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academic performance of male medical students of Belarusian State
Medical University**

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A novel psychophysiological model of the effect of alcohol use on academic performance of male medical students of Belarusian State Medical University

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Abstract

Background: The blood glucose concentration might determine the degree of academic performance. Decrease in the glucose concentration leads to a lowering of cognitive functions.

Objectives: To produce a model of students' alcohol use based on glucose homeostasis control and cognitive functions.

Methods: The study involved 13 male volunteers (8 moderate alcohol users and 5 non-alcohol users) – medical students and took 6.5 hours on fasting. Selection criteria were based on a screening survey conducted among students in Minsk, Belarus. Out of 1499 students, 185 were abstainers, 1052 – moderate drinkers, 262 – problem drinkers. The experiment was divided into three phases: first phase – the students were administered AUDIT, MAST, CAGE, STAI, Academic Performance questionnaires; second phase - the students worked with text № 1 (physiology of bone tissue and subsequently answered on the questions that followed it); third phase – with text № 2 (physiology of autonomic nervous system and also answered subsequently on the questions that followed it). Blood glucose level was measured at 2 hours intervals, including the initial level. Tests on short-term, long-term memory and attention were used in every phase of the experiment. The probability value for significance was set at $p < 0.05$.

Results: The moderate drinkers had significantly lower glucose concentration after 4-6 hours, compared to their initial concentration, as well as to the values of the abstainers. Disturbances in cognitive functions, precisely a decrease in the effectiveness of active attention and a faster development of fatigue after 4-6 hours of

mental work in alcohol users, compared to abstainers was statistically proven. The Intellectual Capacity on various tests/tasks positively correlated with the blood glucose level and in the 2-3 phases of the experiment and according to the results of the academic performances ($\rho = +0.75$; $p < 0.01$). Alcohol users had 12.5–40.0 times higher number of errors on various tests/tasks than the non-alcohol users ($p < 0.001$). The errors made on various tests/tasks increased with decrease in the blood glucose concentration ($\rho = -0.83$; $p < 0.01$). Significant increase in the Visual Productivity Coefficient among abstainers was also observed ($p < 0.05$).

Conclusion: This is the first study to show that alcohol use, even in episodic moderate doses (28ml/person with 1-2 times frequency per month) is accompanied by long-term glucose homeostasis disorders, leading to cognitive function disturbances and a decrease in the effectiveness of mental activities. These disorders in glucose homeostasis, cognitive functions were retained after 7-10 days of moderate alcohol use and might be the reason for the low academic performances among students who use alcoholic beverages.

Keywords: Psychophysiological model, alcohol use, academic performance, glucose homeostasis, cognitive functions, medical students

Introduction

Recently, Welcome and co-authors reported that alcohol use reduces academic performance by about 7-12%. The negative effect of alcohol use in this study was apparent even at a non-regular use of alcoholic beverages in small doses¹. Regardless of the enormous epidemiological data on students' drinking behaviors, the fact that alcohol use reduces academic performance remains disputable². Any scientific data that will address this issue will be of great importance.

Many factors like stress, cognitive abilities, competency in blood glucose maintenance might determine the level of academic performance^{1,3}.

Decrease in the concentration of glucose leads to a lowering of cognitive functions⁴. Glucose is the main energy source for the brain (in anabolic, as well as, in catabolic phase of metabolism)⁴⁻⁶. The functional activity of the central nervous system correlates with intensiveness of brain glucose metabolism⁶⁻⁹.

Next to the nervous system, the liver is the main target organ of the toxic effects of ethanol. The liver plays a central role in maintenance of blood glucose homeostasis^{6,10}.

It might be assumed that intensive mental activities under maximum stressed condition^{4,10,11}, even in a period of fasting, can cause hypoglycemia or even hyperglycemia⁶ as a result of the increase in the energy support for brain functions⁴⁻⁶, and this might allow to finding some peculiarities in blood glucose homeostasis control among alcohol users⁷⁻¹¹.

We therefore, test a model of students' alcohol use (involving the analysis of blood glucose homeostasis control under long-term continuously stressed mental activities of drinkers and non-drinkers) that might define the pathogenetic mechanisms of alcohol use on academic performance of students.

Methodology and Materials

Study design: Case-control study

Study population and location: The study was conducted among male seniors of the Belarusian State Medical University, Minsk, Belarus. Firstly, this was based on the assumption that juniors might not present any statistically significant differences in academic performance between alcohol users and the abstainers. Secondly, considering the dose time dependent effect of alcohol confirmed in our later study¹ among male students, in which the negative effect of alcohol use was only apparent after the second school year. Thirdly, the seniors (especially of fourth year) were much available for the study.

Sampling size and technique: Twenty (20: 10 abstainers and 10 moderate alcohol users) fourth year males medical students of the Belarusian State Medical University, Minsk, were at random explained the study aims and objectives one month before the experiment. All students were told not to use alcoholic beverages of any composition at least one week before the study. Two weeks before the study, consent forms were given to each of the 20 medical students to approve their participation, 7 of them refused to participate for unknown reasons. The medical students who volunteered to participate were briefed on what they should and should not take to ensure their daily calorie intake of 2200-2600kcal/person/day. The students were of simple daily diets with 3-4 times daily food intake [maximum intake per person/day – not more than 400g of glycemic carbohydrates e.g. of parboiled rice, 80-100g of protein, including vegetable oil, spinach, carrots, cornflakes, multi-fruit juice in the previous days before the experiment]^{11,12}.

Inclusion criteria

1. Participants were randomly selected based on a screening survey conducted in the Belarusian State Medical University. Out of 1499 respondents, 17.5% (262) students were problem drinkers and 70.2% (1052) moderate drinkers and 12.3% (185) were abstainers. The criteria used in the screening were based on the following AUDIT scores: 1 through 7 – moderate alcohol users; ≥ 8 – problem drinkers. Abstainers had a zero (0) score¹.
2. Only moderate alcohol users were considered. On the average they use 40ml of absolute ethanol per month. They were told not to exceed their normal alcohol intake, even before the weeks prior to the experiment.
3. Abstinence for at least a week before the experiment day. This was based on the fact that acute effects of alcohol have been greatly studied, however, its aftereffects (even after a week's interval of alcohol use is unknown). Besides, significant differences in the intervals of alcohol use among the moderate alcohol users might lead to different variations in the blood glucose level.
4. No cases of chronic alcohol intoxication, antisocial behavior, and psychiatric anamnesis or multidrug use (two or more, except for alcohol) during the period of

study in the university. Good daily regime – at least 6-7 hrs of rest per day, 3-4 times daily food intake and good physical activeness.

5. Absence of hearing and visual impairments as recorded in their medical histories.

Procedures: The Ethics and Research Committee of the Belarusian State Medical University approved the study protocol. All medical students confirmed their consent form on participation on the day of the experiment.

General outline of the processes of the experiment:

The experiment was divided in three phases (phase I – from 0⁰⁰ – 2³⁰ hrs; phase II - from 2³⁰ – 4⁰⁰ hrs; phase III - from 4³⁰ – 6⁰⁰ hrs) and took 6.5 hrs of intensive mental work of increasing difficulty in a condition of fasting. Mental work of increasing difficulty involved two types of works – performing standard tests (memory and attention tasks) by determining the intellectual capacity (IC), as well as mental work of increasing difficulty (filling of various questionnaires → reading of texts → providing answers to the questions on the read texts). Two texts were considered for use in the study. The first text “Physiology of Bone Tissue”¹³ was administered in the second phase, while the second text “Physiology of Autonomic Nervous System”¹³ was used in the third phase. These two texts were selected as intensive mental activities since they were of significantly large page numbers and included information that had been taught students in their first to third school year syllabus.

The tests on IC, results of blood glucose determination, including all questionnaires filled by the participants were marked and numbered by ordinal numbers as the study was anonymous.

The rationale for using multiple memory tests and many questionnaires in this study was to produce a maximum stressed condition for the subjects. This was based on the assumption that 2-4 hrs unstressed mental activities might not show any significant differences in both the blood glucose level and the mental activities between alcohol users and non-alcohol users^{6,14}. All participants were confined during the study duration so as to ensure no contamination in the experiment. They were all subjected to standard mental activities of the same kind.

Flow of the processes

The phases and order in which the experiment was conducted are described as follows:

Phase I (from 0⁰⁰ – 2³⁰ hrs of the experiment): The 1st phase of the experiment was conducted according to the following layout: The first 1/2 hrs involved the 1st blood sampling, followed by initial tests of Intellectual Capacity, IC on various memory/attention tasks, as well as answering of the Big Five Trait questionnaire and State Trait Anxiety Inventory, and STAI.

For the next 1.5 hrs the participants answered on the following questionnaires – AUDIT (Alcohol Use Disorders Identification Test), MAST (Michigan Alcohol Screening Test), CAGE (the Cut, Annoyed, Guilty and Eye questionnaire), “General”, and Academic Performance (results were filled from result cards).

The last 1/2 hrs of the first phase involved the 2nd blood sampling followed by the 2nd test of IC on various memory/attention tasks, answering of the Big Five Trait

questionnaire, and STAI.

Phase II (from 2³⁰ – 4³⁰ hrs of the experiment): As soon as the participants had finished answering on the last questionnaires in the 1st phase, for the next 1.5 hrs, they worked with the first text (a 20 page text on Physiology of Bone Tissue) with subsequent performance of a control test exercise containing 43 questions.

The last 1/2 hrs of the 2nd phase was meant for the 3rd blood sampling, 3rd test of IC on various memory/attention tasks and answering of the Big Five Trait questionnaire, and STAI.

Phase III (from 4³⁰ – 6³⁰ hrs of the experiment): Immediately after filling the questionnaires on the 2nd phase, participants started reading the second text and subsequently performed a control test exercise that followed it. This took 1.5 hrs.

The last 1/2 hrs of the experiment was meant for the 4th blood sampling, 4th test of IC on various memory/attention tasks, answering of the Big Five Trait questionnaire, and STAI.

Data collection Techniques

Scoring Mechanisms of the various Questionnaires/Texts used in the study

1. **MAST:** A total score of 3 or more was considered problematic alcohol use¹.
2. **CAGE:** Any positive score of 2 through 4 is considered clinically significant (problem drinking)¹.
3. **STAI:** Is a highly reliable instrument for evaluation of the state of anxiety. The result of the STAI was conducted according to Spielberger and coauthors^{15,16}. (See Spielberger & Krasner, 1988 for details of STAI scoring pattern). The test contains two subscales which clearly differentiate between the temporary condition of "state anxiety" (STAIS-Anxiety scale) and the more general and long-standing quality of "trait anxiety" – STAIT-Anxiety scale. The range of scores is 20-80. The higher the score the greater the anxiety level.
4. **The Big Five Trait questionnaire** was modified according to John *et al* (2008) and was meant for the determination of the degree of intensity of neuropsychic stress, in the subjects¹⁷. (See John *et al* 2008 for more information). An average score somewhere at 30-40% is considered normal range.
5. **The questionnaire on "General"** contained 53 questions for determination of general information (exception of name/surname) about the subjects, sex, age, physical activeness, daily routine, food regimen, religion.
6. **Academic performance questionnaire:** All subjects entered their examination scores (including resit examination scores) from examination cards for all periods of study in the Belarusian State Medical University into the questionnaire on "academic performance". The name of examinations were not stated, but were coded by ordinal numbers in relation to the semesters. The filling of examination scores was controlled by one of the authors, M.O.W. The collected data were used

as objective criteria for academic activities of the subjects. Two major criteria were calculated: Grade Point Average (GPA) of examination results for the 1st, 2nd, 3rd, 4th, 5th and 6th semesters; success or effectiveness to sit for examinations for the 1st time – 100%, 2nd time – 50% and 3rd time – 25%. Analysis of academic performances of students in Belarusian institutions is determined on the 10-point scale. An equivalent of this scale is the 100% scale. On the 10-point scale, a score of 1=10%; 2=20%; 3=30%; 4=40%; 5=50%; 6=60%; 7=70%; 8=80%; 9=90% and 10=100%. A minimum score in examination carries a total of 1 point on the 10-point scale. A maximum score is set at 10. A score of 1, 2, and 3 is considered unsatisfactory with a necessity of resit examination for that given subject/course¹.

7. **The control test exercise on the first text “Physiology of Bone Tissue”** contained 43 questions, so results were calculated as IC, ability to master the read text with the formula: $IC = 100 (43 - M) / 43$, where M – sum of two numbers (number of incorrect answers + number of questions without answers).
8. **The control test exercise on the second text “Physiology of Autonomic Nervous System”** contained 46 questions. No student was able to finish the second text and the questions that followed it. As a result IC was calculated thus: $IC = 100 (Q - M) / Q$, where Q – number of questions with answers; M – number of incorrect answers.

Blood glucose measurement: Glucose concentration in the plasma of capillary blood was measured as initial and in course of the experiment (after 2, 4, and 6 hours of mental activities) in all students using the glucometer – Bionime (*Rightest*TM GM100)¹⁸, with an accuracy up to 0.11mmole/L. Blood sampling was done in volumes of 20 microliter from the ring finger of the left hand by skin puncture with disposable lancets under sterile conditions. The blood test was performed by one of the authors, M.O.W.

Determination of mental activity (Intellectual Capacity, IC on various tasks)

Standard tests for determining IC involved the following: estimation of visual short-term memory, auditory short-term memory and operative short-term memory and processes of thinking, as well as conduction of proof-correction tests on attention¹⁹⁻²⁷.

Determination of auditory short-term memory (STM): Auditory STM was determined using single-digit numeral and two-digit vowel letters on increasing row from 3 to 10 numerals or letters, according to the following sequence^{22,26}. The subjects were instructed to write down single-digit numeral into the blank spaces of increasing row (from 3 to 10) provided, immediately after they were voiced by one of the authors M.O.W. Subsequently, after the numbers were voiced, the subjects were required to write down the remembered ones in the sequence in which they have heard it. The determination of auditory STM for two-digit vowel letters was conducted the same way. The time interval to completing the task for each row on the average took 30-60 seconds. The first row, where any incorrectly or not sequentially written numbers or letters occur was considered a mistake with no possibility of calculating the results of other rows below. The number of correct answers was

calculated according to the formula: $IC = 100 (A-M) / 10$, where A – number of answers to be written; M – number of mistakes (incorrectly written numbers or letters).

Determination of visual short-term memory (STM): Determination of visual STM was done according to the following layout^{19,20,23-25} with modifications. The subjects within 40 seconds were introduced 10 two-digit numbers (any from 10th to 99th) in different sequences. Subsequently within 150 seconds after introduction of the numbers, the subjects were supposed to have reproduced all remembered numbers in unconditioned sequence. The number of correct answers was calculated according to the formula: $IC = 100 (A-M) / 10$, where A – number of answers to be reproduced; M – number of mistakes (incorrectly reproduced numbers).

Determination of thinking capacity/operative memory: Determination of thinking capacity was carried out using simple arithmetic (on the level of simple logical deduction with a single correct answer: addition and subtraction). Operative memory calculation was carried out according to the results of solved arithmetical problems with a single-digit answer in the test “arithmetical calculation”^{28,29} which was carried out by the subjects within 20 seconds. The IC and the speed of calculation according to the average duration in accomplishing one problem (task) were analyzed. $IC = 100 (S-M) / P$, where S – total number of solved problems; M – number of mistakes (incorrectly solved problems).

Determination of attention: Attention was determined on the proof-correction test using geometric tables^{21,26,27} (the table contained 1600 symbols, where 200 symbols were needed to be marked or configured correctly, and time of completion of the test - not more than 5 minutes). The Intellectual Capacity was calculated using the formula: $IC = 100 (200-M) / 200$, where 200 – number of symbols of required configuration in the table; M – number of mistakes (un-configured symbols or incorrectly marked symbols). Visual Productivity Coefficient, VPC was calculated thus: $VPC = (0.5436*N - 2.807*M) / T$, where N – number of viewed symbols (maximum number = 1600); 0.5436 (bytes/symbol) – average volume of information that equals one symbol; 2.807 (bytes/symbol) – loss of information that equals one un-configured symbol or incorrectly marked symbols; M – number of mistakes (un-configured or incorrectly marked symbols); T – time spent on the performance of the test in seconds (maximum of 300 seconds).

Data analysis: Statistical calculations were performed using the SPSS (The Statistical Package for the Social Sciences) 16.0 version for Windows. The probability value for significance was set at $p < 0.05$. All volumes of alcohol used are given in values of pure ethanol. A standard drink was set at 8g (10 ml) of absolute ethanol. Results are reported and displayed as means and standard error of means, $M \pm m$, as well as in percentages, %. The Spearman rho, ρ was employed for correlation analysis between the blood glucose level (independent variable) and the effectiveness of mental activities (total number of errors) and academic performance as the dependent variables.

Results

All participants in this study were Christians. The controlled diet intake for both groups and the body weight were recorded (Table 1). The overall response rate for the study was 65% (i.e. 13 out of 20 students participated). According to the screening results 5 students were abstainers (non-alcohol users i.e. controls – group № 1), while 8 were alcohol users (cases – group № 2). The average statistical results of the controls and cases according to the AUDIT, CAGE and MAST, including volume of alcohol used are reported in table 1.

Seventy five percent (75%) of the alcohol users use alcohol once a month, while 25% – twice per month. Six (6) students reported non-alcohol use before entrance into the university.

All moderate drinkers did not use alcoholic beverages of any composition for 7-10 days before the experiment.

Table 1: Mean/range age and body weight values of abstainers (controls, group № 1) and moderate alcohol users (cases, group № 2) and their relationship to alcohol use

Descriptive items	Controls (group № 1, n=5)	Cases (group № 2, n=8)
<u>Mean age (range), yrs</u>	22 (21-23)	22 (21-23)
<u>Mean body weight (range), kg</u>	72.5 (69-74)	73.2 (69-75)
<u>Alcohol use/month</u>		
Frequency/month	0	1.25
Dose (ml)/person/session	0	23
Dose (ml)/person/month	0	38
<u>Average Screening Test Scores</u>		
AUDIT	0	4.50
CAGE	0	0.75
MAST	0	1.63

Among alcohol users, 37.5% cases of alcohol related injuries were reported. The average volume of alcohol use was reported as 23 ml/per session with 1.25 frequency of use per month.

The results of the Big Five Trait Questionnaire showed increase in neuropsychological stress in course of the experiment, especially after 4 hrs among the alcohol users. Also, significant decrease in mood, activeness in the second and third phases of the experiment among the alcohol users was recorded.

The state anxiety (according to the STAI-Anxiety scale – the first subscale of the STAI), among the alcohol users, the anxiety level increased by about 10% immediately after 2hrs of intensive mental activities ($p < 0.05$). Increase of the trait anxiety (according to the STAIT-Anxiety scale – the second subscale of the STAI) was noted only after the 4th hr of the experiment ($p < 0.05$).

Anxiety level among the non alcohol users in both subscales remained generally low in all phases of the experiment ($p < 0.05$).

The academic performance of the non-alcohol users was significantly higher than that of the alcohol users. The GPA and effectiveness to sit for examinations was significantly reduced among the alcohol users. Reduction of the GPA of group № 2 students (alcohol users) in relation to the results of the 1st semester was -1.26 points ($p < 0.05$) on the second course and -1.38 points for third year of study. The effectiveness to sit for exams by non-alcohol users on the 2nd and 3rd courses was by 10.9 % and 11.4 % ($p < 0.05$) respectively higher, compared to that of the alcohol users.

The results in the tests on short term visual and short term auditory memory in course of the experiment showed no significant change in the Intellectual Capacity (IC) in both groups. There was no significant difference in the speed of calculation and the Visual Productivity Coefficient (VPC) between non-alcohol users and alcohol users in course of the experiment (Table 2). Among students of both groups, there was significant increase in the quantity of solved task on the test “arithmetical calculation”, as well as number of configured symbols and speed of viewing each symbol in the test “geometric tables” (Table 2). However, increase in VPC by $+0.88 \pm 0.310$ bytes/sec ($p < 0.05$) was noted only among the non-alcohol users after the 6th hr of the experiment (Table 2).

The result of intellectual capacity (i.e. effectiveness of active attention) among abstainers was significantly higher, compared to the alcohol users (Table 2). Some similarities were also recorded. In the controls, the intellectual capacity in the tests on attention and operative memory under repeated condition remained stable and high. Among the students of group № 2 the effectiveness of mental work capacity was low in relation to the expected value (100%). The number of errors made on the “proof-correction test, using geometric tables” among the students of the 2nd group was 12.5 – 40.0 times ($p < 0.001$) higher in relation to the abstainers during the 1st, 2nd, 3rd, and 4th tests (Table 2). The percentage increase in error commission among students of the 2nd group after six hours of mental work was 72% in relation to their initial level (Table 2).

Table 2: Values of mental work capacity according to the results on the “proof-correction test” of non-alcohol users (group № 1) and alcohol users (group № 2)

Parameters	Group	Values in course of mental activities			
		Initial	After 2hrs	After 4hrs	After 6hrs
Speed of viewing symbols/sec	№ 1	4.840	5.760	5.903	6.527 ^O
	№ 2	6.35*	6.770*	7.199* ^O	6.892
Number of errors in course of experiment	№ 1	2.2 ± 1.3	2.0 ± 0.9	2.6 ± 0.9	2.4 ± 1.2
	№ 2	25.0 ± 6.6**	28.1 ± 8.4**	33.0 ± 8.4** ^O	43.0 ± 10.0** ^O
Intellectual Capacity, %	№ 1	98.9 ± 0.6	99.0 ± 0.5	98.7 ± 0.4 ^Δ	98.8 ± 0.6
	№ 2	87.5 ± 3.3* ^Δ	86.2 ± 4.2* ^Δ	83.4 ± 4.3* ^Δ	78.4 ± 4.9* ^Δ
VPC, bytes/sec	№ 1	2.46 ± 0.20	2.87 ± 0.07	2.95 ± 0.14	3.34 ± 0.30 ^O
	№ 2	2.80 ± 0.13	3.05 ± 0.11	3.18 ± 0.12	3.13 ± 0.23

* – $p < 0.05$; ** – $p < 0.01$ in relation to the corresponding values in group № 1;
^o – $p < 0.05$ in relation to the initial values of its own group;
^Δ – $p < 0.05$ in relation to the expected success index of 100%

Evaluation of the ability of learning new materials by the students, as well as reproduction of already learnt materials in 1 – 3 courses of school years showed high effectiveness among the abstainers (intellectual capacity approximately 75 – 96 %) and lower than average among the alcohol users (intellectual capacity 15 – 37 %). Reduction in the number of answers was noted among group № 2 students, regarding the questions on “physiology of autonomic nervous system”. The correctness of answers (i.e. intellectual capacity) among them was not more than 25%.

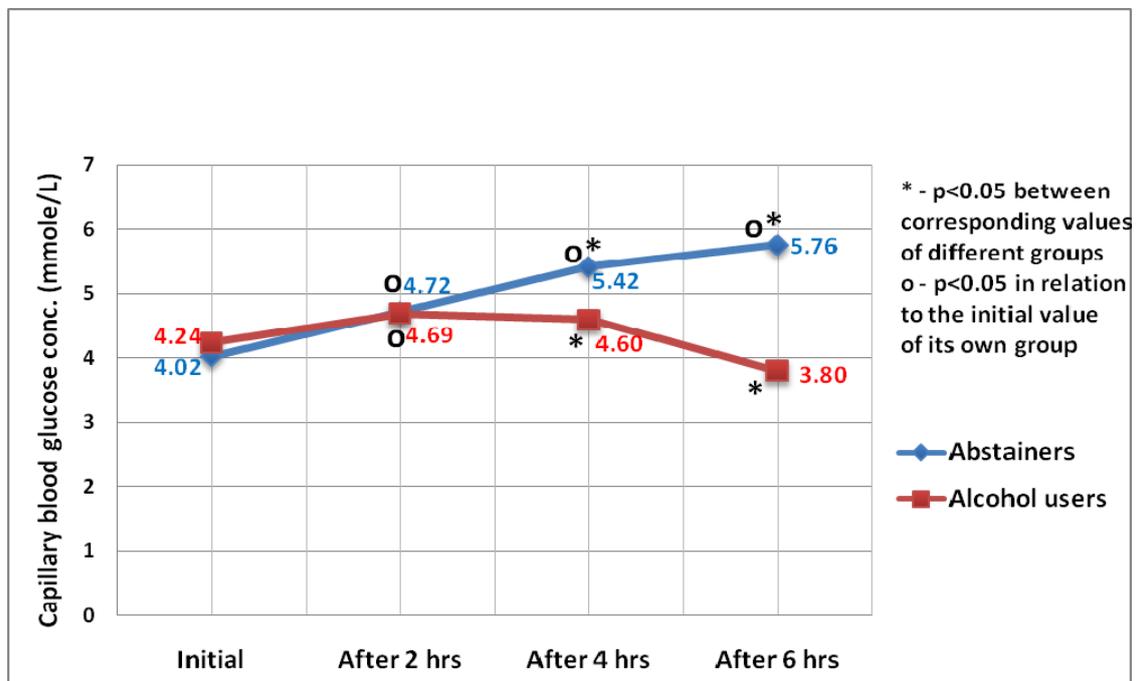


Fig 1: Capillary blood glucose concentration of alcohol users and abstainers in course of intensive mental activities

The initial values of the blood glucose levels of abstainers and alcohol users showed no statistically significant difference (Fig. 1).

The results of the blood glucose sampling showed increasing glucose level (in relation to their initial value) among abstainers (group № 1 or the controls) according to the measure of increase in mental activities: +0.70 mmole/L increase ($p < 0.001$) in blood glucose concentration after 2 hrs, +1.40 mmole/L ($p < 0.001$) after 4 hrs, +1.74 mmole/L ($p < 0.001$) after 6 hrs in relation to the initial level among these students (Fig. 1). The increase in the blood glucose level of alcohol users was observed only within the first 2 hours of mental work (+0.45 mmole/L, $p < 0.05$) (Fig. 1). Thereafter, a fall in blood glucose level after 4 hrs of work was observed. After 6 hours of work blood glucose level among students of the group № 2 dropped by –0.89 mmole/L ($p < 0.05$) in relation to its level after 2 hrs of work, and by –0.80 mmole/L ($p < 0.05$) in relation to its level after 4hrs and had a tendency to fall even in relation to its initial

level (Fig. 1). The rise of fatigue among students of the test group after 4-6 hrs of mental work also testifies on the fall in blood glucose level. At the end of the experiment three students in the test group had symptoms of neuroglycopenia.

Table 3: Correlation (ρ) values of the glycemic levels with the total number of errors committed in course of intensive mental activities

ρ values of blood glucose level with the total number of errors committed in every phase of the experiment under			
Initial	After 2hrs	After 4hrs	After 6hrs
- 0.098	- 0.384	- 0.836*	- 0.909**

* $p < 0.001$; ** $p < 0.0001$

Analysis showed negative correlation between blood glucose level and total number of errors during the 4th hour of work ($\rho = -0.8$, $p < 0.001$). This correlation increased slightly after 6th hr of the experiment ($\rho = -0.9$, $p < 0.0001$) (Table 3).

The correlation analysis between glucose level (on fasting) under intensive mental work and the academic performance of students in different courses of study are reported in table 4. Statistically, significant positive correlation between the glucose level and the academic performance (effectiveness to sit for examinations and the GPA) was noted after the 4th and especially the 6th hours of intensive mental work, starting from the examination results of the 2nd and 3rd courses of study in the university (Table 4). Notably, the statistically significant values were recorded for only the alcohol users and when they were combined (i.e. for all 13 participants).

Table 4: Correlation (ρ) analysis between the blood glucose level among the participants and their academic performance for three years of study in the university

Time of BGS	ρ values of abstainers, n= 5						ρ values of alcohol users, n= 8						ρ values of 13 participants					
	GPA			Effect. Exams			GPA			Effect. Exams			GPA			Effect. Exams		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Initial	+2	-6	-6	-5	-5	+5	-1	-6	-6	-3	+2	+2	-1	-6	-4	-1	-1	-1
After 2hrs	+1	-4	-7	+2	-7	+3	-1	-8	+0	-7	+3	+5	-1	-4	-1	-3	+1	+3
After 4hrs	+5	-1	-3	+4	-4	+2	-3	-1	+6	+2	+7	+8*	+1	+4	+7**	+3	+6*	+8^A
After 6hrs	-6	-9	-6	+1	-5	-2	-7	-3	+5	+1	+9***	+1.0[#]	-1	+4	+8**	+4	+7***	+8[#]

* $p < 0.05$; ** $p < 0.02$; *** $p < 0.01$; ^A $p < 0.005$; [#] $p < 0.001$

N/B: Effect. Exams – Effectiveness to sit for Examinations; I, II, III – 1st, 2nd, 3rd Courses respectively; Time of BGS – Time of Blood Glucose Sampling

Discussion

The results of this study suggest that the reduced academic performance of students who use alcohol might be related to the incompetency in blood glucose regulation, which is accompanied by low cognitive functions. This is the basis of the pathogenetic mechanism of alcohol use on the academic performance. Despite the small quantity and episodicity of alcohol use by the alcohol users their academic performance, as well as cognitive functions were significantly lower.

The results of the blood sampling showed significant increase in the glucose concentration among the non-drinkers (group № 1 or the controls) according to the measure of increase in mental activities. The decrease in the blood glucose concentration after the first two hours of mental activities had negative effects on alcohol users. It therefore follows that long-term intensive mental activities of students who use alcohol (even in episodic and moderate doses) are not accompanied by increase in the blood glucose level and subsequently leading to inadequate energy supply for brain functions. The result of this was the increase in mistakes, decrease in mental work capacity, and even rejection of performance of difficult tasks. A steady increase in the blood glucose level is a necessary physiological mechanism for adequate supply of energy for brain functions under mental activities of increasing difficulties: from questionnaires → texts → answers to the questions on the read texts. Performance of standard tests for the IC evaluation showed high effectiveness among non-alcohol users throughout the 6.5 hr period of the experiment.

Therefore, alcohol use (even episodic, in small doses) leads to negative effect on glucose homeostasis, especially under a condition of long-term intensive mental activities.

Until now, most studies have focused on the acute effect of alcohol use, especially in alcoholics^{3,6,10,30-32}. Little is still known about the effects of alcohol even after a week's interval of moderate alcohol use. Researchers have acknowledged the toxic effects of ethanol, but little efforts have been made to show the aftereffects of alcohol (even at moderate doses) on glucose homeostasis control. The blood glucose concentration is a direct predictor of the brain glucose level, which in turn determines brain functions. On the average the brain glucose concentration is about 30-50% of the blood glucose concentration. As noted by de Galan and co-authors, blood glucose level less than 3.5mmole/L leads to symptomatic hypoglycemia⁶. In the test group, as result of lowering of the blood glucose concentration, leading to fast development of fatigue, 3 participants declined from continuing the tests on physiology of autonomic nervous system (their blood glucose level was <3.0 mmole/L).

The increase in the state and trait anxiety of alcohol users after 4 and 2 hours respectively, was evident of the fact that state anxiety could transform into trait anxiety with time, especially under stress.

Positive correlation noted (only on the 2nd and 3rd courses, but not on the 1st course) between the academic performance and blood glucose level in course of the experiment indicates on the dose-time dependent effect of alcohol use (75% of alcohol users started using alcohol only in the university) (Table 4). The absence of any statistically significant correlation values between the academic performance and blood glucose level among the abstainers might be due to the very low sample size of

only 5 (Table 4).

Decades before now, it has constantly reported by several studies³³⁻³⁵ that alcohol in large doses inhibits gluconeogenesis leading to hypoglycemia and that the hypoglycemic effects of alcohol are as a result of the shift in [NAD⁺]/ [NADH] ratio³⁵. Generally, determination of a safe dose of alcoholic beverages is still a matter of discussion in the general scientific community^{3,6,10,30}.

Study limitations: A major limitation to making general conclusions about the results of this study is the small sample size involved. Therefore, a more comprehensive research on the effects of alcohol use (in various doses) on glucose homeostasis control under varying mental activities and state, putting into consideration the academic performance of students in various levels of study, as well as other factors that might necessarily affect their academic success. Also, research is needed on the phenomenon of increased error commission that was associated with decrease in blood glucose level.

Conclusion

The psychophysiological model presented in this study defines the pathogenetic mechanisms of alcohol use on academic performance of students.

Alcohol use, even in episodic moderate doses by students leads to disorders in cognitive functions (especially under intensive mental activities), and subsequently a reduction in academic performance.

Disorders in cognitive functions, precisely a decrease in the effectiveness of thinking capacity and active attention and development of fatigue (after 4 – 6 hours of mental activities) are detected in students who use alcoholic beverages, even after 7-10 days of alcohol use in small doses.

Episodic alcohol use even in small doses is not safe, as it results in glucose homeostasis disorders, subsequently leading to decrease in cognitive functions.

The detection of glucose homeostasis disorders in episodic moderate alcohol users was possible in a condition of 6.5 hrs intensive mental activities.

The procedures used in this study could well serve as a model and a new method for early detection of alcohol problems.

Recommendation: The results of this study suggest the necessity of limiting time (by two or a maximum of 4 hours) on continuous stressed mental activities of people (students, lecturers and teachers, operators, drivers etc) who use alcoholic beverages and the development of complex measures, aimed at preventing menace of the rise of symptomatic hypoglycemia.

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