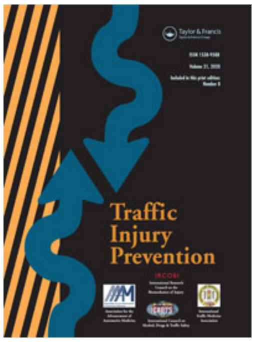

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Land motor vehicle-related fatal drowning in Finland: A nation-wide population-based survey

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ABSTRACT

Objective: WHO mortality statistics overlook land motor-vehicle accident (LMVA)-related drowning. The aim of the study was to provide an overview of the prevalence and trends of fatal LMVA-related drowning in Finland, plus the main crash settings, victims' demographic characteristics, and contributing factors leading to such deaths.

Methods: A descriptive, retrospective, population-based study of drowning deaths associated with LMVA among Finnish residents of all ages, 1971–2013. LMVA-related drownings and applicable variables were extracted from the Statistics Finland (SF) mortality database by cross-analysis of ICD injury- and external cause-of-death codes.

Results: During the study period, 538 LMVAs leading to drowning occurred among Finnish residents (2.5/1 000 000/year; 4.9% of all unintentional drownings, 3.7% of all LMVA). Three main settings, ones responsible for over 95% of LMVA-related drownings, were recognized: traffic vehicle accidents involving a passenger car; non-traffic vehicle accident involving a snowmobile; and non-traffic accidents involving agricultural, industrial, or construction vehicles. Alcohol use was a contributing factor for death in > 40% of the victims, whereas severe injuries were reported in less than 6%.

Conclusion: Because transport safety is crucial to prevent any vehicle entering the water, placing LMVA-related drowning in the category of transport accidents is warranted. Once the vehicle becomes submersed, however, prevention measures to avoid death by drowning remains decisive.

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Drowning; land traffic; motor vehicle; snowmobile; ICD external codes

Introduction

Land motor-vehicle accident (LMVA) and drowning are among the leading causes of unintentional injury deaths. The WHO estimates that more than 1.3 million people die each year worldwide as a result of road-traffic crashes, whereas drowning claims over 300 000 lives annually (WHO 2018).

Land motor-vehicle accidents (LMVA) resulting in drowning are a subgroup of traffic accidents overlooked in WHO statistics. Indeed, no International Classification of Diseases (ICD) codes exists for subcategories of LMVA resulting in vehicle submersion, and WHO statistics report drowning resulting from submersion of a land motor vehicle as a generic LMVA, but not as drowning (Lunetta et al. 2002).

LMVA-related drownings are events triggered by a land motor-vehicle being completely or partially submerged or, more rarely, by a crash in which a vehicle remains on land but its occupants are ejected into water. Submersion of a land motor-vehicle results in different scenarios, all exposing the vehicles' occupants to risk of drowning (Stjernbrandt et al. 2008; Austin 2011; IRSR 2012; McDonald and Giesbrecht 2013a). The vehicle occupant(s) may be directly ejected into water, challenging their ability to float and to swim to reach safety or to await rescue. This occurs for open vehicles, such as snowmobiles or motorbikes, and, at times, when occupant(s) of an enclosed submerged vehicle succeed in escaping the vehicle compartment. In other cases, drowning occurs when occupants are unable to escape the compartment before the water fills it, or when they remain entrapped under or between vehicle components.

General figures on LMVA-related drowning appear in some drowning surveys, usually limited to high-income countries (HIC) (e.g., Peden et al. 2017). Moreover, few in-depth reports on crashes characterized by vehicle submersion have focused on environmental factors and victims' profiles (Wintemute et al. 1990; Yale et al. 2003; Hammett et al. 2007; Stjernbrandt et al. 2008; Giesbrecht and McDonald 2010; Austin 2011; IRSR 2012).

In Finland, surveys on drowning from the 1980s and 1990s have suggested that LMVA may account for 4–6% of overall unintentional drownings (Lunetta et al. 2002, 2004), but no studies have specifically addressed LMVA-related drownings and compared figures with those of other HIC countries.

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The present nationwide 43-year study aims to provide an overview of prevalence and trends in LMVA-related drownings in Finland, vehicle involved and crash settings, as well as victims' main demographic characteristics and factors contributing to deaths.

Material and methods

Statistics Finland (SF) provided individual-level mortality data (permission TK53-277-15) for all unintentional drownings occurring in Finland 1971 through 2013. Unintentional drowning selection was by means of the relevant ICD I- and E- codes in use during the study period (ICD-8: 1971-1986; ICD-9, Finnish version: 1987-1995; ICD-10: 1996-2013) (Supplementary material 1a).[1] Cross analysis of I- and E-coded unintentional drowning then performed was to distinguish between drownings for which the initiating event was a LMVA and other unintentional drownings.

The coverage of the SF mortality database is in practice 100% of the Finnish resident population (Official Statistics of Finland 2018), and its accuracy is improved by the high frequency of medico-legal autopsies (94–97%) for injury deaths (Lunetta et al. 2007). Excluded from this survey were drownings involving Finnish residents but occurring abroad.

The main circumstantial and individual variables of LMVA-related drownings considered throughout the study period were victims' gender and age and their month of death. The type of vehicle involved, the crash site, and the victim's position in the vehicle were examined according to the ICD E-codes for LMVA in use during the study period (Supplementary material 1b). In addition, we scrutinized, for 1996–2013, factors contributing to death (victims' alcohol intoxication,[2] injuries, preexisting diseases), as reported in the cause-of-death certificate.

LMVA-related drowning mortality rates and time-trends were calculated on the basis of population data provided by SF. Moreover, SF provided relevant data for overall LMVA (Courtesy of A. Pajunen, SF; Official Statistics of Finland 2020). On-line SF data, available since 1998, served in determining overall alcohol-positive fatal LMVA and drowning (Official Statistics of Finland 2019).

Statistical methods

The 95% confidence intervals (CI_{95}) for the means were calculated with Students t-distribution, time-trends in incidence rates and 95% confidence limits (CL_{95}) by Poisson regression; differences in time-trends by the Wald z-test. Analyses utilized R software version 3.4.1 (R Core Team 2018).

Results

During the study period (1971–2013), SF recorded 538 deaths which received an I-code for drowning but an E-code for LMVA (here referred to as "LMVA-related drowning") and 10 462 unintentional drownings, which had both an I- and E-code for unintentional drowning (here referred as "other unintentional drowning").

The 538 LMVA-related drownings (2.5/1 000 000/year; mean 12.5/year, CI_{95}: 10.5–14.5) accounted for 4.9% of overall unintentional drownings (50.8/1 000 000, mean 255.8/year, CI_{95}: 230.3–281.4), and for 3.7% of all LMVA (69.4/1 000 000, mean 349.4/year, CI_{95}: 317.1–381.7). A medico-legal autopsy was performed in 518 cases (96.3%).

Time-trends

In total, a progressive, although irregular, downward time-trend in LMVA-related drownings was observable throughout the study period (−1.2%/year; CL_{95}: −1.8, −0.5; $p < 0.001$; Poisson regression) (Figure 1a), a decreasing trend being evident also for other LMVA (-2.3/year; CL_{95}: −2.4, −2.1; $p < 0.0001$) and other unintentional drownings (−2.5%/year; CL_{95}: −2.7, −2.4; $p < 0.0001$) (Figure 1b). At the beginning of the 1970s (1971–1973) the mean was 21.7 LMVA-related drownings/year (CI_{95}: 16.7–27.6) whereas by the end of the study period this figure had dropped to 7.0/year (CI_{95}: 4.3–10.7). The decrease in LMVA-related drowning was, however, less marked than for other LMVA and other unintentional drownings ($p < 0.001$; Wald z-test).

Monthly distribution

The majority of LMVA-related drownings occurred during the cold season, with the 6-month period from November to April accounting for 402 (74.7%) cases. This seasonal profile diverges from that of other unintentional drownings, that most (80.7%) occur during the period from May to October (Figure 2).

Victims' individual characteristics

Mean victims' age in LMVA-related drowning was 37.1 years (CI_{95}: 35.2-38.9) and the male-to-female rate ratio (M:F RR) was 7.8. The M:F RR was similar to that in other unintentional drownings (8), but higher than in all other LMVA (3.3). Age distribution in LMVA-related drownings shows two smooth peaks, the first at 20 to 24 years ($n = 64$) and the second at 40- to 44 ($n = 56$). Other unintentional drownings show a major peak at 45 to 54 years and a minor one between 0 and 9 years, whereas other LMVAs had a single peak between 15 and 24 years (Figure 3).

[1]SF tabulates drowning according to WHO recommendations, by means of both the ICD nature-of-injury and external-cause codes (I- and E-codes, respectively) (Lunetta et al. 2002). The I-codes identify the nature of the injury leading to death (drowning). The E-codes describe the circumstances leading to death (drowning, motor traffic accident, flood). A drowning death has therefore always an I-code for drowning, but the accompanying E-code can be or not be for drowning.

[2]The medical examiners in charge of the medico-legal autopsy evaluate, after toxicological analysis, the role of alcohol as a factor contributing to drowning. This occurs mostly when the victims' blood alcohol concentration is > 50 mg/dl (unpublished data).

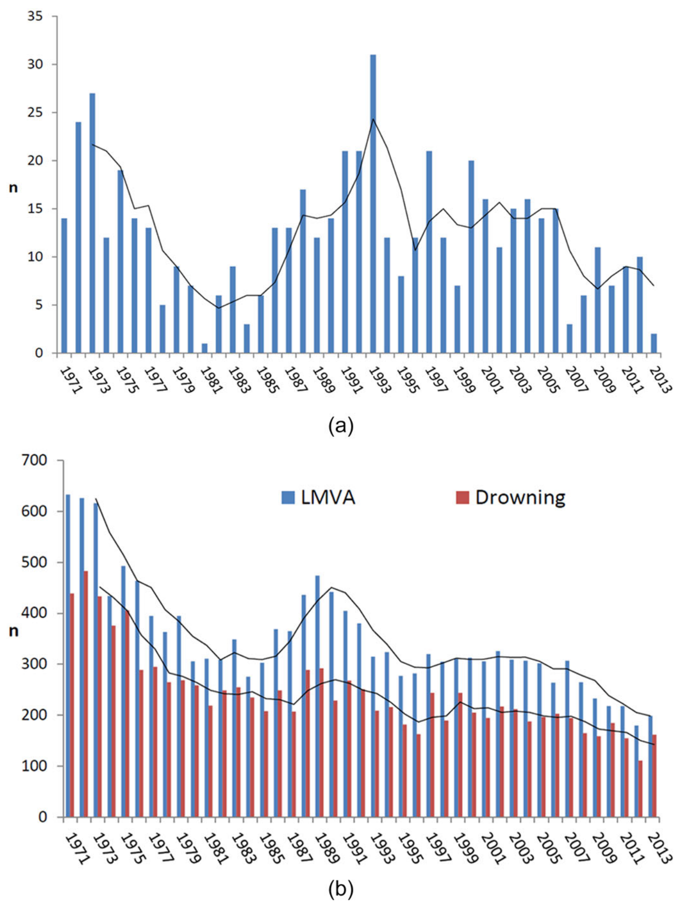

Figure 1. a. Land motor-vehicle accident-related drowning in Finland: 1971–2013 (3-year moving average). **b.** Other land motor-vehicle accident (LMVA) and other drowning in Finland 1971–2013 (3-year moving average).

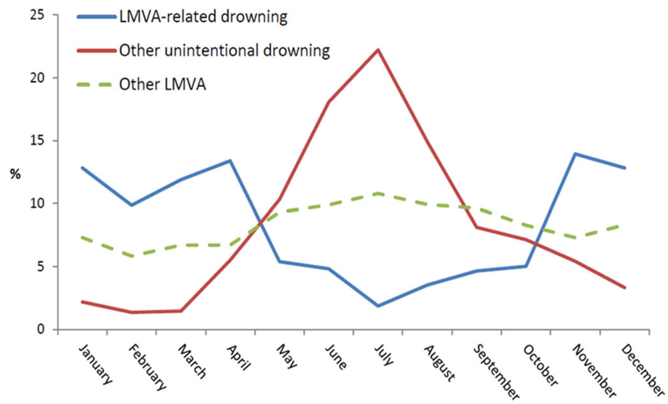

Figure 2. Relative monthly distribution of land motor-vehicle accident (LMVA)-related drowning and other unintentional drowning, in Finland, 1971–2013. The dotted line refers to the monthly distribution of other fatal LMVA, based on SF on-line data, for the period 2003–2013 [Official Statistics of Finland: Statistics on Road Traffic Accidents] [accessed 2020 Apr 7]. http://www.stat.fi/til/.

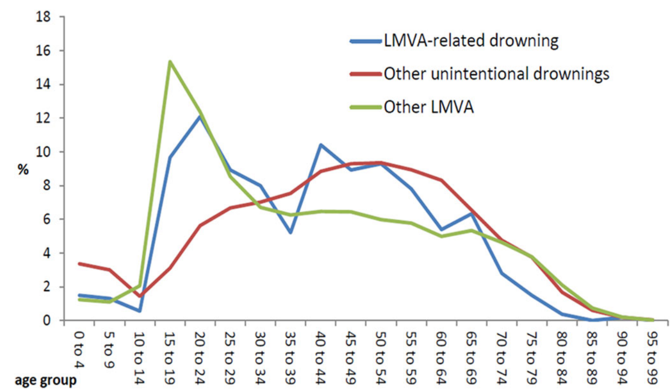

Figure 3. Relative age distribution of land motor-vehicle accident (LMVA)-related drowning, other unintentional drowning, and other fatal LMVA in Finland, 1971–2013.

Crash type and site, vehicle involved, and victims' position

The use, during the study period, of three revisions of the ICD (ICD-8; ICD-9 Finnish version; ICD-10), with significant changes in ICD E-codes describing the subcategories of LMVA, hampered the possibility of having consistent data on crashes type, vehicles involved, and victims' position.

During the period 1971 to 1995 (ICD-8, ICD-9), what emerged was merely that among 331 LMVA-related drownings, 133 were classified as "traffic" accidents, 193 as "non-traffic" accidents, and 5 as "other" or "undetermined accidents." The most common crash involved a motor vehicle "other than a motorbike" and was characterized by driver's loss of vehicle control. Among the 261 victims for whom a description of position in the vehicle was available, 181 (69%) were drivers, and 80 (31%) passengers. Data on LMVA-related drownings tabulated by ICD-8 and ICD-9 (Finnish revision) codes, are available in supplementary material 2 and 3.

Starting in 1996, the ICD-10 allowed a more detailed description of the crashes (Supplementary material 4, 5). The most common types among the 207 LMVA-related drowning were snowmobile crashes, 89 (42.6%) and passenger-car traffic accidents, 87 (41.6%), usually with no collision. The remaining cases involved vehicles utilized in agricultural settings, construction work, and on industrial premises, 24 (11.5%), mostly in non-traffic settings, and motorbike accidents, 7 (3.4%). Overall, the victim's mean age was 45.7 (CI_{95} 43.1–48.2) (snowmobile: 49.2, CI_{95} 46.0-52.5; passenger car 39.5, CI_{95} 35.3-43.7; agricultural-industrial-construction vehicle: 53.3, CI_{95} 48.8-61.7; motorbike: 43.4, CI_{95} 24.4-62.4).

Contributing factors: alcohol, injuries, and diseases (1996–2013)

In LMVA-related drowning, 45.9% (89/194) of victims $\geq$ 18 years of age tested positive for alcohol. Among passenger-car occupants for whom location in vehicle was known, 40.8% (51/125) of drivers and 34.6% of passengers (9/26) tested positive for alcohol. The percentage of alcohol-positive LMVA-related drownings at all ages (43.5%) fell between that for other unintentional drownings (55.8%) and LMVA (20.4%) (Official Statistics of Finland 2019) (Supplementary material 6). The most frequent contributing factors to death, other than alcohol, were hypothermia ($n=20$), preexisting medical conditions ($n=18$), multiple rib fractures ($n=7$), acute use of psychotropic drugs ($n=9$), and intra-cranial brain injuries ($n=5$). Some victims

Table 1. Finland 1996–2013. Land motor-vehicle accidents (LMVA)-related drowning ($n = 207$): contributing factors to death by main group of vehicle involved.

	Snowmobile ($n = 89$)		Passenger car ($n = 87$)		Industrial vehicle ($n = 24$)		Motorbike ($n = 7$)		All vehicles ($n = 207$)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Alcohol	45	50.6	37	42.5	6	25.0	2	28.6	90	43.5
Hypothermia	15	16.9	4	4.6	1	4.2	0	–	20	9.7
Injuries	0	–	11	12.6	1	4.2	2	28.6	14	6.8
Chronic disease	7	7.9	8	9.2	2	8.4	1	14.3	18	8.7
Other drugs	1	1.1	7	8.0	0	–	1	14.3	9	4.3

exhibited two or more contributing factors. Table 1 summarizes the main factors contributing to death, by type of motor vehicle.

Out-of-hospital vs. in-hospital deaths

In the great majority of cases ($n = 506$; 94.1%), death occurred at the site of the crash or before the victim's arrival at hospital, whereas 32 (5.9%) were in-hospital deaths. At the beginning of the study period (1971–1987), the percentage of in-hospital deaths was 3.3%, but this percentage rose to 10.1% during the period 1996–2013. The percentage of in-hospital deaths was as low as 3.5% in snowmobile crashes.

Discussion

During the 43-year study period, 538 LMVA-related drownings occurred in Finland, giving a mortality rate of 2.5/1 000 000/year. The proportion of LMVA-related drownings among all unintentional drownings was 4.9%, a value that falls into the range (3%-15%) reported in most studies (McDonald and Giesbrecht 2013a). Conversely, the proportion of LMVA resulting in drowning among all LMVA (3.8%) was higher than that reported in other studies (< 2.5–3.0%) (McDonald and Giesbrecht 2013a).

The Finnish LMVA-related drowning mortality rate is higher than are the rates for HIC countries where mortality rates can be inferred. In one US study covering the entire US except for two states, 2004 through 2007, the annual average was 384 LMVA-related drownings (Austin 2011). Based on the 2004 US population (ca. 293 000 000), this means a mortality rate of about 1.3/1 000 000/year. In Sweden, from 1992 to 2006, LMVA-related drowning accounted for 74 unintentional deaths (Stjernbrandt et al. 2008), which corresponds to a mortality rate of about 0.6/1 000 000/year. The Swedish study excluded drowning associated with snowmobiles, but mortality rates in Finland remain higher than in Sweden even after exclusion of snowmobile crashes. In the Netherlands, 1999–2003, the average fatalities per year involving a car ending in a body of water were 57 (IRSR 2012). Considering that approximately half the fatalities were due to injuries other than drowning, the mortality rate in the Netherlands remains well under 2/1 000 000/year.

In performing cross-country comparisons, what may be hypothesized is that differing LMVA-related drowning mortality rates depend on the extent of inland waterways and coastline and length of roadway in proximity to sea, river, lakes, and canals. Detailed comparisons are, however, hampered by factors such as coverage of databases and by inclusion criteria. For instance, studies may include or exclude accidents that occur off-road or as a result of a cataclysm (Austin 2011), snowmobile accidents, which have a specific profile (Öström and Eriksson 2002; Stjernbrandt et al. 2008), deaths of residents occurring abroad, deaths of nonresidents, and suicides.

Contrary to other LMVA, most LMVA-related drownings occur in Finland during the cold season. The Finnish monthly profile is in part shaped by snowmobile accidents that typically occur in late autumn, winter, and early spring, on ice-covered bodies of water, especially when the ice coat is forming or is melting. However, even excluding snowmobile crashes, LMVA-related drownings occur in Finland mostly during the coldest season. Considering this fact, one must remember the effects of cold water during victims' immersion; on the one hand, cold-water immersion plays a role in the pathophysiological events leading to drowning, but on the other, the protective effects of hypothermia may allow, in exceptional cases, successful resuscitation after prolonged immersion (Bierens et al. 2016).

In Sweden, LMVA-related drowning (excluding snowmobiles) are rather evenly distributed across the months (Stjernbrandt et al. 2008), whereas in other studies the highest incidence is in summer (McDonald and Giesbrecht 2013a).

In Finland, age- and sex distribution differs from that of other LMVAs. The peak among young adults is similar, but LMVA-related drownings show a second peak in the middle-aged. The M:F RR in LMVA-related drowning is also much higher than in other LMVAs . These demographic differences may reflect, at least in part, the higher use among middle-aged males of snowmobiles and industrial/agricultural vehicles, making men over-represented in LMVA-related drownings.

Alcohol was a factor contributing to LMVA-related drowning in over 40% of cases, a percentage lower than in other unintentional drownings (55.8%), but higher than among other LMVAs (20.4%). Noticeably, in addition to the driver, a significant proportion of passengers also tested positive for alcohol. Alcohol (and psychotropic drug) use by the driver represents a risk factor for the crash itself by causing loss of control of the vehicle; however, once the vehicle has ended in the water, alcohol (and psychotropic drugs) becomes a risk factor for both the driver and passenger(s) by hampering safety action, escape procedures, and swimming ability (Pajunen et al. 2017).

Preexisting medical conditions (e.g., chronic heart diseases), may play a similar role in the chain of events leading to the crash itself but also once the vehicle is submerged. Assessment of such conditions' role is, however, challenging. Even if a medico-legal autopsy is performed, determining whether a chronic disease has played any actual role in causing the crash, in hampering escaping procedures, or in exacerbating clinical consequences of injury or liquid inhalation may be impossible.

Injuries sustained by the occupants before the vehicle becomes submerged may be fatal or be crucial, because they may hamper egress from the vehicle, swimming, and capacity to reach safety. However, only 6–7% of such victims had injuries sufficiently severe to be considered a contributing factor to drowning. A low proportion of injuries has been reported also in other studies (Wintemute et al. 1990; Stjernbrandt et al. 2008; McDonald and Giesbrecht 2013a). This reveals that, in most cases, the victims would have survived the crash if not succumbing to drowning.

Overall in-hospital mortality for LMVA-related drowning is low, less than 6%, with most victims found dead at the scene or dying before admission to a hospital. This is consistent with other studies (Wintemute et al. 1990; Stjernbrandt et al. 2008). Interestingly, in Finland, during the last years of the study period, the percentage of in-hospital deaths increased, suggesting possible improvement in rescue operations at crash sites.

In Finland, LMVA-related drownings – as in Sweden and the Netherlands (Stjernbrandt et al. 2008; IRSR 2012) – have decreased during recent decades. The downward trend observed since the 1970s in overall LMVA is the results of factors ranging from improved road infrastructure, traffic safety, and public education to technical improvement of vehicles and of safety equipment, supervision of speed limits, and use of seat belts, plus more-severe legal blood-alcohol limits. Speed limits specific for the winter season and adapted to weather conditions have likely contributed to this positive trend (Ahlroth and Pöllänen 2011). Interestingly, the gradual and irregular downward trend in LMVA-related drowning was similar to that observed in other LMVA, with a temporary increase in mortality during the 1980s (Ahlroth and Pöllänen 2011). This supports the close connection between traffic safety and risk factors for LMVAs resulting in drowning and those for other LMVAs.

The inclusion in this study of all land-transportation accidents, regardless of type of motor-vehicle involved, highlights the different scenarios of LMVA-related drowning and thus the multifaceted prevention measures that these accidents require. Occupants of open vehicles, such as snowmobiles moving on ice-coated bodies of water, are generally ejected into water, challenging their ability to float and to swim to reach safety or to await rescue. This occurs, also, when occupant(s) of an enclosed submerged vehicle succeeds in escaping the vehicle compartment. In other cases, drowning occurs when occupants of an enclosed vehicle are unable to escape the compartment before water fills it. At times, the victims can be caught under or between parts of vehicles. Prevention of LMVA drowning requires therefore not only improvement of traffic safety but also countermeasures to prevent drowning, once the vehicle becomes immersed. In this context, escape procedures from a submerged vehicle and development of in-water vehicle safety equipment (e.g., automatic window-opening system) are crucial (Gagnon et al. 2012; McDonald and Giesbrecht 2013a, 2013b).

The current study, based on official mortality statistics, addressed a series of circumstances and risk factors leading or contributing to LMVA-related drownings. However, other potential risk factors were not appraised. For instance, while the utility of seatbelt or airbag are well established in land-traffic accidents, in the case of a submerged vehicle, it is debatable how often wearing of a seatbelt or an airbag deflation can prevent or critically delay a victim' escape. Moreover, our data-set prevented analysis of crashes involving vehicle submersion resulting in injury deaths for causes other than drowning.

Despite the relatively high rates of LMVA-related drowning and the implementation of several initiatives to prevent – separately – drowning and traffic crashes, surveillance and prevention of LMVA-related drownings have thus far received limited attention in Finland and in other HICs.

An important barrier to surveillance of LMVA-related drowning relates to WHO ICD coding. First, ICD does not provide LMVA subcategories that allow identification of LMVA resulting in vehicle submersion. Second, a drowning resulting from LMVA will be tabulated by a general ICD E-code for LMVA, without registering of the injury, e.g., drowning, leading to death. As a result, LMVA-related drownings are disregarded in WHO land-traffic- and drowning-mortality statistics (Lunetta et al. 2002).

The WHO recommends that any injury death should be coded by both E-codes and I-codes to identify the circumstances (e.g., motor land-traffic accident) and the injury (e.g., drowning) leading to death (Lunetta et al. 2002). Such a recommendation, however, is not enforced in most countries. In Finland, SF tabulation of injury deaths by means of the E- and I-code axis makes data on LMVA-related drownings available. Another source of Finnish drowning data, based on a newspaper clipping service, however, excludes LMVA-related drownings (Lunetta et al. 2006).

The recently released ICD-11 revision (ICD-11) (WHO 2018) provides significant improvement regarding this issue. The "post-coordination system" allows addition of more details to the main codes by use of extension codes. For "unintentional drowning or submersion, following fall into a body of water" (E-code: PA01), extension codes include the "object or substance producing injury" (e.g., "XE712 Land vehicle or means of land transport") and "place of occurrence" (e.g., "XE5NE Public highway, street or road"). However, as ICD-11 will come into effect in 2022, and no deadline is set for its implementation at the national level, assessing the benefits of this new coding system for identifying LMVA-related drowning will require years.

Changes over the years in ICD E-codes describing the subcategories of LMVA represent another issue when dealing with long-time series. These changes hampered the possibility of having consistent data throughout the study period on types of vehicles involved, sites of crashes, and position of the victim in the vehicle. The ICD-8 and ICD-9 did not allow a distinct, clear identification of the vehicles involved. The introduction of ICD-10 in 1996 has provided a significant improvement. ICD 10 E-codes discriminate four categories of vehicles: passenger car, vehicle designed for off-road use (e.g., snowmobile), vehicle used in agriculture-industrial-construction settings, and motorbikes. Moreover, the ICD-10 emphasizes the victims' "counterpart" (e.g., collision with another vehicle or a fixed object) and, again, the "type of event" (traffic, non-traffic) and the victim's position in the vehicle (driver, passenger) (WHO 2011).

In conclusion, LMVA-related drowning represents an overlooked cause of premature death. Development of traffic-safety measures concerning roadways, vehicles, and driving- and passenger behavior is crucial to reduce the risk of LMVA ending in a vehicle submersion. However, once the vehicle is submerged or the occupants are ejected into water, drowning remains an important target for preventive actions. In low- and middle-income countries (LMIC), data on LMVA-related drownings are lacking. High drowning- and LMVA mortality, poor conditions of the roadways in many regions, and recurring news reports on transportation-related drownings, suggest that LMVA-related drownings in LMIC should also receive more attention. As in HIC, the percentage of LMVA-related drowning is approximately 5–10% of all drownings, and overall drownings claim globally more than 300 000 victims each year, what can thus be expected is that, worldwide, thousands of fatal LMVA-related drownings occur every year.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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