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Article

Job Stress, Working Capacity, Professional Performance and Safety of Shift Workers at Forest Harvesting in the North

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Abstract: The study describes the features of manifestations and interrelationships of job stress, working capacity, professional performance and safety in loggers with shift work organization in the North. The study involved 402 loggers. The research methods include questionnaires and psychophysiological diagnostics of stress and working capacity, as well as questionnaires on the professional performance and safety of workers. The following statistical methods were used: correlation, multivariate dispersion and multi-regression stepwise analysis. It was found that the severity of stress, speed, accuracy and operator working capacity, as well as well-being, activity and mood in logging equipment operators, timber truck drivers and maintenance specialists statistically differ significantly. Higher professional stress and more frequent decrease in professional performance are characteristic of truck drivers. Psychological and psychophysiological job stress and working capacity parameters are associated with professional performance parameters of loggers. According to the results of a number of multi-regression analyses, reduced professional performance markers of loggers include the index of stress, satiety, monotony and fatigue, vegetative balance and stress (method of M. Luscher and coefficients of G.A. Aminev), operator working capacity and reaction speed (CVMR).

Keywords: job stress; professional performance; professional safety; forest harvesting; shift method; forest mechanization

1. Introduction

Logging is considered one of the most dangerous, extreme and physically demanding jobs in the world [1–4]. Currently, both manual (involving felling, branching and cross-cutting operations with a chainsaw [1]) and automated (using operator labor to control harvesters and forwarders [5]) work methods are used in logging, which is usually associated with the following difficulties and obstacles:: poor weather conditions, swampy terrain, great remoteness of forest plots (which requires more time for daily delivery of workers to the workplace), insufficient productivity and machine breakdowns; lack of personnel [6]. In addition to the above factors, the difficulties are aggravated by the climatic and geographical conditions of the North (including extremely low temperatures, polar day and polar night, strong winds, etc.) and the shift method of organizing work, which involves working on forest plots in isolated groups of 10-40 people with different work and rest schedules (15 days of work / 15 days of rest; 7 days of work / 7 days of rest; 30 days of work / 30 days of rest, etc.) [5]. The above-mentioned production factors contribute to the development of stress, anxiety and tension in employees, affecting their safety and work performance [7–11].

The main professional groups in logging enterprises are operators of logging equipment (harvesters and forwarders) and truck drivers (for timber transportation and dump trucks). It has been established that the work of timber truck drivers is stressful, which is influenced by a number

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of external factors: the condition of the vehicle, the intensity of its use, the type of wood and the characteristics of the road [12]. The main factors affecting the work of truck drivers are long periods of intense concentration, as well as quick reactions, severe stress and high long-term muscle load [12]. This leads to adverse effects on the health and psyche of workers and indirectly affects their work productivity [13,14]. Most of the studies on timber truck drivers have focused on the characteristics of their working time distribution and work schedules (long routes, night work, etc.) [15,16], fatigue and exhaustion [17,18], as well as stress conditions associated with work-life imbalance [19–21].

Nowadays, automated cut-to-length harvesting is the most popular system in Europe, which accounts for approximately 60% of all timber harvested in Europe and up to 95% of felling in Finland, Norway and Sweden [22]. With the use of multi-functional forestry equipment, the nature of work in forestry has shifted from physical to mental. As a result, the need for muscular activity of workers has decreased, while the need to remain focused and attentive for a long time, typical of operator work, has increased. The requirements for harvester operators include the ability to process large amounts of information, react quickly and maintain concentration during monotonous, repetitive operations, which indicates a high mental and sensory load [23]. Forestry equipment operators have to work in uncomfortable positions and experience overstrain. The main problems of forest machine operators range from the difficulty of maneuvering machines on uneven terrain to variable soil conditions, which affects their productivity [24]. Increased mental workload is not only associated with discomfort, but can also threaten health and safety of workers: operators with severe fatigue are more likely to make mistakes, and this can lead to injuries or damage [25].

It has been established that working conditions and professional workload have a negative impact on the mental health of chainsaw and skidder operators, expressed in anxiety and nervousness [26]. Scientists have proven that professional stress significantly affects mental health of workers: the longer careers loggers have, the more stressed they are [26].

In a systematic review, K.C. Elliott et al. demonstrated that sleep duration and the number of breaks during a shift affect fatigue in forestry workers. At the same time, higher fatigue levels were associated with higher injury rates [27].

In addition, inflexible working schedule and long working hours are also predictors of fatigue, which in turn leads to injuries at work. According to the survey, 78% of workers who got injured experienced fatigue, which is a major risk factor [28].

According to another study, the most frequently reported forms of stress among forestry equipment operators (fatigue and conflict) were mainly caused by obstacles which people had to overcome in order to achieve productivity targets. When resources and time were sufficient, operators reported a positive impact of work on their well-being [6].

The study purpose is to establish the characteristics of manifestations and relationships between job stress, working capacity, professional performance and safety among loggers in shift work in the North.

Research objectives:

1. To establish job stress and working capacity characteristics of three professional groups of shift workers in the North logging equipment operators, logging truck drivers and maintenance specialists.

2. To compare and describe professional performance and safety parameters of three professional groups of shift workers at a logging enterprise in the North.

3. To establish the relationship between job stress, working capacity, professional performance and safety of loggers in the North.

4. To identify job stress and working capacity parameters that affect the professional performance of loggers in the North.

Hypotheses:

1. Due to the specific nature of their professional activities, truck drivers at a logging enterprise in the North are characterized by a higher job stress level and they more often experience a decrease in professional performance parameters than logging equipment operators and maintenance workers.

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2. Psychological and psychophysiological parameters of job stress and working capacity are associated with professional performance parameters of loggers. We expect a greater number of connections between psychological job stress parameters measured by questionnaires and professional performance parameters of workers.

3. The loggers' reduced professional efficiency markers are stress, monotony and satiety indicators.

2. Materials and Methods

The research program was approved by the ethics committee as complying with the ethical principles of the Declaration of Helsinki (the Higher School of Psychology, Pedagogy and Physical Culture of the Northern (Arctic) Federal University protocol No. 2, 2020).

2.1. Procedure

The empirical material for the study was collected during five trips to separate divisions of a logging enterprise in the Arkhangelsk region (Russian Federation): 1 trip in 2020, 2 -- in 2021 and 2 -- in 2024. Questioning, as wells as psychological and psychophysiological testing of loggers was carried out by four psychologists. The study participants took part in the study on a voluntary basis and signed informed consent.

2.2. Sample

The study involved 402 male loggers aged 19 to 65 years (average age 41.32 ± 0.585 years old), with work experience in the job from 2 months to 42 years (average experience 8.25 ± 0.400 years) and shift work experience from 2 months to 33 years (average experience 7.844 ± 0.262 years). The entire sample was divided into three professional groups, which are the most numerous in logging enterprises: logging machine operators (work schedule: 15 days shift period and 15 days rest period), truck drivers (work schedules: 20 days shift period and 10 days rest period; 15 days shift period and 15 days rest period; 10 days shift period and 5 days rest period) and maintenance specialists (work schedule: 15 days shift period and 15 days rest period).

According to the socio-demographic characteristics (Table 1), the sample is representative and corresponds to the general population of workers in logging enterprises of the Arkhangelsk region of the Russian Federation.

Table 1. Demographic characteristics of the sample.

Age	up to 30 years	from 31 to 40	over 41
quantity	61 people	159 people	182 people
percentage	15.2%	39.6%	45.3%
Education	**General secondary**	**Secondary vocational**	**Higher**
quantity	186 people	208 people	8 people
percentage	46.3%	51.7%	2.0%
Experience in the job	**from 0.1 to 3 years**	**from 3 to 8 years**	**more than 8 years**
quantity	173	123	106
percentage	43.0%	30.6%	26.4%
Shift work experience	**from 0.1 to 3 years**	**from 3 to 8 years**	**more than 8 years**
quantity	102	164	136
percentage	25.4%	40.8%	33.8%
Professional group	**Operators of forestry machines (harvester, forwarder)**	**Truck drivers (for timber removal and dump trucks)**	**Maintenance (auto mechanics, welders, etc.)**
quantity	157	148	97

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percentage	28.3%	26.4%	20.3%

Harvester operators operate a logging machine with an automated control system that simultaneously performs felling, delimbing, skidding, crosscutting and sorting of timber. Forwarder operators, in turn, carry out a set of operations to collect the assortment of forest in bundles, sort and unload them on the upper tier of the loading platform.

Truck drivers remove timber from loading points to wood processing shops or other points, whereas dump truck drivers transport and unload cargo.

The next function performed on a logging site is auxiliary work, which is carried out during main logging operations and aimed at ensuring uninterrupted operation of machines and equipment. It includes technical maintenance and current repairs of machines, mechanisms, equipment and others.

Table 2 presents a description of the main functions, factors of the severity and intensity of work and other professional factors of various logging jobs.

Table 2. Main functions and professional factors of employees at forest harvesting in various positions.

Professional group	Main functions performed	Factors of work severity and intensity	Other professional factors
Harvester operators	1. Technical inspection and preparation for harvester operation 2. Control of the harvester and attachments during movement, tree felling, limbing, cutting the trunk into logs and sorting them. 3. Performing technical maintenance of the harvester	Sensory load: density of signals (light, sound) and messages Noise Local vibration Fixed working posture	Shift work; soil instability, falling trees and their parts; insufficient lighting and low temperatures in winter;
Forwarder operators	1. Technical inspection and preparation for operation of the forwarder 2. Control of the forwarder and attachments during movement, picking up logs, placing them in the cargo compartment, moving to the storage location, unloading into a stack. 3. Performing technical maintenance of the forwarder	Sensory load: density of signals (light, sound) and messages Noise Local vibration Fixed working posture	Shift work; soil instability, falling trees and their parts; insufficient lighting and low temperatures in winter;
Timber haulage drivers	1. Technical inspection and preparation of the vehicle for operation 2. Control of the vehicle during transportation of logs from the upper warehouse. Loading and unloading of logs (if appropriate equipment is available). 3. Filling out paper or electronic accompanying documents 4. Carrying out maintenance and simple repairs of the vehicle	General and local vibration Sensory load: density of signals (light, sound) and messages Fixed working posture Noise	Shift work; unfavorable weather conditions leading to poor visibility; slippery road surface (ice, rain); insufficient lighting and low

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			temperatures in winter; speed control depending on the geozone; video surveillance of the driver throughout the shift
Truck drivers	1. Technical inspection and preparation of the vehicle for work 2. Driving the vehicle during transportation and unloading of goods. 3. Carrying out maintenance and simple repairs of the vehicle	Exposure to vibration Sensory load: density of signals (light, sound) and messages Noise Fixed working posture	Shift work; unfavorable weather conditions eading to poor visibility; slippery road surface (ice, rain); insufficient lighting and low temperatures in winter; speed control depending on the geozone; video surveillance of the driver throughout the shift
Electric welders (maintenance)	1. Welding 2. Cutting metal 3. Manufacturing high-pressure hoses on a machine	Increased concentration of harmful substances in the air (manganese in welding aerosols) Forced working posture during the shift Noise	Shift work, insufficient lighting and low temperatures in winter;

2.3. Methods

The questionnaire for assessing the professional efficiency and safety of shift personnel (Ya.A. Korneeva, N.N. Simonova, T.O. Tyulyubaeva), in addition to socio-demographic parameters (gender, age, education, position, work experience), included the sections presented in Fig. 1. To develop the sections of the questionnaire, experts from among the managers and highly qualified workers of industrial enterprises were involved; hazardous situations were determined based on the results of previous expeditionary studies and analysis of labor protection documentation. The questionnaire was tested during previous studies [5,29,30].

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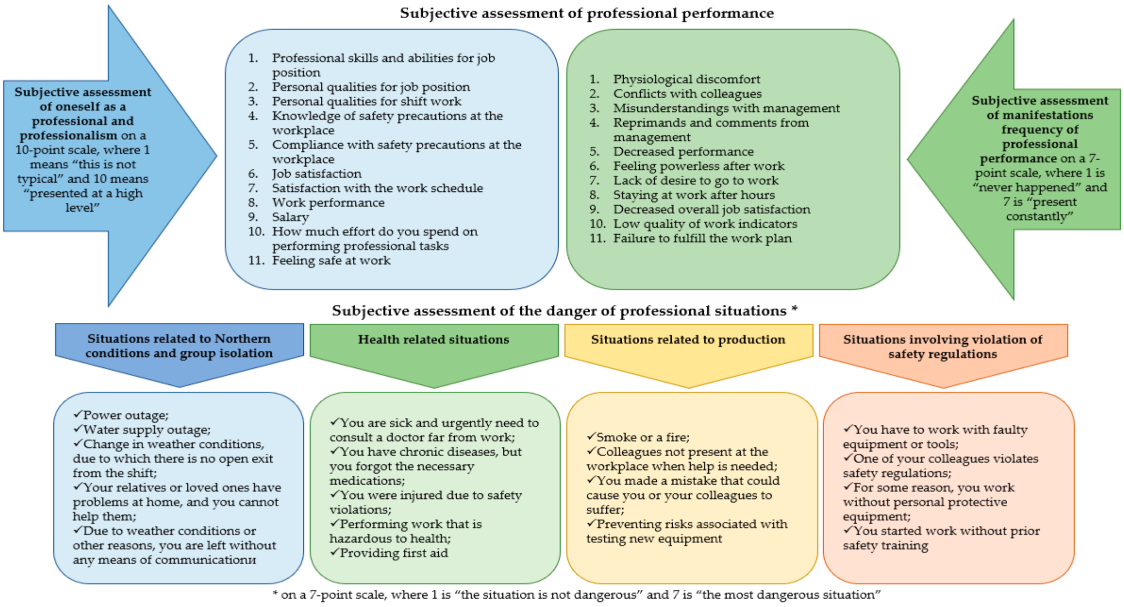

Figure 1. Structure of questionnaire sections of professional performance and safety of shift personnel.

We used the following groups of methods for assessing professional stress and performance.

1) Psychophysiological methods performed using the device for psychophysiological testing UPFT-1/30 "Psychophysiologist" (MTD Medikom, Taganrog, Russia):

1.1. "Variational cardiointervalometry" (VCM) allows determining the level of one's functional state by analyzing 128 cardiac cycles (ECG signal, the time of RR intervals and their standard deviation are recorded). Functional state assessment was differentiated into six categories from negative to [5,31–33].

1.2. The Complex Visual-Motor Response (CVMR) technique, which allows us to determine the operator working capacity level based on an analysis of the level and stability of visual-motor reactions. During the test, the subject is presented with a series of 75 light stimuli with a random distribution of colors (red and green). The time of presenting the next stimulus is a random variable in the range from 2 to 5 s, counting from the moment of the response, accompanied by the extinguishing of the indicator. The subject presses the "yes" button for the green light stimuli, and the "no" button for the red-light stimuli. During the test, the response time and the number of erroneous actions by category are recorded. Based on the calculation results, we used the following indicators: quality and speed of test performance, level of operator performance [31–33].

2) Psychological methods:

2.1. The questionnaire of differentiated assessment of states of reduced working capacity (DASRWC) by A.B. Leonova, S.B. Velichkovskaya [34], which is an adaptation of the BMSII test by H. Plas and R. Richter [35]. The questionnaire consists of 40 questions with a four-point answer scale (from 1 - "almost never" to 4 - "almost always"). The questionnaire allows us to assess the level of severity of monotony, mental satiety, stress and fatigue [34]. The questionnaire has been validated and tested for reliability, which is reflected in the publications of its authors [35].

2.2. The questionnaire of well-being, activity, and mood by V.A. Doskin, M.P. Miroshnikov et al. [36], which consists of 30 polar features reflecting the parameters of well-being, activity and mood (assessment is made on a 7-point scale). The questionnaire has been validated and tested for reliability, which is reflected in the publications of its authors [36]. The questionnaire is used to assess mental states of healthy people and their psycho-emotional reaction to stress. [33]

2.3. M. Luscher's color preference test, adapted by LN Sobchik [37–43]. The parameters of mental states based on this test were calculated using G.A. Aminev's formulas of interpretation coefficients [44]. The following coefficients were used in the present study: working capacity, presence of a stressful state and vegetative balance (which is the balance of manifestations of sympathetic and parasympathetic influences of the autonomic nervous system) [44]. Previous studies have shown good prognostic properties of this technique for assessing the states of industrial workers and correlations between its parameters and questionnaire data and instrumental psychophysiological methods [5,33]. The working capacity coefficient is estimated based on the presence of green, red and yellow colors at the beginning of the choice row and varies from 9.1 to 20.9. The stress coefficient is estimated by finding brown, black and grey cards in the first positions of the choice row (varies from 0 to 41.8) [44].

2.4. Data Analysis

Statistical data analysis methods included descriptive statistics, correlation and multiple stepwise regression analyses (using IBM SPSS Statistics 26.00).

To test the first hypothesis, multiple variance analysis (MANOVA) was used, taking into account the following assumptions: homogeneity of variances (Leeven's criterion - the probability of error is greater than 5%); multivariate normality of data (M-Box criterion - the probability of error is greater than 5%); normality of distributions of residuals. To clarify pairwise differences, the a posteriori Scheffe criterion was used.

To test the second hypothesis, correlation analysis (Spearman's criterion) was used. Only those factors were taken into account that have statistically significant relationships at a level of p less than 0.04 with the parameters of the functional states of workers (group assessment of error probability (I type) according to the Bonferroni method as modified by Holm).

To test the third hypothesis, multiple stepwise regression analysis was used for dependent variables - parameters of professional efficiency, and independent variables - parameters of DASRWC, VCM, CVMR, WAM methods and M. Luscher's method assessed on a continuous scale. The combined stepwise method was used. The criteria for stepwise selection were: F inclusion probability -– 0.05, exclusion probability -- 0.1. The quality of the regression model was determined by the ANOVA criterion and the coefficient of multiple determination. The residuals normality control was carried out. Colleniarity of independent variables was excluded

3. Results

3.1. Peculiarities of Job Stress and Working Capacity of Loggers with Shift Work Organization in the North of Various Professional Groups

To solve the first study goal establishing the characteristics of job stress and working capacity of shift-based loggers in the North in three professional groups: logging equipment operators, logging truck drivers and maintenance specialists, a MANOVA was used, where the professional group acted as a predictor, and the multivariate dependent variable included DASRWC, VCM, CVMR, WAM parameters and M. Luscher's methods. The result of applying the Pillai Sled test to assess the entire multivariate model: for the DASRWC method 0.505, F = 2.023 at p = 0.028; for VCM and CVMR: 0.231, F = 3.941 at p = 0.001; for M. Luscher's and WAM methods: 1.136, F = 13.602 at p = 0.001. The analysis of variance was applied taking into account the following assumptions: homogeneity of variances (Levine criterion - error probability greater than 5%); multivariate normality of data (M-Box criterion – probability of error greater than 5%); normality of residual distributions. To clarify pairwise differences, the Scheffe a posteriori criterion was used.

According to Table 3, statistically significant differences between professional groups were revealed with respect to the stress index (DASRWC), speed, accuracy and operator working capacity (CVMR), working capacity and stress (M. Luscher's method) and well-being, activity and mood (WAM). Logging machine operators demonstrated higher working capacity, both with respect to projective assessments and the instrumental method of CVMR, as well as lower stress severity. Truck drivers demonstrated higher stress values (DASRWC), higher speed of CVMR tasks with lower quality, while, according to subjective assessments, their well-being, activity and mood were better than those of operators. Maintenance specialists had a lower stress level according to DASRWC, above average speed and average accuracy in working capacity of CVMR.

Table 3. The job stress and working capacity parameters of loggers with shift work organization in the North of various professional groups (according to MANOVA results and univariate criteria, N=402).

Job stress and working capacity parameters	Harvester and forwarder operators M±SD; SE	Truck drivers M±SD; SE	Maintenance M±SD; SE	p
Fatigue index (DASRWC)	19.1±4.06; 0.78	20.5±2.73; 0.96	16.0±0.00; 0.00	0.510
Monotony index (DASRWC)	17.7±2.70; 0.52	19.3±3.88; 1.37	13.5±0.71; 0.50	0.086
Satiety index (DASRWC)	18.5±3.71; 0.71	20.0±3.55; 1.25	18.0±1.41; 1.00	0.513
Stress index (DASRWC)	18.4±2.99; 0.58	20.4±3.93; 1.39	11.5±0.71; 0.50	**0.004**
Functional state assessment (VCM)	0.7±1.04; 0.12	0.6±1.00; 0.11	1.1±2.80; 0.29	0.199
Speed (CVMR)	3.5±1.22; 0.15	4.6±1.21; 0.13	4.2±1.48; 0.15	**<0.001**
Error-free (CVMR)	4.6±1.53; 0.18	3.1±1.84; 0.20	3.8±2.01; 0.21	**<0.001**
Operator working capacity (CVMR)	3.3±1.41; 0.17	2.7±1.65; 0.18	2.8±1.52; 0.16	**0.001**
Working capacity (M. Luscher's method)	18.9±1.12; 0.16	17.4±2.28; 0.47	17.9±2.74; 0.26	**<0.001**
Stress (M. Luscher's method)	2.1±3.19; 0.46	6.9±5.37; 1.10	8.5±5.40; 0.52	**<0.001**
Vegetative balance (M. Luscher's method)	0.5±2.55; 0.37	2.6±4.85; 0.99	1.2±5.37; 0.52	**0.044**
Well-being (WAM)	54.2±9.00; 1.30	61.2±3.83; 0.78	59.9±7.89; 0.76	**<0.001**
Activity (WAM)	49.2±9.40; 1.36	56.9±4.88;1.00	54.4±8.42; 0.81	**<0.001**
Mood (WAM)	57.3±8.15; 1.18	60.6±2.30; 0.47	61.5±7.86; 0.76	**<0.001**

3.2. Peculiarities of Professional Performance and Safety of Shift Workers at Forest Harvesting of Various Professional Groups in the North

To achieve our second goal - comparison and description of professional performance and safety parameters of shift workers of three professional groups at a logging enterprise in the North, a MANOVA was used, where the professional group acted as a predictor, and the multivariate dependent variable included the parameters of self-assessment as a professional, assessment of the frequency of manifestations of efficiency parameters and assessment of the danger of professional situations (according to the questionnaire). The result of applying the Pillai's Sled criterion to assess the entire multivariate model: for self-assessment as a professional 0.187, F = 2.003 at p = 0.034; for assessment of the frequency of manifestations of efficiency parameters: 0.436, F = 1.855 at p = 0.004; for assessment of the danger of professional situations: 0.277, F = 4.332 at p = 0.001. Variance analysis was applied taking into account the following assumptions: homogeneity of variances (Levine's criterion - the probability of error is greater than 5%); multivariate normality of data (M-Box criterion – probability of error greater than 5%); normality of residual distributions. To clarify pairwise differences, the Scheffe a posteriori criterion was used. The results are presented in Tables 4 and 5.

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Table 4. The professional performance and safety parameters of various professional groups of shift workers at forest harvesting (according to MANOVA results, according to univariate criteria, N=402).

Professional performance and safety parameters	Harvester and forwarder operators M±SD; SE	Truck drivers M±SD; SE	Maintenance M±SD; SE	p
Professional skills and abilities for the position*	8.6±1.88; 0.31	8.3±1.58; 0.20	7.8±1.26; 0.63	0.515
Personal qualities for the position*	8.8±1.66; 0.28	8.2±1.91; 0.24	8.8±0.96; 0.48	0.383
Personal qualities for shift work*	8.6±1.94; 0.32	8.2±2.28; 0.28	9.5±1.00; 0.50	0.223
Knowledge of safety precautions at the workplace*	8.7±1.52; 0.25	8.6±1.77; 0.22	9.5±1.00; 0.50	0.421
Compliance with safety precautions at the workplace*	8.9±1.41; 0.24	8.9±1.52;0.19	9.5±0.58;0.29	0.848
Job satisfaction*	8.8±1.49;0.25	7.9±2.25;0.28	9.0±1.41;0.71	0.131
Satisfaction with the work schedule*	9.0±1.92;0.32	7.9±2.5;0.31	9.5±1.00; 0.50	**0.020**
Work performance*	8.9±1.83; 0.31	8.7±1.66; 0.21	9.0±1.15; 0.58	0.711
Salary*	7.3±2.51; 0.42	6.6±2.60; 0.32	7.3±2.22; 1.11	0.451
How much effort is spent on completing professional tasks*	8.8±1.51; 0.25	8.6±1.64; 0.20	8.5±1.29; 0.65	0.391
Feeling of safety at the workplace*	8.6±2.08; 0.35	7.4±2.49; 0.31	9.3±0.96; 0.48	0.079
Physiological discomfort**	2.4±1.28; 0.22	2.6±1.46; 0.18	1.4±0.55; 0.24	0.207
Conflicts with colleagues**	2.0±1.36; 0.23	1.9±1.13; 0.14	1.6±0.89; 0.40	0.857
Misunderstanding problems with management**	2.7±1.66; 0.28	3.0±1.81; 0.22	1.4±0.55; 0.24	**0.028**
Reprimands and comments from management**	2.3±1.29; 0.22	2.2±1.51; 0.19	1.6±0.89; 0.40	0.561
Decreased efficiency**	2.2±1.62; 0.28	2.5±1.60; 0.20	1.4±0.89; 0.40	0.098
Feeling of helplessness after work**	2.6±1.78; 0.31	2.9±1.66; 0.20	1.4±0.55; 0.24	**0.006**
No desire to go to work**	2.0±1.42; 0.24	3.0±1.89; 0.23	1.4±0.55; 0.24	**0.003**
Staying at work after hours**	2.9±1.48; 0.25	4.4±1.85; 0.23	1.4±0.89; 0.40	**0.001**
Decreased job satisfaction in general**	2.4±1.32; 0.23	2.7±1.57; 0.19	1.2±0.45; 0.20	0.073
Low performance indicators**	2.2±1.30; 0.22	2.1±1.34; 0.16	1.8±0.84; 0.37	0.112
Failure to fulfill the work plan**	2.2±1.24; 0.21	2.1±1.28; 0.16	1.0±0.00; 0.00	**0.009**

Note: * for all the parameters indicated, subjective assessment was made on a 10-point scale, where 10 corresponds to the most typical situation; ** for all the parameters indicated, the subjective assessment was made on a 7-point scale depending on the frequency of occurrence, where 7 is always ticked.

According to the data in Table 4, statistically significant differences between the groups were established with respect to the following performance parameters: satisfaction with the work schedule, misunderstanding problems with management, feeling helpless after work, lack of desire to go to work, staying at work after hours, and failure to fulfill the work plan. Logging machine operators were more satisfied with the work schedule, sometimes had misunderstanding problems with management and experienced helplessness after work, also stayed at work after hours, very

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rarely failed to fulfill the work plan and had no desire to go to work. Truck drivers had a more unfavorable assessment of the parameters indicated compared to representatives of other groups: they were less satisfied with their work schedule, stayed at work after hours and had no desire to go to work more often, had a lack of energy after work, and a lack of understanding with management. Maintenance workers had a more positive assessment of professional effectiveness compared to other groups: they were highly satisfied with their work schedule and rarely reported cases of misunderstanding with management or mentioned failure to complete the work plan, a feeling of helplessness after work and a lack of desire to go to work.

Table 5. Subjective assessment of the danger of professional situations of various professional groups of loggers of (based on MANOVA results, according to one-dimensional criteria, N=402).

Professional situations of shift workers	Harvester and forwarder operators M±SD; SE	Truck drivers M±SD; SE	Maintenance M±SD; SE	p
You are sick and urgently need to consult a doctor far from your workplace	3.3±2.22; 0.32	4.5±2.49; 0.32	3.2±2.21; 0.64	0.074
You have chronic diseases. but you forgot the necessary medications	2.0±1.58; 0.23	3.8±2.64; 0.34	1.9±1.56; 0.45	**0.001**
You were injured due to safety violations	3.1±2.38; 0.34	4.1±2.62; 0.34	3.3±2.27; 0.66	0.356
Absence of colleagues at the workplace when help is needed	3.6±2.16; 0.31	3.9±2.55; 0.33	3.4±2.57; 0.74	0.693
You have to work with faulty equipment or tools	3.7±2.23; 0.32	4.7±2.46; 0.32	3.7±1.87; 0.54	0.112
You made a mistake that could cause yourself or your colleagues to suffer	3.9±2.70; 0.39	4.2±2.62; 0.34	3.8±2.53; 0.73	0.947
One of your colleagues violates safety rules	3.6±2.44; 0.35	4.3±2.55; 0.33	3.3±1.96; 0.57	0.467
For some reason. you are working without personal protective equipment	3.2±2.52; 0.36	4.5±2.59; 0.33	3.4±2.23; 0.65	0.081
You started work without prior safety training	2.6±2.25; 0.32	3.8±2.56; 0.33	2.6±2.07; 0.60	**0.043**
Power outage	2.2±2.00; 0.30	4.0±3.00; 1.34	2.5±2.54; 0.73	0.061
Water supply outage	2.5±2.13; 0.32	3.2±2.49; 1.11	2.1±1.78; 0.51	0.220
Change in weather conditions. due to which you cannot leave your workplace after shift	2.5±1.84; 0.27	1.6±0.89; 0.40	2.8±2.29; 0.66	0.682
Your relatives or loved ones have problems at home. and you cannot help them	4.0±2.24; 0.33	3.4±2.60; 1.17	3.6±2.35; 0.68	0.860
Due to weather conditions or other reasons. you are left without any means of communication	3.4±2.09; 0.31	1.6±0.89; 0.40	3.5±2.15; 0.62	0.064
Smoke or presence of a fire	3.4±2.52; 0.37	4.8±2.68; 1.20	3.3±2.10; 0.61	0.678
Performing work that is hazardous to health	3.7±2.36; 0.35	3.6±2.79; 1.25	3.2±1.75; 0.51	0.562
Providing first aid	3.3±2.38; 0.36	2.2±1.64; 0.73	3.5±2.20; 0.63	0.750

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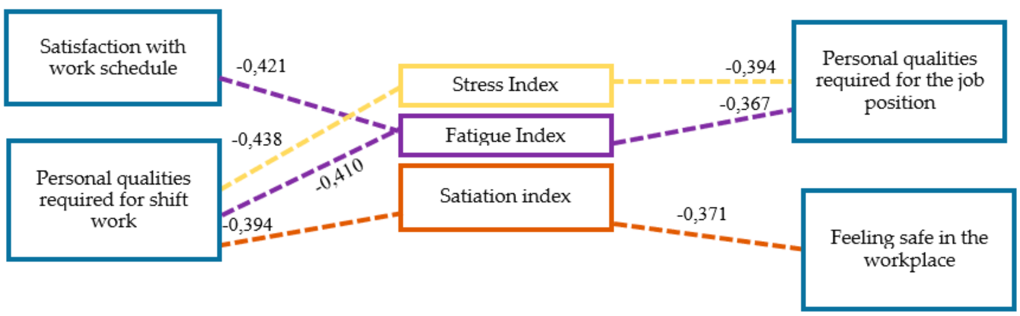
Preventing risks associated with testing new equipment	2.9±2.26; 0.34	3.0±2.83; 1.26	2.9±2.15; 0.62	0.764

As can be seen from Table 5, statistically significant differences were found between the groups of loggers in assessing the danger of the following professional situations: "when you have chronic diseases, but you forgot to take the necessary medications" and "when you started work without prior safety training". Truck drivers assess both of these situations as more dangerous than the representatives of the other two groups. Employees of all groups give a high assessment of the danger of situations of working with faulty equipment or tools, which may indicate a higher frequency of such situations, difficulties in resolving them, as well as an understanding of the importance of preventing them.

Thus, the first hypothesis of the study that, due to the specifics of their professional activities, truck drivers at a logging enterprise in the Far North are characterized by a greater severity of professional stress and a more frequent decrease in professional efficiency parameters than logging equipment operators and maintenance workers, was confirmed empirically.

3.3. The Relationship between Working Capacity, Job Stress and Professional Performance of Loggers in the North

At the next stage of the study, to identify the relationship between working capacity, job stress and professional performance of loggers working on a shift basis in the North, we used correlation analysis (Spearman coefficient). Using its results, two correlation pleiades were compiled for those parameters that have statistically significant relationships (Fig. 2 and 3). The correlation analysis was applied to professional self-assessment and the frequency of manifestations of professional efficiency parameters, as well as job stress indicators (measured by DASRWC, VCM, CVMR, WAM and M. Luscher's methods) of forest harvesting workers. In the correlation pleiad, only those factors were noted that have statistically significant relationships at a p level less than 0.04 with loggers' job stress parameters (group assessment of error probability (I type) according to the Bonferroni method in the Holm modification).



——	Positive correlation (p≤0.04)	- - - -	Negative correlation (p≤0.04)
——	Positive correlation (p≤0.01)	**- - -**	Negative correlation (p≤0.01)

Figure 2. Correlation pleiad of statistically significant relationships between job stress indicators and professional performance parameters and professional self-assessment among shift-working loggers in the North.

According to Fig. 2, statistically significant relationships have been established between the parameters of professional performance and self-assessment with stress, fatigue and satiety indicators (according to DASRWC). The higher the employees assess their professional qualities and readiness for shift work, the lower their stress and fatigue levels. Also, the higher satisfaction with the work schedule, the less fatigue is expressed by employees.

The more pronounced the employees' personal qualities necessary for shift work (according to their subjective assessments), and the higher feeling of safety in the workplace, the less satiety is expressed.

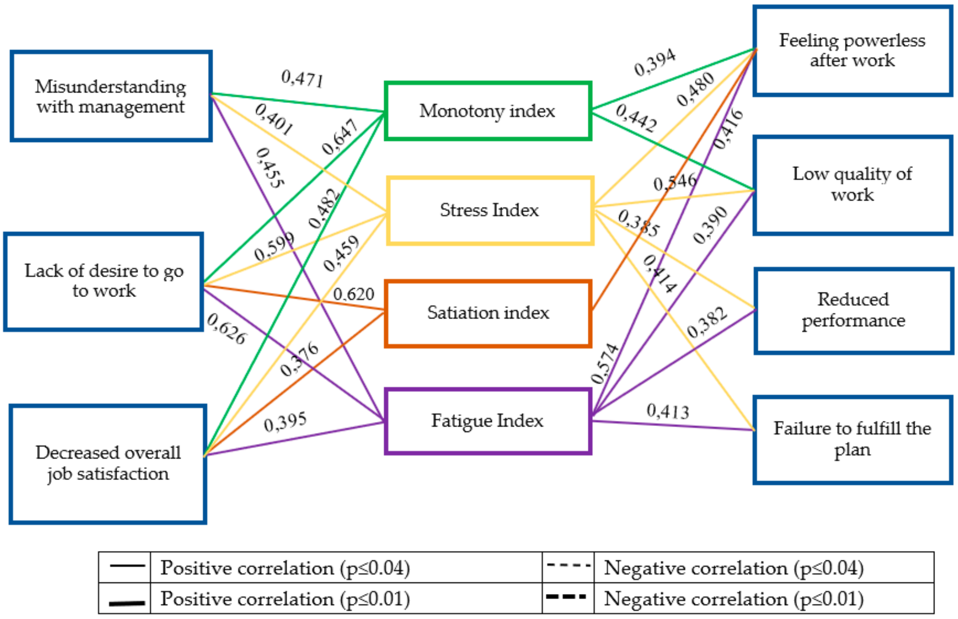


Figure 3. Correlation pleiad of statistically significant relationships between job stress indicators and the frequency of manifestations of professional performance parameters among shift-working loggers in the North.

According to the data in Fig. 3, there exists a statistically significant relationship between the frequency of manifestations of professional performance parameters and the levels of monotony, stress, fatigue and satiety (according to the DASRWC). The more pronounced the monotony, the more often employees experience a lack of desire to go to work, a decrease in job satisfaction in general, and a feeling of helplessness after work. Misunderstanding problems with management and low performance indicators are also characteristic of them.

The more stressed the employees are, the more often they do not fulfill the work plan, have low performance indicators and decreased efficiency. There are also misunderstanding problems with management, feelings of helplessness after work, a lack of desire to go to work and a decrease in job satisfaction in general.

The more pronounced the satiety of loggers is, the more often they experience a feeling of helplessness after work, a lack of desire to go to work and a decrease in job satisfaction in general. The more tired the employees are, the more often they fail to fulfill the work plan, demonstrate poor quality and decreased efficiency of work, have a lack of energy after work and decreased job satisfaction in general. Moreover, they do not want to go to work and have misunderstanding issues with management. Thus, the second hypothesis of the study was confirmed in general. It was shown that psychological and psychophysiological parameters of professional stress and performance are associated with the parameters of professional efficiency of loggers. We expect a greater number of connections between the psychological parameters of professional stress measured using questionnaires and the parameters of professional efficiency of workers. Statistically significant connections were identified in relation to the parameters assessed by questionnaires.

3.4. Job Stress and Working Capacity Parameters Influencing Professional Performance of Loggers in the North

To determine the job stress and working capacity parameters that affect professional performance, 8 step-by-step regression analyses were consistently conducted, where the dependent

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variables were the values of the professional performance parameters assessed using a questionnaire, and the independent variables were DASRWC, VCM, CVMR, WAM parameters and M. Luscher's method. Table 6 summarizes the multiple regression equations for each of loggers' professional performance parameters.

Table 6. Job stress and working capacity parameters that affect the professional performance of loggers based on the results of multiple regression analyses(N=402).

Parameters	Job satisfaction	Feeling of safety at the workplace	Reprimands and comments from management	Feeling of helplessness after work	Lack of desire to go to work	Decreased overall job satisfaction	Poor quality of work indicators	Failure to fulfill the plan
Coefficient B	12.798	12.333	0.473	-1.515	-2.765	-2.496	-0.095	-1.242
Stress index (DASRWC)	-0.225		0.098				0.067	0.181
Satiety index (DASRWC)		-0.208						
Vegetative balance (Luscher' test)			-0.108					
Monotony index (DASRWC)					0.266	0.240		
Fatigue index (DASRWC)				0.150				
Operator working capacity (SZMR)				0.218				
Speed (CVMR)							-0.212	
Stress (Luscher' s test)						0.054		
R^2	0.513	0.429	0.516	0.516	0.715	0.634	0.630	0.500

Note: the cells contain the values of the regression coefficients of the equation for those variables that were included in the final equation for the corresponding parameter of professional performance.

According to the results of multi-regression analyses, the less stress employees have, the higher their job satisfaction, and vice versa, with increased stress, the frequency of reprimands and comments from management increases, low performance indicators and more frequent failure to fulfill the work plan are observed.

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The less satiety employees have, the higher their sense of safety in the workplace.

The more pronounced the fatigue and the higher the operator working capacity, the more often employees experience helplessness after work. With growing monotony, employees often have no desire to go to work, and job satisfaction generally decreases.

Thus, the third hypothesis that markers of reduced professional performance of loggers include stress, monotony and satiety indicators was confirmed.

4. Discussion

Our study revealed the features of manifestations and interrelationship of job stress, working capacity, professional performance and safety among loggers in shift work organization in the North. Based on the results of testing the first study hypothesis, it was found that truck drivers (for timber removal and dump truck drivers) were characterized by more pronounced stress (but within moderate values), higher speed and lower quality of CVMR tasks, while higher values of subjective assessment of well-being, activity and mood were found in comparison with logging equipment operators and technical inspection workers. P. Škvor's study revealed a 22.5% higher stress load for drivers of loaded timber trucks when driving on narrow roads [12]. Driving a timber truck with a trailer involves a higher muscular load (46.5%) compared to driving a loaded passenger car [12]. The results of numerous studies of stress factors and performance of truck drivers [15–18] established the great importance of social, family and economic factors. Hege et al. (2019) found moderate or high levels of stress in 62.6% of drivers [45].

It has been established that truck drivers are often exposed to the following adverse factors: long shifts, strict cargo transportation deadlines, stressful conditions, insufficient number of breaks, and irregular work and sleep patterns [45,46].

At the same time, in the current study, it was found that forestry machine operators are in the second place in terms of stress level (according to DASRWC) of the three studied professional groups. However, their operator working capacity (in performing a CVMR) is higher than that of truck drivers and maintenance specialists. This may be due to the fact that even when operators are exposed to severe professional stress, they have sufficient work experience to demonstrate good performance. Some other studies have shown that the most experienced operators were 25% and 50% more productive than their least experienced colleagues [25,47–49]. More experienced and productive operators may use a different work technology than their less experienced and productive colleagues [50]. More experienced operators performed better as task complexity increased [51]. However, Spinelli found that more experienced operators had an advantage when task complexity increased, but they had a similar decline of performance in the adaptation situation as their less experienced counterparts [25]. These findings help explain the relationships found in the present study: the more employees perceived their personality traits to be suited to shift work and the higher their sense of job security, the less satiation was expressed.

J. Dvořák found that professional education and experience are very important in predicting the operator's success [52]. When comparing the time, it took to perform harvesting work on a harvester for operators with two years of experience and without experience, it was found that the average difference in their time was 64.9 seconds at one stage of work [52]. The statistical significance of the differences in time was proven in technically difficult sections of the felling area (extending the boom from the felling head and processing the tree). The study also proved that experience is more important than education for the operator's success. [52]

The assessment of efficiency can be influenced by changes in working conditions and employee motivation over time [53]. Operating a forest machine on steep slopes results in a significant increase in mental workload (the harvester operator experienced a higher mental workload when the slope gradient increased from 9% to 47%) and requires appropriate work and rest regimes [54]. Working in a more diversified “mixed wood” environment resulted in a noticeable loss of productivity, estimated at between 40 and 57%: an increase in mental workload was found among operators when moving from the “pure coniferous wood” cutting area to the “mixed wood” cutting area [25].

When testing the second hypothesis about the relationship between psychological and psychophysiological job stress and working capacity parameters with the professional performance parameters of loggers, it was found that the more pronounced monotony, fatigue, stress and satiety are in employees, the more often they note reduced performance indicators: low quality of work indicators, failure to fulfill the work plan, decreased job satisfaction, misunderstanding problems with management, a feeling of helplessness after work and lack of desire to go to work. In this case, the hypothesis was confirmed, since more correlations were established between the psychological parameters of job stress measured using questionnaires and the professional performance parameters of workers. This may be due to the fact that questionnaires allow for a clearer differentiation of various states of reduced working capacity, taking into account their causes. While psychophysiological tools allow for diagnosing changes at the level of the body and psyche associated not only with work, but also with health and external environmental factors. We can assume the priority of the role of the totality of the professional's attitudes to the object of labor and its features, to himself as a subject of labor in the formation of professional stress in comparison with the current objective state of the body. At the same time, a significant influence of the objective state remains.

When testing the third hypothesis, it was found that reduced professional performance markers of forest harvesters are stress, monotony and satiety. Based on the application of statistical analysis of accidents, it was proved that one of the common causes of road accidents is fatigue [14,55–57], which is a result of excessive strain due to prolonged stay in a static position, as well as mental overload or monotony of work [58].

As for the relationship between the well-being and labor productivity of forest harvesting equipment operators, the following was established [59].

Operators' mental workload is associated with two main contradictory causes: 1) the complexity of the task, which requires concentration and coordination, and 2) the simplicity of the task, characterized by the number of repetitions, which causes a state of reduced vigilance as a side effect of long-term performance of monotonous tasks [60]. These factors are explained by the Yorkes-Dodson law and cause fatigue, which leads to decreased concentration, difficulty of focusing, slower and weaker perception, decreased motivation and emotional disorders [61,62]. As a result, work efficiency decreases, whereas the risk of accidents increases [63,64].

Therefore, determining the mental workload experienced by operators and drivers working in difficult environmental conditions is an important condition to consider when designing safe and efficient working methods. For example, the number of rest breaks should be adjusted according to the level of workload [65].

Another important factor in increasing labor productivity is the length of the work shift. In a study by Passicot, the productivity of workers in mechanized operations in Chile increased with increasing working hours. It was also found that average hourly productivity decreased by 9-30% when shift length increased from 9 to 18 hours [66]. The following factors reduced productivity: work schedule, type of operation performed, season (summer or winter), tree species and size. It was shown that increasing shifts beyond 9 hours per day did not lead to an equivalent increase in operator productivity [66].

Change of seasons is important for productivity for various reasons. Logging operations are less productive in summer than in winter. One reason for this is hot weather (35° to 37°C), which causes equipment to overheat and requires more frequent cleaning of air filters when working near dusty roads, as well as more equipment problems. Hot weather increases operator fatigue, which affects their productivity [66].

In addition, in summer trees need to be passed 4 or 5 times through the harvester head to better debark the log, while in winter 1-2 passes are enough. Operator fatigue and equipment problems in summer are aggravated by long shifts, which leads to a decrease in average productivity per shift of up to 34% [66].

Gingras (2004) showed that in Canadian logging industry differences between day and night shift worker productivity could be minimized through proper equipment selection, maintenance scheduling, and production planning (e.g. working the most difficult terrain on day shifts) [67].

Limitations of the study. A limitation of the study was the inclusion of the representatives of only three professional groups (logging equipment operators, truck drivers and maintenance workers) in the study sample. Foremen at the felling site, auxiliary workers, car drivers and senior management were not taken into account. Also, the study was conducted only in one of the Russian Federation regions, therefore the results could be different in other regions with different climatic conditions and terrain specifics. The results obtained are based on the methods of survey, questionnaire, psychophysiological and psychological testing. The method of expert assessment and correlation of data on the states of employees with their actual work results recorded in documents were not used due to the need to maintain confidentiality. The use of a cross-sectional study design, not longitudinal, also leaves an imprint on the use and dissemination of the research results..

5. Conclusions

Statistically significant differences were found between the groups in terms of the stress index (DASRWC), speed, accuracy and operator performance (CVMR), performance and stress (M. Luscher's method) and well-being, activity and mood (WAM). It was found that truck drivers at a logging company in the Far North are characterized by greater severity of job stress and more often experience a decrease in professional performance parameters than logging equipment operators and maintenance workers.

Psychological and psychophysiological job stress and working capacity parameters are associated with professional performance parameters of loggers. It was found that the more pronounced monotony, fatigue, stress and satiety are in employees, the more often they note reduced performance indicators: low quality of work indicators, failure to fulfill the work plan, decreased job satisfaction, misunderstanding problems with management, a feeling of helplessness after work and a lack of desire to go to work.

The markers of reduced professional efficiency of loggers are the index of stress, satiety, monotony and fatigue (DASRWC), vegetative balance and stress (M. Luscher's method and G.A. Aminev's coefficients), operator working capacity and reaction speed (CVMR). The methodology for assessing professional stress should take into account, along with objective instrumental diagnostics of job stress, diagnostics of one's own attitude to one's condition by means of special questionnaires.

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