1.24 and 125.59±1.01 mmHg, $p>0.05$) and diastolic blood pressure parameters (72.35±0.48, $p>0.05$; 72.16±0.76 mmHg, $p>0.05$). The obtained results prove there was a disorder in daily blood pressure periods both in air traffic controllers with the morning biorhythmologic type and the evening one. Instead of an expected decrease in blood pressure parameters during a night shift related to higher parasympathetic nervous system activity, we detected high blood pressure levels during day working hours which showed that desynchronization occurred.

Similarity in physiological reactions occurring in people with two different biorhythmologic types whose labor was apparently very intense (3.2 hazard category) was that they all had disorders in daily systolic and diastolic blood pressure periods. Discrepancies were revealed in blood pressure parameters being higher than physiological standards set forth for workers with mental activities in people with the morning biorhythmologic type, but the same parameters in people with the evening one corresponded to them.

Hemodynamics peculiarities analysis allowed us to reveal that a great share of "early risers" had hypokinetic circulation type; more favorable eukinetic type prevailed among operators from "late risers" group. Hypokinetic circulation type formation in workers is known to indicate primary hypertension risk.

Calculated functional changes index (FCI) which characterizes circulatory system adaptation potential [20] amounted to 2.20±0.05 scores for early risers and to 2.19±0.04 scores for late risers as per average shift level during a morning work shift of an occupational group with working conditions belonging to the 2nd hazard category (RTS operators). The same parameter in the same group amounted to 2.40±0.04 and 2.27±0.05 scores correspondingly during an evening shift, and to 2.29±0.06 and 2.21±0.04 scores correspondingly during a night one. According to a scoring scale these FCI values correspond to satisfactory adaptation. However, we detected a trend for a bit higher values in early risers, especially during evening shifts.

Cigarettes-making lines operators whose working conditions also belonged to the 2nd hazard category had functional strain as FCI amounted to 2.64±0.05 scores in early risers from this occupational group during a day shift, and to 2.66±0.03 in late risers; it was 2.57±0.01 and 2.59±0.05 scores correspondingly during a night shift. The obtained results are likely to be caused by a long 12-hour working shift. When labor intensity grows and labor can be ranked as having 3.2 hazard category, adaptation becomes unsatisfactory in people with the morning biorhythmologic type. Values of functional changes index for the circulatory system here amounted to 2.93±0.05 scores during a day shift and to 2.64±0.06 scores during a night one. These values were lower in people with the evening biorhythmologic type (2.64±0.06 scores during a day shift; 2.63±0.05 scores during a night one). The detected statistically significant discrepancy in values ($p<0.05$) obtained for two groups of the examined people with different types ("early risers" and "late risers") means there is less apparent functional body strain in people with the evening biorhythmologic type ("late risers") and it allows to assume their adaptation to work in shifts is more successful.

The obtained results show that daily rhythms of circulatory system functional changes index in RTS operators react to workloads and rearrange themselves within satisfactory adaptation limits. But at the same time there were no differences in functional changes index during a day and a night in cigarettes-making lines operators whose labor has the same hazard degree as RTS operators' (the 2nd permissible hazard category) but whose working day is longer. This regularity is also detected in air traffic controllers with labor ranked as having 3.2 hazard category and reveals a disorder in FCI daily rhythm as an integral parameter showing the cardiovascular system state and indicates that desynchronization occurs.

Physiologic research results are also validated by data obtained via subjective estimations of one's health and labor motivation. Air traffic controllers (with highly intense labor) estimated their health as being poor, they were less active and had bad mood during a night shift in comparison with a day one; it was especially apparent in case of people with the morning biorhythmologic type (the 1st group). Cigarettes-making lines operators (the 2nd hazard degree) didn't have any statistically significant discrepancies in their health, activity, and mood. Labor motivation of air traffic controllers, as it can be seen from the Table 2, was authentically lower during a night shift than during a day one. Decrease in air traffic controllers' labor motivation was the most apparent in people from the 1st biorhythmologic (morning) group which showed fatigue occurrence in them.

Table 2

Labor motivation parameters in people with different biorhythmologic type during different shifts

Occupational group	Biorhythmologic type	Health		Activity		Mood		Motivation		Hazard category
		day	night	day	night	day	night	day	night	
Cigarettes-making lines operators	Early risers	5,92 ± 0,14	5,90 ± 0,14	5,86 ± 0,15	5,91 ± 0,17	5,67 ± 0,21	5,41 ± 0,19	5,87 ± 0,13	5,61 ± 0,15	2
	Late risers	6,02 ± 0,23	6,0 ± 0,13	5,83 ± 0,17	5,88 ± 0,15	5,56 ± 0,11	5,60 ± 0,14	5,90 ± 0,16	5,85 ± 0,15	
Air traffic controllers	Early risers	5,0 ± 0,20	4,38* ± 0,14	5,515 ± 0,17	4,66* ± 0,14	4,91 ± 0,12	4,40* ± 0,13	4,80 ± 0,11	4,31* ± 0,14	3.2
	Late risers	5,51 ± 0,12	5,02** ± 0,13	5,60 ± 0,14	5,34** ± 0,16	5,31** ± 0,12	5,0** ± 0,16	5,23** ± 0,15	5,19** ± 0,18	

Note: * means discrepancies between shifts are statistically authentic ($p<0,05$)
** means discrepancies between "early risers" and "late risers" are statistically authentic ($p<0.05$)

We judged on fatigue accumulation as per two criteria: functions which didn't fully recover after work and a week dynamics in the examined parameters. Analysis of the results obtained for PC operators occupational group revealed there was a decrease in their health, activity, and mood, as well as nervous processes instability, poorer functioning of analyzer systems and vegetative activity provision systems; all these parameters became worse each consequent weekday in comparison with the previous one. Here initial parameters were worse on Wednesday and Friday than on Monday, and they were also worse each consequent day than on a previous one as per subjective evaluations. Thus, mood parameter amounted to 5.95±0.56 scores at the beginning of a work shift on Monday; to 5.55±0.32 scores, on Tuesday; to 5.66±0.33 scores, on Wednesday; to 5.50±0.43 scores, on Thursday; to 5.43±0.29 scores on Friday. Initial time level of a simple visual-motor reaction was equal to 226.07±1.32 msec on Monday, to 230.88±1.30 on Wednesday, and to 236.81±1.57 msec on Friday, and it indicates that functions don't fully recover, and fatigue accumulates. Research performed during weekly cycles of operators' work revealed that 40% operators had poorer parameters by the end of a week cycle, as well as from week to week, and it proved functional shifts slowly accumulated.

To prevent overfatigue, we tested various functional state correction techniques in actual working conditions. We detected that autogenic training was an efficient technique for cardiovascular system state correction: heart rhythm stabilized and heart rate went down in people from all the occupational groups regardless of their labor intensity and shift regime, hypotensive effect also occurred in all of them. We didn't observe such changes after electric analgesia and electric puncture. Autogenic training in general exerted positive effects on body functional state during shift work and it allows us to recommend this technique to people with the morning biorhythmologic type.

Conclusions. Fatigue risk analysis performed on aircraft crew members revealed basic reasons for unfavorable overfatigue occurrence: limited sleep due to short rest, sleep divided into short time periods during breaks between flights, disorder and phase shift in circadian rhythms caused by night work or multiple passing through various time zones, high work load, and long working hours.

We detected an increased fatigue risk for operators with the morning biorhythmologic type ("early risers") which became obvious through disorders in daily heart rate periods under average labor intensity (RTS operators), blood pressure parameters being higher than permissible levels (set forth for workers with mental activity) under high labor intensity (air traffic controllers), as well as through prevalence of unfavorable circulation regulation type (hypokinetic one).

Vegetative provision of body functioning in operators with the evening biorhythmologic type as per cardiovascular system state showed there was a favorable hemodynamics response to workloads: their heart rate preserved its daily rhythm, systolic, diastolic, and average dynamic blood pressure, and functional changes index were within physiologically permissible levels and were stable during their working day.

We developed certain techniques aimed at lowering risks related to fatigue and overfatigue occurring during shift work. Strain in circulatory system regulation, lower labor motivation and poorer health in people with the morning biorhythmologic type call for body functional state correction when they have to work in shifts and especially when their labor is highly intense.

Practical recommendations developed for civil aviation personnel include several stages: crew members fatigue measuring, risk assessment, developing and implementing activities aimed at risk reduction (rules for controlled rest in a cockpit etc.).

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Bukhtiyarov I.V., Yushkova O.I., Fesenko M.A., Merkulova A.G. Fatigue risk assessment for workers with neuro-enmotional labor. Health Risk Analysis, 2018, no. 1, pp. 66–77. DOI: 10.21668/health.risk/2018.1.08.eng

Received: 12.01.2018
Accepted: 16.03.2018
Published: 30.03.2018