Journal of Behavioral Health
www.scopemed.org
DOI: 10.5455/jbh.20140811101711

Original Research

GESDAV

Fatigue and mental performance during prolonged mental activities on fasting in young people with different attitudes to alcohol use

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Received: April 30, 2014
Accepted: August 11, 2014
Published: August 25, 2014

ABSTRACT

Background: Fatigue and mental performance are closely related parameters of higher integrative brain functions. These indices of higher brain functioning had been implicated in general intellectual abilities, effectiveness of the diurnal performance, especially in people with active brain development and high cognitive demand such as young adults and students. Unfortunately, there is a paucity of data on the effects of alcohol consumption on the fatigue and mental performance level of young adults (students) with different attitudes to alcohol consumption. The aim of this study was to investigate the differences in fatigue and mental performance of young adults (university medical students) with different attitudes to alcohol consumption. **Materials and Methods:** Altogether, 27 participants (alcohol users and non-alcohol users, males, age range 20-29 years) volunteered for the study. The first period of this study took 6.5 h of mental activities on fasting. Thereafter, for a period of rest (2 h) following administration of glucose (75 g), functions of the participants were examined. Alcohol users did not use alcoholic drinks of any composition for 1-4 weeks before the study. All participants were administered standardized questionnaires (alcohol use disorders identification test, WAM, WAM-8, etc.), and assigned specific tasks in four phases. Standard psychophysiological tasks were administered to them, so as to produce a working environment that would necessary produce fatigue on the long-run. The rate of error commission was also examined. Blood glucose sampling was done at 2 h intervals. The statistical level for significance was set at $P \leq 0.05$. **Results:** Comparative analysis of the objective (number of errors in the test of attention and all five tests) and subjective (scores on "WAM" and "WAM-8") parameters of fatigue and mental performance in young people (students) at baseline and in the course of mental work, and the rest after work, indicates a fast development and high level of fatigue in alcohol users. In 52.6% respondents who reported alcohol use, 2 h of rest and consumption of 75 g of glucose were inadequate for full recovery of their functional state and performance following fatigue, caused by prolonged work on fasting. In 38.9% cases, alcohol users had signs of chronic fatigue. **Conclusion:** The high level of fatigue and impaired performance in alcohol users indicate unsafe use of even low-to-moderate quantity of alcohol by young students.

KEY WORDS: Alcohol, fatigue, glucose, mental performance, student, young people

INTRODUCTION

The problem of fatigue is one of the major problems in applied physiology, primarily labor and sports physiology [1,2]. The term "fatigue" has about 100 different definitions [1,2]. According to the "Guidelines on terminology in physiology of labor," fatigue is the process of a temporary reduction in the functional capacity of a person under the influence of intense or prolonged work, manifested in the deterioration of the quantitative and qualitative performance and dis-coordination of physiological functions [3]. More widely known, and common in the scientific literature is the definition of fatigue as a temporary reduction in efficiency caused by previous work [1,2].

Until date, owing to its immense practical importance; the problem of fatigue is still causing a broad discussion on a range of issues and, above all, its nature (causes and mechanisms of development); diagnosis of fatigue and performance evaluation; ways and means of combating fatigue and stimulating efficiency of work [1-3]. A lot of factors can cause fatigue: Physiological (state of health on the day of examination or study, adherence to sleep and wakefulness regimen, work and leisure); hygiene (microclimate), socio-economic, aesthetic [1-3]. Nevertheless, insufficient attention has been given to the assessment and analysis of the duration of abstinence from alcohol on fatigue, especially in a sober person following a few days or even weeks after alcohol consumption.

Mental performance is a key indicator of brain functioning, vital in the daily activities of humans. Mental performance is especially necessary for adolescents and young adults (students) and also indicates the level of brain development. Among the factors known to negatively affect mental performance, alcohol, which is the most prevalent psychotic substance among adolescents, young adults and students in the world, exerts greater negative impact on the intellectual abilities of this group of people [4-7]. It is widely known that the most vulnerable population to the effect of alcohol consumption is the adolescents, young adults and students since this group of people are in the stage of active development of the brain areas for intellectual, and other socio-behavioral abilities – decision making, social skills, foresight, abstract reasoning. The level of development of these societally beneficial abilities determines to a great extent the individual's life outcome. The intellectual, behavioral outcomes might even be more beneficial for young adults-students, due to the high demand for intellectual and behavioral functioning [4,5,8,9].

Fatigue and mental performance are closely related indices of higher integrative brain functions. Evidences indicate that these indices play a crucial role not only in general intellectual abilities, but also, effectiveness of the diurnal performance (including physical activities), especially in people with active brain development and high cognitive demand (e.g., adolescents, young adults [students]). The effects of alcohol consumption on the level of mental performance are known for decades. The effects of large doses of alcohol (acute or chronic) on some behavioral indices of adolescents, young adults and students have been well documented [6,7,9]. However, there is a paucity of data on the differences in the development of fatigue and mental performance of young adults (students) who episodically consume alcohol (even in low-to-moderate doses) and total abstainers [5,9].

In a previous study, it was identified that the majority of students were episodic, occasional alcohol users [4]. In spite of the low-to-moderate level of alcohol use by the students, a substantial level of alcohol-related problems was reported amongst them [4]. The effect of high doses of alcohol consumption (acute or chronic) on intellectual and behavioral indices such as fatigue and mental performance is quite known. Unfortunately, little attention has been given to the effect of alcohol use (especially episodic, low-to-moderate consumption, in varying periods of abstinence) on fatigue and mental performance in the young student's population. Therefore, the aim of this study was to conduct a comparative analysis of the development of fatigue and level of mental performance in alcohol users-young adults (students) during the period of abstinence and non-alcohol users (total abstainers).

MATERIALS AND METHODS

Study Participants

The study was conducted at the Belarusian State Medical University, Minsk, Belarus. The Ethics and Research Committee of the Belarusian State Medical University approved the study protocol. The participants of the present study were those who took part in an earlier study conducted in the same university [4]. A month before the study, males who previously participated in an earlier study [4] were randomly approached to volunteer for participation after the aims and objectives of the study had been explained. After 2 weeks, they were administered consent forms to volunteer their participation. Only those who agreed to participate and fulfilled the inclusion criteria were requested to read and sign an informed consent. After 1 week, the participants who completed the consent forms were reminded for the study and told to come for participation on an identified weekend (Saturday). The study was conducted with the voluntary participation, through informed and written consent of 27 male students of the medical university. Out of them, respondents who reported alcohol use during the past 1-4 weeks were 19, whereas 8 were non-alcohol users (abstainers). The methodology used in this study had been previously reported [5].

Inclusion Criteria

1. A sincerity test score of at least 70% according to earlier recommendations [4]
2. Absence of any hearing or visual problem that would limit the student's participation in the study
3. Willingness to participate
4. All participants had undergone compulsory yearly medical check-up based on the information on their medical cards
5. No history of diabetes or glucose intolerance based on data of recent compulsory yearly medical check-up
6. Alcohol abstinence of at least 1 week.

For the diagnosis of fatigue, the following basic rules and recommended guides were applied: (1) Use the most appropriate indicators for a given condition; (2) use not just one, but a set of indicators; (3) analyze the dynamics of indicators on the basis of repeated registration, beginning at the initial level, and in the course of the study [1,2]. Given these recommendations, appropriate design of the study was developed.

Study Design

All respondents performed the same type, standard mental work on fasting at the same time of the day for 6.5 h, and then they rested for 2 h, and again performed mental work for about 30 min. The time spent on each participant in the study was 9 h. Design of total time expenditure for each participant is as follows. The first ½ h involved first blood sampling for glucose and the initial determination of the indicators of fatigue and mental performance. Then, for 1½ h, participants filled questionnaires (first phase). After which the second blood sampling for glucose and the second determination of indicators of fatigue and mental performance were performed (½ h), subsequently, participants worked with Phase II of questionnaires (1½ h). Thereafter, a third blood sampling and determination of glucose followed, together with the third testing of the indicators of mental performance (½ h) and

Phase III (1½ h). Then the fourth blood glucose determination and fourth determination of indicators of fatigue and mental performance followed (½ h). Phase IV included the rest of students in a condition of glucose administration and final blood sampling for glucose determination. After the final determination of blood glucose, the fifth testing of fatigue and mental performance was conducted (½ h). This final testing was conducted to determine the effect of moderate glucose intake on fatigue and mental performance. Thus, the study was prolonged and lasted for about 9 h. The study began at 8/9 and was terminated at 17/18. The study was performed in a series of days. In each study, 2-5 subjects participated: 1-2 non-alcohol users and 1-4 sober respondents who reported abstinence during the past 7-28 days.

Determination of Blood Glucose

The level of glucose in whole capillary blood was determined in each participant. The first determination was done (at baseline) before the start of the study. In the dynamics of mental work, three measurements were conducted: After 2 h (second measurement), 4 h (third) and 6 h (fourth measurement). After 30 min, after the 4th glycemia measurement, glucose was administered to all participants. After oral administration of water (200 ml water) solution of glucose (in a dose of 75 g for each participant), the blood glucose level were measured after 2 h. The measurement was carried out using a glucose monitoring system in 1-3 ml of blood "Rightest GM100" (Bionime, Switzerland) with accuracy of up to 0.1 mmol/l.

Questionnaires and Tests

Standardized tests to determine fatigue and the state of mental performance were represented by five types [5,10-12]. They included tests for the analysis of short-term visual memory for two-digit numbers (1), short-term auditory memory for a sequence of digits (2), short-term auditory memory for a sequence of vowels (3), operant memory and thinking processes (4), as well as attention function (5). Determination of mental performance was conducted 5 times: Immediately after each blood sampling and at baseline (1st test) and in the course of mental activities from 2 h (2nd), 4 h (3rd) and 6 h (4th), and after 2 h of rest, that is 8½ h from the start of the study (5th). Analysis of mental performance was conducted on the basis of errors commission on the tests.

Since diagnosis of fatigue may be considered not only in the case of reduction in the effectiveness of labor (as an objective criterion), but also in case of change of mental and emotional state of a person (as a subjective criterion). As such, subjective criteria evaluation following the measurement of objective indicators of fatigue and mental performance each time by identifying subjective indicators of well-being, activity and mood ("WAM" and "WAM-8" tests [13,14]), the subjective parameters of anxiety state trait anxiety inventory (STAI) [15,16], neuro-psychological adaptation" were determined each time phase [17]. The number of errors on carefully designed groups of standard mental tests and test scores on WAM-8 according to recommendations [1-3,5,10-14] was used for the subjective and objective assessment of fatigue and mental performance. There are numerous tests used in the assessment of fatigue, but recent reports indicate a high reliability of the "WAM" test (especially WAM-8) [13,14,18] and number of errors in mental tests involving attention and memory. The "WAM" test is used for the analysis of fatigue in students and athletes [13,18], while the shortened "WAM" test referred to "WAM-8" has a high reliability for use among pilots [14]. Average score on "WAM-8" equal to 4.0 or less indicates poor functional state of the pilot (participants), which result in the suspension of the pilot from flights to restore full functionality. The analysis of the STAI [15,16] and neuro-psychological adaptation [17] are well-documented. Thus, 8 objective and 6 subjective indicators were constantly recorded in the students in the study. This corresponds to the second rule in the diagnosis of fatigue – complexity of the resulting amount of evidences at the psychophysiological, psycho-emotional and biochemical levels. Dynamic observation of the specified 14 indicators is also consistent with the third rule in the diagnosis of fatigue and allows for an objective assessment of fatigue and mental performance of participants during prolonged mental work and rest afterwards.

This study applied numerous questionnaires as stated below and was meant to produce substantial level of load for mental activities. Mental activities carried out by participants included filling of questionnaires and analysis of medical texts. At the first phase, for 1½ h the subjects filled a series of questionnaires: "General" and built in "Sincerity" test, "Academic Achievement", including questionnaires widely used in Narcology and general practice for the determination of problems caused by alcohol, "alcohol use disorders identification test (AUDIT)," "CAGE," "Michigan alcoholism screening test (MAST)" and "post-alcohol intoxication (PAS)" [5,19,20]. At the 2nd phase (also for 1½ h - 2½ to 4 h), participants worked with the text "physiology and morphology of bone" and then performed a control test of 43 questions. At the 3rd phase (also for 1½ h - from 4½ to 6 h), respondents worked with the text "physiology of the autonomic nervous system" and then performing a control test of 46 questions. At the 4th phase, students rested, in a condition of glucose-tolerance test. Detailed description of the tests and questionnaires used in this study is outlined in the monograph [5].

Data Analysis

Statistical analysis was conducted using a computer program Statistical package for the social sciences 16.0 version (Chicago, IL, USA). The χ^2-test was used to test for a normal distribution. Comparison between groups was made with *t*-test. Correlation tests were carried out with Pearson correlation coefficient to determine the association between objective (number of errors) and subjective (WAM-8 score) measures of fatigue. The share of mutual inter-relationship of the analyzed indicators was calculated on the basis of the coefficient of determination (r^2) by the formula $r^2 \bullet 100\%$ [21]. The level of significance was set at $P < 0.05$.

RESULTS

Table 1 shows mean scores on the screening tests and reported doses of alcohol use. From the table, it is seen that means of tests scores are far lower than the level of problem drinking (8 for AUDIT, 2 for CAGE and 6 for MAST).

The reported level of alcohol consumption by the alcohol users ranges from low to moderate. The average score on the "PAS" test was about 4, which was significantly lower than the cut-off point (10) for intoxication.

Analysis of the results showed that both objective and subjective measures of fatigue are pronounced in alcohol users, compared with their fellow abstainers at all phases of the study - at baseline (i.e., after a full night's rest), in the course of mental work and after 2 h of rest.

Analysis of the dynamics of the number of errors in the test on attention and the total number of errors in all five tests [Table 2] showed a significant increase (15.8-115.8%) in alcohol users, in the course of mental work, beginning from the 2nd h of mental work. This confirms the presence of pronounced fatigue in students who consume alcohol at the end of the week and its significant increase during mental activities. Conservation of an increased number of erroneous actions by alcohol users after 2 h of rest indicates the apparent inadequacy of this period of rest for this category of persons consuming alcoholic beverages.

Table 1: Average scores (M±m) on the AUDIT, CAGE, MAST and PAS and the reported quantity of alcohol use by students - abstainers (Group 1) and alcohol user (Group 2)

Group	Average test scores			Alcohol use		
	AUDIT	CAGE	MAST	Frequency/month	ml/per session	ml/month
Group 1, n=8	0	0	0	0	0	0
Group 2, n=19	5.1±1.1	0.6±0.2	1.7±0.4	2.3±0.6 (1-12)	38±4 (10-60)	94±26 (10-480)

AUDIT: Alcohol use disorders identification test, MAST: Michigan alcoholism screening test

Table 2: Number of errors at baseline and its dynamics in the course of mental work in relation to the initial number during work (M±m) in abstainers (Group 1) and alcohol users (Group 2) in the test "correction probe" on attention and all five tests

Time of testing	Number of errors and its dynamics in the attention test		Number of errors and its dynamics in all five tests	
	Group 1	Group 2	Group 1	Group 2
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*†

*P<0.05, **P<0.01 compared with students in its own group at the first testing (at baseline); †P<0.05; ††P<0.01 compared with analogical data of Group 1 at the same stage of testing. The values were calculated using the Student's test

In 79% cases, concentration of attention among the alcohol users (15 out of 19 respondents) was already reduced at the initial testing. Analogical parameter of abstainers was 6.3 times lower (1 out of 8). This fact clearly shows that after 5 days (Monday to Friday of school work) of mental work, for most alcohol users, even a good night's rest is insufficient for full recovery. They made on average 5.4 times more errors [Table 2] and had a 6.3-fold ($P < 0.002$; Pearson $\chi^2 = 10.3$; df = 1) greater risk of reduction in the concentration of attention compared to abstainers.

Dynamic observation of performance "well-being," "activity" and "mood" of the respondents who use alcohol, showed a significant reduction during mental work after 2 h from the beginning of the experiment [Table 3]. All three indicators of the test "WAM" in the sober students during mental activities were on one or more points lower, compared to the non-drinkers. In the dynamics of mental activity, difference between the scores of "activity" and "mood" subscale on the test "WAM" in sober respondents increased to 1.4 and 1.5 points at 4 h and 6 h work-load respectively [Table 2]. After 2 h of rest (under the condition of satiety), this difference reduced to 1.0 ($P < 0.05$; $t = 2.1$; df = 17) points, but remained statistically significant for ascertaining the fact of conservation of fatigue among respondents who consume alcohol [Table 3]. The tendency for some reduction in the points on all subscales "WAM" at the end of mental work (after 6 h from the beginning) in the abstainers after 2 h rest was reversed, leading to full normalization of "well-being," "activity" and "mood" [Table 3].

The good results of the abstainers on "WAM," compared with the alcohol users was confirmed by the results of the glucose test. There was constant increase in the blood glucose level of the non-alcohol users (on fasting), compared with the initial level (4.2 ± 0.2): +0.7 mmol/l ($P < 0.001$) after 2 h; +1.2 mmol/l ($P < 0.001$) after 4 h; +1.5 mmol/l ($P < 0.001$) after 6 h of mental work. Among the alcohol users, increase in the blood glucose occurred only after 2 h of mental work (+0.3 mmol/l, $P < 0.02$) with its return to the initial value after 4 h of mental work (−0.01 mmol/l) and the development of hypoglycemia (−0.6 mmol/l, $P < 0.05$) after 6 h of mental work (initial level of 4.5 ± 0.2). The final determination of blood glucose level, after 2 h of rest, following administration of 75 g of glucose, showed that all values were in the range of normal (~4.4 mmol/l). 2 h of rest (in a condition of glucose intake) were sufficient for the abstainers to fully restore all three parameters on the "WAM" test. For alcohol users, after 2 h of rest [Table 3], none of the three indicators of "WAM" did not recover to the initial value, and remained reduced by 1.0-1.4 points relative to similar indicators of the abstainers on the subscale "well-being" and to the initial value (−0.9 points).

The results in Table 4 indicate that the number of alcohol users who had reduced test "WAM-8" score down to 4 points, or less, steadily increased: After 2 h – 3 students; after 4 h – 5 students; 6 h – 7 students [Table 4]. The average test scores of the seven alcohol users who had a decline on "WAM-8," ranged from 3.0 to 5.1 points, which is considered as chronic fatigue and even exhaustion. Due to fatigue and hypoglycemia development, three participants (alcohol users) refused to continue the

Table 3: Self-assessment of the functional state on the test "WAM-8" and on the three subscales "WAM" (M±m) by the abstainers (Group 1) and alcohol users (Group 2), at initial, in the course of mental work, and after rest

Time of testing	"WAM-8" Test		Subscale "Well-being"		Subscale "activity"		Subscale "mood"	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Initial	6.1±0.2	5.7±0.2	6.1±0.3	5.9±0.1	5.6±0.3	4.9±0.2	6.4±0.2	6.1±0.2
After 2 h of work	6.0±0.3	4.9±0.3†	6.1±0.2	5.2±0.3	5.4±0.3	4.2±0.3*†	6.5±0.1	5.3±±0.4†
After 4 h of work	5.6±0.4	4.3±0.4*†	5.8±0.4	4.6±0.4*	5.4±0.4	3.7±0.3*†	6.1±0.2	5.1±0.4*
After 6 h of work	5.5±0.4	4.0±0.4*†	5.6±0.4	4.6±0.4*	5.2±0.5	3.6±0.3*†	6.3±0.2	5.0±0.4*†
After 2 h of rest	6.1±0.2	4.5±0.4*†	6.0±0.2	5.0±0.4*†	5.7±0.3	4.3±0.3†	6.6±0.1	5.3±0.4†

*$P<0.05$, **$P<0.01$ compared with students in its own group at the first testing (at baseline); †$P<0.05$; ††$P<0.01$ compared with analogical data of Group 1 at the same stage of testing. The values were calculated using the Student's test

Table 4: Self-assessment of functional state on the test "WAM-8" at baseline, during mental work and after rest by the abstainers (Group 1) and alcohol users (Group 2)

Number and time of testing	Group	Number of students who rated their functional state as			
		Excellent WAM-8>6.0	Good WAM-8=5.0-6.0	Satisfactory WAM-8=4.1-4.9	Non-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=1.8; P>0.05 (for 3 degrees of freedom)			
2nd, after 2 h of work	1, n=8	5	2	1	0
*In relation to the initial in its own group		χ^2=1.8; P>0.05 (for 2 degrees of freedom)			
2nd, after 2 h of work	2, n=19	3	9	4	3
*In relation to the initial in its own group		χ^2=0.8; P>0.05 (for 3 degrees of freedom)			
†Differences between groups		χ^2=6.3; P>0.05 (for 3 degrees of freedom)			
3rd, after 4 h of work	1, n=8	3	2	3	0
*Relation to the initial in its own group		χ^2=3.8; P>0.05 (for 2 degrees of freedom)			
3rd, after 4 h of work	2, n=18+1	3*	2*	9*	4+1*
*Relation to the initial in its own group		*χ^2=14.3; P<0.005 (for 3 degrees of freedom)*			
†Differences between groups		χ^2=6.0; P>0.05 (for 3 degrees of freedom)			
4th, after 6 h of work	1, n=8	3	1	3	1
*Relation to the initial in its own group		χ^2=5.9; P>0.05 (for 3 degrees of freedom)			
4th, after 6 h of work	2, n=18+1	1*†	5*†	6*†	6+1*†
*Relation to the initial in its own group		*χ^2=13.2; P<0.005 (for 3 degrees of freedom)*			
†Differences between groups		†χ^2=9.4; P<0.025 (for 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=9.0; P<0.025 (for 3 degrees of freedom)†			

Reduction in the number of respondents was due to the fact that one student of Group 2 discontinued participation in the experiment during the 2nd phase of the study. The significance of differences was calculated using the Student's t-test: *Significant difference (P<0.05) compared with students in its own group at the first testing; †Significant difference (P<0.05) compared with analogical data of Group 1 in the same phase (number) of testing

experiment and one student from the execution of the control test on "Physiology of the autonomic nervous system" on the 3rd phase. Thus, 38.9% (P < 0.001) of alcohol users had signs of chronic fatigue [Table 5].

Functional state of the abstainers under the same conditions was much better [Tables 4 and 5]. The magnitude of the average score on "WAM-8" in the abstainers only had a tendency for decrease and was at all phase by 1.2-1.4 points higher than the alcohol users [Table 3]. The stable performance scores on the same scale of the state anxiety (30-33 points) and trait anxiety (33-30 points) on Spielberger-Hanin test were indicative of a good functional status in abstainers. In the same sober respondents who periodically consume alcohol at stable assessment of trait anxiety (34-38 points), had an increase in state anxiety score from 35 points to 41-43 during mental work (which was significantly higher than that of non-drinkers) with a return to the initial value (37 points) after administration of glucose, and 2 h of rest.

Nevertheless, prolonged mental work (6 h) even in abstainers resulted to a decrease in well-being in four students. The 2 h rest for the abstainers was sufficient to restore their functional state fully [Tables 4 and 5] and the elimination of psychological signs of fatigue. The absolute number and proportion of abstainers in excellent functional state was significantly higher, and those in satisfactory and unsatisfactory condition (none) were significantly lower than the alcohol users [Tables 4 and 5]. All abstainers (100%) after rest assessed their functional state as excellent or good [Table 5]. Among alcohol users, only 9 people (47.4% of respondents) a similar self-rating of their functional state after 2 h of rest. In 52.6% cases, alcohol users were unable to recover fully during the time of rest.

Correlation analysis of the relationship between objective and subjective measures of fatigue shown in Table 6, revealed no significant associations on the 1st testing, on the morning after a full night's rest. In the process of mental work, this relationship, between the absolute number of errors and

Table 5: Number of participants with fatigue according to the results of self-assessment of functional state on the test "WAM-8" at baseline, during mental work and after rest by the abstainers (Group 1) and alcohol users (Group 2)

Number and time of testing	Number (%) of students without fatigue, WAM-8±0.9 point		Number (%) of students with fatigue, ↓WAM-8≥1 point	
	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)*†

Reduction in the number of respondents was due to the fact that one student of Group 2 discontinued participation in the experiment during the 2nd phase of the study. The significance of differences was calculated using the Student's *t*-test: *Significant difference ($P<0.05$) compared with students in its own group at the first testing; †Significant difference ($P<0.05$) compared with analogical data of Group 1 in the same phase (number) of testing

Table 6: The relationship between subjective (mean score on "WAM-8") and objective (number of errors on all five tests) at baseline, in the dynamics of mental work and after rest

Parameter	Values of the parameters and their changes in the course of mental work and after rest				
	Before work	During work, time (number of testing)			After 2 h of rest
	Initial (1st)	After 2 h (2nd)	After 4 h (3rd)	After 6 h (4th)	After 8½ h (5th)
Respondents	$n=27$	$n=27$	$n=26$	$n=26$	$n=26$
"WAM-8"	5.8±0.1	5.2±0.3	4.8±0.3 *	4.6±0.3 *	5.2±0.2*
**t*-test in relation to initial value		$P>0.05$	$t=3.2$; $P<0.01$	$t=3.8$; $P<0.001$	$t=2.7$; $P<0.02$
Error on five tests	24.2±3.0	27.0±3.3	31.3±4.2†	37.0±5.9†	29.0±3.8†
Pearson (*r*) between "WAM-8" and absolute no. of errors on 5 tests	$r=+0.1$; $P=0.416$	$r=-0.2$; $P=0.213$	$r=-0.4$; $P=0.016$	$r=-0.6$; $P=0.001$	$r=-0.4$; $P=0.037$
% Contribution	1.0	4.0	16.0†	36.0†	16.0†
Dynamics of number of errors	-	+2.8±1.6†	+7.2±3.1*†	+12.9±4.5*†	+4.9±2.1*†
*Significance in relation to initial value		$P>0.05$	$t=2.3$; $P<0.05$	$t=2.8$; $P<0.01$	$t=2.3$; $P<0.05$
Pearson (*r*) between "WAM-8" and dynamics of number of errors	-	$r=-0.4$; $P=0.027$	$r=-0.7$; $P<0.001$	$r=-0.8$; $P<0.001$	$r=-0.4$; $P=0.023$
% Contribution	-	$r^2 \cdot 100=16.0$†	$r^2 \cdot 100=49.0$†	$r^2 \cdot 100=64.0$†	$r^2 \cdot 100=16.0$†

*Significance of differences with respect to the initial values in the first (initial) testing based on Student's *t*-test; †The significance of the correlations between parameters using Pearson *r*. The share of mutual inter-relationship of the analyzed indicators was calculated on the basis of the coefficient of determination (r^2) by the formula $r^2 \bullet 100\%$

WAM test scores, appeared after 4 h and 6 h [Table 6]. The relationship was of medium strength with a negative value, i.e., the better the functional state of the students, the lower the error commission rate. This significant negative correlation of medium strength was maintained between the pairs of indicators in the participants and after 2 h of rest [Table 6], which probably reflects the inadequacy of 2 h of rest for most of the alcohol users.

Significant negative medium 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 mental activities, after 2 h and after rest [Table 6]. Inter-relationship between the subjective (functional state on the test "WAM-8") and objective (number of errors) signs of fatigue increased from 14.7% to 57.3%, respectively [Table 6] and remained after 2 h of rest under administration of 75 g glucose.

DISCUSSION

This present study investigated the differences in fatigue and mental performance of university male medical students with different attitudes to alcohol consumption. The observed results indicate a high level of fatigue and impaired performance in alcohol users, compared to the non-alcohol users. The rapid development of fatigue and low efficiency of mental work could be seen as important factors limiting the success of educational activities of students and increase in the likelihood of obtaining unsatisfactory scores in examinations.

Effectiveness of mental performance during prolonged mental work (~6-9 h) is a necessary condition necessary for medical education. As in the Belarusian State Medical University, the timetable of daily studies is structured to last approximately 6-9 h on the average, through Monday to Friday. Labor of students is traditionally viewed as the 5th kind (group, type) of mental work [2,3]. The first four ones are classified thus: Operator (1), management (2), creative (3), health workers (4). Labor of students requires challenging basic mental functions, such as attention (one of the most fatigue-prone cognitive functions), memory (primarily visual), thinking [1-3]. This is why standard tests involving these functions were designed to be used in combination for the determination of the level of fatigue and mental performance.

In accordance with the first rule of the diagnosis of fatigue and mental labor, the students were invited on weekend (Saturday) to perform a prolonged (6.5 h) mental work, which was closer to their educational activities. Mental load in all students was completely identical and included two kinds of work – performance of standard tests to determine the psychophysiological and psychological indicators of mental performance, as well as work with questionnaires and educational medical texts. This provided a standard design for the analysis of fatigue in the students.

The "WAM-8" is designed for subjective rapid diagnosis of the functional state of pilots before a flight, in inter-flight intervals during work and on the completion of flight [14]. It follows from the data presented in Table 3 that the average score on the test "WAM-8" in the alcohol users after 6 h of mental work was on the critical level. This critical level was noted in 7 alcohol users (out of 19), which was the result of their poor functional state, and one of them even refused to continue the mental work at the end of Phase II (before the 3rd test). It is [1] recommended that the number of errors made during standard tasks and, above all, correction probe test for attention to be used as a leading indicator of fatigue and mental performance. Attention is one of the most demanding functions in learning and at the same time one of the mental functions most liable to fatigue [3]. Fatigue in the students was a valuable indicator of the dynamics of the total number of errors made in the five standard tests (three tests on short-term visual and auditory memory, thinking and test for attention) in the process of mental work.

Higher rate of error commission was identified for the alcohol users. This result is in agreement with an earlier report [1]. Higher rate of error commission among the alcohol users in this study was comparable not only with values for males, but also with the values for females, according to the results of a previous study involving a single testing on a large sample of students [5]. The presence of fatigue at the beginning of the work and the inadequacy of a night rest in sober respondents, who occasionally consume alcoholic beverages (i.e., Group 2 students – alcohol users), was also confirmed by their subjective self-assessment on the test scales "WAM" and test "WAM-8" [Table 2]. Hence, their average score on the "Activity" subscale was 1.2 lower, compared to the average score on the "Mood" subscale [Table 2], which, according to Doskin *et al.* (1973), is the subjective sign of fatigue [13]. Although WAM scores of the alcohol users were lower, even the non-drinkers showed a tendency for a decrease in all three indicators of the "WAM" test [Tables 2 and 3] after 6 h from the start of the study, which can be explained by the development of fatigue in some of the respondents due to a lengthy and fairly complex task execution on fasting in the catabolic phase of metabolism.

How blood glucose changes during mental work could be an important indication of fatigue and mental performance [5,8]. In this study, glucose level in blood was measured to determine how the blood glucose level changes during prolonged mental work and how administration of oral glucose affects the fatigue and mental performance level. The gradual increase in blood glucose level in the abstainers could be viewed as a phenomenon of working functional hyperglycemia, necessary for adequate energy supply for brain functions. On the contrary, a gradual decrease in the level of glycemia during mental work among the alcohol users, and especially after 6 h of work could be referred to as functional relative hypoglycemia. The obtained result of subjective recovery (on the "WAM") of the functional state in abstainers is reported as high effectiveness of mental work [5] and retention of high concentration of attention in the test "correction probe" [Table 2]. The absence of full recovery in the alcohol users is an evidence of subjective feelings of conservation of fatigue and inadequacy of 2-h rest. These data confirm the notion that glucose has a positive effect on cognitive function [22-24].

It should be noted that the administration of 75 g of glucose and 2 h rest for four alcohol users were clearly insufficient to restore their functional state, as the score on "WAM-8" remained <4 points. These facts show the limitations of the positive action of glucose on mental performance in alcohol users even during a substantial period of abstinence. The mechanism of its occurrence can be caused by a decrease in gene expression of GLUT1 and reduction in glucose uptake in brain cells (this has been reported for neurons and astrocytes in animals even after a single administration of ethanol [25]). Limitations of the positive action of glucose on the correction of fatigue in people who consume alcohol (episodically, even in low-to-moderate doses) may be considered in mental activity of humans (drivers, pilots, machinists, etc.).

These facts strongly suggest that alcohol, even in episodic, rare consumption in relatively small doses, has a long-term (1-4 weeks) negative impact on the cognitive functions of young healthy person [5,8]. This is manifested primarily in a reduction of the concentration of attention, and the effectiveness of thinking and memory [Table 2], as well as impaired performance and the rapid development of fatigue [Tables 4 and 5]. Thus, these findings indicate the decline in the effectiveness of learning activities of students, who consume alcoholic beverages [5], and the inability to fully engage in prolonged mental work (due to reduced attention concentration and rapidly development of fatigue) (even after a long period following alcohol use: 7-28 days). All these are required for successful learning not only medical school, but also, generally in higher education.

Correlation tests were carried out with Pearson correlation coefficient to determine the association between objective (number of errors) and subjective (WAM-8) measures of fatigue and mental performance. The correlation results between the number errors and WAM-8 scores confirm the appropriateness of the use of the shortened test "WAM-8" for the assessment of the functional state, fatigue, and human performance (for students, not just for pilots).

Results of this study could be useful in explaining some of the contradictions existing in the study of the action of glucose on the processes of fatigue and restoration of performance and state of psychophysiological functions in humans [22,23,26,27]. It is possible that for abstainers and alcohol users, following 1 month or more, after drinking, administration of glucose during fatigue is associated with improved performance and functional state [Tables 2 and 3] [5]. Contradiction on the association between glucose and brain functions, as well as fatigue has been reported previously in the literature [26,27].

Limitations

Only males were considered for this study, which limits generalization of the results of this study. This limitation was justified by the complex hormonal analysis needed before inclusion of the opposite gender (females) in the study. Gender differences in hormonal influences on glucose metabolism, and even mental performance are well known. For females, a thorough analysis of the menstrual cycle would have been conducted before involving them in the study, whereas, for the males, no such analysis was needed. Therefore, further research would be conducted to analyze the differences in fatigue and mental performance in female students with different attitudes to alcohol use, putting into consideration the phases of the menstrual cycle.

CONCLUSIONS

1. The concentration of active attention in abstainers was high, whereas in the majority of the alcohol users, it was reduced throughout the study
2. 2 h of rest following administration of 75 g 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 h rest and 75 g of glucose were inadequate for full recovery of their functional state and mental performance after fatigue caused by prolonged work on fasting
3. Subjective (test scores "WAM" and "WAM-8") and objective (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 the alcohol users showed signs of chronic fatigue
4. Fatigue and impaired performance in the alcohol users indicate unsafe use of even low to moderate amounts of alcohol by young students
5. The "WAM-8" test can be used for rapid diagnosis of the functional state and prediction of performance and fatigue in students.

REFERENCES

1. Zolina ZM, Izmerov NF, editors. Manual on Labor Physiology. Moscow: Medicina; 1983. p. 227-50.
2. Aghajanian NA, Tsirkin VI, editors. Physiology of labor processes. Human Physiology. Saint-Petersburg: Sotis; 1998. p. 418-37.
3. Zybkovets LY, Navakatikyan AO. In: Zolina ZM, Izmerov NF. Manual on Labor Physiology. Moscow: Medicina; 1983. p. 251-79.
4. Welcome MO, Razvodovsky YE, Melnichuk VI, Pereverzeva EV, Pereverzev VA. About the phenomenon of "preventive paradox" in drinkers-students of different genders. Vestn Smolensk Med Acad 2012;1:12-20.
5. Welcome MO, Razvodovsky YE, Pereverzeva EV, Pereverzev VA. State of cognitive functions of students-medics with different relationship to alcohol use. Minsk, Belarus: Belarusian State Medical University Press; 2013. p. 20-144.
6. Thoma RJ, Monnig MA, Lysne PA, Ruhl DA, Pommy JA, Bogenschutz M, *et al.* Adolescent substance abuse: The effects of alcohol and marijuana on neuropsychological performance. Alcohol Clin Exp Res 2011;35:39-46.
7. World Health Organization. Global Status Report on Alcohol and Health. Switzerland: World Health Organization; 2011. p. 10-45.
8. Welcome MO, Pereverzev VA. Basal ganglia and the error monitoring and processing system: How alcohol modulates the error monitoring and processing capacity of the basal ganglia. In: Barrios FA, C Bauer, editors. Basal Ganglia – An Integrative View. Croatia: InTech; 2013. p. 65-86.
9. Crews FT. Alcohol and neurodegeneration. CNS Drug Rev 1999;5:379-94.
10. Aver'yanov VS, Kapustin KG, Vinogradova O. Physiological mechanisms of performance. Physiology of work activities. Saint-Petersburg: Nauka; 1993. p. 62-82.
11. Allahverdyev AR, Efendiev ST, Kafarova RZ. Parameters of attention and short-term memory in normal and adolescent neurosis. Hum Physiol 1989;15:35-9.
12. Zagryadsky VP, Sulimo-Samuyllo EK. Research methods in occupational physiology. Leningrad: Leningrad Military Medical Academy Publishing House; 1991. p. 12-99.
13. Doskin VA, Lavrentiev NA, Miroschnikov MP, Sharai VB. Differentiated self-evaluation of functional state. Issues Psychol 1973;6:141-5.
14. Aviation regulations of flight of medical support of state aviation of the republic of Belarus. Minsk: Belarusian State Aviation; 2005. p. 53-64.
15. Igumnov SA. Stress management: Contemporary psychological and medical approaches. St. Petersburg: Rech; 2007. p. 99-101.
16. Hanin YL. The study of anxiety in sports. Iss Psychol 1978; 6:94-106.
17. Gurvich IN. Neuropsychological adaptation test. Vestnik Hypnol Psychother (St. Petersburg). 1992;3:46-53.
18. Vlasenko VI. Psychophysiology: Methodological principles of professional psychological selection. Minsk: Belarusian State Medical University Printing House; 2005. p. 53-112.
19. Ogurtsov PP, Nuzhny VP. Express diagnosis (screening) of chronic alcohol intoxication in patients of somatic profile subdivision (clinical guidelines). Clin Pharmacol Ther 2001;10:34-41.
20. Babor TF, Higgins-Biddle JC, Saunders JB, Monteiro MG. The Alcohol Use Disorders Identification Test (AUDIT). 2nd ed. Geneva, Switzerland: World Health Organization; 2001. p. 7-34.
21. Taylor R. Interpretation of the correlation coefficient: A basic review. J Diagn Med Sonogr 1990;1:35-9.
22. Bellisle F. Glucose and mental performance. Br J Nutr 2001;86:117-8.
23. Fischer K, Colombani PC, Langhans W, Wenk C. Carbohydrate to protein ratio in food and cognitive performance in the morning. Physiol Behav 2002;75:411-23.
24. Welcome MO, Pereverzev VA. A mini-review of the mechanisms of glucose memory enhancement. Int J Med Pharm Sci 2013;4:17-30.
25. Abdul Muneer PM, Alikunju S, Szlachetka AM, Mercer AJ, Haorah J. Ethanol impairs glucose uptake by human astrocytes and neurons: Protective effects of acetyl-L-carnitine. Int J Physiol Pathophysiol Pharmacol 2011;3:48-56.
26. Foster JK, Lidder PG, Sünram SI. Glucose and memory: Fractionation of enhancement effects? Psychopharmacology (Berl) 1998;137:259-70.
27. Gonder-Frederick L, Hall JL, Vogt J, Cox DJ, Green J, Gold PE. Memory enhancement in elderly humans: Effects of glucose ingestion. Physiol Behav 1987;41:503-4.

Source of Support: Nil, Conflict of Interest: None declared.