Evaluation of Fatigue Development and Mental Performance among Young Adults who are Low-to-Moderate Alcohol Users and Lifetime Abstainers

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Abstract: - Comparative evaluation of the objective (error commission on attention and memory tests) and subjective ("WAM" and "WAM-8" tests) indicators of fatigue and mental performance at baseline, in dynamics of mental work, and after rest, suggest a high rate of fatigue development in low-to-moderate alcohol users (during the period of sobriety) compared to lifetime abstainers. In 52.6% of moderate alcohol users, a 2 hour period of rest following administration of 75 g of glucose was not sufficient for full recovery of their functional state and performance caused by prolonged mental work on fasting. In 38.9% of cases, the sober alcohol users had symptoms of chronic fatigue or exhaustion. Fatigue and impaired performance in sober alcohol users indicate unsafe use of even low-to-moderate quantities of alcohol by young students.

Key-Words: - Fatigue, mental performance, alcohol, lifetime abstainers, low-to-moderate alcohol users

1 Introduction

The problem of fatigue is one of the major problems of applied physiology, primarily labor and sports physiology, as well as in other fields such as ergonometrics [1, 2]. The term "fatigue" has about 100 different definitions [1, 2]. According to the "Guidelines on terminology in physiology of labor", fatigue refers to the process of a temporary reduction of functional capacity of an organism under the influence of intense or prolonged work, and is manifested in the deterioration of quantitative and qualitative performances, as well as dys-coordination of physiological functions [3]. Notwithstanding, however, the most common definition of fatigue in the scientific literature is "the temporary reduction of efficiency caused by previous work" [1, 2].

The problem of fatigue has immense practical importance, and is still causing a broad discussion on a range of issues and, above all, by its nature (causes and mechanisms of development); diagnosis of fatigue and performance evaluation; ways and means in combating fatigue and stimulating efficiency [1-3]. Fatigue can be caused by a number of factors, including physiological (health state, sleep, work, leisure); hygiene (microclimate), socio-economic, aesthetic. However, among the factors that cause fatigue, much attention has not been given to the assessment and analysis of the duration of action (or aftereffect) of alcohol use on fatigue development, especially in low-to-moderate alcohol users even in the period of sobriety (abstinence). It is widely known that heavy alcohol users and alcoholics are more prone to fatigue development than their peers who are non-alcohol users [4, 5]. Data on the differences in fatigue development between non-alcohol users and non-heavy alcohol users (i.e. low or moderate alcohol users) in different periods of sobriety, particularly, in course of varying functional states, have not been reported. Fatigue is closely related with mental performance. Both fatigue and mental performance are parameters of higher brain functioning and are implicated in general intellectual abilities, effectiveness of everyday activities. Importantly, those systems involved in the development of fatigue and mental performance deterioration are those ones that are also involved in alcoholism [6].

The aim of this investigation was to conduct a comparative evaluation of mental performance and the course of fatigue development in respondents who are alcohol users, not currently classified as heavy users, and are not frequent consumer of alcoholic beverages, and people who are lifetime abstainers (non-alcohol users).

2 Methods

Respondents who were rated as non-heavy drinkers (based on the AUDIT criteria) in our previous study were approached and explained the study aim. Only those who voluntarily agreed were considered to participate in the study. The study was carried out through a written consent involving 19 non-heavy alcohol users and 8 lifetime abstainers – students of the Belarusian State Medical University, Minsk, Belarus. These students had successfully passed through the yearly medical check-ups and they had no known illness or apparent disorders in functioning.

For the diagnosis of fatigue, three basic rules, which are recommended include: 1) selection of the indicators most appropriate for a given condition; 2) the use of not only one, but a set of indicators; 3) analysis of the dynamics of indicators based on their repeated registration at baseline and in the course of carrying out the activity [1, 2]. In view of these recommendations, we developed an appropriate research design for the study.

All participants performed the same type of standardized mental work on fasting at the same time of day for 6.5 hours, and then they had a period of rest for 2 hours, and thereafter, performed short-term mental work that lasted for about 30 minutes. The overall design of time expenditure is as follows. During the first ½ hour, the 1st blood sampling and determination of glucose together with the 1st determination of the indicators of fatigue and mental performance (FMP) were carried out. Then within the next 1½ hours, phase I, involving filling of questionnaires was performed. After which the 2nd blood sample with the determination of glycemia and 2nd indicators of FMP (½ hour) with phase II (1½ hours) were carried out. Immediately after this phase, the 3rd blood sample and determination of glucose with the 3rd test of indicators of FMP (½ hour) and phase III (1½ hours) were conducted. Then the 4th blood sample with the determination of glycemia and 4th test of indicators of FMP (½ hour) were conducted. Phase IV included a period of rest in conditions of glucose tolerance test with 5th, 6th, and 7th blood sampling for glucose determination. After the 7th determination of blood glucose, the 5th test of indicators of FMP (½ hour) was conducted. Thus, the study lasted for 6½ hours, plus 2 hour of rest and another ½ hour of short-term work, beginning from 8:00/9:00 and ended in 17:00/18:00 in different sets of days, allowing for a more efficient monitoring of the participants and their adherence to instruction. From the outline described above, it is seen that blood glucose level was determined 7 times in all participants. The 1st measurement was performed immediately before work (initial) on fasting. In the dynamics of mental work, three repeated measurements were made, after 2 hours (2nd measurement), 4 hours (3rd measurement) and 6 hours (4th measurement) from the beginning of work. After 30 minutes following the 4th glycemic measurement, glucose tolerance test was performed. During the glucose tolerance test, glycemic level was measured three times after 30 minutes (5th measurement), 60 minutes (6th measurement) and 120 minutes (7th measurement) after receiving per os, 75 g of glucose dissolved in 200 mL of water. Measurement was carried out with "Rightest GM100" system through painless puncturing of the skin of the fourth finger at the tip (left hand) to obtain 1-3 ml of blood. The accuracy of the system is up to 0.1 mmol/l.

Mental work of students is traditionally considered as the 5th kind (group, type) of mental work [2, 3] after operator's (1), manager's (2), creative people's (3) and health worker's (4). Mental work of students requires challenging basic mental functions such as attention (one of the cognitive functions most susceptible to fatigue), memory (mostly visual) and thinking [1, 2, 3]. That is why standardized tests were used to monitor the performance of major parameters of mental functioning (attention, memory, thinking) starting from the beginning of work to its completion.

In accordance with the first rule of the diagnosis of fatigue, and also, putting into consideration the character of mental work, the study was conducted only at weekends (Saturdays). The study was modeled to resemble academic activities. Mental load of all students were completely identical and included two types of work – carrying out standardized tests to determine the psycho-physiological and psychological indicators of FMP, as well as work with questionnaires and educational (medical) texts.

Standardized tests to determine the FMP indicators (cognition, memory, thinking and attention) were represented by five types [7-9]. They included two-digit numbers for short-term visual memory (1) sequence of digits for short-term auditory memory (2), sequence of vowels for short-term auditory memory (3), operant memory and thinking processes (4), as well as evaluation of attention function (5). Determination of FMP was conducted five times, immediately after each blood sampling at baseline (1st testing) and during mental work after 2 hours (2nd testing), 4 hours (3rd testing) and 6 hours (4th testing), and at 2 hours after rest, that is 8½ hours from the start of the study (5th testing).

Diagnosis of fatigue should be considered not only by the reduction of the effectiveness of labor (as an objective criterion), but also by the change of mental and emotional state of the person (as a subjective criterion). As such, subjective criteria followed by measurement of objective indicators of FMP and psychophysiological functions (attention, memory and thinking) should immediately accompany every controlled measurement of subjective indicators of well-being, activity and mood (tests "WAM" and "WAM-8" [10, 11]), neuro-psychological adaptation [12], state and trait anxiety [13, 14].

Thus, in course of the dynamics of mental work, 8 objective and 6 subjective indicators were constantly recorded in the students. This corresponded to the 2nd rule of diagnosis of fatigue – complexity of the resulting amount of evidence at the psycho-physiological, psycho-emotional and biochemical levels.

Dynamic monitoring of the 14 indicators specified was in line with the 3rd rule of diagnosis of fatigue and allowed for an objective assessment of FMP in the participants during prolonged mental work and after rest.

Mental work done by the participants included the filling of questionnaires and analysis of educational texts. At the 1st phase, participants filled in a number of questionnaires for a period of 1½ hours: "General" and built in "Sincerity", "Academic buoyancy"; including tests "AUDIT, CAGE, MAST and PAS" for the identification of problems related to alcohol use [15-18]. At the 2nd phase, also within 1½ hours (from 2½ to 4 hours), they worked with the educational text "Physiology and morphology of bone" and then performed a control test exercise containing 43 questions. At the 3rd phase, also within 1½ hours (from 4½ to 6 hours), the participants worked with the educational text "Physiology of the autonomic nervous system", and then performed another control test exercise containing 46 questions. At the 4th phase, they took a 2 hour rest in a condition of glucose-tolerance test.

Statistical analysis was performed using the SPSS, version 16.0 for Windows; parametric and nonparametric methods. The level of significance was set at $p < 0.05$.

3 Results and Discussion

Effective execution of long-term mental work is an essential and necessary condition for the successful assimilation of large volume of new information, which is in turn important in obtaining higher (including medical) education. The rapid development of fatigue and low efficiency of mental work are considered as important factors limiting success in the learning process by increasing the likelihood of obtaining unsatisfactory grades in examinations.

Among the objective criteria of fatigue, Rosenblatt (1983) recommends the use of quality indicators of reduced performance "... in the performance of specific control tasks of different nature". The leading factor of the quality of performance is the number of errors made during standardized tasks and, above all, tests on attention function. Attention is one of the most engaged mental functions for learning and at the same time one of the most fatigable [3]. Fatigue as an important indicator of the dynamics of the total number of errors in the standardized tests (involving tests for analysis of short-term visual and auditory memory, thinking and attention), remains a useful measure of the progress of ongoing work. Among the subjective criteria of human fatigue, the most feasible is the number and dynamics of points obtained on the scale of “Well-being”, “Activity”, and “Mood” in the test “WAM” (for students and athletes [10, 18]) and the scale of test “WAM-8”, designed for pilots [11]) in course of work performance.

Analysis of the dynamics of the number of errors on attention test and the total number of errors in all tests (five tests) (Table 1) showed a significant increase in error commission rate (15.8 - 115.8%) in all alcohol users during work, after 2 hours from the beginning of the study. This indicates the presence of fatigue as well as its increase during mental work among this group of students. Increased number of erroneous actions remained among alcohol users after 2 hours of rest, indicating the apparent failure of recovery process for students who use alcohol.

The presence of fatigue at the beginning of work and inadequacy of the night’s rest among alcohol users were confirmed by the test result of subjective self-assessment on the “WAM” and “WAM-8” (Table 2). So, their average score on the subscale of “Activity” was 1.17-fold lower than the same average score on the subscale of “Mood” (Table 2), which, according to [10], is a subjective symptom of fatigue state. In the dynamics of mental performance, difference between the scores of the two subscales on the “WAM” test in alcohol users increased to 1.38 and 1.45 at 4 and 6 hours of mental work, respectively (Table 2). After 2 hours of rest, this difference was reduced to 1.02 ($p < 0.05$; t-test = 2.118; df = 17) points, but remained statistically significant for establishing the fact about the conservation of fatigue among the alcohol users.

TABLE 1. Number of errors at baseline and its dynamics in relation to the initial value during mental work (M ± m) in the lifetime abstainers and alcohol users

Time of testing	Number of errors and its dynamics on attention test		Number of errors and its dynamics on all tests (memory, thinking, attention)	
	Lifetime abstainers	Alcohol users	Lifetime abstainers	Alcohol users
Initial	2.8 ± 0.8	15.2 ± 3.5 ۞	14.1 ± 1.3	28.4 ± 3.9 ۞
After 2 h of work	– 0.4 ± 0.5	+ 3.0 ± 1.4 *	– 1.1 ± 1.0	+ 4.5 ± 2.1 *۞
After 4 h of work	+ 0.3 ± 0.8	+ 9.0 ± 3.5*۞	– 0.4 ± 1.3	+ 10.6 ± 4.2 *۞
After 6 h of work	– 0.2 ± 0.6	+17.6 ± 5.8*۞۞	– 0.9 ± 0.6	+ 19.1 ± 6.1 **۞
After 2 h of rest	– 0.3 ± 0.9	+ 13.2 ± 6.9	– 1.0 ± 1.5	+ 7.4 ± 2.8 *۞

Notes: Lifetime abstainers scored zero on the AUDIT test; alcohol users had an average of 5 points on the AUDIT test, and their duration of sobriety (or abstinence) ranged from 1 to 4 weeks before the study. * - Significant differences (*$p < 0.05$; **$p < 0.01$) compared with values of students in its own group at baseline; ۞ - significance of differences (۞$p < 0.05$; ۞۞$p < 0.01$) compared with similar data of lifetime abstainers at the same phase of testing. Values were calculated by Student's test.

Analysis of the results of the study showed that both objective and subjective measures of fatigue were higher in alcohol user compared to their lifetime abstaining counterparts at all phases of the study [Tables 1 and 2].

Concentration of attention in 79% of cases among alcohol users was reduced already at baseline. Analogical parameter in lifetime abstainers was 6.32 times better compared to the alcohol users. This fact clearly shows that even a good night's rest after five days of brainwork (schoolwork from Monday to Friday), most students-alcohol users could not sufficiently recover their functional states. They committed on average 5.42 times more errors (Table 1) and had a 6.32-fold ($P < 0.002$; Pearson $\chi 2 = 10.296$; df = 1) greater risk of reduced attention concentration compared with lifetime abstainers. And this is true not only for males, but also for females which was established in a previous study involving a larger sample of participants in which only a single test on attention function was performed [18].

Dynamic observation of the parameters “Well-being”, “Activity” and “Mood” of alcohol users revealed their significant reduction during mental work after 2 hours of its onset (Table 1). As a result, all alcohol users had on the “WAM” test, one or more points lower than the lifetime abstainers (Table 2). However, even the lifetime abstainers showed a tendency of decrease in all three indicators

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on the “WAM” test (Tables 2 and 3) after 6 hours from the start of the study. This can be explained by the development of fatigue in some of the respondents, caused by the execution of prolonged and fairly difficult mental work on fasting during the catabolic phase of metabolism.

The tendency in the reduction of scores on all subscales of the “WAM” test at the end of mental work (after 6 hours from the beginning) among the lifetime abstainers following 2 hours of rest, changed to the opposite direction, which led to the complete normalization of the parameters of the “Well-being”, “Activity”, and “Mood” (Table 2). Thus, 2 hours of rest for the lifetime abstainers (following ingestion of 75 g of glucose) was enough for a full recovery of all three test indicators on “WAM”. The obtained results on the recovery of the functional state in lifetime abstainers was confirmed by complete recovery of the speed of simple arithmetic processing, which was up to 100% efficiency [18], while maintaining a high concentration in the attention test (Table 1). These results confirm the data reported elsewhere [20, 21], indicating that glucose has a positive effect on cognitive function (concentration and stability of attention, thinking capacity), and thus, its increase in blood should be evaluated as a positive phenomenon during the period of mental work [22].

Alcohol users following 2 hours of rest (Table 2) could not recover from any of the parameters on the “WAM” test and the values of the parameters remained reduced by 1.03 - 1.43 points in relation to that of the lifetime abstainers, and on the subscale “Well-being” and in relation to baseline, it was reduced by 0.92 points. This can be seen as an evidence of the subjective feelings of fatigue in the alcohol users and the failure to recover from a 2-hour period of rest. This assumption is confirmed by the analysis of the performance test “WAM-8” (Table 3), developed for the subjective, rapid diagnosis of the functional state of pilots before flying, between flights, and after completion of flight [11].

An average test score on “WAM-8” equal to 4.0 or lower indicates a poor functional state of the pilot (or participant), which leads to timely suspension of the pilot from flying until full recovery of functional state. Given the data in Table 2, the average score on the “WAM-8” test of alcohol users after 6 hours of mental work approached the critical value and was 4.04 ± 0.39 points. In this circumstance, functional state of 7 students of the alcohol users was rated poor (Table 3), and one of them even refused to continue the work at the end of phase II (before the 3rd test).

During the study, number of alcohol users who had their test score on the WAM-8 reduced to 4 or less, increased steadily after 2 hours of mental work – 3 participants, after 4 hours – 5 participants, and after 6 hours – 7 participants (Table 3). The decrease in the average test score on “WAM-8” in these seven alcohol users ranged from 3.0 to 5.1 points, which is considered as chronic fatigue and even exhaustion. The inability of three participant-alcohol users to continue the study on the 3rd phase of the study was indicative of this exhaustion. Thus,

TABLE 2. Self-assessment of the functional state on the test “WAM-8” and on the three subscales “WAM” (M ± m) by lifetime abstainers and alcohol users, at initial, in course of mental work, and after rest

Time of testing	WAM-8		Subscale “Well-being”	
	Lifetime abstainers	Alcohol users	Lifetime abstainers	Alcohol users
Initial	6.06 ± 0.23	5.67 ± 0.16	6.08 ± 0.25	5.87 ± 0.13
After 2 h of work	6.04 ± 0.25	4.86 ± 0.34⊛	6.06 ± 0.22	5.18 ± 0.31
After 4 h of work	5.55 ± 0.37	4.25 ± 0.38*⊛	5.76 ± 0.40	4.61 ± 0.39*
After 6 h of work	5.46 ± 0.44	4.04 ± 0.39*⊛	5.56 ± 0.42	4.56 ± 0.38*
After 2 h of rest	6.06 ± 0.17	4.54 ± 0.35*⊛	5.98 ± 0.24	4.95 ± 0.35*⊛
Time of testing	Subscale “Activity”		Subscale “Mood”	
	Lifetime abstainers	Alcohol users	Lifetime abstainers	Alcohol users
Initial	5.55 ± 0.28	4.92 ± 0.□2	6.35 ± 0.19	6.09 ± 0.17
After 2 h of wo□k	5.41 ± 0.33	4.15 ± 0.29*⊛	6.46 ± 0.09	5.30 ± 0.37⊛
After 4 h of work	5.40 ± 0.35	3.74 ± 0.31*⊛	6.11 ± 0.17	5.12 ± 0.41*
After 6 h of work	5.18 ± 0.50	3.59 ± 0.31*⊛	6.30 ± 0.16	5.04 ± 0.41*⊛
After 2 h of rest	5.69 ± 0.26	4.26 ± 0.31⊛	6.60 ± 0.05	5.28 ± 0.35⊛

Note: designations are same as in Table 1.

38.9% ($p < 0.001$) of the alcohol users showed signs of chronic fatigue or exhaustion.

TABLE 3. Self-evaluation of the functional state on the test "WAM-8" by the lifetime abstainers (group 1) and alcohol users (group 2), at baseline, during mental work, and after rest

Number and time of testing	Group	Количество студентов, оценивающих своё ФС □ак			
		excellent WAM-8>6.0	good WAM-8=5.0–6.0	satisfactory WAM-8=4.1–4.9	not satisfactory WAM-8≤4.0
1st, initial	№ 1, n=8	4	4	0	0
	№ 2, n=19	6	10	3	0
☼ – differences between groups		χ^2 = 1.786; P>0.05 (3 degrees of freedom)			
2nd, after 2 h of work	№ 1, n=8	5	2	1	0
* - in relation to the initial value in its own group		χ^2 = 1.778; P>0.05 (2 degrees of freedom)			
	№ 2, n=19	3	9	4	3
* - in relation to the initial value in its own group		χ^2 = 0.767; P>0.05 (3 degrees of freedom)			
☼ - differences between groups		χ^2 = 6.322; P>0.05 (for 3 degrees of freedom)			
3rd, after 4 h of work	№ 1, n=8	3	2	3	0
* - in relation to the initial value in its own group		χ^2 = 3.810; P>0.05 (2 degrees of freedom)			
	№2, n=18+1	3 *	2 □	9 *	4 + 1 *
* - in relation to the initial value in its own group		* χ^2 = 14.333; P<0.005 (3 degrees of freedom) *			
☼ - differences between groups		χ^2 = 5.964; P>0.05 (3 degrees of freedom)			
4th, after 6 h of work	№ 1, n=8	3	1	3	1
* - in relation to the initial value in its own group		χ^2 = 5.943; P>0.05 (3 degrees of freedom)			
	№2, n=18+1	1 *☼	5 *☼	6 *☼	6 + 1 *☼
* - in relation to the initial value in its own group		* χ^2 = 13.238; P<0.005 (for 3 degrees of freedom) *			
☼ - differences between groups		☼ χ^2 = 9.375; P<0.025 (3 degrees of freedom) ☼			
5th, after 2 h of rest	№ 1, n=8	5	3	0	0
	№2, n=18+1	2 ☼	7 ☼	6 ☼	3 + 1 ☼
☼ - differences between groups		☼ χ^2 = 8.964; P<0.025 (3 degrees of freedom) ☼			

Number/order of testing and time of conduction	Number (proportion, %) of student without fatigue, WAM-8 ±0.9		Number (proportion, %) of student with fatigue, ↓WAM-8≥1	
	group № 1	group № 2	group № 1	group № 2
2nd, after 2 h of work (M ± m)	8 (100)	13(68.4±10.7)*☼	0 (0)	6 (31.6±10.7)*☼
3rd, after 4 h of work (M ± m)	6 (75.0±15.3)	8 (42.1±11.3)*	2 (25.0±15.3)	11 (57.9±11.3)*
4th, after 6 h of work (M±m)	6 (75.0±15.3)	8 (42.1±11.3)*	2 (25.0±15.3)	11 (57.9±11.3)*
5th, after 2 h of rest (M±m)	8 (100)	9 (47.4±11.5)*☼	0 (0)	10 (52.6±11.5)*☼

Notes: Reduction in the number of alcohol users during the third testing was due to the fact that one participant declined from continuing the study on the phase II. The significance of differences was calculated taking into account the Student t-test: * - significant differences ($p < 0.05$) compared with those of students in its own group at the first testing (baseline); ☼ - significant difference ($p < 0.05$) compared with similar data of lifetime abstainers (group 1) at the same phase of testing.

It should be noted that for 4 alcohol users, intake of 75 g of glucose and 2 hours of rest were clearly inadequate to restore their functional state (the test result of "WAM-8" remained less than 4 points). These facts show the limitations of the positive action of glucose on FMP of alcohol users. The mechanism of this occurrence may be related to a decrease in gene expression of GLUT1 and decrease in glucose uptake in brain cells (which was established for neurons and astrocytes in animal models even after a single dose of ethanol [23]). The limitations of the positive action of glucose on correction of fatigue in alcohol users must be considered in operator (mental) performance and may, even in certain cases, restrict alcohol users from manning or controlling transportation devices (drivers, pilots, machinists, managers and other professionally relevant services) for two weeks following consumption of alcoholic beverages.

Functional state of lifetime abstainers in the same conditions was much better. The mean score on "WAM-8" in the lifetime abstainers in course of mental work only had a tendency towards decrease and was 1.18 - 1.42 points higher at all phases of mental work compared to the alcohol users (Table 2). The stable score on the scale state anxiety (30-33 points) and trait anxiety (33-30 points) was indicative of the good functional state of the lifetime abstainers during mental work. At the same, alcohol users under stable self-estimation of their trait anxiety (34 - 38 points) showed an increase in state anxiety from 35 to 41-43 points during mental work (and became significantly higher than that of lifetime abstainers) and return to the initial value (37 points) after glucose administration and 2 hours of rest.

However, even among the lifetime abstainers, prolonged mental work (6 hours) in 4 students caused a decrease in well-being (Table 3), and reduced the rate of self-evaluation down to "satisfactory" level (in 3 participants) and to "poor" (in 1 participant). Two-hour period of rest in lifetime abstainers was sufficient to fully restore their functional state (Table 3) and eliminate psychological signs of fatigue. In this case, the absolute number and proportion of lifetime abstainers in excellent functional state was significantly higher, whereas those that were in satisfactory and unsatisfactory states were significantly lower than the alcohol users (Table 3). All lifetime abstainers (100%) after rest had no subjective symptoms of fatigue and their functional state was evaluated as excellent or good (Table 3).

Among the alcohol users, only 9 participants (47.4%), after 2 hours of rest were able to rate their functional state in similar fashion as the lifetime abstainers. In 52.6% of cases, alcohol users were unable to fully recover after the 2 hour period of rest. Therefore, the subjective assessment of the functional state by the lifetime abstainers after 2 hours of rest (Table 3) was significantly better than that of their colleagues-alcohol users.

The results of this study are important in explaining some of the contradictions in the literature concerning the action of glucose on fatigue and recovery of psycho-physiological functions in humans. Some researchers have pointed that there is association between these parameters [17, 18], whereas others [21, 22] did not find any relationship. Probably, in combined sample of abstainers and alcohol users (as well as their prevalence in the group of participants), following one or more months after alcohol use, administration of glucose on the background of fatigue is associated with improved mental performance and functional state (Tables 2 and 3). Conducting the study among the group of alcohol users alone could not have identified any relationship between intake of glucose and full recovery of functional state (Tables 2 and 3) and mental performance of fatigued humans [21, 22]. The analysis of correlation between objective and subjective measures of fatigue, shown in Table 4, revealed no significant relationship on the 1st testing, on the morning after a full night's rest. During mental work, the relationship appeared after 4-6 hours for the absolute values of the indicators (Table 4). The strength of the relationship was medium and negative, i.e., the better the functional state of the participants, the lesser they are likely to commit errors. This significant negative correlation of medium strength was maintained between the pairs of indicators in the participants after 2 hours of rest (Table 4), which probably reflects the lack of 2 hour period of rest for majority of alcohol users (Table 3).

Significant negative average and strong relationship between test scores "WAM-8" and the dynamics of the total number of errors on the five tests was observed at all phases of testing: during mental work (at 2nd, 3rd, and 4th testing) and after the 2 hour period of rest (Table 4). Mutual relationship between the subjective (functional state on "WAM-8") and objective (number of errors) signs of fatigue grew from 14.7% to 57.3%, respectively (Table 4) and persisted after 2 hours of rest in condition of administration of 75g glucose. This indicates inadequacy of 2 hours rest required to restore functionality in most fatigued participants of the group of alcohol users, since, after the full night's rest, this relationship (between the score on 'WAM-8" and the number of errors) was absent (Table 4).

Furthermore, these findings support the feasibility of using the short test "WAM-8" to assess the functional state of fatigue and human performance (in students, and not just pilots) during mental activity.

These facts strongly suggest that alcohol, even when it is used occasionally, in relatively low-moderate doses has a long-term (1 - 4 weeks) negative impact on cognitive functions. This is manifested primarily in reduced concentration (for some people, already at baseline and on the whole duration of the study), and the reduced effectiveness of thinking and memory (Table 1), as well as the inability to maintain an adequate level of long-term performance and the rapid development of fatigue (Table 3). Thus, these findings explain the decline in the effectiveness of learning activities of students who consume alcoholic beverages [18], their inability to fully engage in prolonged mental work (due to reduced concentration and fatigue sets in more quickly) even following a long duration of sobriety (7 - 28 days), which is also required to succeed at the university.

(number of errors in the test on attention and all five tests) indicators of fatigue and mental performance in alcohol users showed increased fatigue (in 57.9% cases). Altogether, 38.9% of alcohol users showed signs of chronic fatigue. Fatigue and impaired performance in the alcohol users indicate unsafe use of even low to moderate amounts of alcohol by young students. The "WAM-8" test can be used for rapid diagnosis of the functional state and prediction of performance and fatigue in students.

TABLE 4. Relationship between subjective (mean test score on "WAM-8") and objective (number of errors in all five tests) indicators of fatigue and performance at baseline, in the dynamics of mental work, and after rest.

Parameter	Values of parameters and their changes during mental work and rest				
	Before work	During mental work			After 2 h of rest
	initial (1st)	after 2 h (2nd)	after 4 h (3rd)	after 6 h (4th)	after 8½ h (5th)
Participants	27	27	26	26	26
WAM-8, score * t-test in relation to the initial	5.8 ± 0.1	5.2 ± 0.3 P > 0.05	4.8 ± 0.3 * P<0.01; t=3.155	4.6 ± 0.3 * P<0.001; t=3.785;df=25	5.2 ± 0.2 * P<0.02; t=2.679
No. of errors in all 5 tests $r_{Pearson}$ "WAM-8" – No. of errors in all 5 tests % interrelationship	24.2 ± 3.0 r = +0.043 P=0.416 0.18%	27.0 ± 3.3 r = –0.163 P=0.213 2.66%	31.3 ± 4.2 ۞ r = –0.420 P=0.016 17.64%۞	37.0 ± 5.9 ۞ r = –0.576 P=0.001 33.18%۞	29.0 ± 3.8 ۞ r = –0.356 P=0.037 12.67%۞
Dynamics of no. of errors * t-test in relation to the initial	– –	+ 2.8 ± 1.6 ۞ P > 0.05	+7.2 ± 3.1 *۞ P<0.05; t=2.319	+ 12.9 ± 4.5*۞ P<0.01; t=2.846;df=25	+ 4.9 ± 2.1 *۞ P<0.05; t=2.288
$r_{Pearson}$ between WAM-8 and dynamics of no. of errors % interrelation-ship: WAM-8 and dynamics of no. of errors		r = –0.383; P=0.027 r^2·100= 14.67%۞	r = –0.673; P<0.001 r^2·100= 45.29%۞	r = –0.757; P<0.001 r^2·100= 57.30%۞	r = –0.394; P=0.023 r^2·100= 29.83%۞

Notes: * - significant differences in relation to the initial data at the first (initial) testing using the t-test; ۞ - significant correlation between indicators taking into account the Pearson r. The 1st, 2nd, 3rd, 4th, 5th - number of testing, combined with the determination of blood glucose. Reason for reduction in the number of these students from 27 to 26 has been earlier mentioned. The proportion of mutual (interrelationship) of analyzed parameters was calculated based on the coefficient of determination (r^2) by the formula r^2 • 100%.

4 Conclusion

The concentration of active attention in abstainers was high, whereas the majority of alcohol users had reduced attention concentration throughout the study. Two hours of rest following administration of 75 g of glucose was sufficient for all the abstainers to fully restore their efficiency and functional state. In 52.6% of alcohol users, it was identified that 2 hours of rest and administration of 75 g of glucose were inadequate for full recovery of their functional state and mental performance after fatigue caused by prolonged work on fasting. Subjective (test scores "WAM" and "WAM-8") and objective

References:

[1] V. V. Rosenblat, *Manual on labor physiology*, Z. M. Zolina, N. F. Izmerov, Eds., Moscow: Medicina, 1983, pp. 227-250.

[2] N. A. Aghajanian, V. I. Tsirkin, Eds., *Physiology of labor processes. Human Physiology*, Saint-Petersburg: Sotis, 1998, pp. 418-437.

[3] L. Y. Zybkovets, A. O. Navakatikyan, *Manual on labor physiology*, Z. M. Zolina, N. F.

Izmerov, Eds., Moscow: Medicina, 1983, pp. 251-279.
[4] P. Philip, F. Vervialle, P. Le Breton, J. Taillard, and J. A. Horne, Fatigue, alcohol, and serious road crashes in France: factorial study of national data, *BMJ*, Vol. 322, No. 7290, 2001, pp. 829–830.
[5] P. M. Suter and Y. Schutz, The effect of exercise, alcohol or both combined on health and physical performance, *International Journal of Obesity*, Vol. 32, 2008, S48–S52.
[6] S. J. Moeller, D. Tomasi, J. Honorio, N. D. Volkow, R. Z. Goldstein, Dopaminergic involvement during mental fatigue in health and cocaine addiction, *Transl Psychiatry*, Vol. 2, No. 10, 2012, e176.
[7] V. S. Aver'yanov, K. G. Kapustin, O. Vinogradova, *Physiology of work activities*, Saint-Petersburg: Nauka, 1993, pp. 62-82.
[8] A. R. Allahverdyev, Sh. T. Efendiev, R. Z. Kafarova, Parameters of attention and short-term memory in normal and adolescent neurosis, *Human Physiology*, Vol. 15, No. 4, 1989, pp. 35-39.
[9] V. P. Zagryadsky, E. K. Sulimo-Samuyllo, *Research methods in occupational physiology*, Leningrad, 1991.
[10] V. A. Doskin, N. A. Lavrentiev, M. P. Miroschnikov, V. B. Sharai, Issues in Psychology, No. 6, 1973, pp. 141-145.
[11] *Aviation Regulations of flight of medical support of state aviation of the Republic of Belarus*, Belarusian State Aviation: Minsk, 2005.
[12] Y. L. Hanin, The study of anxiety in sports, *Issues in Psychology*, No. 6, 1978, pp. 94-106.
[13] I. N. Gurvich, *Vestnik Hypnology and Psychotherapy*, St. Petersburg, 1992, pp. 46-53.
[14] S. A. Igumnov, Stress management: modern psychological and medical approaches, Saint Petersburg, 2007.
[15] A. A. Aleksandrov, *Medicina*, No. 1, 2007, pp. 12-15.
[16] P. P. Ogurtsov, Express diagnosis (screening) of chronic alcohol intoxication in patients of somatic profile subdivision (clinical guidelines), *Clinical pharmacology and therapy*, Vol. 10, No. 1, 2001, pp. 34-41.
[17] T. F. Babor, J. C. Higgins-Biddle, J. B. Saunders, M. G. Monteiro, *The Alcohol Use Disorders Identification Test (AUDIT),* Second Edition, World Health Organization: Geneva, Switzerland, 2001.
[18] V. A. Pereverzev, Ed., *State of cognitive functions in medical students of Belarus with different habits to alcohol use*, Belarusian State Medical University Printing House: Minsk, 2013.
[19] V. I. Vlasenko, *Psychophysiology: methodological principles of professional psychological selection*, Minsk, 2005.
[20] F. Bellisle, Glucose and mental performance, *Br. J. Nutr.*, Vol. 86, 2001, p. 117.
[21] K. Fischer, P. C. Colombani, W. Langhans, C. Wenk, Carbohydrate to protein ratio in food and cognitive performance in the morning, *Physiol. Behav.*, Vol. 75, No. 3, 2002, pp. 411–423.
[22] A. O. Navakatikyan, *The physiological basis for improving the efficiency of labor*, V. I. Medvedev, Ed., Leningrad: Nauka, 1978, pp. 98-116.
[23] A. Brown, *Department of Health Promotion and Protection*, Addiction Services Province of Nova Scotia, Nova Scotia, 2007.
[24] J. K. Foster, P. G. Lidder, S. I. Sunram, Glucose and memory: Fractionation and enhancement effects? Psychopharmacology, *Psychopharmacology*, Vol. 137, No. 3, 1998, pp. 259–270.
[25] L. Gonder-Frederick, J. L. Hall, J. Vogt et al., Memory enhancement in elderly humans: effects of glucose ingestion, *Physiol. Behav.*, Vol. 41, 1987, pp. 503–504.