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The Impact of Psychoactive Substances on Fatal Traffic Accidents

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Abstract

Deaths due to road traffic accidents continue to represent a pressing global public health challenge. Reports from the World Health Organization and other international agencies indicate that millions sustain injuries and hundreds of thousands lose their lives annually due to traffic collisions. Most fatalities occur in nations with limited economic resources, where inadequate road infrastructure, limited use of seatbelts and helmets, disregard for speed limits, and the prevalence of operating a vehicle while impaired by alcohol or other psychoactive substances substantially increase the risk of death. In the investigation of fatal traffic accidents, postmortem examinations combined with systematic toxicological analyses are indispensable for clarifying accident mechanisms and informing the development of targeted preventive strategies.

Keywords: Fatal traffic accident, alcohol, psychoactive substance, toxicology, autopsy

INTRODUCTION

Traffic accident-related fatalities are defined as deaths occurring either immediately at the crash site or within 30 days of the incident. Every year, road traffic accidents claim the lives of approximately 1.35 million individuals, translating to a fatality every few seconds. Furthermore, between 20 and 50 million individuals suffer non-fatal injuries, a significant portion of which results in long-term disabilities. Among these fatalities, 92% are reported in nations with restricted and intermediate levels of economic development; Africa experiences the highest incidence rates, while Europe experiences the lowest incidence rates. More than 50% of road traffic fatalities involve vulnerable road users, including pedestrians, cyclists, and motorcyclists. Infrastructure shortcomings were a major contributor: 80% of the evaluated facilities failed to meet the minimum three-star safety threshold for pedestrian protection and dedicated cycling lanes. Such deficiencies amplify collision risks and magnify the severity of injuries.[1]

From a demographic standpoint, road traffic accidents remain one of the primary causes of mortality among individuals aged 5 to 29 years. Males are almost three times more likely than females to be victims, and nearly two-thirds of fatalities occur among individuals aged 18-59 years, who are the economically productive segment of the population. This emphasises significant socioeconomic consequences as well as human costs.[1]

Urban Transportation: Injuries and Fatalities Surrounding Micro-Mobility Devices

Notably, new data show a significant increase in the number of traffic crashes involving bicycles, motorcycles, electric scooters, and other micromobility vehicles. According to a study conducted by Poulos et al.[2] and colleagues in Australia, there are 0.29 bicycle accidents per 1,000 km. In a study examining hospital admissions due to bicycle injuries in the Netherlands, a 5.7% mortality rate and 41% incidence of multiple traumas were identified.[3]

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In a study analysing data on the clinical and demographic characteristics, time of accident, injury conditions, and helmet use of emergency department patients involved in bicycle accidents in Rome, Italy, between 2019 and 2022, a mortality rate of 0.3% and multiple trauma frequency of 30.4% was found among 763 patients. The results of the investigation revealed that collisions with other automobiles led to higher trauma scores and intensive care unit (ICU) admission rates, whereas helmet use decreased head trauma severity and prevented more ICU admissions.[4]

The national database in the United States (US) reviewed 1,933,296 micromobility-related injuries (including electric scooters, electric bicycles, electric skateboards, and bicycles) from 2019 to 2022. The study results showed a large increase in e-bike (from 293%) and e-scooter (from 88%) injuries during the four-year period.[5]

Electric scooters are emerging as alternatives to bicycles and public transportation systems, particularly for short distances. Owing to their high availability from mobile applications and relatively small size, they have gained popularity in urban transportation as micromobility electric vehicles, that can be easily maneuvered between or alongside vehicles on roads or sidewalks. In Poland, an analysis of nine fatalities in traffic accidents involving electric scooters revealed that accidents primarily occurred during the summer, on weekdays, and during peak morning traffic hours. In only two of the cases examined, blood analysis indicated the presence of alcohol at the time of the incident.[6]

Substance Use and Traffic Risk

A person who drives a vehicle under the influence of alcohol or other psychoactive substances is subject to criminal liability if, as a result of impaired driving, there is an accident with serious or fatal consequences. Studies, which focus on alcohol and illegal drugs, show that such substances only lead to an increased probability of road events, as they impair the brain functions needed for driving.[7]

Forensic sciences are crucial in elucidating both the causes and the situational aspects of deaths resulting from road traffic accidents. In cases of fatal traffic accidents, autopsy examinations and systematic toxicological analyses are vital for determining the circumstances of the accident, as well as the physiological state of the driver or the victim's condition at the time of the incident, including potential influencing factors. Toxicological analyses are typically performed to determine whether the driver or victim was affected by alcohol, illicit drugs, or medications at the time of the incident. Blood, urine, stomach contents, brain tissue, liver, and lungs were collected for toxicological and biochemical analyses. Forensic toxicology analyses of biological samples were used to determine whether the driver exceeded the legal limits or was influenced by drugs (medications used for medical and/or recreational purposes). In addition, postmortem biological changes are considered to estimate the level of a substance at the time of the incident.[8]

Alcohol is the most commonly detected psychoactive substance in traffic accidents. After alcohol, the most commonly detected drug classes include cannabinoids (cannabis/marijuana), benzodiazepines, stimulants, and opioids.[9]

Ethanol, commonly referred to as alcohol, is a prevalent euphoric substance that exerts a depressant effect on the central nervous system. Beyond its impact on cognitive functions, it impairs judgment, induces memory deficits, reduces alertness, and causes disturbances in emotional regulation and physical coordination; this includes balance, speech, vision, hearing, and reaction time. At elevated concentrations, alcohol consumption can result in severe outcomes, such as vomiting, loss of consciousness, and even death. The absorption rate of alcohol from the gastrointestinal system varies depending on the amount consumed, ethanol concentration in the beverage, interactions with medications, presence of food in the stomach, and digestion time.[10]

Extensive research indicates that individuals impaired by alcohol consumption have a significantly higher propensity for involvement in traffic collisions compared to those who abstain from alcohol. Alcohol consumption affects drivers' speed preferences, increasing the risk, severity , and extent of injuries in accidents.[11]

The relationship between high blood alcohol concentration (BAC) and accident frequency has been demonstrated in numerous studies. These findings have led many countries to implement regulatory policies against drunk driving. A BAC of ≥0.50 g/L is typically considered the threshold at which driving capabilities are impaired, thereby posing a risk to road safety.[12] Canada, the US, and New Zealand are recognized as having the highest rates of traffic fatalities linked to alcohol consumption.[10]

Two longitudinal studies from Greece have shown that the proportion of drivers involved in traffic collisions who were impaired by alcohol was 37% during the period from 1995 to 1997. This percentage increased to 41% in the following years, from 1998 to 2004.[13]

Further research is required to clarify the long-term risk of traffic accidents due to alcohol consumption. Serum carbohydrate-deficient transferrin (CDT) levels have been measured by researchers observing correlations between CDT and post-accident BACs. This may provide evidence suggesting that CDT is a new biomarker for detecting road traffic crashes associated with chronic alcohol consumption.[12]

Over a five-year period (2017 to 2021), a retrospective study, performed in the Iraqi Nineveh province, revealed that most victims (injured or dead) of traffic accidents were male. This is believed because not as many women are driving. The research also found that motorcyclists had a greater tendency to be involved in crashes compared to drivers of other vehicles, and the rate of motorcyclist accidents was generally on the rise. The predominant causes of mortality were identified as head trauma and fractures of the lower extremities.[14]

A study comparing alcohol use among fatal and injured motorcycle and bicycle riders, using data from three national public databases, emphasized that the likelihood of fatal and non-fatal injuries being alcohol-related was higher among middle-aged adults and men. The findings indicated that over 38% of motorcycle riders who died each year from 2008 to 2020 and 20% of bicycle riders involved in traffic accidents were under the influence of alcohol.[15]

In Lithuania, an analysis of BAC from 2013 to 2023 was conducted concerning sex, user category, location of death, and time of death in 136 traffic accident cases. The analysis was based on the frequency of alcohol detected in blood specimens collected during autopsy. A total of 31% of the individuals who succumbed to fatal injuries suffered from alcohol intoxication. Specifically, alcohol consumption was identified in 32% of vehicle drivers, 41% of vehicle passengers, 37% of motorcycle riders, and 37% of bicycle riders at the time of the collision. BAC was highest during the period from 9:00 PM to 5:00 AM, and over a slightly smaller time window of 4 h, from 5:00 PM to 9:00 PM.[16]

Studies conducted in Scotland[17], Portugal[18], and Greece[19] indicate that car and motorcycle drivers are the primary contributors to alcohol-related traffic fatalities, whereas research from Côte d'Ivoire, China, Russia, and Pakistan highlights higher mortality rates among pedestrians. Such cross-national differences may reflect variations in cultural norms and behaviors, the dominance of certain motorized transport modes, and the broader conditions for cycling and walking.[20-22]

While the effect of alcohol on impaired driving ability is the most frequently studied and documented factor, scientific data on the effects of illicit and prescription psychoactive substances on drivers are quite limited. Therefore, there is a lack of information on the frequency of substances other than alcohol in fatal traffic accidents worldwide.[23] Nevertheless, existing studies indicate that other substances that affect the central nervous system (e.g., medical and/or recreational drugs) also seriously impair driving ability and cause road traffic accidents. Extensive research has demonstrated that the intake of alcohol and mind-altering substances markedly increases the probability of fatal road traffic collisions.[24]

Papalimperi et al.[10] analyzed 1,841 autopsy cases from fatal traffic accidents to assess the role of alcohol and psychoactive substances. Toxicological tests showed that 40.7% of deaths were alcohol-related, while 18.9% involved drugs, including such as cannabis (46.6%), benzodiazepines (25.9%), opiates (16.4%), and cocaine (11.1%). Alcohol was combined with other substances in 4.5% of cases. Fatalities were most common among males (87.3%) aged 21-30 years with high blood alcohol levels.[10]

The misuse of illegal, naturally derived, or artificially synthesised, psychoactive compounds often leads to mood changes. The repeated use of such substances often causes addiction, resulting in health, social, and environmental problems. Today, drug use has increased at an unprecedented rate on a global scale, becoming a major public health issue that directly affects crime rates, social stability, and the economy.[25]

According to the World Drug Report, 284 million adults worldwide aged between 15 and 64 years used at least one illicit drug, with a majority being male.[26] Regarding the coronavirus disease-2019 pandemic, increased drug use due to social isolation, as well as concerns about mental health and heightened economic insecurity, have been further advanced can be set for the above reasons.[27]

Drugs are subject to various restrictions based on their origin, pharmacological effects, chemical structures, and legal status. Within this classification, substances are categorised as natural, semi-synthetic, or fully synthetic and further classified based on their legal status as either prescription, legal, or illegal. Illegal drugs are those drugs whose production, transportation, and sale are in contravention of laws.[28]

In recent years, the heterogeneity of drugs available to individuals has expanded, use pattern complexities have intensified, and the co-consumption of several substances simultaneously has increased. By 2022, the global estimated number of drug users was 292 million (5.6% of the population aged 15-64), representing a 20% increase from a decade ago. Illicit abuse is more frequent with opioids than any other substance except cannabis; the third most commonly abused substances are amphetamine-type stimulants, followed by cocaine and MDMA (ecstasy).[29]

In a study conducted in the US, toxicological test results for one or more psychoactive substances were positive in 71-99% of five different driver populations. Additionally, approximately 50% of drivers tested positive for multiple substances. The most commonly detected substances across all groups were alcohol and cannabis; alcohol emerged as the most commonly identified substance in isolation, whereas cannabis was most often detected in conjunction with alcohol and additional psychoactive agents.[30]

The rapid expansion of synthetic drugs within the illicit drug market is largely due to their uncomplicated production methods, use of inexpensive chemical components, and the ease of manufacturing irrespective of geographical constraints. This development presents intricate and substantial challenges to public health and safety, particularly in low- and middle-income nations. The detection and frequency of psychoactive substances are shaped by the country's patterns of drug misuse, its economic landscape, its regulatory stance on alcohol, and the use of both prescription and illegal drugs.[29]

Recent studies have highlighted that in some populations, the likelihood of vehicular accidents is higher when drivers are impaired by cannabis than when they are impaired by alcohol. This risk is predicted to increase in the coming years, and it is emphasised that this situation will have increasingly negative impact on road safety.[31]

Medications can have different effects depending on an individual's genetic makeup, physical characteristics, or current medical condition.[32] Driving a motor vehicle is a complex activity that requires attention, coordination, and the simultaneous execution of cognitive multitasking. Research investigating the impact of pharmaceuticals and various medications on driving performance has assessed multiple parameters, including lane changes or deviations, vehicle speed and variability, response time to environmental cues, and levels of attention. In most studies in this field, participants are administered controlled doses of drugs, after which their driving performance is measured in simulated environments or closed courses. While performance tests provide valuable information about the effects of a particular substance on driving, they also have limitations, such as the inability to experimentally test illegal substances due to legal and ethical restrictions and the fact that controlled environmental conditions do not fully reflect real-world drug use and driving conditions.[30,33]

The "Drug and Human Performance Fact Sheets" were published in 2004, encompassing 16 distinct drugs or categories of drugs. Developed by an international panel of experts on driving under the influence of drugs, these fact sheets contain scientific data on each drug's chemical properties, effects on the body, method of use and dosage, and its potential effects on driving performance. These updated information sheet provide scientific information on the substances most commonly involved in traffic accidents caused by alcohol and drugs.[34]

In the "Drug, Alcohol, and Medication Influence on Driving" (DRUID) project, which involved 36 institutions from 18 European countries and lasted five years (2006-2011), the frequency of use of various psychoactive substances and their risk levels on driving performance were assessed, and the general effects of different drug categories on performance were identified through meta-analyses.[35]

Recent studies have supported the findings of the DRUID project. McCartney and colleagues highlighted that cannabis consumption results in deficits across various driving-related abilities. These impairments are more pronounced in occasional users compared to habitual users.[36]

Simmons et al.[37] reported that the consumption of alcohol and cannabis, as well as their simultaneous use, significantly impaired driving performance. Moreover, the concurrent intake of these substances results in a more pronounced detrimental effect than the consumption of either substance individually.[37]

Additionally, impairments in driving performance have been observed in the morning following the use of certain hypnotic medications. The effects of sedative hypnotics such as zopiclone, flunitrazepam, and ramelteon are similar to the impairing effects of alcohol on driving performance.[38]

Toxicological Analysis of Biological Samples Collected from Drivers: Applications and Limitations

A law enforcement officer who arrests a driver suspected of operating a motor vehicle while impaired by alcohol and/or other psychoactive agents, will request that the driver provide a biological sample (breath, blood, urine, or oral fluid) for screening or testing for the presence of alcohol and other controlled substances. In some circumstances, the officer may compel the driver to do so. Toxicological analyses of biological samples are conducted as part of forensic investigations of living drivers and post-mortem investigations of individuals involved in fatal traffic accidents.[39]

Breath

In cases where drunk driving is suspected, portable breathalysers are routinely used to reliably estimate the BAC. However, because the current technology can only measure alcohol levels through breath, it is not suitable for the detection of other psychoactive substances.[40]

Urine

Urine is a commonly preferred biological specimen, particularly for assessing drug consumption. Urine analysis is a valuable method for detecting the history of drug use or exposure. There is debate about whether urine is a suitable test sample for driving under the influence of drugs,. Urinalysis is unable to determine the exact time of substance ingestion or the precise concentration of a substance affecting the body in relation to the timing of a traffic accident or driving violation.[41]

Blood

Blood is widely regarded as an optimal biological specimen for toxicological evaluation aimed at detecting psychoactive substances. However, for a blood sample to be obtained in a suspected driving violation, the driver must be transported to a healthcare facility. During this time, the medications in the driver system continue to be metabolised. Therefore, the findings from toxicological assessments may not accurately indicate the concentration of drugs in the driver's bloodstream at the time of the incident, as the substance could have been completely metabolized within the time elapsed since the event.[42]

Oral Fluid

Saliva is a biological sample, an oral fluid composed of substances such as cell debris found in the mouth and particles of swallowed materials, that can be easily and quickly collected at the time of the event compared to blood and urine. Currently, in some countries, oral fluid analysis devices are used during roadside checks to screen for specific drug groups. Rapid and qualitative (positive/negative) results regarding the presence of drugs can be obtained using these devices. Toxicology laboratories can use oral fluid specimens for confirmatory testing, resulting in a full drug panel and quantitative determination of drug concentration.[43]

Biological samples collected from living individuals often include blood (whole blood, plasma, or serum), urine, hair, nails, exhaled air, oral fluid (saliva), and stomach content. For post-mortem investigations, critical samples for toxicological analysis encompass arterial or venous femoral blood, cardiac blood, urine, vitreous fluid, stomach contents, and organ tissues, particularly liver and lungs. Furthermore, under specific circumstances, alternative samples, such as blood clots, blood from the thoracic or abdominal cavities, cerebrospinal fluid, brain tissue, spleen, bile, bone, synovial fluid, bone marrow, skeletal muscle, and larvae may be utilised if traditional samples are unavailable or compromised.[44]

Interpretation of Drug Concentrations in Postmortem Toxicology

Interpreting drug concentrations in postmortem biological samples presents several challenges. For example, urine is a simpler sample than blood or intraocular fluid; however, substance detection in urine is only an indicator of exposure. Concentrations found in urine are usually intermediate to high and may not yield useful information in terms of quantification because there is no correlation with blood levels or toxic effects.[45]

The postmortem alterations in drug concentrations complicate the assessment of a substance's role in fatal road traffic incidents. The chemical and biological degradation processes during human decomposition, however, bring about the fluctuation of drug levels. In addition, the chemical stability of drugs is an important factor to consider. For instance, some substances rapidly decompose other highly volatile compounds, including biological molecules, and are quickly broken down into various states of decomposition after death. In addition, improper handling or long-term storage deteriorates the structural preservation of active pharmaceuticals, leading to incorrect toxicological evaluation.[46]

A study in Wisconsin (2019-2021) examined the blood toxicology results of 8,923 drivers arrested for alcohol-impaired driving after traffic accidents. As drug levels vary with the onset, peak, and duration of action, delays between crashes, arrests, and blood sample collection can reduce accuracy. The findings showed that both blood alcohol (BAC) and delta-9-tetrahydrocannabinol concentrations decreased significantly with longer collection times. Accident severity and the time of day were linked to such delays. Researchers have stressed that measured concentrations may not reflect actual levels at the time of a crash due to ongoing drug metabolism and elimination.[47]

Effectiveness of Legal Regulations

Since the publication of the first global road safety report in 2004, countries have agreed on the adoption of numerous road safety policies, including lowering legal alcohol limits. The World Health Organization and the European Transport Safety Council have recommended that countries lower their legal BAC limit to 0.05 g/dL to reduce drunk driving and its consequences.[48]

Empirical evidence from multiple studies demonstrates a reduction in the occurrence of alcohol-impaired driving subsequent to the introduction of legal measures and the imposition of statutory penalties. Reducing the BAC limit to 0.05 g/dL has been associated with a 48% decrease in road traffic deaths in Australia, a decrease in alcohol-related fatal accidents in Japan, a 9% decrease in Austria, and a 36% decrease in France (74). 25% A large-scale analysis that decreased the BAC value to 0.05 g/dL and was carried out in 27 European countries led to an 11% reduction in road traffic deaths.[49]

Legal interventions such as lowering BAC limits are considered one of the most effective strategies for reducing drunk driving. Indeed, lowering the BAC to below 0.05 in Japan and Sweden has led to significant decreases in alcohol-related traffic accidents. However, there are also findings that legal regulations are not always as effective as expected. According to a study conducted in Australia, licence restrictions for drunk driving do not provide an effective deterrent, and the tendency to drive under the influence of alcohol reaches its highest level when offenders expect sanctions.[50]

The United Nations aims to reduce deaths and injuries from traffic accidents by 2030 within the framework of the sustainable development goals and in this regard, encourages local governments to effectively implement traffic laws.[1]

CONCLUSION

To reduce the rates of deaths and injuries related to traffic accidents, it is important to develop legal regulations, strengthen inspection mechanisms, and increase awareness campaigns aimed at preventing impaired driving by alcohol and/or other psychoactive substances. In addition to legal intervention, equal importance should be given to other prevention strategies aimed at improving road safety. Implementing multifaceted, holistic policies, such as regulating alcohol sales, community-based education programs, and increasing access to alcohol treatment services, can help raise awareness about and discourage driving under the influence.

MAIN POINTS

- Traffic accidents are a serious global public health concern.
- Vulnerable road users (pedestrians, cyclists, and motorcyclists) accounted for more than half of the deaths.
- Alcohol is the most commonly encountered psychoactive substance in fatal traffic accidents.
- The combination of alcohol and other substances poses a higher risk than either alcohol alone.
- Lowering the blood alcohol concentration limit to 0.05 g/dL has resulted in a significant decrease in traffic fatalities in many countries (Australia, 48%; Japan, 25%; France, 36%).

Footnotes

Authorship Contributions

Concept: C.E.Ö., Design: C.E.Ö., Data Collection and/or Processing: C.E.Ö., Analysis and/or Interpretation: C.E.Ö., Literature Search: C.E.Ö., İ.D., E.H.Y., Writing: C.E.Ö., İ.D., E.H.Y.

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