Forensic Science, Medicine and Pathology
https://doi.org/10.1007/s12024-023-00748-6

ORIGINAL ARTICLE

The role of alcohol and patterns of alcohol-related deaths in Republic of North Macedonia within the period 2007–2020

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Accepted: 2 November 2023

Abstract

Excessive alcohol consumption is one of the most important factors in a substantial number of violent deaths. The aim of our study was to investigate alcohol-related deaths in the Republic of North Macedonia in the period from 2007 to 2020, in order to study the influence of elevated blood alcohol levels in violent deaths. Five hundred sixty-four post-mortem blood samples from alcohol-related death cases—natural deaths and violent deaths (suicides, accidents, and homicides)—were analyzed, and the results were evaluated according to sex, age, and cause of death. Among 564 cases, traffic accidents were the leading cause of violent death (54.3% of the cases) followed by suicides (19.9% of the cases). In the examined *post-mortem* samples, BAC values ranged from 0.15–6.20 g/L. The average age was 45 ± 16 years for the male and 49 ± 19 years for the female group. The biggest proportion of high BAC values was found in the group of accidents specifically road traffic accidents and accidental intoxication as well as in the group of bolus deaths. The analysis of BAC in the cases of violent deaths in the Republic of North Macedonia confirmed that consumption of alcohol is strongly related to violent deaths. The data obtained from this study could raise caution and give aid in a national strategy for the prevention of alcohol-related violent deaths.

Keywords Blood alcohol concentration · Intoxication · Violent death · Post-mortem data

Background

Alcohol is one of the most commonly used psychoactive and dependence-producing substances in Europe; thus alcohol, consumption is one of the major public health problems in the European region along with tobacco smoking, being overweight, and obesity, and it is a risk factor for premature mortality globally [1–3]. According to the WHO, an association exists between the income level of the country and the overall levels of alcohol consumption. A study conducted by Anderson showed that EU countries experiencing an increase of more than 3% in the unemployment rate have experienced as much as a 28% increase in deaths due to alcohol misuse [2, 4]. Despite being a major risk factor for the burden of disease, with substantial impacts not only on individual drinkers but also on society at large, alcohol consumption in Europe continues to be double the global average [1].

The use of alcohol increases the risk of dying from unnatural and/or violent death, as well as alcohol-related injury, as acute intoxication may compromise rational thinking and decrease motor and sensory function, while also leading to increased risk-taking behavior, aggression, and self-destructing tendencies [5–7]. After drinking small quantities of alcohol to reach a fairly low blood alcohol concentration (BAC), people become more talkative and less inhibited. Higher BAC (> 1 mg/g) leads to mental confusion and impairment of cognitive and psychomotor functioning. Administration of massive amounts of alcohol resulting in very high BAC (> 3 mg/g) is a serious risk of death from respiratory depression and circulatory collapse [8–11].

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Published online: 10 November 2023

Elevated BAC is a prominent finding in all out-of-hospital deaths and depends on alcohol control policies, availability, and the price of alcohol in different countries. Overconsumption of alcoholic beverages and drunkenness have always played a major role in fatal accidents, trauma deaths, drowning, suicide, and many crimes of violence. Moreover, heavy drinking and alcohol-induced impairment are common underlying factors in traffic accidents and emergency department records [12]. According to the official report for substance use disorders in North Macedonia, alcohol consumption ranges from 5.0–7.4 L per inhabitant, and the highest consumption is among people aged 25–34 (76.9%) [13].

In general, the concentration of ethanol measured in postmortem blood samples needs to be interpreted in relation to whether the person had consumed alcohol and might have been drunk at the time of death or if the concentration exceeded some threshold limit. The diagnosis of alcohol influence has deep-rooted social-medical ramifications owing to the existence of punishable BAC limits for driving in most countries, such as 0.20 mg/g in Sweden, 0.50 mg/g or 0.50 mg/mL in most European countries, and 0.80 mg/mL in the UK, USA, and Canada. Accident and insurance claims might be null and void if the person involved in the fatal accident was declared above the legal limit for driving [12].

Reduction of negative consequences due to drinking and alcohol intoxication is a key global health priority [14]. It has been suggested that the drinking levels of the population are an important predictor of violence-related mortality [15]. Also, monitoring rates of alcohol-induced deaths over time is very important for the development of preventive national healthcare measures [16]. Therefore, the aim of our study was to investigate the influence of elevated blood alcohol levels and violent deaths in the Republic of North Macedonia (2007–2020) in order to assess the lowest BAC which poses a risk of dying under unnatural circumstances.

Methods

The data set used for this study was obtained from autopsy reports from the archives of the Institute of Forensic Medicine, Criminology, and Medical Deontology at the Medical Faculty in Skopje. A retrospective study on post-mortem samples, covering the period 2007–2020, was performed. All blood alcohol-positive cases with known *post-mortem* interval and cause of death for which toxicological analyses were requested were included in the study. Samples obtained from cases with signs of putrefaction were excluded from further analysis.

Ethanol-related deaths were divided into two groups: natural deaths and violent deaths which were further classified as suicide, accident, and homicide. The data set was analyzed using age, sex, manner of death, and BAC.

In all cases, femoral blood samples were collected during the autopsy in sterile tubes containing NaF/oxalate and stored at + 4 °C until analysis. BAC was determined within 5 days of collection/sampling using a fully validated GC method in the range of 0.1–4 g/L. Before the chromatographic analysis, n-propanol used as an internal standard (0.5 g/L) was added to each blood sample in 20 mL glass vials. After the sample preparation step, they were analyzed using head-space gas chromatography with a flame ionization detector (HS GC/FID, GC 2010 Plus, Shimadzu, Japan). The chromatographic separation was performed using a capillary column InertCap624, GL Science, Japan, 30 m × 0.53 mm × 3 µm. Head-space sampling seems to be the preferred method for the determination of volatile substances and offers the advantage that the chromatographic column is protected from being overloaded with nonvolatile blood constituents [12].

Blood alcohol concentration was reported in grams per liter. The blood samples with BAC values ≤ 0.25 g/L were used as the control group, whereas the test group had BAC values > 0.25 g/L. This criterion was chosen based on literature data that psychoactive effects can be manifested at a BAC of as low as 0.3 g/L [17].

A descriptive statistical analysis was performed using mean, standard deviations, median, and 95% confidence intervals. The obtained data for age and gender were analyzed and expressed as mean ± standard deviation (SD) and median. For the BAC levels, 90th, 95th, and highest concentrations in each studied group were used as descriptive statistics [18]. All numerical variables were tested with the Kolmogorov–Smirnov test for normal distribution. Further analysis of the data was performed using the Mann–Whitney *U*-test. A p value of 0.05 has been considered statistically significant. The SPSS software 17.0 was used for the statistical analysis.

Results

A total of 564 cases with positive blood alcohol findings were included in the study. The case classification was based on autopsy findings and investigation authorities' reports, such as natural death (19.15%), suicide (20.04%), accidents (54.08%), and homicide (6.74%). Blood alcohol concentration ≤ 0.25 g/L had been confirmed in 12.77% of all the studied cases.

Death cases of the data set included in the study were classified according to age, gender, and BAC values (Table 1). According to the presented data, the predominance of males is obvious. Further, 108 or 19.15% of the studied cases were identified as natural deaths. In the summary of violent death cases, 88.30% were males. Females represent only 11.70% of the cases. Victims who died in homicide were the youngest

Table 1 Age, gender, and BAC values in death cases of natural and violent death

Death cases	**Number (%)**	**Gender**		**Age***		**BAC** (g/L)**	**BAC median**	**BAC percentile**		
		Male (%)	Female (%)	Male	Female			90th	95th	Highest
Natural	108 (19.15%)	91 (84.26%)	17 (15.74%)	56 ± 14	54 ± 19	0.97 ± 0.91	0.66	2.40	2.95	3.88
Suicide	113 (20.04%)	92 (81.4%)	21 (18.6%)	49 ± 15	44 ± 14	1.20 ± 1.0	0.87	2.64	3.14	4.65
Accident	305 (54.08%)	280 (91.80%)	25 (8.20%)	45 ± 9	49 ± 21	1.55 ± 1.16	1.36	3.09	3.79	6.20
Homicide	38 (6.74%)	35 (92.11%)	3 (7.89%)	39 ± 13	68 ± 11	1.11 ± 1.10	0.58	2.73	3.54	3.93
All cases	305 (54.08%)	498 (88.30%)	66 (11.70%)	45 ± 16	49 ± 19	1.35 ± 1.10	1.07	N/A	N/A	N/A

*Mean age ± SD; **Results expressed as mean BAC ± SD

among the studied groups. Females were older than males in all the studied groups except in the homicides. The average age of all male victims was 45, and on average, female victims were 49 years old.

As can be seen from the results shown in Table 1, the mean BAC was 0.97, 1.2, 1.55, and 1.11 g/L for the natural death, suicide, accident, and homicide groups, respectively. The median BAC was highest (1.36 g/L) in the group of accidental deaths, whereas the median BAC was lowest in homicides (0.58 g/L). In the group of accidental deaths, the 90th percentile BAC was 3.09 g/L which indicates that 10% of victims had BAC exceeding 3.1 g/L. Further, the comparison of BAC levels among natural death and suicides, accidents, and homicides revealed a statistically significant difference between the groups of natural death and accidents ($U = 11{,}016$, $p < 0.0001$) and between suicide and accident ($U = 14{,}141$, $p = 0.00634$).

Figure 1 represents the relationship between BAC levels and the age of men and women. Results presented in Fig. 1 indicate that a strict relationship between BAC and age in both genders was not observed; nonetheless, extremely high BAC is noticed in men between 35 and 60 years. Comparison between the age of men in the control (BAC ≤ 0.25 g/L) and in the test group (BAC > 0.25 g/L) showed that there was no statistical significance of this parameter ($U = 11{,}479$, $p = 0.3843$). Also, women in the control group were not older than the women in the study group ($U = 116$, $p = 0.76418$).

The comparison between BAC levels in the control group revealed that there was no statistically significant difference in BAC levels between men and women ($U = 368$, $p = 0.76418$). The same observation was made from the comparison of BAC levels between men and women in the test group.

Many investigations into unnatural/violent deaths verify that alcohol consumption and elevated BAC levels are highly prevalent [19]. For this aim, the available data in our study was classified using three categories of violent death. In the group of suicides, the most common method was hanging (27.43%) followed by firearm injury (20.35%), intoxication (19.47%), and drowning (17.7%). In the group of accidental deaths, the highest number of cases was seen in the road traffic accident group (56.72%) followed by intoxication (16.39%). The data for the distribution of cases, gender, age, and mean BAC for the different subgroups of violent death, according to manner of death, are presented in Table 2.

The analysis of BAC levels among different subgroups of suicides showed that there is no statistically significant difference between any of the subgroups. In contrast, the BAC levels were significantly different among cases from different subgroups of accidents. In the group of accident deaths, the highest value for mean BAC was in the group of bolus death (mean BAC 2.82 g/L), followed by the group of death cases due to mixed intoxication (BAC 2.14 g/L) and freezing (BAC 2.09 g/L). In the group of

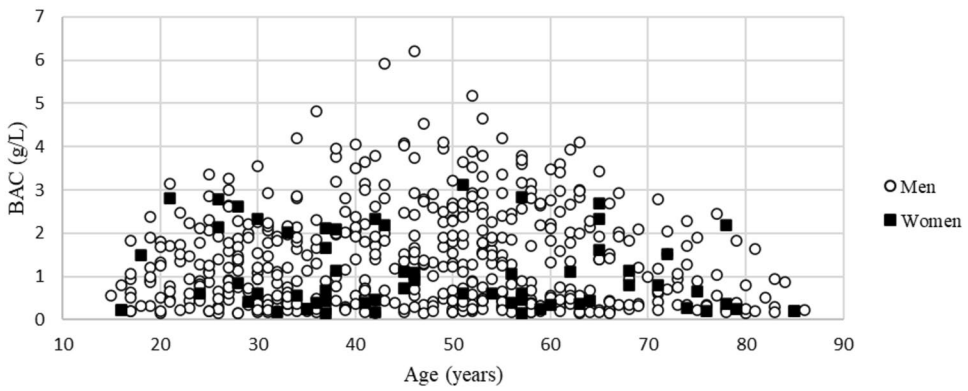

Fig. 1 Relation between BAC and age for men and women in alcohol-related deaths

Table 2 Distribution, gender, age, and average BAC for different subgroups of violent death

Manner of death	Number (%)	BAC (g/L)*	BAC median	Gender	N^0 cases	Age**
Suicide						
Hanging	27.43	1.23 ± 1.1	0.87	Male	27	48
				Female	4	46
Firearm	20.35	1.33 ± 0.94	1.19	Male	23	44
				Female	0	/
Stab wound	2.65	0.68 ± 0.29	0.54	Male	3	46
				Female	0	/
Drowning	17.7	1.19 ± 1.11	0.59	Male	17	59
				Female	3	57
Intoxication	19.47	1.14 ± 1	0.71	Male	16	44
				Female	6	48
Falling from height	11.50	1.43 ± 0.99	1.50	Male	7	46
				Female	6	29
Accident						
Firearm injury	0.33	0.2		Male	1	32
				Female	0	
Drowning	4.26	1.35 ± 0.96	1.41	Male	3	48
				Female	10	78
Intoxication	16.39	1.97 ± 1.81	1.02	Male	46	36
				Female	4	41
Burn/fire	5.25	1.77 ± 1.21	1.67	Male	15	47
				Female	1	65
Falling from height	6.56	1.53 ± 1.18	1.46	Male	17	56
				Female	3	49
Road traffic accidents	56.72	1.46 ± 0.87	1.4	Male	161	41
				Female	12	42.5
Bolus death	3.28	2.82 ± 1.1	2.96	Male	10	56
				Female	0	/
Freezing	1.97	2.09 ± 0.76	2.17	Male	6	60
				Female	0	/
Electrocution	2.30	0.41 ± 0.19	0.43	Male	7	60
				Female	0	/
Unspecified asphyxia	2.30	0.73 ± 0.54	0.55	Male	7	31
				Female	0	/

*Results expressed as mean BAC ± SD; **Mean age

accidents, the oldest victims were found in women who died by drowning, followed by men whose deaths occurred as a result of freezing and electrocution.

Figure 2 represents BAC in natural and violent deaths according to the BAC range. The greatest proportion of cases belonged to a BAC range of 0.5–1.5 g/L. Increased number of cases was observed in the BAC range of 0.25–0.5 g/L in comparison with the control group, except for the group of suicides.

In total, 30 cases had BAC ≥ 3.5 g/L, mostly found in the accident group (23 cases, 76.7%). The highest measured value for BAC was 6.20 g/L. BAC exceeding the legal limit of 0.5 g/L (‰) was found in 249 cases. Of them, in the group of road traffic accidents, male victims represent 93.6%, while female victims represent only 6.4%.

Discussion

Overconsumption of alcohol and drunkenness are common findings in cases of violent death when investigated in forensic medicine [9]. Examination of the pattern of alcohol-positive death cases in the Republic of North Macedonia has undeniably shown that violent deaths are mostly associated with alcohol use. Namely, more than 80% of the cases were from the group of violent deaths,

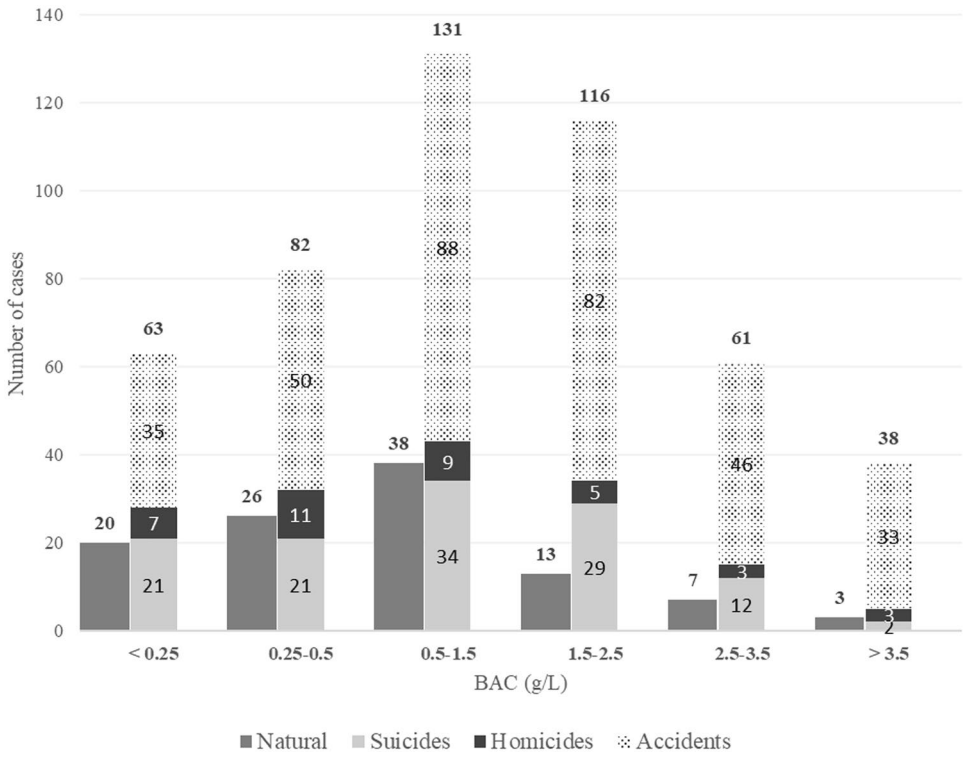

Fig. 2 Distribution of alcohol-related deaths according to BAC range

predominantly in men. This finding is comparable with the results of other studies, moreover indicating the increasing trend in alcohol-related violent deaths [20–23]. The male predominance can be explained in a historical context in which traditional social norms do not accept heavy drinking in women [6, 24]. Despite that, there is no difference in BAC between genders in this study. However, women (49 years old on average) were found to be older than men (45 years old on average). This finding is comparable to the results obtained from similar studies conducted in the neighboring countries [6]. These results as well as the results of our study are apparently distinctive from the findings in some Brazilian studies where alcohol-positive victims were found to be much younger, without difference in age between genders [8, 25].

Another divergence in the literature is found in the presented homicide cases. In Gonçalves et al. and Modelli and Lourenco's studies, more than 30% of the alcohol-positive cases have been reported as homicide [8, 25]. Homicide victims in our study have been rarely under the influence of alcohol (6.74%), even though its use is often linked to violence leading to fatal outcomes, mostly related to males and the use of firearms [26, 27]. The average (1.11 g/L) and median BAC (0.58 g/L) calculated from the cases of homicides represent the lowest BAC values from all subgroups of violent death in our study. Also, the youngest male as well as the oldest female were found here (39 and 68 years old, respectively).

The second most prevalent group for alcohol-positive cases was found to be the group of suicides, representing 20.04% of all cases. Also, the second-highest BAC was observed in the suicide group. Suicide is among the leading causes of injury-related mortality associated with alcohol consumption [28]. An Australian report indicates that the highest proportion of alcohol-related injury deaths belonged to the suicide group, more precisely 48% in males and 43% in females [23]. Many studies have addressed the effect of high BAC on suicide, and several countries have established programs to monitor the link between alcohol use and suicide. Our results are consistent with other studies where suicide victims are of older age (around 50 years old), and they are males which is considered a risk factor for suicide [6]. Exceptions can be found in Modelli and Lourenco's study where only 0.8% of alcohol-positive cases are described as suicides, mostly at the age between 30 and 39 years [8]. Further, results from our study are in line with literature data, suggesting that firearm injuries and hanging are the most common methods of suicide among victims with positive alcohol findings [21, 28]. Several studies for comparison are available for the nearby region. Study performed in Slovenia in the period between 2001 and 2020 reported that 8952 lives had been lost due to suicides, of which two-thirds as a result of hanging [29]. In Bosnia, suicides were commonly connected with alcohol use, as well. The most common method of suicide was hanging, followed by firearm injuries, also seen in a Serbian study [6, 30]. According to

Conner et al. in many instances, the use of firearms has been associated with the highest BAC, compared with other types of suicide [28]. In our study, mean BAC for cases of suicide by firearm was 1.33 g/L, and it was found to be the second-highest BAC value in the group of suicides. Although there was no statistically significant difference in BAC among subgroups of suicide, it is worth mentioning that the highest BAC (1.43 g/L on average) was found in the cases of falls from height. Herein, the distribution between genders is equal, which is not the case for the other subgroups. Females who had committed suicide by falling from height are found to be the youngest (29 years old on average), and at the same time, they represent 33.33% of all female suicide victims. Additionally, suicides by drowning and intoxication are also very common, with notable differences in BAC. In these cases, the measured BAC on average is lower than in cases of firearm injuries, but not rarely presence of other psychoactive drugs and medications has been confirmed.

Accidental deaths were the most common manner of death in the 564 studied cases, and in this group, the highest BAC was observed, which is in parallel with the results of other European studies [21, 22]. Evidently, road traffic accident victims account for the majority of violent deaths considering alcohol use. In comparison with studies on similar topics, we found comparable frequency of the cases and gender distribution, but a lower mean BAC for traffic accident victims was observed [6, 8]. However, alcohol use remains to be the highest risk factor for violation of traffic safety, including all traffic participants. Similar conclusions had been drawn in studies aimed at alcohol use among victims of traffic accidents performed in the near region. A 15-year survey on fatal traffic accidents in the region of Central Serbia has shown strong male predominance in total number of victims with positive alcohol findings (32.9%), with average BAC between 1.01 and 1.5 g/L [31]. The study conducted in Greece showed that in 44% of the fatally injured drivers, alcohol presence had been confirmed, while a Croatian study conducted in Split-Dalmatia County found that 40.3% of the autopsied pedestrians had been under the influence of alcohol during the fatal traffic accident [32, 33]. Pedestrians represent a significant share of total number of traffic accident victims [34]. Concerning this and the fact that BAC legislation applies to all traffic participants, in our study, the total number of traffic accident victims was studied.

Other important results obtained from our study include an obvious difference in BAC among subgroups of accidents, and the lowest BAC was observed in the group of death cases caused by electrocution. The victims of bolus death and freezing were the ones where the influence of high blood alcohol levels was most evident. We have found that these subgroups of death cases are mostly related to high BAC (> 2 g/L), especially in the elderly. Alcohol reduces airway sensitivity and the pharyngeal reflex leading to an increased risk of foreign body aspirations [35]. Likewise, adverse effects of alcohol are more pronounced in the elderly as a result of physiological changes with aging as well as the presence of chronic diseases in this population [36]. The oldest victims of all studied cases (78 years old on average) were represented by female victims of accidental drowning, which is the only subgroup with female predominance. Suzuki et al. pointed out alcohol influence as a significant variable in drowning cases [20].

Although the results from our study support the relationship between alcohol consumption and violent deaths, there are certain limitations that should be taken into account. There is not enough information on whether victims of violent death were acute or chronic alcohol users. Also, there are different physiological and behavioral responses resulting from alcohol consumption in different individuals [25]. Another important limitation of the presented study is insufficient data concerning other toxicologically relevant substances. In this context, mixed intoxications were observed, particularly in young men with a median BAC of 1.02 g/L. Drugs of abuse and medications were concomitantly detected in these death cases indicating frequent use of a few or more psychoactive substances over alcohol, which lead to fatal outcomes.

Besides the given limitations, this study described the role of alcohol in detail as well as important patterns of alcohol-related deaths in the Republic of North Macedonia. The length of the investigated period as well as the randomized data selection when it refers to forensic retrospective investigations can be considered as an advantage. Among the findings, higher BAC was found to be associated with a higher number of violent deaths, especially in the group of accidents. Herein, most cases in this group had BAC ranging from 0.5–2.5 g/L. In addition, it was observed that a concentration above 0.25 g/L was associated with an increased number of accidents when compared with the control group. Interestingly, we did not find an age target group, because there is no difference in this variable between death cases with BAC > 0.25 g/L and the control group.

Conclusions

The results have confirmed that alcohol is highly related to cases of violent death. As in many other countries, alcohol-related death is one of the largest public health issues. On one hand, the results from this study may help in building a national mortality database for alcohol-related deaths in order to assess the influence of alcohol on any form of aggressive behavior, human health, and mortality. On the other hand, these results would be helpful in revising alcohol policies and contribute to the prevention of alcohol-related violent deaths. More studies are needed to draw conclusions

on whether lowering the acceptable driving BAC limits would contribute to reducing the number of deaths due to overconsumption/misuse/abuse of alcohol.

Key points

1. Most cases of alcohol-related deaths belonged to a BAC range of 0.5–1.5 g/L.
2. The highest number of cases, as well as the highest BAC, were found in the group of accidents.
3. Blood alcohol concentration above 0.25 g/L was associated with an increased number of accidents when compared with the control group.
4. The results from the study can contribute to national alcohol-related harm prevention strategies.

Author contribution Conceptualization and design: MBP and AS. Data analysis and interpretation of the results: MBP and LA. Technical support in data analyses: ZZ. Writing the article: MBP and LA. Critical revision of the article: AS, VP, and LPT. Final approval of the article: all authors.

Funding No funding was received for conducting this study.

Data and materials The data that support the findings of this study are available from the Institute of Forensic Medicine, Criminology and Medical Deontology, Medical Faculty, Ss. Cyril and Methodius University in Skopje, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from authors upon reasonable request and with permission of the Institute of Forensic Medicine, Criminology and Medical Deontology, Medical Faculty, Ss. Cyril and Methodius University in Skopje.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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