Firearm deaths in Sweden
Epidemiology with emphasis on accidental deaths and prevention

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Section of Forensic Medicine
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i am of the earth
and to the earth i shall return once more
life and death are old friends
and i am the conversation between them
i am their late-night chatter
their laughter and tears
what is there to be afraid of
if i am the gift they give to each other
this place never belonged to me anyway
i have always been theirs

Rupi Kaur
The Sun and Her Flowers 2017
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Abstract

Prevention of firearm deaths and injuries is an important public health issue that may save human lives. The aim of this thesis was to investigate the epidemiology and attributes of accidental firearm fatalities in Sweden, and to provide a basis for further preventive measures. Data were obtained from the database of the National Board of Forensic Medicine, the National Patient Register, the Prescribed Drug Register, the Firearm Register, and from questionnaire responses.

All 48 accidental firearm fatalities that involved hunting in 1983-2008 were investigated (Paper I). The victims’ mean age was 50 years, 96% were males. During moose hunting, most victims were mistaken for game (41%), whereas during small game hunting, fatalities were mostly related to falls (31%) and improper weapon handling (15%). Hunters’ habits and attitudes towards preventive measures and their experience of firearm incidents were investigated through a questionnaire, which was sent to 1,000 hunters (Paper II). The response rate was approximately 50%. The mean age of the respondents was 54 years and females accounted for 5%. One quarter of the respondents stated that they had witnessed a firearm incident caused by another hunter, of which more than half suggested that improper handling of the weapon and inappropriate hunting strategies were the main causes of these events.

All 43 accidental non-hunting firearm deaths in Sweden 1983-2012 were investigated (Paper III). In 56% of cases, the fatality was caused by another person. Victims were mostly young males (mean age 25 years). The main cause of the incidents was human error. The majority of cases (63%) involved legal firearm. Most victims killed by illegal firearm (85%) were under the influence of alcohol and/or drugs at the time of death. Both the risk of being killed as a result of hunting (Paper I) and non-hunting accidental firearm injury (Paper III) decreased after the introduction of the mandatory hunter’s exam in 1985 (p < 0.001).

Firearm deaths in Sweden including 52 accidental fatalities and 3 cases with undetermined manner of death in 1987-2013, as well as 213 suicides and 23 solved homicides in 2012-2013, were studied (Paper IV). The number of firearm suicides was positively correlated to the number of licensed firearm owners. Legal firearm use predominated in firearm suicides and accidental deaths, illegal in firearm homicides. The majority of the shooters in accidental deaths and suicides had no registered visits to inpatient care or specialized outpatient care. Less than half (42%) of all suicide victims had had a health care contact due to mental health problems. Physician’s mandatory reporting to the
police of patients deemed unsuitable for possessing a firearm license did not include any of the suicide victims and the shooters in accidental deaths.

This thesis confirmed that accidental firearm deaths are rare, and indicates that the firearm law changes in 1985 contributed to a decline of such fatalities. Human error was the main “cause” of the fatalities and future prevention measures should target improper weapon handling. Physician’s mandatory reporting to the police was suboptimal and barely contributed to the decline of accidental firearm deaths. If streamlined it may, however, represent an important prevention strategy in firearm suicides, claiming most lives among firearm deaths. A significant fraction of non-hunting fatalities, firearm suicides and homicides was associated with illegal firearm use, a fact calling for prevention issues targeting such firearm use.
Aims

The aim of this thesis was to study firearms deaths in Sweden, in particular accidental fatalities, and suggest preventive measures.

The more specific aims were to investigate:

- epidemiology and possible temporal trends (Papers I and III).
- fatal events regarding victims, causes and circumstances (Papers I and III).
- safety and risk behaviour in both fatal and non-fatal firearm events (Paper II).
- legality of firearms involved in accidental deaths, suicides, homicides and cases of undetermined manner of death (Paper IV).
- relevant health problems of the shooter reported by the doctor to the police (Paper IV).
Papers

This thesis includes four papers:


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## Abbreviations, acronyms and definitions

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>ATC</td>
<td>Anatomical Therapeutic Chemical</td>
</tr>
<tr>
<td>BAC</td>
<td>Blood Alcohol Concentration</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>ICD</td>
<td>International Classification of Diseases</td>
</tr>
<tr>
<td>MOD</td>
<td>Manner of Death</td>
</tr>
<tr>
<td>NBHW</td>
<td>National Board of Health and Welfare (In Swedish: <em>Socialstyrelsen</em>)</td>
</tr>
<tr>
<td>SAHWM</td>
<td>Swedish Association for Hunting and Wildlife Management (In Swedish: <em>Svenska Jägareförbundet</em>)</td>
</tr>
<tr>
<td>SFS</td>
<td>Svensk författningssamling (In English: <em>Swedish code of statutes</em>)</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
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<td>WHO</td>
<td>World Health Organization</td>
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### Terminology

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Accident</td>
<td>An accident is an unforeseeable and unexpected turn of events that may cause loss in value, injury, or increased liabilities; the event is not deliberately caused</td>
</tr>
<tr>
<td>Big game</td>
<td>In this thesis big game includes larger animals such as moose, bear, and wild boar</td>
</tr>
<tr>
<td>Extended suicide</td>
<td>Homicide followed by the perpetrator’s suicide; also called dyadic death or homicide-suicide</td>
</tr>
<tr>
<td>Firearm accident</td>
<td>An accident in which a weapon was unintentionally discharged or was intentionally discharged at an unintended target</td>
</tr>
<tr>
<td>Homicide</td>
<td>An intentional act of causing another’s death</td>
</tr>
<tr>
<td>Hunting</td>
<td>In this thesis hunting included hunting activity with firearm, or transport in direct connection with a hunting activity</td>
</tr>
<tr>
<td>Intentional injury and death</td>
<td>Injury and death attributed by intent to harm (suicide and homicide)</td>
</tr>
<tr>
<td>Illegal firearm use</td>
<td>Use of non-licenced firearm or illegal use of licenced firearm (regardless of MOD classification)</td>
</tr>
<tr>
<td>Illegal firearm</td>
<td>Stolen firearm, or firearm manufactured out of the legal (controlled) production</td>
</tr>
<tr>
<td>Terminology</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>Illicit drugs</td>
<td>Drugs under international control, which may or may not have licit medical purposes - produced, trafficked and/or consumed illicitly</td>
</tr>
<tr>
<td>Legal intervention shooting</td>
<td>Shooting by police officer in the line of duty</td>
</tr>
<tr>
<td>Manner of death</td>
<td>Explains how the cause of death came about, as natural death (e.g. disease) or unnatural death (e.g. accidental, suicidal or homicidal)</td>
</tr>
<tr>
<td>Non-hunting</td>
<td>Not related to hunting (e.g. target shooting, military service, at home etc.)</td>
</tr>
<tr>
<td>Small game</td>
<td>In this thesis a small game includes smaller animals, e.g. roe deer, fox, grouse, and duck</td>
</tr>
<tr>
<td>Suicide</td>
<td>Act of intentionally causing one’s own death</td>
</tr>
<tr>
<td>Unnatural death</td>
<td>Death resulting from an external cause, such as injury or poisoning</td>
</tr>
</tbody>
</table>
Enkel sammanfattning på svenska


Jägarnas jaktvanor, attityd kring säkerhet under jakten och erfarenhet av skjutvapenrelaterade incidenter undersöktes i den andra delstuden. En enkät skickades till 1,000 jägare och svarsfrekvensen var kring 50%. Medelåldern för dem som svarade var 54 år, och 5% var kvinnor. Omkring 1/4 del hade bevittnat en incident med skjutvapen som orsakats av en annan jägare. Jägarna föreslog ”den mänskliga faktorn” som orsak till dessa incidenter. Rapporterade
incidenter ledde sällan till att en människa blev skadad eller dödad. Endast få jägare uppgav flera riskfaktorer eller flera riskbeteenden.


BACKGROUND

Injury and prevention

Unnatural death and firearm injury
Injury is a common cause of unnatural deaths. Injury can be defined as “physical damage that results when the human body is suddenly or briefly subjected to intolerable levels of energy”, e.g. mechanical, thermal, or chemical trauma [1]. Globally, 5 million people die due to injury each year [2]. The economic burden to the society, of unintentional injuries in particular, is huge [3]. Besides the immeasurable cost of human lives, there are direct costs for treatment and rehabilitation for physical and mental health issues in survivors [4], and indirect costs for productivity loss and police/judicial services as well. In South Africa, the costs per patient (inpatient care for firearm injury) ranged USD 196-19,600 [5]. The annual health care costs in 53 member states of the WHO European Region amounted to 1-6 x 10⁹ EUR for health care of patients who would subsequently die from the injury, and 80-290 x 10⁹ EUR for patients treated for non-fatal injuries [4]. This report did not distinguish firearm injury from other types of injuries and estimations of the total costs of fatal and/or non-fatal firearm injuries in Europe has yet not been charted.

In addition, all reports of economic burden may be underestimated due to costs affecting the victims’ relatives, workplace, school, etc. Prevention efforts may thus bring individual, societal and economic benefits.

Hence, the tragic and unexpected nature of unnatural deaths brings a negative effect on the individual, relatives and the whole society. Around 5,000 such deaths occur annually in Sweden [6]. The manner of death in these cases can be classified as unintentional (accidental) and intentional (suicidal or homicidal), concluded by the forensic pathologist after the death investigation.

Accidental injury fatalities comprised 67% of all injury fatalities in Sweden in 2016 (Figure 1) [6]. Although accidental firearm fatalities comprise only a small proportion of all firearm deaths in Sweden (Figure 1) [6-8], firearms are effective in causing severe injury and death, regardless of the intention. Firearm injury has a much higher lethality compared to many other means among suicides and patients admitted to hospital after a suicide attempt [9], e.g. 2.6 times higher than suffocation and 8 times higher than jump from a high place and a crash into a moving object [10]. Thus, firearm injury is a challenging issue in prevention efforts to save lives.
In addition, economic benefits of firearm injury prevention have not yet been mapped in Sweden. However, the direct costs for health care of 57 patients with firearm injury admitted in an 18 month period at the University Hospital in Gothenburg, Sweden, was estimated to be 6 x 10^6 SEK [11].

![Figure 1. Distribution by manner of death of injury fatalities in 2016 [6] and of firearm deaths in 2014 [6-8] in Sweden.](image)

**Injury prevention**

Along with experience and deeper knowledge about factors behind accidents, injury prevention became a separate discipline first in the 20th century. Previously, accidents were commonly interpreted as unpreventable or random situations of “bad luck”. Several scientists, engineers, public health workers and psychologists have contributed to the current knowledge about injuries and their prevention.

Hugh DeHaven’s scientific connection between the force properties and injury [12] influenced future safety innovations affecting the force, such as safety belts and airbags. Epidemiological trichotomy of the *agent*, the *host* and the *environment* as etiological factors of the injury was suggested by John E. Gordon [13].
In 1972, William Haddon Jr modified some of the previous theories and developed the Haddon Matrix as a theoretical concept of the epidemiological trichotomy in the time-line of motor vehicle three injury phases: pre-event, event and post-event [14] (Figure 2). This matrix became a precursor of modern concepts and has also been applied in accidental injury prevention, e.g. in drownings and occupational injuries.

Furthermore, Haddon suggested 10 prevention strategies for different injury phases [15] (Figure 2). The conceptual model of primary, secondary and tertiary prevention comprise the injury control and may be applied on the time-line of Haddons’s strategies as those related to the pre-event (primary prevention), event (secondary prevention) and post-event (tertiary prevention) (Figure 2). Although Haddon’s matrix and strategies are useful epidemiological tools helping to understand and identify risk factors, they have not yet been applied on the issue of accidental firearm deaths.

In unintentional injuries, such as those caused by traffic accidents, human error has been identified as the main causal factor. There is no clear definition of human error, but it usually refers to the failure to perform a planned action to achieve a specific and desired outcome. In contrast to the individual approach, the system approach of the human error theory, often used in the patient safety domain, explains other factors behind the error, besides active actions of the human [16] (Figure 2). Human error was explained to represent a symptom of the failure of the system, rather than the factual causal factor in injury analysis. The major characteristics of this concept are defences or barriers in between hazards and losses. If all protective layers become porous (e.g. lack of technical protection and lack of procedures), an unsafe act (active failure) may lead to the loss. Some of the protective layers may be damaged by latent conditions in the system (e.g. inadequate equipment, lack of experience) [16]. The existence of the perfect system including humans, having all barriers constantly intact, is doubtful. According to this model, it is sufficient if one layer is fully protective to avoid the loss. However, errors may bring learning opportunities thus leading to improvement of the factors relevant to the specific situation.

In spite of the broadly accepted system approach, developing injury prevention measures that may affect individual factors of safety behaviour has been necessary, but challenging. In the early 1960’s, Haddon distinguished between active and passive preventive strategies. While passive strategies regarded to factors not requiring individual safety acts, e.g. technology (airbags) or public health measures (immunisation), active prevention strategies involved individuals using safety devices and performing safety actions (use of helmets) [14]. Additionally, three general prevention strategies aiming at human behaviour and environmental design were suggested, each step being more
effective than the previous one [17] (Figure 2). The last step of environmental or product design that protects the individual, as in Haddon’s concept of passive prevention, is the strongest protection layer for high-risk individuals resistant to behavioural changes, even if it is required as mandatory.

Human behaviour and its dynamics that may affect the injury process has been an important issue in the scope of behavioural sciences [18]. However, the topic is still not developed towards incorporation in the injury epidemiology [19]. This may be partly explained by modern trends of system approach, as described above.

While above mentioned theoretical concepts may help in understanding injury etiology, the public health model contributes with its evidence-based approach to disease/injury control. According to the model, the condition (injury) is firstly monitored by identifying the problem of, e.g. mortality, morbidity and/or costs, and then risk factors are identified (individual, social or environmental). In the next step, intervention is developed and introduced, and finally evaluated [20].
Figure 2. Theory models of injury etiology and prevention

### INJURY ETIOLOGY AND PREVENTION

#### Haddon’s trichotomy in time-line of injury process [14]

**PRE-EVENT**
- Vector (agent)
- Host (human)
- Physical and social environment

**EVENT**
- Vector (agent)
- Host (human)
- Physical and social environment

**POST-EVENT**
- Vector (agent)
- Host (human)
- Physical and social environment

#### Haddon’s 10 prevention strategies [15]
1. Prevent creation of the agent.
2. Prevent amount of energy released from the agent.
3. Prevent energy release from the agent.
4. Provide protection for the host through energy release modification.
5. Separation of the agent and the host in time and space.
6. Separation between the agent and the host through material barriers.
7. Modification of interaction surface between the agent and the host.
8. Increase resilience of the host.
9. Provide a rapid treatment of the host.
10. Provide further treatment and rehabilitation of the host.

#### Reason’s model of accident causation [16]

**Barriers**

**Hazard**

**Latent conditions**

**Loss**

**Active failure**

#### General prevention strategies [17]
1. Persuade individuals at risk of injury to alter their behaviour for better protection.
2. Require change of behaviour by law or administrative rules.
3. Provide protection through product and environmental design.
Firearms and owners

Firearms

Firearms have been a part of human history and culture since the ~1200’s [21]. Over the past eight centuries firearms have been improved and developed to become increasingly effective and user-friendly [22]. Economic and social benefits of firearms’ use to the society have been investigated, such as in hunting [23, 24], and target shooting [25]. Furthermore, firearm culture may be deeply established, as in the USA where the ownership of a firearm is a civil right according to the Second Amendment of the United States Constitution [26].

The definition of firearms varies, but the United Nations (UN) considered portability as a defining characteristic [27]:

“Firearm shall mean any portable barrelled weapon that expels, is designed to expel or may be readily converted to expel a shot, bullet or projectile by the action of an explosive”.

The definition in the Swedish firearm law includes also devices that are charged by carbon dioxide or compressed air, and devices that may be non-portable (heavier firearms) [28]. Exempt from the definition are items produced before the year 1890. Ammunition is defined as projectile and cartridge for small arms [28].

In this thesis, only small firearms were studied. A small firearm is a portable barrelled weapon that can launch projectiles by the action of an explosive force. Small arms may be divided into handguns (pistols and revolvers), rifles, shotguns, submachine guns, and machine guns [29]. Some firearms are automatic (military) and are not - according to the European Union Firearm Directive [30] - supposed to be owned by a private person. Semiautomatic firearms are preferred by some hunters due to a weaker recoil and faster firing of the next shot.

Development of firearms’ shape, mechanism and construction have successively enhanced the kinetic energy (KE) of the projectile. The higher kinetic energy, the higher the ability of the projectile to cause damage. KE = 1/2 mv^2 where m = mass and v = velocity. The degree and type of damage to tissues depends on the mode of energy release during the interaction of the projectile with the tissue, and the tissue type.

Ballistics is the science of mechanics about the launching, flight, behaviour and effects of the projectile. In a medicolegal autopsy, examination of the ballistic
effects is a part of the investigation. One of the major tasks of the pathologist is to determine the manner of death, i.e. to differ between natural and unnatural death, and between unintentional and intentional injury. This is a challenging task and one part of the puzzle is to find out if the injury pattern correlates to an assumed or evident shooting distance. Although every firearm and projectile combination is associated with a typical pattern of injury [31], projectiles with the same KE but with different construction may show considerable differences in injury pattern [32].

In addition, the firearm and ammunition used in hunting must be adapted to the specific game. These requirements are described in detail in the Hunting Act [33], the Hunting Regulation [34], and the Swedish Environmental Protection Agency Regulations [35].

Illegal firearms
The European Union has a serious illicit firearm trafficking problem [36]. Ever since the war in former Yugoslavia in the 1990’s, illicit firearm transfer to Sweden has included mostly Western Balkan countries, but also EU member countries, such as Germany, Slovakia, the Czech Republic and Bulgaria [37]. Although the path of illegal firearms has been mapped, the quantity of illegal firearm imports has been much more difficult to estimate, although reports on confiscation, weapon amnesty and thefts may give a rough idea. Comprehensive reports concerning illegal firearms in Sweden are, however, lacking.

Swedish Customs confiscate very small volumes of illegal firearms (55 firearms in 2013 and 61 in 2017) [37, 38], while a total of ~900 illegal firearms (see Definitions) are confiscated annually by the police [37]. Handguns accounted for approximately half the amount of all confiscated weapons. Three previous firearm amnesties (in 1993, 2007 and 2013) collected ~46,000 firearms in total, mostly hunting arms and handguns [39]. In 2018 there has been an national gun amnesty as well [39].

The picture of firearm thefts in Europe is not clear, but thefts from licensed owners seem to be rare in Sweden. An annual average of 269 firearms were stolen from licensed owners in the period from 2003 to 2010 [40]. Most (~80%) of reported stolen and lost firearms were hunting weapons [41].

Only a few studies have investigated the use of illegal firearms concerning firearm injuries and deaths. In Denmark, illegal firearm use was found in 21% of all firearm fatalities in 1970-1979 [42]. Compared to the period 1980-1981, an increase of illegal firearm use in homicides was observed in 1990-1991 in three eastern Swedish counties [43]. Also the Swedish National Council for Crime Prevention has reported that the use of illegal handguns in criminal
conflicts in Swedish metropolitan areas has increased recently, as well as the relative involvement of illegal handguns in firearm homicides [8].

**Licensed firearm owners**

Understanding firearm availability through the ownership and weapons’ flow between countries is highly relevant for the epidemiological approach in studying firearm injuries and fatalities. Owners and firearms may be licensed or unlicensed and the firearm use may be legal or illegal (see Definitions). Most (~75%) of the world’s firearms are privately owned independently of legality, while armed forces account for ~22% of ownership and law enforcement for ~3% [44].

The household ownership rates in 25 European survey participants 2004-2005 were unevenly distributed. The highest rates were reported from Finland, Switzerland, Norway and Iceland, followed by Greece, Sweden and Portugal, while the lowest rates were reported from the Netherlands, the United Kingdom and Poland [45]. The survey questions about ownership did not differentiate between legal and illegal ownership and the reported rates should be interpreted with caution. There is also a lack of European studies comparing numbers of private licensed owners in between countries.

According to the Swedish Police, as the most reliable source in Sweden, ~600,000 civilians possess altogether a total of ~2 million firearms, of which ~88% are licensed for hunting purposes [41]. The number of firearm owners [46] had in 2015 increased by ~17,000 compared to 2012.

In contrast to the USA, self-protection is not a legal motive for civilian firearm ownership in Sweden. Private ownership is instead associated mostly with hunting and sports, and in a smaller range to collecting.

Each hunting season, around ~290,000 Swedish hunters are active (2012-2017), of which ~28,000 are hunters from other countries [47]. The oldest and the largest national hunting organisation is the Swedish Association for Hunting and Wildlife Management/SAHW (”Svenska Jägareförbundet”), which had 156,357 members ≥18 years and 6% female members in early 2009 [48]. This organisation was established in 1830 and since 1938, it is also assigned for the national wildlife management. The second largest hunting organisation, “Jägarnas riksförbund”, was established in 1938 and had approx. 38,000 members in 2015 [49]. These hunting associations organise the hunter’s exam and other types of training.

The share of hunters in the general population in European countries was, in 1995, highest in Scandinavia [50]. Common methods for collecting the statistics on the number of hunters in Europe are lacking, and research on hunters’ socio-
economic status related to knowledge about hunting practices and game management is deficient [50]. According to the questionnaire based thesis about hunters in Scania (“Skåne”), Sweden, in the late 1970’s, hunters showed variations in hunting activity and motive to hunt, related to age, socioeconomic status, education, and urban/rural setting [51]. There were no follow up studies either locally in Scania or nationally regarding this issue. The questionnaire in the present thesis, as the first of its kind in Sweden, included hunting habits as well, but focused on hunters’ safety behaviour rather than on socioeconomic factors.

Although the number of active hunters was somewhat higher (~300,000) in 1986/1987 compared to the latest statistics in 2016/2017 (~284,000), an average hunter seems to hunt longer each season in the 2000’s than in the 1980’s [47, 52]. Statistics about hunters who are not members of any hunter’s organisation or are members of several hunting and other sports organisations are lacking. Furthermore, not all hunters who pay the seasonal hunting fee (required for each hunting season) are active during the season. An older investigation showed that in the late 1960’s, 6% of hunters who paid a seasonal fee did not participate in hunting at all [53]. In addition, 91% of respondents/hunters in Scania, Sweden, reported they did not care if they would harvest an animal during a hunt, supporting the recreational motives of hunting presented in the same study [51]. The number of active hunters, the number of hunting days per season and the annual number of game taken represent only approximations of the total hunting activity, as the individual level activity may vary from season to season. The true hunting activity level is obviously very difficult to estimate.

Besides hunting organisations, there are several sports shooting associations, and firearms are owned also by smaller groups of licensed weapon collectors, museums and weapon dealers. Official statistics about the number of weapons owned by collectors or museums as owners have not been found.

Epidemiology of firearm deaths

General
The incidence of firearm fatalities and injuries and their share of all injuries varies between countries, related to judicial, cultural, and socioeconomic factors. The firearm death rates are, e.g. considerably higher in South Africa [54] and the USA than in European high-income countries [55]. International differences have, however, rarely been studied [56, 57]. In the USA and 17 high-income countries in Europe, firearm suicides outnumber firearm homicides [55], while in some Latin America countries [56] and in South Africa [54], the situation is the opposite. In 2010, Sweden’s total firearm death rate was higher
than in Spain and Germany, but lower than in Austria and Finland (Figure 3) [55].

Accidental deaths account for only a small proportion of all firearm fatalities globally [55, 56]; there are also discrepancies between countries. The true numbers of unintentional firearm injuries and fatality rates may be underestimated due to insufficient reporting [58].

**Figure 3.** Firearm deaths per 100,000 population in high-income countries, 2010 [55].

According to the WHO’s model of the injury pyramid, the number of fatalities at the top of the pyramid is smaller than the number of patients in inpatient care, which in turn is smaller than the number of those treated in outpatient care. Finally, the largest number of injuries are most likely not reported or treated at all, forming the basis of the injury pyramid [59]. Nevertheless, European national studies on unintentional *non-lethal* firearm injuries are scarce. In Finland, almost half (44%) of all patients hospitalised with firearm injuries were unintentional, while the incidence of hospitalisations for intentional firearm injuries remained unchanged in the period 1990-2003 [60].

In Sweden, the number of inpatient care patients treated for a firearm injury due to a firearm assault, increased by 48% from 2006 to 2014 [61]. Furthermore, the victims of a *non-lethal* firearm injury had an increased morbidity and trauma recurrence rate, since suicide, homicide and assaults were more common in this
group than among controls [62, 63]. The comprehensive picture of all firearm injuries is still unclear due to the lack of national reports on all firearm injuries (intentional and unintentional, major and minor), treated in both inpatient and outpatient care. It is also doubtful if the injury pyramid basis comprises the unreported/untreated firearm injuries, since the firearm’s high energy impact causes significant tissue damage with a high risk of fatal outcome.

**Unintentional firearm deaths**

The reported incidence of unintentional firearm deaths in Sweden was relatively low, similar to Denmark and Finland, but lower than in Bulgaria, Albania and the USA (Table 1) [64]. According to a previous Swedish study (1970-1982), more than half (59%) of the accidental firearm deaths were related to hunting [65]. In Finland, accidental firearm deaths remained at the same level in the period 1990-1999 [66], while in Norway such deaths among males dropped in the period 1969-2009 [67].

**Table 1.** Unintentional firearm death rate per 100,000 population in the USA and five European countries [64].

<table>
<thead>
<tr>
<th>Country</th>
<th>Unintentional firearm deaths per 100,000 population</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>0.2</td>
<td>2008</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.2</td>
<td>2014</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.04</td>
<td>2008</td>
</tr>
<tr>
<td>Finland</td>
<td>0.02</td>
<td>2014</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.02</td>
<td>2014</td>
</tr>
<tr>
<td>USA</td>
<td>0.2</td>
<td>2014</td>
</tr>
</tbody>
</table>

An unintentional firearm death may be the result of a self-inflicted injury or of a two-party incident. The share of self-inflicted fatal injuries was 41% in a previous Swedish investigation of unintentional non-hunting firearm deaths [65], but was 9% of all unintentional firearm deaths in Germany [68], and 50% in Denmark [42]. Interestingly, studies have overlooked the importance of shooters in two-party incidents, which was not in the scope of previous studies until recently [69]. This may be explained by, e.g. ethical and/or methodological issues.

Furthermore, only a few studies have differentiated between accidental hunting and non-hunting firearm deaths, in spite of obvious differences in circumstances between these two subgroups. The characteristics and the rates of hunting-related firearm injuries vary by hunted game (e.g. moose vs. small game) [70, 71]. Heterogeneous circumstances permeate the group of non-hunting firearm fatalities as well [65]. Variation in the size of the study population, incidence,
geographical regions, time periods, game species hunted, and demographics in between the few studies on this topic aggravate a proper comparison.

The incidence of hunting firearm fatalities varies between 0.2 and 1.6 per million population annually [42, 58, 71-74]. In rural settings, hunting firearm fatalities comprise 19-59% of all accidental firearm deaths [42, 68, 71, 75] as compared to 0-7% in urban settings [73, 76-78].

In the period 1970-1982, there were on average 2.5 non-hunting firearm fatalities and 3.6 hunting firearm fatalities annually in Sweden [65], but the later development remains unknown. The share of firearm injuries was 12-33% of all hunting injuries treated in health care in the USA [79, 80], compared to merely 2% in Sweden [81].

In addition, apart from the knowledge gap about the shooters in two-party fatalities, little is known about the owners of firearms involved in unintentional fatalities. In a study from Tennessee, USA, only 19 of 103 firearms belonged to the victim in such deaths, whereas in most of the cases family members and neighbours were owners [74], thus illustrating the importance of safe firearm storage.

Intentional firearm deaths

Suicides
Globally, suicides represent a major public health problem, taking ~ 800,000 lives annually. Suicide was also the second leading manner of death in 2015 among 15-29 years-old while the number of attempts were much higher than the number of deaths [82].

Among WHO European Region countries, the highest rates were observed in eastern countries, e.g. Lithuania (51.6/100,000 population) and the lowest in Germany (14.3/100,000 population) [83].

Each year ~1,200 persons die as a result of suicide in Sweden [7]. Although the total number of suicides in Sweden has decreased since the 1980’s, the decrease has declined in the past decade, and an increase in the age group 15-24 years has been observed [84].

In an international comparison, firearm suicide rates decreased in Australia, Canada, New Zealand, Norway and the United Kingdom in the period 1983-2000 [57]. The observed decline in the number of firearm suicides since the 1990’s stagnated in 2003-2014 [8], and overall mortality in intentional firearm deaths, related to annual general population changes, did not change during the period 1999-2012 in Sweden [85].
Firearm suicides accounted for 9.6% of all suicides ≥15 years of age in 1985-1994, 10% in 1995-2004 and 8% in 2015 [7]. The pattern of suicide methods has changed over time; among males, the share of hangings/suffocations and firearm suicides increased whereas intoxications decreased, and the share of jumps and drownings remained unchanged (1970-2003) [86]. Similar patterns were reported for females for the same period, except for a decreased share of drownings and a constant level of firearm suicides [86]. The official reports about patterns of suicide method do not, however, present reliable trend analyses and interpretation of pattern changes over time.

**Homicides**

Globally, homicides claimed ~ 400,000 lives in 2012 [87]. International comparisons are hampered by differences in the definition of homicide, in legal aspects and in reporting systems between countries [88].

Although the total number of homicides in Sweden decreased in the 1990’s, no evident trends were observed in 2002-2016 [89]. Stabbing has been the most common cause of death in homicides ever since the mid 1970’s in Sweden, compared to the dominance of firearm injuries in a global context [90]. In the Swedish setting, firearm injury has become the second most common method of homicide since the 1990’s [90].

In Sweden, among the methods in all homicides, the share of blunt force trauma and asphyxiation seems to have decreased, while an increase was reported for homicides due to stabbing and shooting (Table 2) [8, 90, 91], especially among young males (15-29 years age) [92]. Young male victims killed due to an illegal firearm use had records of previous criminal activity and were unemployed [8]. The official statistics, however, lack comparison of trends of different homicide methods, related to population changes over the years.

The clearance rate of firearm homicides in Sweden was lower than for other homicide means [93], probably since in firearm homicides the crime scene more often was a public place. Such circumstances are commonly characterised by the lack of physical contact between the victim and the perpetrator [8], and by the fear of witnessing.
Table 2. Homicides in Sweden by method, presented as percentage of all homicides. N = number of all homicides.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Stabbing</td>
<td>42%</td>
<td>39%</td>
<td>45%</td>
<td>45%</td>
</tr>
<tr>
<td>Blunt force trauma</td>
<td>23%</td>
<td>16%</td>
<td>14%</td>
<td>13%</td>
</tr>
<tr>
<td>Firearm</td>
<td>17%</td>
<td>22%</td>
<td>19%</td>
<td>30%</td>
</tr>
<tr>
<td>Asphyxiation*</td>
<td>12%</td>
<td>11%</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>Other methods</td>
<td>6%</td>
<td>12%</td>
<td>13%</td>
<td>4%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*including drowning

Undetermined manner of death
If the manner of death cannot be determined as natural, accidental, suicidal or homicidal, it remains undetermined. Fatalities are more often classified as undetermined in Sweden than in Denmark and Norway [94]. Poisonings and drownings are especially challenging in manner of death (MOD) determination, which explains the higher proportion of such deaths classified as undetermined [95]. Among accidental fatalities in Denmark, Norway and Sweden, the expertise agreement was lowest for accidental drownings and poisonings [96], but accidental firearm fatalities were not included in the study.

The majority (70-75%) of deaths with undetermined MOD are most likely to be suicides [97]. Consequently, Swedish suicide statistics commonly include both cases classified as suicides and cases with undetermined MOD (~20% of the total number of suicides) - often erroneously called “unresolved suicides” - in order to avoid underreporting [97]. In a study of reclassification of suicides in three Scandinavian countries, most suicides were classified as such, but in the Swedish data the main classification disagreement was found among deaths with undetermined MOD, where ~20% of such deaths were reclassified as suicides. In addition, only a few cases in Swedish data were reclassified from suicide to accidental or natural death, or from accidental death to suicide, natural death, or undetermined MOD [98].
**Risk factors and risk-taking behaviour**

Previous research has revealed numerous risk factors associated with unnatural deaths. Individual risk factors presented in this thesis are age and gender, relationship and health issues. Risk-taking behaviours are also connected to an individual and may reflect several risk factors at the same time. Firearm ownership and availability have been identified as common risk factors for all firearm deaths.

**Age and sex:** Male victims are more common than female in firearm deaths [55]. In *accidental* firearm injury events, children are at higher risk than adults. Children and youth play with guns when guns are available [99], and when they are not supervised [100].

Relatives or friends are at risk of being affected in firearm homicides [101] and in two-party accidents, especially among the young in the USA [69].

**Health issues:** While knowledge of health status as a risk factor for accidental firearm injury events is lacking, mental illness is a well-known risk factor for suicide [102]. Some other conditions may also bring an increased suicide risk, such as malignancy [103], dementia [104], and chronic pain [105]. However, mental illness as a single factor does not strongly predict the risk of firearm homicide and other crimes involving firearms [106].

**Risk-taking behaviour:** Risk-taking behaviour has been studied mostly in unintentional injury events such as traffic crashes. Poor driving behaviour, driving when fatigued, and risk-taking predicted road traffic incidents [107]. Factors that may affect drivers’ speeding were the following: attitudes to safety, authority and rules, estimation of one’s ability, social expectations and external pressure [108]. These factors may also be relevant for firearm activities, but have not yet been studied. Prospective studies on risk-taking behaviour in incidents causing firearm injury are lacking.

Firearm related activities are incompatible with substance use and abuse due to prolonged reaction time, disturbance of vision and coordination, and impaired judgement. In general, the risk of injury significantly increased with acute alcohol consumption, even when situational and other risk factors were considered [109].

A scientific consensus about how deaths due to Russian roulette should be classified, i.e. as a suicide or as an accidental death, has not been established. The activity represents an obvious risk-taking behaviour, related to urban environment, mental health treatment, and to a high blood alcohol concentration [110].
The risk of homicide victimisation increased with previous traumatic brain injury, alcohol dependence, physical abuse and criminal recidivism [111].

In addition, illegal firearm use as a risk behaviour has not been previously studied in Sweden, probably due to legal and methodological difficulties to perform such studies.

**Firearm availability and ownership:** Firearm availability and ownership increased the risk of firearm suicide [112, 113], firearm homicide [112-116] and of fatal firearm accidents [117]. In the USA, having guns at home constituted a risk factor for children to be involved in an accidental firearm incident [74, 118], while unsafe firearm storage was associated with accidental firearm deaths in all age groups [119]. Thus, firearm availability should be considered in a broader perspective and not only related to the ownership, but also to firearm storage.

**Firearm regulation**

In spite of the low rates of firearm deaths, several mass shootings also in Europe have resulted in a call for more attention and prevention work in the near future. Reports on rising illegal firearm trafficking, increasing homicide rates in organised criminal groups and rising threats of terrorist attacks have also contributed to the focus on firearm legislation in Europe. Accordingly, new firearm laws have been introduced in several European countries during the past decades. Evaluation of the effectiveness of these changes upon firearm deaths and injuries have, however, rarely been performed.

Firearm ownership and firearm storage regulations aim at limiting the access to legally owned firearms and hence to reduce the risk of firearm injury and death. In 2017, the EU Parliament adopted a new Firearm Directive, making control of acquisition and possession of firearms more rigorous. According to the Directive, certain semi-automatic firearms should be banned, and the rules on marking and deactivation/reactivation of firearms strengthened. The minimum regulation of cooperation between EU member states has also been set out [30], due to heterogeneous firearm legislations within EU. In Sweden, there is an ongoing inquiry about the Directive implementation in the Swedish legislation.

Comparing the strength of different firearm legislation is a challenging issue due to different local conditions between countries and regions. In 2013, a new approach was used by studying the correlation between the strictness of the firearm laws in different states and the rates of firearm deaths in the USA. States which had stricter firearm laws also had fewer firearm homicides and
suicides [120]. After controlling for firearm ownership rates, only background checks had a significant correlation across all outcomes [120]. The scoring system presented was, however, not validated and there is no similar system for European conditions. Comparison of the firearm legislation between European countries is thus lacking, as the European background check policies have not yet been evaluated [90].

The Swedish firearm regulation
The Swedish firearm regulation has been strengthened in the past three decades through increased penalties for violation of the regulations. The main aspects of the legislation included in this thesis are: ownership (possession), storage and reporting obligation of physicians.

In Sweden the possession or use of any firearm without a license, with the exception of some low energy release air guns, is prohibited by the Firearms Act [28] and the Firearms Regulation [121]. The current firearm legislation originates from the Firearm Proclamation in 1934 (Vapenkungörelse 1934:315), which has been replaced by new laws in 1949, 1973 and in 1996 [122, 123].

The minimum age when applying for a firearm license is 18 years and the purpose of the application must be either target shooting, hunting or collecting. All applicants for a new firearm license specifically for hunting purposes must, since January 1985, have passed the hunter’s exam [121]. The Swedish hunter’s exam comprises both theoretical knowledge about hunting, game and weapons and practical tests including target shooting and safe weapon handling.

The Swedish Police also performs background checks of the applicants, and the severity and frequency of any previous crime is taken into account for the decision regarding licence issuing. Background checks, license issued by the police, licence withdrawals due to medical conditions and storage regulations were already mentioned in the law from 1949 [124]. In 1999, changes in the law brought up mandatory local police registers, as the separate central police register was established. Firearm and ammunition storage regulation was sharpened according to changes in the Firearms Act in July 2000 [28]. Weapons and ammunition must now be stored in authorised safety lockers.

According to the Firearms Act [28], a physician who deems a patient as unsuitable for possessing a firearm due to a medical condition has to report the patient to the police. This law enforcement was introduced in 1980 [125] and regarded psychiatric inpatient care, and has been expanded in recent years [126]. Conditions treated in all types of psychiatric healthcare were included since the year 2000, all relevant diseases and conditions since 2006, and conditions detected in forensic psychiatry assessments since 2012. Since the purpose of a legal weapon is hunting, target shooting and collecting firearms, legal weapons are not expected to appear in a criminal context other than
exceptionally. Additionally, licensed firearms should ideally not be used in a suicide by an owner with a known mental illness or other medical condition relevant according to the law.

The National Board of Health and Welfare (NBHW) and the Swedish Police [41, 127] presented national data of the number of reports from physicians to the police (Figure 4). In the 6 month period between 1st July and 31st December (for each year reported), a gradually increased physician reporting was recorded in 2000-2005, with a decrease at least in 2008 and in 2012.

![Figure 4. Number of physician reports of patients deemed unsuitable to possess a firearm, in the period of 1st July-31st December in each year, in Sweden [41, 127].](image)

Data from reports in other years than presented here are missing. The number of patients taken into compulsory care due to a serious mental health issue and the number of patients with dementia is, however, much higher than the number of physician reports [127]. Hence, the NBHW and the Swedish Police proposed measures to encourage more entries of physician reports. However, until now there is no national-based research forming the background for such a proposal.
Evaluating impact of a stricter firearm legislation

According to the prevention strategies model [17], it is more effective to require behavioural change by law than trying to persuade individuals to alter their behaviour. However, proving the relationship between cause and effect is challenging when analysing the effect of stricter firearm legislation on firearm deaths and injuries.

In general, most studies evaluating the effect of a stricter firearm legislation on firearm deaths and injuries have not included an analysis of accidental firearm deaths, but focused on firearm suicides and homicides. European studies on the effect of firearm legislation are scarce and show that the introduction of stricter firearm laws has been associated with a decrease of firearm deaths in Denmark [78], Austria [128], and of firearm suicides in Switzerland [129].

In the USA, where unintentional deaths present a significant public problem, Child access prevention laws were evaluated (1970-2000). The findings showed that the states which had enacted these laws had a larger decline in the rates of accidental firearm deaths among children 0-14 years of age, than states which had not introduced such laws [130]. Furthermore, in Canada, stricter gun control was accompanied by a decrease in accidental death rates from firearms [131].
MATERIALS AND METHODS

Design, setting and participants

The study design, setting and participants is summarised in Table 3.

Table 3. Design, data sources, study periods and study cases. N = number of cases.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Design</th>
<th>Data sources</th>
<th>Study period</th>
<th>Study cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Retrospective, national data, register study</td>
<td>Statistics Sweden, National Board of Forensic Medicine Database</td>
<td>1983-2008</td>
<td>All accidental firearm hunting fatalities (N = 48)</td>
</tr>
<tr>
<td>II</td>
<td>Descriptive, cross sectional</td>
<td>Questionnaire</td>
<td>(February 2009)</td>
<td>Respondents, members of the SAHWM (N = 482)</td>
</tr>
<tr>
<td>III</td>
<td>Retrospective, national data, register study</td>
<td>National Board of Forensic Medicine Database</td>
<td>1983-2012</td>
<td>All accidental firearm non-hunting fatalities (N = 43)</td>
</tr>
<tr>
<td>IV</td>
<td>Retrospective, national data, register study</td>
<td>National Board of Forensic Medicine Database, National Patient Register, Prescribed Drug Register, Firearm Register</td>
<td>1987-2013 (accidental and undetermined MOD), 2012-2013 (suicides and homicides)</td>
<td>Accidental firearm fatalities (N = 52), firearm fatalities with undetermined MOD (N = 3), firearm suicides (N = 213), solved firearm homicides (N = 23)</td>
</tr>
</tbody>
</table>

SAHWM = Swedish Association for Hunting and Wildlife Management
MOD = manner of death

Data sources

Statistics Sweden (Paper I)
Statistics Sweden is an administrative agency that produces and develops official government statistics. All death certificates on which the cause of death was firearm injury, either unintentional (ICD: E922) or undetermined (ICD: E985), were collected from Statistics Sweden.

An autopsy determines the (underlying) cause of death, stated in a death certificate that in turn forms the basis of the national mortality statistics.
Mortality statistics may be used to, e.g. explore epidemiological aspects and to introduce or follow-up preventive measures.

In Sweden, a medico-legal autopsy is performed at one of six Departments of Forensic Medicine in Sweden, located in Umeå, Uppsala, Stockholm, Linköping, Gothenburg and Lund. Such autopsies are requested by the Swedish Police, which investigates all unnatural and possibly unnatural deaths.

After the collection of the death certificates through Statistics Sweden, police and autopsy reports with toxicological results were retrieved from the National Board of Forensic Medicine Database.

National Board of Forensic Medicine Database (Papers I, III and IV)
National data including police reports and autopsy reports with toxicological results were retrieved through the National Board of Forensic Medicine Database, which was established in 1992. This database contains information about cause and manner of death, demographics and circumstances of each individual death.

Blood, urine, vitreous fluid and, occasionally, other tissues are collected during the autopsy and sent for toxicological analyses to the Department of Forensic Genetics and Forensic Toxicology, National Board of Forensic Medicine, Linköping, Sweden. The samples are then analysed for alcohol, and licit and illicit drugs. In this thesis, illicit drugs refers to those without medical purpose and defined according to Swedish law [132]. When all firearm deaths were studied, the blood concentrations were evaluated and categorised as non-toxic, toxic and highly toxic (Paper IV) [133-139].

National Patient Register (Paper IV)
The Patient Register was founded in 1964 and became nationwide in 1987 [140]. This register covers the inpatient and specialised outpatient care, but not primary care. The variables about health care contact (date and diagnosis) were collected for one year prior to each fatality, except for shooters in homicides, due to the small number of such cases. Approximately 85-95% of all diagnoses in the Inpatient Care Register, presenting a part of the National Patient Register, were found to be valid [141].

Prescribed Drug Register (Paper IV)
The Prescribed Drug Register was started in 2005 and contains information about all health care prescribers and all prescriptions [142]. Information about the prescription date and prescribed drug for deceased shooters one year prior to his/her death was retrieved. Data was not retrieved for homicide shooters due to the small number of such cases. The WHO’s Anatomical Therapeutic Chemical
(ATC) codes [143, 144] were used for the data extraction in all prescribed drugs from the register.

Firearm Register (Paper IV)
The Central Police Register consists of three sub-registers: The Firearm Register, the Firearm Owner Register and the Register of Firearm Handlers [28]. These three sub-registers must not be linked to each other according to law. Data about firearm license status and physician report for deceased shooters were retrieved from this register. Also the number of firearm owners by county (21 Swedish counties) was retrieved from the Swedish Police. Information about physician reporting in 2012 was obtained from a report from the Swedish Police and the National Board of Health and Welfare [127], whereas information about physician reportings in 2013 were not available.

Data collection and reevaluation
The manner of death classification (Paper I, III, IV) was in all cases reevaluated by an experienced forensic pathologist (Anders Eriksson), in order to avoid heterogeneous classification due to shifting individual preferences of different forensic pathologists. The main factor affecting this reclassification was the preponderance of available medical and investigative evidence before and after the autopsy, extended police investigations and witness statements supporting the manner of death. The reevaluated MOD classification was used, regardless of possible juridical epilogue.

Data were also collected from the questionnaire (Paper II), made specifically for the study purposes.

Classification of diseases and drugs
In clinical work, the International Statistical Classification of Diseases and Related Health Problems (ICD) has been used as a standard diagnostic tool during one century [145]. It has also been useful when investigating and monitoring the patterns of diseases and health problems. The WHO became responsible for ICD maintenance in 1948 [145]. There have been ten revisions to date.

In Papers I, III and IV, both ICD-9 and ICD-10 were used in the selection of study cases, and in Paper IV also for data collection (diagnosis related to health care contacts) from the Patient Register.
As a measure of drug use, WHO’s ATC coding system was established in the 1960’s, and was in 1981 recommended by WHO as the standard for drug utilisation studies [146]. ATC codes were used in this thesis (Paper IV) and psychoactive licit drugs were presented as the subgroups: benzodiazepines (N05B), antidepressants (N06A), neuroleptics (N05A), opiates (N02A), antiepileptics (N03) and non-benzodiazepine hypnotics (N05CF).

**Paper I and III**

Figure 5 presents the case selection and exclusion criteria when fatalities in firearm hunting accidents were studied (Paper I). The inclusion criterion was that the shooter and/or the victim was hunting or transporting in direct connection with a hunting activity. The shooting itself did not necessarily occur during an active hunt (see Definitions).

![Diagram](diagram.png)

**Figure 5.** Case selection and reevaluation in Paper I (1983-2008). N = number of cases.

When fatalities in firearm non-hunting accidents were studied, the corresponding method for case selection (N = 171), exclusion and reevaluation (N = 128) was used (Paper III). The final material included 43 non-hunting firearm fatalities (Paper III).

All cases were analysed for several parameters: sex and age of the shooter and the victim, time and place of death, circumstances, location of the fatal injury,
type of firearm used, shooting distance, relation between shooter and victim, and toxicological findings in the victim.

**Paper II**

*Participants*

A random sample of 1,000 Swedish hunters and members of the Swedish Association for Hunting and Wildlife Management (SAHWM) was selected. This size of the study population was chosen as a compromise between costs and a desired variation of reported incidents. In the beginning of 2009, SAHWM had 156,357 members aged ≥18 years [48]. A questionnaire was posted in February 2009 and a reminder after two weeks. Survey responses were anonymous, but the respondents were offered to provide contact information voluntarily. Respondents were remunerated by the SAHWM with a brochure product.

*Study questionnaire*

The study was based on a questionnaire (see Appendix) which was developed after a literature research [147-151]. Its contents were subsequently discussed with senior safety professionals from SAHWM and senior researchers to ensure face validity. To improve the questionnaire, it was tested on 10 active hunters and modified according to relevant comments. The posted questionnaire did not contain any codes enabling identification.

A total of 48 questions covered demographics (N = 2 questions), hunting experience/hunting habits/safety behaviour/attitudes and experience of careless weapon handling (N = 26), hunters’ weapons and safety behaviour relating to weapons (N = 5), health status (N = 8), firearm incidents (incidents in which a weapon was unintentionally discharged or was intentionally discharged at an unintended target) and its preventability (N = 4), and personal comments on the questionnaire, with the possibility to provide contact information (N = 3). Both nominal and ordinal scales were used and some questions were open, allowing free responses.

**Paper IV**

In the final study material, there were 213 suicides, 52 accidental deaths, 23 solved homicides, and 3 cases with an undetermined manner of death. Cases not included were: erroneously coded cases, unknown shooter, minor shooter, military or police shooters, deaths abroad, cases in the beginning of 1987 (due
to study design and the fact that the Patient Register started in 1987), and unsolved homicides.

Police reports and autopsy reports with toxicological results were collected through the database of the National Board of Forensic Medicine. Homicides followed by the perpetrator’s suicide were identified. Information about the clearance status of the remaining homicides was retrieved through the Karnov verdict database service [123].

Data were retrieved from three registers: the Swedish National Patient Register, the Swedish Prescribed Drug Register, and the Swedish Police Firearm Register.

Diagnoses regarding 16 living shooters involved in accidental cases were retrieved only from the in-patient care, according to the ethical approval. Register data from the Drug Register and the Firearm Register were thus not retrieved for these individuals.

In this thesis (Paper IV), the number of firearm owners (not the number of firearm licenses) was used in an analysis of possible correlation to firearm deaths. It is doubtful that the number of firearms should be generally applied in analyses of such relationship in all societies. In Sweden, one owner may have several licences, one licence per firearm. In countries with more liberal firearm laws (e.g. USA) the number of firearms may be a relevant approach in studies of the epidemiology of firearm injuries and deaths. This is due to the higher number of firearms in circulation, lower limits for purchase and higher availability to non-owners due to variation in storage regulations, compared to countries with stricter firearm laws (e.g. Sweden). Thus, in a Swedish setting, it may be more appropriate to use the number of firearm owners when studying such issues and the most reliable resource for firearm ownership data is from the Swedish Police.

**Statistical analyses**

Descriptive statistics were used in all papers. Comparisons between the numbers of deaths and annual risk change before and after the introduction of the mandatory hunter’s exam were performed by the optimal test of comparing to Poisson distributions (Paper I and III). The risk of being killed by an unintentional shot was also estimated as the annual incidence rate per game taken as a continuous function of calendar time by using the same type of Poisson model with the number of game as an offset (Paper I).
For data analysis, SAS version 9.2 for Windows (Paper II) and SPSS (version 24) for Windows were used (Paper IV). In all tests statistical significance was defined as a p-value of < 0.05.

Chi-square test was used for comparison of the percentage of deaths caused by rifles and shotguns, before and after the introduction of the mandatory hunter’s exam (Paper III). For the comparison of differences between legal and illegal firearm use, and between alcohol or licit drug positive and negative victims, chi-square test and Fisher’s exact test were used (Paper IV). Fisher’s exact test also assessed the association between a positive toxicological test and the use of an illegal versus a legal firearm (Paper III).

Logistic regression was performed to investigate the association between age, sex, hunter’s exam and the annual number of hunting days with various outcomes (Paper II); respondents were divided into three age groups: young (≤45 years), middle-aged (46-65 years) and elderly (≥66 years). The univariate analysis followed by the multivariate when items showed a p-value < 0.10 in the univariate analyses. Associations between responses to different questions were also assessed utilising logistic regression and presented as odds ratios (OR).

The analysis of the correlation between numbers of firearm suicides and number of physician reports, and of the correlation between the number of firearm owners and the number of firearm suicides by county was performed by Spearman’s rank-order correlation test (Paper IV).

**Ethical considerations**

Ethical approval was not required following Swedish regulations in (register) research on deceased persons (Papers I, III and IV) [152, 153]. When living persons (shooters) were studied (Paper IV), ethical approval was required by the same legislation and obtained by the Regional Ethical Review Board of Umeå, Sweden, # 2015/129-131Ö. All data were anonymised and presented on group level, not on an individual level. Hence, the results cannot be linked to a specific individual.
RESULTS

Paper I and III

**Behind the numbers (Paper I and III)**

*On his way to hunt, a 67-year-old moose hunter lifted a loaded and unsafetied rifle from the car and accidentally shot himself in the chest. He had passed the hunter’s exam according to the firearm legislation and toxicology results were negative (a study case in Paper I).*

*Two teenagers were playing with a pistol at home when an accidental shot killed one of them. The weapon was licensed by a parent and kept in the safety locker (a study case in Paper III).*

**Frequency, date, and time:** There were 48 fatal accidental hunting shootings over a 26-year period (1983-2008) with an annual average of 1.9 fatalities (Figure 6). The incidence was highest in the autumn, the main hunting season, and most fatalities occurred on Saturdays and Sundays (51%) and during daylight hours. A total of 22 fatalities occurred during moose hunts; the remaining 26 occurred during small game hunts.

During the 30-year period studied (1983-2012), 43 fatalities were attributed to accidental firearm injuries in a non-hunting situation with an annual average of 1.4 fatalities (Figure 7). No such fatalities were recorded in 2010 through 2012.

**Temporal trends:** Temporal trend analyses in both Papers I and III included the annual number of cases from previous Swedish studies (1970-1982) [65, 71].

After the introduction of the mandatory hunter’s exam in January 1985, the risk of being killed due to an unintentional firearm injury decreased significantly (p < 0.001 for hunting and p < 0.001 for non-hunting deaths). Before 1985, the risk of being killed due to an unintentional shot while hunting decreased by 1.5% per year and after 1985 by 5.8% per year. The annual risk of being killed during hunting, estimated from the number of game taken as a continuous function of calendar time, also decreased: 5.1% before 1985 and 4.3% after 1985. The number of game taken was assumed to represent an indirect measure of hunting intensity and risk exposition.
**Figure 6.** The annual number of unintentional firearm fatalities in Sweden during hunting, 1970-2008. Figures from the period 1970-1982 were obtained from the previous Swedish study [71]. Black areas = moose hunting, blank areas = small game hunting.

**Figure 7.** The annual number of unintentional non-hunting firearm fatalities in Sweden, 1983-2012.
Victims and shooters: In hunting fatalities, the mean age of the victims was 50 years (median 49) (unpublished results). The mean age of the shooters in two-party accidental deaths was 51 years (median 56) (unpublished results). All but 2 victims were males, while all shooters were males. In 13% (6/48) of all study cases and 21% (6/28) of all two-party accidental deaths, a close relative shot the victim.

Of all fatalities during moose hunting (N = 22), 4 were self-inflicted and 17 were caused by another person. In one case, a dog caused the fatality. Of all small game hunting fatalities (N = 26), 15 were self-inflicted and 11 were caused by another person.

Eleven hunters who had either killed themselves or another person had partially or fully passed the exam. They accounted for 30% of the 37 fatal hunting deaths after January 1985, when this kind of information was made available. In only 3 of 8 victims, who were mistaken for game, the victim’s clothing was documented. One of these 3 was wearing signal colours.

In non-hunting fatalities, the mean age of the victims was 25 years (median 20). The mean age of the shooters in two-party accidental deaths was 26 years (median 20) (unpublished results). A total of 12 victims were aged 0-17 years (mean 12 years) while 8 shooters were 0-17 years (mean 14 years). Among the victims, 86% were males. The shooter and the victim were close relatives in 5 cases and acquainted in 12 cases. All accidents with female victims were two-party accidents. Two-party accidents, where the victim was shot by another person, accounted for 56% of the deaths.

Firearms and shooting distance: All hunting fatalities during moose hunting involved moose hunting rifles, while small game fatalities involved shotguns in 14 cases and rifles in 12 cases. In the majority of the hunting fatalities, the distance from the muzzle to the victim was less than 5m. Only in 3 cases of small game hunting-related deaths did this distance exceed 10m. Defective firearms were found in 3 cases.

The firearms used in non-hunting fatalities were rifles in nearly half (49%) of the cases, handguns in 37%, and shotguns in 14%. In more than half of the cases (63%) the firearms used were legal. The majority of handguns used were illegal and of the 16 illegal firearms, 13 were handguns. All shotguns and the majority of the rifles (military and hunting) used were legal. In accidents where the victim was under the age of 18, the firearm used was legal in 8 and illegal in 4 cases.

Before the introduction of the mandatory hunter’s examination in 1985, 51% of the firearms used were hunting rifles and shotguns, compared to 25% after 1985.
(p < 0.032). The distance between the firearm and the victim was less than 1m in 53% of cases and exceeded 1m in 40% of cases. In the majority of two-party accidents (79%) the distance exceeded 1m, while in 83% of self-inflicted cases it was within 1m and 17% had a contact injury. In 4 cases, the firearm was defective.

**Fatal injury:** In most hunting fatalities, the fatal injury was localised to the chest and/or abdomen. Three victims did not die at the scene, one survived for 1.5h, one moved about 150m after receiving the fatal injury, and the third died from cardiac complications after surgery.

In self-inflicted non-hunting accidents, the majority of the fatal injuries were localised to the head followed by injuries to the chest or the abdomen. In two-party accidents, the patterns were the opposite. The victims died at the scene in 77% of the accidents, after admission to hospital in 21% and during ambulance transport in 2%.

**Circumstances:** In 9 of 22 cases during moose hunting, the victim was mistaken for a game. The most common circumstances in small game fatalities were that the victim fell with a loaded weapon (8/26), or the victim handled the weapon improperly (4/26). Other less common causes of these fatalities are listed in Table 4 of the Paper I. Four of the fatalities occurred after the hunt was finished.

Of all 48 victims, 6 were non-hunters and most were mistaken for game (N = 4) while among hunters 8 were mistaken for game.

The dominant circumstances in non-hunting accidents were: playing with firearm (13/43) and other improper weapon handling (9/43) (Table 1, Paper III). Accidents occurring in a military setting involved military recruits. One case involved a man “playing” Russian roulette with an illegal weapon in the presence of witnesses. In 8 cases, a child shot another child, of which 5 occurred during play.

**Toxicology:** All hunting fatalities but 2 were tested for presence of alcohol in blood and/or urine. Five of the 46 cases tested positive; 4 cases had a blood alcohol concentration between 0.1 and 1.9 g/L, and one case with no blood alcohol detected had a urine concentration of 0.2 g ethanol/L. Four of these test positive victims were killed during small game hunting (2 by themselves and 2 by another person due to improper handling of a weapon), and one hunter was mistaken for game during moose hunting. A total of 27 cases were tested for other drugs than alcohol. No illicit drugs were detected in any of these and licit drugs were present in concentrations corresponding to therapeutic use.
All but 6 of the 43 victims of non-hunting accidents were tested for alcohol, licit drugs, and illicit drugs. While the majority (62%) tested negative for all these substances, 3 tested positive for alcohol, 3 positive for alcohol and licit drugs, 3 for alcohol, licit drugs, and illicit drugs, one for alcohol and illicit drugs, 2 for illicit drugs and 2 for licit drugs. In the accidents with test positive victims (any combination), most firearms (79%) were illegal. Victims positive for alcohol and illicit drugs were more commonly killed by an illegal firearm use than a legal firearm use (p < 0.0001) (Table 2, Paper III). There was a lack of objective information about the sobriety of the shooter in two-party accidents, but in 4 such cases, it was noticed that the shooter “was drunk.”

Paper II

<table>
<thead>
<tr>
<th>Behind the numbers (Paper II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“With the introduction of hunter’s exam, weapon handling has become safer. Many hunters now think before they act.” (respondent)</td>
</tr>
<tr>
<td>“The questionnaire is valuable. Safety can never be too high.” (respondent)</td>
</tr>
</tbody>
</table>

Respondents/non-respondents: 1,000 surveys were distributed and the response rate was 49%. Eight responses did not contain any answer and were excluded. The average non-response rate per question was 4%. Since all respondents were offered full anonymity, the non-respondent group could not be analysed. Instead, analyses of all respondents, the random sample of 1,000 hunters, and all members of SAHWM were performed.

Demographics: Statistical comparisons of age and sex were made between respondents, all members of SAHWM and the sample. The proportion of female respondents was 5% [95% confidence interval (CI) 3.4, 7.4]; 6% of SAHWM and 5.5% of the sample were females. The mean age of all respondents was 54 years (SD: 13.5). The mean age of female respondents was 50 years (SD: 13.2), compared with 46 (SD: 13.0) for all female members and 49 (SD: 15.3) for females in the sample; for males the mean age was 55 (SD: 14.8), compared with 53 (SD: 14.8) for all male members and 53 years (SD: 14.9) for males in the sample. There was no significant difference in mean age between males and females. Of all female respondents, the proportion of middle-aged females was higher (73%) than the proportion of young females (23%).

Hunting experience, hunting habits and safety behaviour: The hunter’s exam was passed by 80% of all respondents (100% of females and 79% of males). 40 percent had hunted for more than 30 years, and most respondents
(91%) hunted in Sweden only. Some 54% hunted on their own hunting ground and/or in an area within 25 km from their residence, while 46% hunted in the hunting area within 25-100 km from their residence (unpublished results). The vast majority hunted together with other hunters (92%). One-third of the respondents sometimes hunted with underage companions, most (88%) of whom were more than 7 years old.

Only a minority (13%) of the respondents stated that they hunted when visibility was bad. Almost all (98%) respondents used signal colour clothing. Half of the respondents who hunted unaccompanied and almost half (40%) of the respondents who hunted with others used camouflage clothes.

**Alcohol:** Four respondents reported having hunted occasionally under the influence of alcohol, of whom 3 reported that they had hunted the day after excessive alcohol intake. Nine percent of the respondents, who reported that they had never hunted under the influence of alcohol, stated that they had sometimes hunted the day after excessive alcohol intake. “Excessive alcohol intake” was defined as the hunter did not feel ‘his/her normal self’ during hunting, and was subjectively assessed by each respondent.

**Attitudes to, and experience of, careless weapon handling:** Personal knowledge of another hunter, who was not suitable for hunting weapon ownership in the respondent’s opinion, was presented by 16% of the respondents. The respondents stated that 78% of these “non-suited” hunters still hunted. The reasons for stating others’ unsuitability for weapon ownership were summarised (Table 1, Paper II). Careless weapon handling by another hunter was experienced by 35% of the respondents. Young and middle-aged respondents were more likely than elderly to have experienced another hunter’s careless weapon handling and to have reported knowledge of individuals not suitable for weapon ownership.

The number of days spent hunting during the year 2008 was categorised as 0–9 days, 10–19 days, 20–29 days and ≥30 days. Individuals that hunted ≥30 days per year were more likely to have experienced another hunter’s careless weapon handling than those who hunted less than 30 days (Table 2, Paper II).

**Hunters’ weapons:** Of all respondents, 97% possessed one or more rifles, and 88% one or more shotguns. Weapons and ammunition were stored in an authorised safety locker by the vast majority of the respondents (99% regarding weapon storage and 96% regarding ammunition storage). Almost all respondents (96%) checked their weapon/s each year and before each hunt. Only one respondent never checked the function of the weapon. The checks were mostly performed by test-shooting (78%) and during cleaning (31%).
**Health status:** Most of the hunters (91%) stated that they were “healthy”. Impaired vision was reported by 44% of the respondents and impaired hearing in 30%. Almost all respondents with impaired vision (97%) used glasses and/or lenses. A neurological disorder (Parkinson’s disease) was reported in one case and a history of stroke in another. Cardiovascular disease was reported by 17% of the respondents, of which 63% (10% of all respondents) had hypertension. A minority of the respondents (5%) had to stop hunting at least once because of feeling ill during a hunt.

**Risk factors and risk behaviour:** A risk factor was defined as one of the following: bad health, or impaired vision, or impaired hearing, or a neurological or cardiovascular disease, or stopping a hunt due to feeling ill. Since we did not know if the respondents’ impaired vision/hearing and cardiovascular or neurological disease was sufficiently well compensated/treated, these conditions/diseases were considered to be risk factors. Most respondents reported none or only one risk factor (32.4% and 42.0%, respectively). The most common risk factor was impaired vision, which was present in 57% of all hunters with one risk factor. Young hunters were less likely to have at least one risk factor than middle-aged and elderly hunters (Table 2, Paper II).

Risk behaviour was defined as: not using signal colours, or using camouflage clothes when hunting with others, or hunting under the influence of alcohol, or hunting the day after excessive alcohol intake, or hunting in spite of impaired visibility, or not checking the function of the weapon before the hunt, or having caused a firearm incident. Most respondents reported only one (33.2%) or 2 (32.4%) risk behaviours. The most common risk behaviour was the use of camouflage clothes when hunting with other hunters. Young age, male sex and ≥30 days of hunting per year were positively associated with risk behaviour (Table 2, Paper II). There was no evidence of an association between risk behaviour or risk factor and hunter’s exam.

**Experience of firearm incident and preventability:** Experience of another hunter causing a firearm incident was reported by 23% of the respondents while 5% of the respondents reported having caused such an incident by themselves. Some 120 hunters described 190 such incidents during the last 5 years. A female hunter was reported as the shooter in 6% of these incidents, and the mean age of all shooters was 52 years. It was not possible to detect an association between having caused a firearm incident and sex, age or number of hunting years. Causing a firearm incident was positively associated with reporting such an incident caused by another hunter (OR 3.2, 95% CI 1.3, 7.8). A further exploratory analysis on this outcome was not performed due to the low number of reported cases. There was a positive association between reporting a firearm incident caused by another hunter and the number of years of hunting experience (OR 0.98 per year, 95% CI 0.97, 0.99). Respondents who
hunted for $\geq 30$ days per year had higher odds of reporting a firearm incident than those who hunted for only 0–9 days (OR 4.2, 95% CI 2.12, 8.51). Three personal firearm injuries were reported, two were non-fatal and “caused” by discharge of an unsafetied weapon while one was fatal and occurred after slipping. In addition, a dog was mistaken for game and killed. Material damage was reported in only 20 incidents, while in 153 of the incidents no injury or damage was reported.

Accidental firearm discharge occurred during target shooting in connection with hunting in 9 cases. More than half of the incidents happened during hunting, the rest before or after the hunt.

The respondents’ opinions on the preventability of firearm incident and their suggestions regarding prevention were listed in Table 3 of the Paper II. The most common “cause” that was deemed to be “unpreventable” was a defective weapon. Most suggestions regarding prevention concerned safer handling of the weapon and safer planning of the hunt.

**Paper IV**

<table>
<thead>
<tr>
<th>Behind the numbers (Paper IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A licensed firearm hunter in the upper middle age, who had been previously diagnosed and treated for malignant disease, killed himself using his rifle. In the year prior to his suicide, benzodiazepines and sleeping pills were prescribed at numerous occasions through the primary healthcare. There were no contacts with psychiatric care. (a study case in Paper IV)</td>
</tr>
<tr>
<td>An adult was intentionally shot and killed with an illegal firearm by a former partner. (a study case in Paper IV)</td>
</tr>
</tbody>
</table>

Illegal firearm use dominated among solved homicides (73%) and among undetermined MOD deaths (67%), whereas legal firearm use dominated among accidental deaths (75%) and suicides (79%) (Table 4). The use of long- and short-barrelled firearms differed between suicides and accidental deaths on one hand, *versus* homicides and undetermined MOD deaths on the other (Table 4).
Table 4. Legal and illegal firearm use in firearm deaths in Sweden. N = number of cases.

<table>
<thead>
<tr>
<th>Firearm use</th>
<th>Suicides (N = 213)</th>
<th>Homicides (N = 39)</th>
<th>Accidental deaths (N = 52)</th>
<th>Undetermined MOD (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal firearm use</td>
<td>79%</td>
<td>15%</td>
<td>75%</td>
<td>33%</td>
</tr>
<tr>
<td>Illegal firearm use</td>
<td>21%</td>
<td>41%</td>
<td>25%</td>
<td>67%</td>
</tr>
<tr>
<td>Unknown</td>
<td>-</td>
<td>44%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Firearm use</th>
<th>Suicides</th>
<th>Solved homicides</th>
<th>Accidental deaths</th>
<th>Undetermined MOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal firearm use</td>
<td>N = 168</td>
<td>N = 6</td>
<td>N = 39</td>
<td>N = 1</td>
</tr>
<tr>
<td>Long-barrelled</td>
<td>86%</td>
<td>67%</td>
<td>97%</td>
<td>0%</td>
</tr>
<tr>
<td>firearms</td>
<td>14%</td>
<td>33%</td>
<td>3%</td>
<td>100%</td>
</tr>
<tr>
<td>Illegal firearm use</td>
<td>N = 45</td>
<td>N = 16</td>
<td>N = 13</td>
<td>N = 2</td>
</tr>
<tr>
<td>Long-barrelled</td>
<td>47%</td>
<td>13%</td>
<td>46%</td>
<td>50%</td>
</tr>
<tr>
<td>firearms</td>
<td>53%</td>
<td>87%</td>
<td>54%</td>
<td>50%</td>
</tr>
<tr>
<td>Short-barrelled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>firearms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MOD = manner of death

Accidental and undetermined MOD firearm deaths: Half (50%) of all 52 accidental deaths were self-inflicted. The mean age of the shooters was 47.1 years (median 49.5), and there was only one female shooter.

A total of 20 victims (39%) were drug or alcohol positive (Table 1, Paper IV). All drug concentrations categorised as toxic (N = 10) were related to alcohol. A quarter of the victims tested positive for licit drugs (Table 1, Paper IV). The share of illegal firearm users was significantly larger than legal firearm users among both alcohol positive victims (p = 0.045) and licit drug positive victims (p = 0.006) (unpublished results). Among legal firearm users, the share of alcohol negative victims was significantly larger than the share of alcohol positive victims (p < 0.001), while no such significant difference could be found among illegal firearm users (p = 0.8) (Paper IV). One victim had highly toxic concentrations of a central nervous system stimulant, and eight victims were positive for illicit drugs (mostly tetrahydrocannabinol).

Only 6% of all shooters involved in accidental deaths were found in the Patient Register. Due to the small number of cases found in the registers, no further analyses of diagnoses and prescriptions were performed.

All 3 cases with an undetermined MOD were self-inflicted and involved males with a mean age of 47 years (median 47). Two victims were drug and alcohol
negative. No analyses were made in the third case. None was found in the Patient Register or in the Prescribed Drug Register.

None of the shooters in accidental and undetermined MOD cases had previously been reported by a physician to the police.

**Firearm suicides:** There were 213 fatal firearm suicides, accounting for 9% of all suicide victims ≥ 20 years of age (there were no victims aged 18 or 19 years), and 13% of all male suicide victims ≥ 20 years of age [6]. There was a positive correlation between the number of firearm owners and both the number of all firearm suicides and the number of firearm suicides with legal firearm use in the 21 Swedish counties, all under the same firearm law (Table 2, Paper IV). There was no significant correlation between the number of firearm suicides and the number of physician reports to the police (Table 2, Paper IV).

The mean age of the victims was 60.6 years (median 62) and 97% were males. There were 5 cases of extended suicide (homicide followed by the perpetrator’s suicide), all shooters were men and had an association with the victim.

The lethal injury was in 85% of the deaths located in the head or neck, 15% to the chest and/or abdomen (unpublished results).

A total of 156 cases (73%) were drug and/or alcohol positive in blood or urine (Table 1, Paper IV). The share of illegal firearm users was not significantly larger than the share of legal firearm users in both alcohol positive victims (p = 0.458) and licit drug positive victims (p = 0.757) (unpublished results). Among both legal and illegal firearm users, the share of alcohol negative victims was significantly larger than the share of alcohol positive victims (p < 0.001 vs. p = 0.037). The most common finding (N = 100) was that the decedent had a non-toxic concentration of one or more drugs and/or alcohol. In cases with a drug concentration classified as toxic (N = 52), most were related to alcohol (N = 36), or to zopiclone (N = 4). Two cases had a highly toxic blood concentration of a drug (tramadol and nitrazepam, respectively).

The majority of the victims (67%) were not found in the Patient Register (Table 5). Approximately half (52%) of all suicide victims, who were found in both the Patient Register and the Prescribed Drug Register, had mental health issues (Table 5), which accounted for less than half (42%) of all suicide victims in the study material. Among all suicidees, the share that had a known mental disorder was significantly larger among illegal firearm users than among the legal firearm users (p = 0.005). Almost one-fifth of those with inpatient care died due to suicide within one week of the discharge (Table 5). Malignant disease was the second most common diagnosis (10%) after mental health issues. Malignant, neurological and circulatory system diseases were more common among
victims with legal than among those with illegal firearm use (Table 3, Paper IV). Victims with a previous suicide attempt, diagnosis of schizophrenia or dementia were rare. The most common psychoactive drugs prescribed to victims were antidepressants (Table 5). No firearm suicide victim had been reported according to the firearm law. Firearm license withdrawal, previous to the fatal outcome, occurred in 3 cases (unpublished results). The license was issued within one year before the suicide in 7 cases, all of them already possessing licences for other firearms (unpublished results).

**Firearm homicides:** There were 20 shooters in 23 solved firearm homicides. Two shooters killed two persons each, and in one case the shooter was unknown, but the accessory was convicted.

All shooters were males and eight victims (35%) were females. The mean age of the victims was 48 years (median 49) and of the shooters, it was 39 years (median 36). Multiple firearm injuries were found in 57% of the victims (unpublished results). In 43% the lethal injury was localised to the chest in combination with other injuries, in 35% to the head and in 22% to the chest only (unpublished results). A total of 15 victims (65%) were drug or alcohol positive (Table 1, Paper IV). One case had a *highly toxic* blood concentration of buprenorphine.
Table 5. Victims’ contacts with health care, diagnosis and prescribed drugs within the period of one year before the suicide. International Statistical Classification of Diseases and Related Health Problems, ICD9 and ICD10 (WHO, 2010) was used for subgrouping of diagnosis. N = number of cases.

<table>
<thead>
<tr>
<th>Firearm suicides</th>
<th>N/total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inpatient care and/or outpatient specialist care</td>
<td></td>
</tr>
<tr>
<td><strong>Yes</strong></td>
<td></td>
</tr>
<tr>
<td>N in the Prescribed Drug Register</td>
<td>70/213 (33%)</td>
</tr>
<tr>
<td>N in the Prescribed Drug Register</td>
<td>68/70 (97%)</td>
</tr>
<tr>
<td><strong>No</strong></td>
<td></td>
</tr>
<tr>
<td>N in the Prescribed Drug Register</td>
<td>143/213 (67%)</td>
</tr>
<tr>
<td>N in the Prescribed Drug Register</td>
<td>104/143 (73%)</td>
</tr>
<tr>
<td>One or more psychiatry visits</td>
<td>40/70 (57%)</td>
</tr>
<tr>
<td>Discharged within one week prior to the suicide</td>
<td>7/40 (18%)</td>
</tr>
</tbody>
</table>

(All types of inpatient care)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>N/total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F00-F99</strong> 2 Mental, behavioural and neurodevelopmental disorders</td>
<td>49/70 (70%)</td>
</tr>
<tr>
<td><strong>C00-D89</strong> Neoplasms and diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism</td>
<td>21/70 (30%)</td>
</tr>
<tr>
<td><strong>G00-G99</strong> Diseases of the nervous system</td>
<td>10/70 (14%)</td>
</tr>
<tr>
<td><strong>I00-I99</strong> Diseases of the circulatory system</td>
<td>18/70 (26%)</td>
</tr>
<tr>
<td><strong>X60-X84</strong> Intentional self-harm</td>
<td>33/70 (4%)</td>
</tr>
<tr>
<td><strong>Others in ICD9/ICD10</strong></td>
<td>28/70 (40%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prescribed drugs</th>
<th>N (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzodiazepines</td>
<td>46 (19)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>70 (30)</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>17 (4)</td>
</tr>
<tr>
<td>Opiates</td>
<td>59 (33)</td>
</tr>
<tr>
<td>Antiepileptics</td>
<td>18 (8)</td>
</tr>
<tr>
<td>Non-benzodiazepine hypnotics 6</td>
<td>64 (30)</td>
</tr>
<tr>
<td>Lithium</td>
<td>3 (0)</td>
</tr>
<tr>
<td>Dementia medication</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Medication against substance abuse</td>
<td>7 (5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F-diagnosis and contact for prescription of antidepressants, benzodiazepines and neuroleptics (without overlap)</th>
<th>N/total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of victims with inpatient care</strong></td>
<td>90/213 (42%)</td>
</tr>
</tbody>
</table>

| N/total in both registers (%) | 90/174 (52%) |

1. Number of victims with inpatient care
2. With the exception for diagnosis F50-F59, F70-F79 and F99, not found in the whole material of firearm deaths
3. In all three cases previous suicide attempt with poisoning
4. Number of victims with at least one prescription
5. The share not found in the Patient Register
6. Non-benzodiazepine hypnotics: zolpidem and zopiclone
DISCUSSION

Incidence and firearm legislation

This is the first study to undertake a longitudinal analysis of the time trends in accidental firearm fatalities and exploring possible effects of the legislative changes on these trends. The analysis revealed a decrease in the incidence of accidental firearm deaths over the past decades in Sweden (Paper I and III). The average annual number of hunting firearm deaths dropped from 3.6 deaths/year (1970-1982) [71] to 1.9 deaths/year (1983-2008) (Paper I). Non-hunting firearm deaths also decreased from 2.5 deaths/year (1970-1982) [65] to 1.4 non-hunting deaths/year (1983-2012) (Paper III).

A strict firearm legislation (“environmental factor” in Haddon’s matrix) is assumed to go hand in hand with a low incidence of accidental firearm deaths; thus the strengthening firearm legislation in Sweden has been expected to influence upon such deaths. A decrease in accidental firearm deaths was attributed to such changes in firearm legislation in the USA, Canada and Norway [67, 130, 131]. After the introduction of the hunter’s exam in Sweden in 1985, the annual risk and the risk ratio of being killed by an accidental hunting firearm injury (Paper I) and by a non-hunting firearm injury (Paper III) decreased significantly, compared to the period before 1985 [65, 71].

Furthermore, in non-hunting accidental deaths, a possible effect of the new legislation is supported by the significant decrease in the hunting firearms’ use in such fatalities after 1985 (Paper III).

Although all cases in Sweden were studied over a long time period, the number of accidental firearm deaths in the present thesis is small, and the results about the effect of the hunter’s exam must thus be interpreted with some caution. When the number of game taken was included into analysis, as an indirect measure of hunting intensity and risk exposition, the annual risk of being killed during hunting also decreased, with 5.1% before 1985 and 4.3% after 1985; this difference was, however, not statistically significant (Paper I). It must be mentioned, though, that the methods for reporting the number of harvested game has changed over the 26 years. The risk exposition is also higher during hunting than can be measured by the number of game taken. Due to the nature of hunting activity (target in movement and outdoor environment), the number of firearm shots not leading to a game taken is higher than the number of harvested game. In addition, the hunting intensity may be affected by, e.g. variations in the hunters’ activity (type and organisation of hunting activity, activity duration) and changes in the game population.
The very restrictive firearm legislation in Sweden, education/training and increased safety awareness associated with the hunter’s exam were, at least partially, responsible for the larger decline in fatalities after 1985 than during the period before. Among prevention strategies, education and enforcement together would have the most effect as active interventions [70, 154]. Introduction of the hunter’s exam represents such an intervention combination. Furthermore, injury fatalities are ranked first in the ranking order of outcomes to be used in the evaluation of an intervention in injury prevention [154]. If the effect of an intervention is not proven, it does not mean that there is no effect [154].

Accidental firearm deaths, the smallest share of all firearm deaths, challenge a determination of other contributing factors to decreasing trends, especially in the absence of other well-known active prevention efforts against firearm injury, as a reasonable explanation for the increased safety. Previous European research did not reveal effects of other factors (e.g. socioeconomic changes in society) upon accidental firearm deaths. The possible effect of the new firearm legislation in 1985 was previously also not evaluated in relation to firearm suicides and homicides. Interestingly, recent research of trends in intentional lethal firearm injury revealed no change during the period 1999-2012 [85], when a continuous decrease was still observed, both in hunting and non-hunting firearm deaths (Paper I and III). This may be related to differences in prevention efforts, but also in different background factors between unintentional and intentional firearm deaths, such as presence of intention or mental health issues in intentional deaths.

The requirements upon a new weapon owner in Sweden have also remained essentially the same during the period covered by the present (Paper I) and a previous investigation [71], with the exception of the introduction of the hunter’s exam in 1985. Besides increased safety through education and training, a logical effect of the new legislation would be a decrease in the number of firearm owners. Reliable longitudinal annual statistics and trend analyses about firearm owners in Sweden are, however, missing. It is not clear to what degree there is an overlap between licensed hunters and licensed target shooters (i.e. the number of individuals who own weapons for both activities). The statistics on the distribution between hunters and target shooters among all owners are namely missing, as official reports usually compare number of firearm licences between different years - not the number of firearm owners. The trends regarding owners are thus not available for analysis.

A continuous decrease over a longer time period after 1985 may be partly explained by a prolonged effect of such legislation until all hunters have passed the exam. Immediately after the legislation was introduced, new requirements affect all new licence applicants but also those who already had a license for a
hunting firearm, but applied for an additional hunting firearm. It is quite common for hunters to have more than one hunting firearm.

A declining incidence in accidental firearm deaths is, however, hardly affected by changes in hospitalisation policies. Firearm injuries are indisputably highly lethal [9, 10, 155], and the prehospital lethality of penetration firearm injuries is high [85], as found also in the present thesis (Paper I and III).

A possible contributing factor to the decline of accidental fatalities could be an increased quality and safety of the weapons during the study period. Although firearms ("agent" in Haddon’s matrix) from 1970’s still have a good quality and functionality, some technical improvements may have occurred in the past decades to make firearms safer. The share of hunting deaths due to defective weapons dropped from 21% (1970-1982) [71] to 6% (1983-2008) in Sweden (Paper I), while the share of defective weapons in non-hunting deaths was 6.3% (1970-1982) [65] and 7% (Paper III), respectively. However, a defective firearm was rarely reported as the “cause” of a hunting firearm incident (Paper II), or found to be a “cause” of lethal outcome in hunting or non-hunting deaths (Paper I and III), as previously reported [68, 71, 156]. When such a defective firearm was involved in a fatality, it was mostly old or homemade (Paper I and III). Since the quality of firearms improves continuously, defective firearms are expected to gradually decline in number.

Although the decline in incidence was larger after 1985, it is unclear which factors contributed to the observed decline in incidence already in the period 1970-1984. Firstly, it might have been related to the general decline of the accidental death rate in the 1970’s [157]. Secondly, the firearm legislation was strengthened in 1973 and 1974 with new regulations for, e.g. weapon storage (a weapon must be kept in a locked room of the residence) and reparation (only by firearm technicians), possibly affecting the availability for others and ensuring professional firearm reparations.

Thirdly, prevention work emphasising crime prevention and preventive social care intensified in the 1970’s in Sweden [158], which may have influenced general safety culture and the decline mentioned above.

Finally, among possible contributing social factors (Haddon’s matrix) is an alternation of the purpose of hunting, from providing food to a recreational activity. This shift started in Sweden already at the beginning of the 20th century, but accelerated in the 1970’s [51]. The dominant hunters’ motives to hunt in late 1970’s in Scania, Sweden, were reported to be recreation, a social and nature-close activity [51]. The alternation was followed by an increase in hunters’ understanding of ecology and hunting ethics as requirements,
expectations and norms were built up [24]. Normative safety climate may in turn influence safety achievement and injuries [159]. Moreover, the hunter’s exam from 1985 includes safety education and training, and thus may have even enhanced such safety climate and achievement in the late 1970’s, now reaching all new applicants of a hunting firearm license.

Most respondents of the study questionnaire (2009) had passed the hunter’s exam (Paper IV), as expected. Some respondents had, however, obtained their weapon license before 1985 and were consequently not compelled to pass this exam. Nevertheless, there is of course no guarantee of non-involvement in a hunting incident for those with hunting education; 30 percent of Swedish hunters who killed themselves or another hunter had previously passed the hunter’s exam (Paper I). Among hunters with non-fatal hunting firearm injuries in Wisconsin (USA), 25% had completed a hunting-safety course [79], while the corresponding share was 34% among hunters with tree-stand related injuries (including firearm injury) in Georgia (USA) [160]. Yet, there is no evidence showing how many hunters who had not completed a hunting safety course were involved in a firearm incident not leading to an injury. Hunter’s education should thus be evaluated in a larger scale regarding its preventive effect.

In this thesis, reported firearm incidents were not uncommon and obviously far more often non-fatal than fatal (Paper II). Accurate estimates of the actual number of firearm incidents through a questionnaire are, however, difficult to perform. An incident is sometimes witnessed by more than one person, and some of the incidents may have gone unreported. In the issue of firearm injuries, the basis (largest share) of the injury pyramid [59] could thus be epidemiologically modified and presented by all firearm incidents not leading to an injury, rather than unreported firearm injuries as the concept implies.

In addition, very few individuals reported they had caused a firearm incident, thus lowering the possibility of finding any associations with sex, age or number of hunting years (Paper II). The few reports about hunters’ own firearm incidents may also indicate a sensitive questionnaire item, risking non-response or false response. However, reporting a firearm incident caused by another hunter was positively associated with longer hunting experience and greater hunting activity, which is a logical and expected finding (Paper II).

Although the number of active hunters differs between Swedish counties [47], the habitat and the availability of the hunting area vary as well. Hunters are also mobile when they hunt (unpublished results, Paper II) and may pass the county border, similar to hunters travelling from other countries to Sweden. Furthermore, hunting activity is related not only to each hunter’s (“host” in Haddon’s matrix) activity, but may also reflect differences in game population, hunting organisation or climate conditions (“environmental and social factors”
in Haddon’s matrix). A single hunter’s activity has in turn been related to several factors, such as age, socioeconomic status, education and training, living in an urban versus a rural setting, hunting motives and hunting habits [51]. Due to this diversity of factors affecting hunting activity and disproportion between the magnitude of hunting activities and small annual number of accidental hunting deaths, the geographical distribution of such fatalities was not explored in this thesis. In addition, firearm legislation as hunter’s exam requirements are the same in the whole country, and the aspect of illegal firearm use was not relevant for hunting fatalities (Paper I). The number of non-hunting deaths was also too small for further analysis of the geographical distribution.

Demographics

In line with previous studies [71, 156], most victims in hunting firearm accidents were between 40 and 50 years old (Paper I), with a mean age well above the mean age of those involved in non-hunting accidents (Paper III) and in a previous Swedish study [65]. The hunting study questionnaire included adults only, and both the mean age of the respondents and the proportion of female respondents were representative of the SAHWM adult members in 2009 (Paper II).

In agreement with another publication [55], most shooters and victims of firearm suicides and homicides were males (Paper IV) – as are most firearm owners [161]. Furthermore, females were more likely to be the victim of a solved firearm homicide (35%) (Paper IV), than of a firearm suicide (3%) (Paper IV) or a firearm accident (4%-12%) (Paper I and III). The low female involvement in accidental firearm deaths (Paper I and III) was also observed previously [42, 58, 65, 71, 73-76, 78].

Circumstances

The seasonal variation of hunting deaths was expected and the incidence was highest during the autumn [58, 71, 74-76, 156, 162], while the temporal distribution of non-hunting accidents differed from that in a previous Swedish study [65], yet without any obvious pattern.

Among both self-inflicted and two-party accidental fatalities, the proportion of self-inflicted hunting deaths, 40% (Paper I), was similar to the 42% in non-hunting accidents (Paper III) and 41% in a previous investigation of non-hunting deaths [65]. Although other studies did not distinguish between hunting and non-hunting accidents, the proportion of self-inflicted non-hunting fatalities
in the present thesis was slightly lower than the 50% found in Denmark [42] and the 52% in Miami-Dade County, USA [73], but much higher than the 9% in Germany [68].

The relationship between a shooter and the victim in two-party accidents has not been investigated previously in Sweden. Relatives constituted 25% of all two-party non-hunting shooters (Paper III), similar to the 21% found in hunting two-party accidental deaths (Paper I), in spite of very different circumstances and the family nature of hunting activities [68, 73]. In addition, one-third of the hunting questionnaire respondents sometimes hunted with underage companions.

As revealed in previous Swedish studies [65, 71], the majority of all accidental firearm deaths were due to human error (Paper I and III). Unsafe firearm handling was dominant in small game hunting (Paper I), in non-hunting firearm deaths (Paper III), and was also reported by questionnaire respondents in all incidents involving injured humans (Paper II). Improper and unsafe weapon handling was also previously found to be the most common factor in hunting deaths in Sweden [71], in North Carolina [58], and in Germany [156], as well as in non-hunting deaths in Sweden [65] and elsewhere [68, 73-75], and in non-fatal accidental firearm injuries [58, 156]. However, the circumstances differed between hunting and non-hunting deaths.

In hunting deaths, the most common factor during moose hunting was that the victim was mistaken for game (Paper I), still the predominant “explanation” for these deaths [71, 72, 76, 163]. Falls accounted for a high percentage of firearm hunting fatalities in both the present (Paper I) and a previous Swedish material [71]. The respondent’s reported case of a hunter being killed was related to slipping with a loaded weapon (Paper II). In Georgia (USA), injuries due to accidental falls from tree stands was a common mechanism of hunting-related deaths, regardless of firearm discharge [160, 164]. Non-hunters as victims in hunting fatalities (Paper I) was a new finding [cf 71], and circumstances in these deaths were characterised by a rather short shooting distance, restricted visibility due to undergrowth and hazy or rainy weather in at least one case. Bad visibility was pointed out as a contributing factor also previously [58, 156]. Understandably, hunting occurs mostly in rural areas, sometimes in thick vegetation (environmental factor in Haddon’s matrix), far from a hospital and difficult to approach for a rescue team. Such conditions may be a factor contributing to the high prehospital lethality in hunting firearm injury incidents.

In non-hunting deaths, the majority of the underage victims were killed in two-party accidents and occurred during “play.” Firearm availability at home has shown to be a risk factor for both suicide and accidental death among children, compared with homes without guns [74, 118]. In the USA, the incidence of
accidental firearm deaths is higher in states where guns are stored loaded and unlocked, than in states where guns are stored loaded but locked [119]. Sweden’s strict storage regulations limit children’s access to firearms and ammunition, hence protecting underage individuals from firearm injury [165]. Legal storage of firearms and ammunition in safety lockers was reported by most responders (Paper II), but an owner of an illegal firearm (Paper III) cannot be expected to follow storage regulations, hence why it is important to target also the availability of illegal weapons.

The incidence of accidental fatalities in a military setting has not changed much since a previous Swedish study [65], and no such case was recorded after 2008. Military service was, however, not mandatory in the period 2010-2017, thus why only a few deaths during military training would be expected during this period. A long-term effect of this may, however, be that the number firearm accidents and fatalities increases, due to the lack of basic knowledge about weapon handling among people without mandatory military training.

In spite of classification issues, Russian roulette was described in other studies concerning accidental firearm deaths [73], and was the contributing cause in one death in both the present (Paper III) and a previous Swedish study [65]. As in the present study (Paper III) urban environment, mental health treatment, and a high blood alcohol level were attributed to deaths due to Russian roulette [110].

Cases of undetermined MOD were rare among firearm fatalities studied in the present thesis (Paper IV). In a study of suicide and undetermined MOD cases in northern Sweden, no firearm related death was found in the group of undetermined MOD (September 1983-December 1985). The authors concluded that the uncertainty in MOD classification is higher in cases of poisoning compared to other causes of death [95].

### Injuries and firearms

Determination of the shooting distance and investigation of injury ballistics are important parts of a medico-legal investigation of a firearm death. Shooting distance showed a broader range in hunting than in non-hunting deaths, which may be explained by the character of the hunting activity. The majority of the victims in both types of accidents were, however, killed at a distance less than 5m and in self-inflicted deaths at less than 1m (Paper I and III).

In most of the hunting-related accidental deaths, the fatal injury was located to the chest and/or abdomen (Paper I), and in non-hunting to the head (Paper III), confirming findings in previous studies [65, 68, 71, 73, 75]. Similar to findings in non-hunting deaths (Paper III), none of the two-party accidental deaths
involved contact injury, and less than 10% of two-party accidents in North Carolina, USA, involved close-range injuries [75]. Contact injury was uncommon in self-inflicted accidental fatalities (Paper III). Such injuries must be meticulously investigated in order to exclude the possibility of homicide or suicide. As in previous studies [43, 68, 166, 167], the dominant lethal injury location in suicide victims was the head, and around half of homicide cases had multiple injuries (unpublished results).

Legitimacy of firearms used in firearm deaths has, in general, been rarely studied in the past. The findings in this thesis represent an important contribution to the existing knowledge on the subject. Legal firearms predominated in accidental deaths and suicides (Paper IV), and illegal firearms in homicides in eastern Sweden [43], as in the whole country (Paper IV). An additional finding of the difference between hunting/non-hunting deaths regarding legal versus illegal firearm use confirms the importance of separating each subtype of accidental death. No illegal weapons or handguns were used in hunting deaths (Paper I), in contrast to 37% of non-hunting deaths (Paper III).

However, it is not known whether the presence of illegal firearms in accidental non-hunting firearm deaths has changed since the 1970’s as there were no data of legal versus illegal firearms in the previous Swedish study [65].

Contrary to previous Italian [168] and German [68] studies, suicides were mostly carried out with long-barrelled firearms (Paper IV) [cf 43, 166]. Short-barrelled firearms were mostly used in homicides (Paper IV) [166, 168]. The variation of long- and short-barrelled firearms’ involvement between countries may be related to the environmental factors, such as legislation.

Alcohol and drugs

The proportion of alcohol positive victims in non-hunting deaths (27% of all tested) (Paper III) did not differ much from a previous Swedish study (33%) [65], and was higher than the 11% found in hunting firearm fatalities in Sweden (Paper I). A low percentage of victims in hunting firearm deaths influenced by alcohol was found also in the previous Swedish study [71], as well as in accidental fatal and non-fatal hunting-related injuries in North Carolina [58], in a study of non-fatal hunting-related injuries in Wisconsin [79] and in Ohio [164], as well as in a study of natural deaths during hunting in Sweden [169]. Only a small proportion (1%) of the respondents reported alcohol use while hunting as well (Paper II). Alcohol was, however, involved in 2.3-21% of falls from tree stands according to three studies from the USA [164, 170, 171].
Remarkably, information on the sobriety of the shooters in two-party hunting accidents was not available in the police reports, and there were also no remarks that the shooter was suspected of being under the influence of alcohol (Paper I). In four two-party non-hunting accidental deaths it was, however, noted that the shooter was “drunk”.

Notably, illicit drugs were not detected in any of tested victims in hunting accidents (Paper I). In contrast, illicit drugs were found in victims of non-hunting deaths, more commonly among illegal than among legal firearm users (Paper III). The toxicological findings in the present thesis thus strengthened the evidence of the different circumstances in hunting versus non-hunting accidental fatalities.

**Risk factors**

Males were more often than females victims in firearm deaths in the present thesis, as is the case globally [55]. Adult victims were more often represented in all firearm deaths compared to underaged victims, and were older in hunting accidental deaths and suicides than in non-hunting accidental deaths and homicides (see Demographics).

Although the risk for relatives or friends to become a victim of a firearm homicide and of a two-party accidental fatality was not investigated, the proportion of such a relationship among all two-party accidental fatalities was not negligible (Paper I and III).

Among respondents, most risk factors concerning health and multiple risk factors were rarely present in the same individual (Paper II). Hence, it is not surprising that young hunters were less likely than middle-aged and elderly hunters to report risk factors. This finding strengthens the internal validity of the study (Paper II). The vast majority of the respondents also reported that they were healthy. However, 10% reported they had hypertension, an important risk factor for cardiovascular events [172] such as myocardial infarction, the most common cause of death during hunting (much more common than fatal firearm injury) [169].

The possible association between mental illness and violence is very complex. Both individual factors (e.g. substance/alcohol abuse and male sex) and social/environmental factors (e.g. availability of means) are some of the risk factors for both suicide and homicide [102]. In Sweden, psychiatric patients pose a high risk to be subjected to violence, while their base rate of violent behaviour towards others is relatively low [173]. Mental illness as a single
factor does not strongly predict the risk of firearm violence [106], but the association with suicide is strong [102]. In the present thesis, 19% of all suicide victims had at least one psychiatry visit within one year prior to their suicide (Paper IV), compared to a third of the suicide victims (all means), presented in an international review of 40 studies from the period in the 1960s-1990s [174]. In 2007, 40% of all suicide victims in Sweden had a contact with the inpatient care and specialised outpatient care within one month before the suicide [175], compared to 15% among all firearm suicide victims (Paper IV). Due to the study design using the Patient Register, besides contacts for prescriptions, visits within primary care could not be included in the present thesis. The number of patients with health care contacts prior to their suicide is, thus, probably underestimated.

Remarkably, registered previous suicide attempts were rare among suicide victims (Paper IV). When compared with suicide victims using other means, a history of prior suicide attempt was less common among firearm suicide victims [176], indicating that firearm suicide victims may differ from suicide victims in general. Possible differences between firearm suicides and suicides with other means should be clarified in the future, since this may affect specific prevention strategies.

Mental health problems and toxicological findings of illicit drugs were more common among suicide victims with illegal firearm use than among those with legal firearm use (Paper IV). In contrast, malignant disease, dementia, and treatment with opiates were more common in victims with legal firearm use (Paper IV). Although not analysed in firearm suicides specifically, but in overall suicides, other conditions may also bring an increased suicide risk, e.g. malignant disease [103], dementia [104], and chronic pain [105].

The finding that the county incidence of firearm suicides correlated significantly with the number of firearm owners was a new finding since all Swedish counties were included in the calculation [cf 177]. Firearm ownership and availability have been strongly associated with the risk of firearm suicide [112] and homicide [112, 114-116]. According to a Swedish study on unnatural deaths among teenagers, 26 firearm suicides among teenagers were observed [178], indicating possible preventive effects of restricting the availability of firearms to non-owners. In the European setting, knowledge is, however, lacking about whose firearm underage persons (< 18 years) used in their own suicide, if it was licensed to, e.g. a parent, or illegally possessed by the teenager or a relative/friend.

In addition, the majority of homicide-suicides in Sweden [179], Switzerland [180], Netherlands [181] and Finland [182] involved firearms. The offender in homicide-suicide was typically a male, having a relationship with a victim [179-
182], as found also in the present study (Paper IV). Several studies suggested that restriction of firearm availability may prevent homicide-suicide deaths [180-183].

One third of the 12 underage victims in non-hunting deaths were killed with an illegal firearm (Paper III), and storage regulations are difficult to relate to such cases. In comparison, no fatal accidental firearm injuries among children (0-14 years) at home were reported during a 3-year period in 16 European countries [184]. The discrepancy between these two studies may be partly explained by differences in study periods and that we included also fatalities outside of the home. Underage shooters (N = 8) in two-party accidents (Paper III) were not reported in previous Swedish studies; in general, shooters were rarely studied in accidental firearm deaths, apart from in a recent study from the USA [69]. The annual number of children killed in firearm accidents in Sweden is, however, low (Paper III) and, compared to the US setting, possibly related to storage regulations. Unsafe gun storage was associated with fatal firearm accidents in all age groups in the USA [119].

Information on the origin of illegal firearms in suicides included in this thesis was lacking. Consequently, it is unknown if some firearms were taken/stolen from a family member or a friend due to unsafe storage, or traded on the black market.

**Risk behaviour**

When respondents of the hunting questionnaire were asked about both safety and risk behaviour, multiple risk behaviours per respondent were rare (Paper II). One such risk behaviour is not using signal colour clothing. Signal colours decrease the risk of being “mistaken for game”, common in moose hunting firearm fatalities in Sweden (Paper I) [71]. Such clothing helps to discriminate a hunter from game [72] and was used by almost all respondents (Paper II). Wearing signal colours is not mandatory by law in Sweden but Swedish moose hunters have used signal colours for decades, which may have contributed to a low overall incidence of hunting firearm fatalities (Paper I). Importantly, the introduction of the “Orange hunting law” in North Carolina, USA, requiring hunters to wear an article of bright orange clothing while hunting, significantly reduced firearm-related hunting fatalities [163].

Young age and male sex was positively associated with risk behaviour (Paper II), which is interesting since some previous studies found that young hunters were more frequently involved in both fatal and non-fatal firearm hunting accidents [42, 58, 60, 70, 76], although other studies showed the opposite [68].
In Sweden, young hunters were not often involved in hunting firearm fatalities in 1970-2008 (Paper I) [71], but we do not know if they were affected more often by non-lethal firearm injuries. In some countries (e.g. USA) hunters may be younger than in Sweden, which may be due to differences in firearm regulation.

The results may also be interpreted in light of Reason model of human error [16], explaining that the combination of latent conditions (e.g. lack of experience/deficient training) and active failure (improper firearm handling) makes damage to several barriers and may lead to a loss. Thus, it is possible that, besides the risk behaviour and unsafe act, several conditions at the same time are needed for causing an injury. One single risk behaviour may also be corrected/neutralised by other hunters or family members or previous negative own/others experience, not leading to a final loss.

Performing some activities (e.g. driving a vehicle) while inebriated is a well-known risk behaviour. Research has shown that, even when situational and other risk factors were considered, acute alcohol consumption significantly increased the risk of injury [109]. In Sweden, alcohol was more commonly involved in deaths of males than of females and among intentional deaths than in unintentional deaths [185].

A meta-analysis of peer-reviewed studies from different parts of the world shed light on notable knowledge gaps regarding the issue of alcohol as a risk factor in firearm deaths [186]. The analyses showed, however, a higher risk of being a victim of firearm injury after drinking, especially for heavy alcohol users and among victims of self-inflicted and suicide firearm injury. Additionally, a significant association was reported between alcohol use and the firearms’ ownership on the one hand, and the use of a firearm as a suicide means on the other. The authors suggested more intervention studies and randomised controlled trials on this issue [186].

Toxicological findings in victims of hunting firearm fatalities (Paper I) [71] and in victims of natural deaths during hunting [169], as the respondents’ reporting of alcohol use during hunting (Paper II), indicate that alcohol use during hunting may be an uncommon risk factor during hunting in general. In contrast, toxicological findings in victims of non-hunting accidents (Paper III), suggest that owners of illegal weapons exhibit a risk-taking behaviour, such as handling firearms under the influence of alcohol and/or illicit drugs.

Additionally, suicide victims had the highest mean blood alcohol concentration (BAC) (Paper IV), but the share of alcohol positive suicide victims was lower than in a previous Swedish study of suicide victims’ blood alcohol concentration in relation to victims’ demographics [187].
In spite of the high overall homicide clearance rate in Sweden (~85%), firearms are negatively associated with clearance status [93]. Only 59% of all firearm homicides in 2012-2013 were solved (Paper IV). Risk behaviours among offenders in solved firearm homicides were not investigated in the present thesis. However, the majority of solved homicides involved illegal firearm use, which is an inherent risk behaviour (Paper IV).

Although studies on the risk behaviour of illegal firearm users are lacking in Sweden, two studies from Michigan (USA) explored this issue among assault-injured youths (14-24 years) treated at an emergency department. This particular group had high rates of firearm possession, especially of illegal firearms [188]. In addition, the risk of involvement with firearm violence increased among youths with severe substance use, in combination with firearm access and positive attitudes towards retaliation [189].

**Physician reporting**

Although half the number of suicide victims had health care contacts due to mental health issues within one year before the suicide, no single suicide victim (or shooter in a two-party accidental death) had been reported to the police by his/her physician. This finding may be remarkable but is not unexpected when physician reporting frequency and accuracy is taken into a consideration. In only 16% (162/1040) of all patients reported by physicians (including also those without a licence), and in 51% (162/317) of all reported patients actually having a firearm licence, the licence was finally recalled [127]. This small share of license recalls was explained partly by the following: physicians’ reassessment, finding the patient not unsuitable to possess a firearm, ongoing appeal, and patients’ disposal of the firearm before the license was recalled [127].

The reasons for not reporting patients to the police were: physician’s conflict between the clinical task and the community task, ambiguity about what “unsuitable of possessing a firearm” means, and administrative deficits [190]. The lack of training of health professionals about the implication and enforcement of the firearm law, and the lack of feedback from the police were also mentioned in the report [190].

Underreporting may also be related to the dynamics of a patient’s condition; a worsening phase may pass undetected. All patients do not meet a physician, but other health professionals as well. Furthermore, identification of risk individuals is difficult as the mentally ill form a very heterogeneous group. Abuse and many other diseases are not always diagnosed. A patient may be dishonest
about his/her health problems, or avoid health care due to the stigma of mental illness.

Along with an even lower physician reporting before 2012 [41, 127], the number of intentional firearm deaths was relatively stable in the period 1999-2012 [85]. The association between physician reporting and firearm suicides before 2012 is thus expected to be similar to the results of the present thesis.

**Prevention**

A variety of strategies and interventions may prevent firearm injuries and deaths, and they vary between those for intentional (suicidal and homicidal) versus unintentional (accidental) injuries [102]. There is, however, evidence of some common approaches in the prevention of all firearm injuries, e.g. limiting the availability of such weapons [78, 128, 129]. According to safety research, fields of intentional and unintentional injury prevention should be more integrated [191], and risk factors in both types of intentional actions are relevant for intervention [191]. Diversity of both risk factors and risk behaviours involved in firearm deaths may require multidisciplinary interventions.

This thesis highlights factors in the pre-event and event phase of injury, related to all three components of the Haddon’s matrix (agent, host and environment). Due to the high pre-hospital lethality of firearm injury, the pre-event stage, involving the primary prevention, is of particular importance.

**Unintentional firearm deaths**

The low incidence of accidental firearm fatalities (Papers I and III) may be challenging in future prevention efforts. In addition, the puzzle misses a piece about non-fatal firearm injuries for evidence cumulation, as the basis for development of future strategies.

Factors that may affect injury process according to Haddon’s matrix are presented in Table 4 [19, 154, 192-194]. Such factors are considered to be adjustable or influencable by adequate measures. Modification of the matrix in Table 4 also highlights behavioural factors that may affect injury process [18], following general prevention strategies previously presented in the Background chapter [17].
**Table 4.** Haddon’s matrix, modified for the prevention issue of unintentional firearm injury.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Host</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Firearm</strong></td>
<td><strong>Human</strong></td>
<td><strong>Physical and social</strong></td>
</tr>
<tr>
<td>Type of firearm and ammunition&lt;sup&gt;a&lt;/sup&gt;[192,193],b</td>
<td>Male sex&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Weather and terrain&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Technical condition&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Age, children and adults&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Firearm ownership regulation&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Child protection and/or other safety devices&lt;sup&gt;a&lt;/sup&gt;[193]</td>
<td>Health&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Storage regulation&lt;sup&gt;a&lt;/sup&gt;[193]</td>
</tr>
<tr>
<td>Availability (storage)&lt;sup&gt;a&lt;/sup&gt;[193]</td>
<td>Task related education&lt;sup&gt;a&lt;/sup&gt;,&lt;sup&gt;b&lt;/sup&gt;[19,192],&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Enforcement and penalties of the legislation&lt;sup&gt;c&lt;/sup&gt;[154]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pre-event</strong></th>
<th><strong>Event</strong></th>
<th><strong>Post-event</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Type of firearm and ammunition&lt;sup&gt;a&lt;/sup&gt;[193]</strong></td>
<td><strong>Age&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Health&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Severity of the injury&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Access to rescue team&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Age&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td><strong>Education and equipment for first aid&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Health&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td><strong>Phone, radio&lt;sup&lt;c,194&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Accompanied vs. alone&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td><strong>Rapid rescue&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Alcohol and drugs&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td><strong>Rehabilitation services and counselling&lt;sup&gt;a&lt;/sup&gt;[192],&lt;sup&gt;c&lt;/sup&gt;[194]</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Exposure of the vital organs&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> factors relevant in accidental firearm injury [19, 192, 193]

<sup>b</sup> factors studied in this thesis (Paper I-IV)

<sup>c</sup> factors applicable to injuries in general [154, 194]

Haddon’s passive strategies, also included in general prevention strategies [17], would involve technical improvements of the agent (e.g. the weapon’s safety mechanism) and anti-ballistic devices for the host protection (e.g. bulletproof clothing). On the other side, active strategies would involve individuals performing safety actions [14] (e.g. signal clothing in hunters).
In addition, some of Haddon’s 10 prevention strategies [15] are applicable on the issue of accidental firearm injury and death. In the pre-event phase, primary prevention would include a control of firearm/ammunition manufacturing, ownership, storage and illicit trafficking, and limiting firearm/ammunition’s lethality. In the event phase, the strategy would include physical protection from injury, while in the post-event period, providing a rapid treatment and rehabilitation of the host are important at tertiary prevention stage.

**Agent:** Development and manufacturing of the agent with new technologies, such as 3D firearm printing, will be challenging for the authorities to trace and detect [195].

**Host:** Among factors related to the host, transporting loaded and sometimes unsafetied firearms is a risk situation (Paper I) and incidents before and after hunting should not be neglected in prevention efforts. Falls commonly preceded fatal firearm injury in hunters (Paper I), hence falls in outdoor situations should be emphasised in the prevention work.

Safety behaviour, e.g. wearing signal colour clothing while hunting was discussed as an important preventive measure since it increases visibility [58]. It is relevant for hunting deaths in Sweden due to the dominance of the “mistaken for game” situation in moose hunting (Paper I). Although not mandatory by law in Sweden, there is evidence of its benefits in the USA [70, 163].

Prevention efforts should focus on the safe handling of firearms; the conclusion supported by the results of the present thesis (Papers I, II and III). Training and continuous educational models are conceivable methods, as well as supervision of young novice hunters [70]. The fact that adults also play with firearms (Paper III) suggests that further education about firearm safety is necessary, but for obvious reasons, this does not fully affect persons using illegal firearms or those who are under the influence of drugs. Safety in target shooting situations should also be illuminated. In addition, one fifth of accidental non-hunting fatalities occurred in a military setting. Mandatory military training has been reintroduced recently, why safe firearm handling has to be especially highlighted during such training.

The presence of alcohol and illicit drugs in victims of non-hunting deaths (Paper III), especially those who died of self-inflicted injury and/or used illegal firearms, identifies a group with risk behaviour among the victims. It also confirms the allied nature of these two risk-taking behaviours. Both the availability of alcohol and firearms should be targeted by policies in public health [186]. Sweden’s politics of alcohol has a century long intensive history [196] and in the period 2007-2016, alcohol consumption has decreased by 8% in the general population [197]. The Swedish Transport Administration also
recommends not driving a vehicle the day after excessive alcohol consumption, since driving ability can be reduced by up to 20% [198] even if blood alcohol is negative. Similar advice could be applicable to, e.g. hunting the day after excessive alcohol intake.

In addition, only 6% of the shooters in accidental fatal incidents had previous contact with inpatient care and outpatient specialist care, which suggests that physician’s reporting obligation according to the firearm law probably have only a very limited effect upon this subgroup of firearm deaths.

**Environmental factors:** Prevention strategies affecting *environmental* factors of the firearms’ availability have been introduced in Sweden already, such as strengthening the firearm legislation. Although it is a challenging research task, the evaluation of the stricter firearm law through the incidence of accidental firearm deaths revealed a significant decrease of such deaths in the period after the new law was introduced (Paper I and III). Small numbers of accidental firearm deaths may also be more sensitive to a specific intervention due to their unintentional nature and due to well defined and known target population (licensed owners). With emphasis on intention and the presence of illegal firearm use, prevention of intentional firearm deaths may need additional changes in both firearm legislation (e.g. physicians’ reporting obligation) and in other prevention strategies.

In further primary prevention work, compliance with the storage restrictions is important for the protection of non-owners from firearm injury and death. Firearms should not be available to children [68], an aspect important also in the future.

The public health model recommendation of intervention, preceded by problem monitoring and identification of risk factors [20], are relevant to the firearm injury prevention. An evaluation of the effectiveness should also follow new interventions.

**Intentional firearm deaths**

General population strategies in suicide prevention are numerous and include action on alcohol, drugs, physical illness and disability, and controlling access to means of suicide [199]. Physicians’ education about depression and lethal means restriction was evidently effective in suicide prevention according to an international systematic review [200]. The Swedish national action program for suicide prevention in 2008 embedded the strategy of availability restriction of the lethal means in the program [201]. Furthermore, restriction of a single means does not necessarily mean that the individual will choose another suicide method [202].
In the present thesis, physicians’ reporting obligation has been evaluated through the victims of firearm deaths (Paper IV). The reporting obligation aims to counteract “misuse, accidents and criminal activity involving legal firearms” [203]. The results (Paper IV) indicate that this part of the firearm legislation falls short of its aim to prevent firearm suicides. However, it is unknown if someone, whose licence was recalled according to the report in 2013 [127], switched the planned suicide method or died from using an illegal firearm instead. Hence, the number of saved lives through the current reporting is difficult to conclude, but Sweden’s zero vision for suicide [204] means that potentially ~100 lives lost in firearm suicides annually could be saved. The issue of firearm suicides calls for improvement of prevention strategies.

Legal firearm use brings other kinds of challenges in prevention, as compared to illegal. A detailed recommendation for mandatory assessment of licence applicants has been rarely presented in previous research. According to an Australian study, such recommendations may be comprised of those for both risk (physical, psychiatric, cognitive, behavioural, personality factors and addiction) and capacity assessment (e.g. patient’s understanding his/her own responsibility if risk factors are present) [205]. Mandatory assessment of licence applicants and reassessments of licence holders on a regular basis by trained health workers would of course burden the healthcare system. The major challenge is, however, to detect and evaluate the risk, as such risk is yet far from clearly defined in relation to legal firearm possession. In spite of detailed recommendations for driver’s licence assessment, the physician’s obligation to report patients unsuitable for a driver’s licence is also suboptimal [206].

Moreover, an observed increase in life expectancy, globally [207] as well as in Sweden, has brought an increase in the number of people with dementia [208], confirmed by, e.g. an increasing dementia mortality [92]. The issue of cognitive impairment challenges existing firearm legislation as it represents only one part of the injury prevention.

Similar to the issue of suicides, among numerous prevention strategies, the firearm availability and risk behaviours (alcohol and drugs) should be targeted in the future prevention of firearm homicides. There is strong evidence of a positive association between alcohol and both firearm suicide and homicide [186]. In Sweden, the number of homicides related to alcohol has decreased since the 1990s, partly due to changes in alcohol consumption patterns [8]. A decrease in the involvement of legal firearms in homicides and a reduction of alcohol related homicides in interpersonal close relationships were suspected to be related to each other. The legal firearms were, namely, mostly used in this specific homicide subgroup, in contrast to the involvement of illegal firearms in homicides among gangs and organised crime groups [8].
As legal firearm use was uncommon among solved firearm homicides (Paper IV), physician reporting, even if fully enforced, would hardly bring a significant reduction in the number of firearm homicides. There is also a suspicion that illegal firearm use is involved in most of the unsolved firearm homicides as well. Among different circumstances of both solved and unsolved firearm homicides, the share related to criminal conflicts, with predominance of illegal firearm use, increased from 18% in 1990-1995 to 48% in 2008-2013 [8]. Consequently, the issue of illegal firearm use has come into focus of the Swedish authorities in recent years. Besides increased penalties for illegal firearm possession, several ongoing measures against illegal firearms have been reported. The uniform national statistics over crimes involving firearms, such as crime outcomes (e.g. death), and their connection to criminal conflicts and to public places is also going to be established. To assure uniform and reliable statistics of firearm confiscation, effective methods will be developed in prevention of illegal firearm use and in tracking the origin of illegal firearms [209].
Strengths and limitations

Observational studies are important in research of possible benefits of interventions and of rare outcomes, and guidelines were presented for accurate reporting in such studies [210]. These guidelines, also called Reporting of Observational Studies in Epidemiology or STROBE, were followed in the papers of this thesis (Paper I, III and IV).

When trends in firearm deaths were studied, longitudinal data, accurate data sources and re-examining official statistics have been crucial sources for such studies [211]. The use of nationwide register data and longitudinal studies thus represents a strength of this thesis. Retrospective register studies about accidental firearm fatalities (Paper I, III and IV), firearm suicides, firearm deaths with undetermined MOD and solved firearm homicides (Paper IV) included all cases during the study periods.

Since all firearm fatalities, as unnatural deaths, should have undergone a medico-legal autopsy according to law [212], there should be no missed cases. Yet, there may be some firearm deaths among missing people.

A quasiexperimental study model of single time series design (Papers I and III), also evaluating intervention in injury prevention, avoids the disadvantage of short-term studies close to the introduction of the intervention (e.g. a random variation in a single year) [154]. A longitudinal trend of all accidental firearm deaths in Sweden was investigated in 39 (Paper I) and 43 (Paper III) year periods for larger sample size, avoiding the type II error.

In addition, there are no testing effects (providing knowledge by test itself, as in surveys) or selection effects (as in intervention and comparison group) in this thesis [154]. However, there may be some history effects. These are going on at the same time as an intervention, although not being directly related to the intervention. Such history effects may affect prevention, e.g. news about the intervention issue or repeated notifications from public service [154]. Descriptive studies are useful in trend analysis and surveillance, but indeterminate temporal relationships between cause and effect can disadvantage such a study design [213]. This explains why causal relationship between hunter’s exam and fatality trend cannot be strongly stated.

As an additional strength of this thesis, multiple sources were used when circumstances, cause and manner of death were charted around each victim/shooter, such as police reports, witness statements, deaths certificates, autopsy reports including toxicological data (Papers I, III and IV) and the Firearm Register (Paper IV). When the shooter’s health care contacts were studied, two national registers (the Patient Register and the Prescribed Drug
Register) were used to cover as much as possible of such registered contacts (Paper IV).

Studying firearm fatalities through hospital records would miss cases of prehospital deaths that never reached the hospital, but were transported directly to the morgue. In addition, when statistics and trend analysis are based exclusively upon ICD codes based on death certificates, and not on autopsy reports, there is a risk of erroneous estimations of study cases. This is due to the unavoidable incorrect classification of some cases and the impossibility to reevaluate cases classified as undetermined MOD. Furthermore, some of the fatal injury events may not be specifically classified as hunting/non-hunting.

Although the validity of the autopsy reports is increased by complementary analysis (e.g. toxicological, histopathological, genetical, and anthropological analyses) the classification issues may differ in between individual forensic pathologists. It is also possible that some cases were not reclassified by the manner of death after completion of the police investigation.

Thus, one strength of this thesis is that all cases were reevaluated by an experienced forensic pathologist. This approach was especially important when the number of cases is small, since small changes in numbers may have a high effect on the final statistics.

Due to the development of the Patient Register over the years, data consistency varied. This limited the analyses of firearm accidents but not the analyses of suicides and homicides, which were only studied in recent years (Paper IV). However, most of the accidental fatalities involved legal firearm use and registered health issues in such victims were rare. Consequently, there was no reason for physician reporting to the police in these cases. In addition, data about mental health issues in the study material may be somewhat underestimated. If victims were treated by other means than medications, and/or by other health workers than physicians, data are probably missing in the registers.

Toxicological analyses were performed in a high percentage of the study cases (Papers I, III and IV). Toxicological reports are highly reliable since they are based on analyses performed at the Department of Forensic Toxicology, Linköping, accredited according to international standards [214].

Cross-sectional, descriptive studies give us an instantaneous picture of the population in specific time and may generate a hypothesis [213]. However, the hunter’s questionnaire study (Paper II) exhibited several challenging issues. Firstly, there was no previously published and validated questionnaire about safety issues that could be used in the present thesis. Secondly, some items were
potentially sensitive (e.g. self-reported personal compliance with legislation, causing a firearm incident, alcohol intake), which is why it was important to offer anonymity to all respondents. Sensitive questions might be the subject of bias and are suspected of causing problems to survey outcomes, lowering overall and item response rates and reducing accuracy [215, 216]. The anonymity, consequently, prohibited information about non-respondents. Against this background, the response rate of almost 50% must be considered satisfactory. In addition, there are very few studies for adequate comparison of response rates; in a survey of Danish hunters, the response rate was 45% [217], and 41% in a survey of auditory status in USA waterfowl hunters [218]. Declining response rates in postal questionnaires have been observed in recent years [219]; an average response rate of 57.5% was found in 350 postal surveys targeting healthcare professionals in USA, Canada, Australia/New Zealand, UK/Ireland and other countries (1996-2005) [220]. The response odds are higher with shorter questionnaires [216, 221], indicating that the extensive questionnaire in the present study (48 items) may have lowered the response rate. The historical aspect of postal questionnaires, as well as the aspects of sensitive questions, may possibly explain a higher (78%) response rate in the 119 items questionnaire used on hunters in Scania, Sweden, in the late 1970’s [51]. This thesis focused on socio-demographic data and did not include sensitive questions, such as those incorporated in the present work. Furthermore, a survey with a relatively high response rate in which non-respondents differ from respondents might produce far more biased results, conversely to a survey with a lower response rate from a representative group of respondents [222]. Finally, we do not know if there were any differences between respondents and non-members of SAWHM who account for a minority of all Swedish hunters. The respondents in the present study were, however, representative of SAHWM members, and the risk of voluntary bias in this study was thus limited.
Concluding remarks

- The findings in this thesis show a significant decrease in the number of unintentional hunting and non-hunting firearm fatalities in Sweden during the last decades. The changes in the Swedish firearm legislation, involving safer weapon handling by education and training through the mandatory hunter’s exam, at least partly contributed to this decrease after 1985. This legislation, as an environmental factor of injury prevention, has been certifying a hunter’s competency, and should stimulate an increased awareness of safety principles regarding all aspects of hunting.

- The host factor “human error” dominated among observed circumstances in all accidental fatalities. Multiple risk factors and multiple risk behaviours were rare among surveyed hunters, and reported firearm incidents involved only a few individuals that were injured or killed. Further hunting-related preventive work should focus on training of all aspects of safe firearm use and on prevention of falls.

- Legal firearm use dominates in accidental firearm deaths and suicides, while most of the solved firearm homicides involve illegal firearm use. Illegal firearm use should also be the focus of future prevention programs.

- The presence of alcohol/illicit drugs dominates in non-hunting accidental cases where illegal firearms were used. Due to the high lethality of firearms, prevention efforts towards risk groups should target the pre-event injury phases, i.e. the primary prevention level.

- Of all firearm deaths, suicides claimed most lives. Physicians’ identification of risk individuals and reporting them to the police has not been an efficient means of firearm suicide prevention in the studied cases. In addition, the number of firearm suicides was positively correlated to the number of firearm owners in Swedish counties. For more accurate reporting, physicians will need supplementary guidelines and training in risk assessment. Any intervention should be evidence-based and regularly evaluated.

- To allow for conclusions on preventive measures to be taken, all firearm deaths should be meticulously investigated for accurate classification of the manner of death. In all fatalities, any suspicion of suicide or homicide has to be investigated in detail.
Future research

In the light of the criticism towards the European research community, due to their previously sparse attention to the issue of firearm deaths [223], scientific contributions to the knowledge gap and to the policies need to increase. The present study hopefully represents one step in bringing more scientific evidence for future firearm policies.

The results of the present thesis, which show a low and declining incidence of accidental firearm deaths, indicate that this kind of firearm deaths are closer to the *zero vision* than firearm suicides and homicides. However, further surveillance of both fatal and nonfatal firearm injuries is needed to monitor time trends, to generate new prevention strategies, and to assess the effectiveness of prevention programs.

Additional legislation changes in Sweden toward legal weapons would probably have a limited effect on unintentional firearm deaths. Instead, further studies are needed regarding illegal weapons in Sweden. Following the public health model [20], interventions have to be evaluated. Firearm storage compliance, relevant in assessing the risk for non-owners, has not yet been evaluated. More and consistent evidence of intervention effectiveness in similar settings (e.g. the Scandinavian countries) is necessary to generate further knowledge. Moreover, it is important not to reject the possible effect of interventions when the effect cannot be proved because of bad study design and/or a small number of study cases [224].

The influence of possible confounding factors in firearm deaths, such as socioeconomic status or criminal activity of shooters and victims, also remains to be explored. Prospective and/or randomised control studies may possibly reveal the differences between e.g. firearm owners and non-owners, or suicides with firearms and with other methods.

With respect to an already strict firearm legislation in Sweden, more research is needed to evaluate possible benefits of the present physician’s reporting obligation. Additionally, it is not known which attitudes do firearm owners, patients or general population, have towards the physicians’ obligation.

Future research should also try to evaluate the costs of firearm injuries separately from other injuries. If evaluated on an EU level, differences in health service and other costs in between countries should be considered.

Mental health issues and the possible need of psychiatric health care among shooters in two-party accidental fatalities and among relatives to the victims of
firearm deaths should be explored for adequate support from the health care and the society.

One of the obstacles for research in this area is the lack of uniform, reliable and regular official statistics about firearm availability, including time trends of firearm owners, firearm confiscation data, the origin of illegal firearms used in firearm deaths/injuries and the firearm involvement in violent acts. Hopefully, recent efforts to improve such statistics [209] will illuminate issues related to firearms and will motivate researchers in their further contributions to the knowledge gap.

Finally, the scientific community should be aware of possible influences of the weapon industry and economic or political interests that may threaten this research topics (e.g. about the effect of the firearm legislation). It is thus important to preserve the integrity of research.
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References


11. Holmström B, Alhbin S, Pazooki D, Granhed H. *58 personer skottskadade i Göteborg under 18 månader, Visar på behovet av beredskap och kompetens inom traumasjukvården. [58 people injured with firearms in Gothenburg during 18 months, Showing the need for emergency preparedness and competence in trauma care]*. Läkartidningen, 2015;112:29-31.


41. Swedish Police. Vapenlagstiftningen m.m. [Firearm regulation etc.]. Report 2006.
(Accessed June 14, 2018)


170. Crockett A, Stawicki SP, Thomas YM, Jarvis AM, Wang CF, Beery PR, Whitmill ML, Lindsey DE, Steinberg SM, Cook CH. Tree stands, not guns, are the Midwestern hunter’s most dangerous weapon. Am Surg, 2010;76:1006-1010.

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208. National Board of Health and Welfare. En nationell strategi för demenssjukdom. [National strategy for dementia.]. Available from:


Appendix

Questionnaire (Paper II)

Department of Forensic Medicine, Umeå University
In collaboration with the Swedish Association for Hunting and Wildlife Management

QUESTIONNAIRE
FIREFARM INCIDENTS DURING HUNTING

What are your experiences of firearm incidents during hunting? How common are such incidents and what causes them? We want to explore these questions (and others) using this questionnaire, the first of its kind in Sweden.

You are one of 1,000 randomly selected Swedish hunters who have received this questionnaire. Your participation is voluntary, but your answers are very important. The study intends to shed light onto if and how often firearm incidents occur, even if no-one is injured or killed. The purpose of the survey is to provide a basis for discussion about how to prevent such incidents. Hunters’ involvement in this study is also very important for future training of new hunters. Consequently, we are very interested in hearing about hunters’ own experiences.

Your answers will be treated confidentially
The questionnaire was designed and sent out by scientists at Department of Forensic Medicine at Umeå University who are also responsible for compiling your responses. You were randomly chosen from the membership register of the Swedish Association for Hunting and Wildlife Management, which is responsible for the distribution of this questionnaire and the collection of responses.

The enclosed envelope is coded so that the Swedish Association for Hunting and Wildlife Management can check if your response has been received, and to enable them to send you a reminder if you for some reason have not responded to the survey.

When compiling the responses we will work with de-identified data. Your information will also be treated as confidential, which means that everyone who works on this project has a duty of professional secrecy.

Please send the completed questionnaire as soon as possible (preferably within a week) to the Swedish Association for Hunting and Wildlife Management in the enclosed envelope.

As a thank you for participation, you will receive a nice and useful product from the Swedish Association for Hunting and Wildlife Management’s catalogue.

Any questions?
If you have any questions, you can contact any of us who are working on this investigation:
• The contact person at the Swedish Association for Hunting and Wildlife Management is
  Andreas Herlitz (hunter and person responsible for the project ‘Safer Hunting’)
  email address andreas.herlitz@jagareforbundet.se, telephone 0703-39 92 70
• Mensura Junuzovic (MD, General Practitioner, and researcher at Umeå University, who has
  worked with firearm incident projects for some years)
  email address mellie-m@rocketmail.com, telephone 040-623 44 17
• Anders Eriksson (hunter and Professor of Forensic Medicine at Umeå University)
  email address anders.eriksson@rmv.se, telephone 090-10 07 00
**Instructions:**
Answer questions by choosing the best alternative.
Put a cross in the appropriate box.
If you want to change your answer, cover the entire box: □

The term "hunting" in the following questions includes, wherever applicable, trapping and tracking of wounded game. All questions concern hunting *in Sweden*.

**Do you hunt abroad only?** If so, please put a cross in this box □ and then return the questionnaire without filling it in.

### Demographics

1. I am _____ years old.

2. I am:  □ male    □ female

### Hunting experience, hunting habits and attitudes

3. Place a cross next to the right answer:
   □ I have passed the hunter’s exam
   □ I have not passed the hunter’s exam » go to question 6

4. I passed the hunter’s exam in year: ___________(year)

5. My hunter’s exam is:  □ Incomplete
   □ Complete

   5a. If you have not completed the hunter’s exam, please specify which part(s) you have completed:
   _______________________________________________________________________

6. I have hunted regularly for: _____ years.

7. I regularly hunt in:  □ both Sweden and other countries
   □ Sweden only
8. The distance between my residence and my main hunting ground (the area where you mostly hunt) is:

- [ ] I live on my main hunting ground and I mostly hunt there
- [ ] less than 25 km
- [ ] 25-50 km
- [ ] 51-100 km
- [ ] more than 100 km

9. I regularly hunt:
(choose all answers that apply)

- moose
- bear
- roe deer
- other deer species
- wild boar
- fox
- hare
- rabbit
- beaver, badger, mink
- willow grouse
- forest birds
- field birds
- waterfowl
- other birds
- other game:

10. During 2008 I hunted for:

- [ ] 0-9 days
- [ ] 10-19 days
- [ ] 20-29 days
- [ ] >30 days

11. During 2008 I successfully hunted in Sweden:
(choose all answers that apply)

- [ ] ______ (number) deer species (moose, deer including roe deer)
- [ ] ______ (number) other four-legged animals (e.g. bear, wild boar)
- [ ] ______ (number) small game - birds
- [ ] ______ (number) small game - four-legged animals (e.g. hare, fox, badger)

12. During 2008 I also practised trapping:
(choose all answers that apply)

- [ ] no, not at all
- [ ] yes, with traps
- [ ] yes, with foot snares
- [ ] yes, other forms of trapping

13. During 2008 I killed wounded game during tracking:

- [ ] never
- [ ] ________ times
14. I usually hunt:

□ alone, without a dog
□ together with other hunters, but without a dog
□ alone, but with a dog
□ together with other hunters and a dog
□ in another way (please specify):
________________________
________________________

15. I have children (individuals aged <18 years) with me when I hunt:

□ never □ sometimes □ often □ always

16. The child/children’s age is _______________ years.

17. I have a signal colour (yellow-green, orange red or other) on my hunting clothes:

□ never □ sometimes □ often □ always

18. The following clothing items have a signal colour:

________________________________________________________

19. Some of my clothes have a camouflage pattern when I hunt alone:

□ never □ sometimes □ often □ always

20. Some of my clothes have a camouflage pattern when I hunt together with other hunters:

□ never □ sometimes □ often □ always

21. I have hunted under the influence of alcohol:

□ never □ _____ times during the past 5 years

22. I have hunted the day after excessive alcohol intake (to the extent that I did not feel ‘my normal self’ during hunting):

□ never □ _____ times during the past 5 years

23. I have shot at animals in spite of poor visibility (e.g. due to bad weather, thick vegetation, bad light):

□ never □ _____ times during the past 5 years
24. I know one or more people who possess a hunting weapon, but who in my opinion should NOT possess weapon:

- [ ] yes  - [ ] no

» go to question 27

25. If you answered YES to the previous question, please indicate whether this person/these people:

<table>
<thead>
<tr>
<th>Person</th>
<th>Hunts</th>
<th>Does Not Hunt</th>
<th>I Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[ ]</td>
<td>[ ]</td>
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<td>5</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

» go to question 29

26. Tell us briefly why you think that this person/these people is/are unsuitable to possess a hunting weapon.

Person 1: _________________________________________________

Person 2: _________________________________________________

Person 3: _________________________________________

Person 4: _________________________________________________

Person 5: _________________________________________________

27. I have experienced careless weapon handling.

- [ ] yes  - [ ] no

» go to question 29

28. Describe briefly how the weapon handling was careless. If you have experienced more than one incident of careless handling, please write down all such incidents (if you need more space, please continue writing on a separate sheet of paper).

situation 1: __________________________________________________________

situation 2: __________________________________________________________

situation 3: __________________________________________________________

situation 4: __________________________________________________________
situation 4: __________________________________________________________
____________________________________________________________________

### Weapons

29. I have a license for the following weapons:
   (choose all answers that apply)
   - rifles:
     - □ class 1 □ class 2 □ class 3 □ class 4
     - calibres:________________________
   - shotguns:
     - □ side by side □ over and under □ single-barrelled
     - calibres:________________________
   - □ other:
     - □ specify: ___________________
     - calibres:________________________

30. I store my weapons:
   - □ in an authorised safety locker
   - □ other:________________________

31. I store my ammunition:
   - □ in an authorised weapon safety locker
   - □ other:________________________

32. I check that my weapon works:
   - □ never               □ once a year
   - □ several times a year □ before each hunt

33. My check includes:
   (choose all answers that apply)
   - □ test shooting
   - □ disassembly and cleansing of the weapon
   - □ other (please specify):________________

### Health

34. I am healthy:  □ no  □ yes » go to question 36

35. The disease(s) I suffer from is/are: ____________________________________
36. I have impaired vision: □ yes □ no » go to question 37

36a. If YES: My vision is impaired due to: ____________________.

36b. If YES: I use: □ glasses □ lenses
□ both glasses and lenses
□ neither glasses nor lenses

37. I have impaired hearing: □ yes □ no

37a. If YES: I wear a hearing aid: □ yes □ no

38. I have a neurological disorder (e.g. Parkinson’s disease, epilepsy, involuntary tremor): □ yes □ no

38a. If YES: My neurological disorder is (name): ____________________.

39. I have cardiovascular disease: □ yes □ no

39a. If YES: My disease(s) is/are:
(choose all answers that apply)
□ angina
□ hypertension
□ previous myocardial infarction
□ atrial fibrillation
□ other: ____________________

40. I take medication on a regular basis: □ yes □ no

40a. If YES: My medication is (name):
____________________________________
____________________________________

41. I have felt ill while hunting (for any reason) to the extent that I had to stop the hunt:
□ never □ sometimes □ often □ always
Firearm incidents

A “firearm incident” includes incidents in which a weapon was unintentionally discharged or was intentionally discharged at an unintended target because of misjudgement.

42. I have caused a firearm incident myself: □ never □ ______ times during the past 5 years

43. I know one or more hunters who have caused a firearm incident:

□ no » go to question 46
□ yes: ______ times during the past 5 years

44. Since you have experienced a firearm incident during the past 5 years, please answer the five questions below for each such incident. If you have experienced more than 5 firearm incidents, please describe additional incidents on a separate sheet of paper.

<table>
<thead>
<tr>
<th>Incident 1</th>
<th>Incident 2</th>
<th>Incident 3</th>
<th>Incident 4</th>
<th>Incident 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Who caused the firearm incident?</td>
<td>□ I did</td>
<td>□ I did</td>
<td>□ I did</td>
<td>□ I did</td>
</tr>
<tr>
<td>□ someone else</td>
<td>□ someone else</td>
<td>□ someone else</td>
<td>□ someone else</td>
<td>□ someone else</td>
</tr>
<tr>
<td>Sex and age of the shooter</td>
<td>□ man</td>
<td>□ man</td>
<td>□ man</td>
<td>□ man</td>
</tr>
<tr>
<td>□ woman</td>
<td>□ woman</td>
<td>□ woman</td>
<td>□ woman</td>
<td>□ woman</td>
</tr>
<tr>
<td>_____ years old</td>
<td>_____ years old</td>
<td>_____ years old</td>
<td>_____ years old</td>
<td>_____ years old</td>
</tr>
</tbody>
</table>

2. What was the consequence?

| A human was: | □ injured | □ injured | □ injured | □ injured | □ injured |
| □ killed | □ killed | □ killed | □ killed | □ killed | □ killed |
| A dog was: | □ injured | □ injured | □ injured | □ injured | □ injured |
| □ killed | □ killed | □ killed | □ killed | □ killed | □ killed |
| Another domestic animal was: | □ injured | □ injured | □ injured | □ injured | □ injured |
| □ killed | □ killed | □ killed | □ killed | □ killed |
| Material damage? – specify | | | | |

Nobody was injured/nothing was damaged □ □ □ □ □
3. The firearm incident occurred:

<table>
<thead>
<tr>
<th>Time of Incidence</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the hunt</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>During the hunt</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>After the hunt</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>When killing captured game</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>When killing wounded game during tracking</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other (please specify):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. In my opinion, the cause of the firearm incident was (choose all answers that apply):

<table>
<thead>
<tr>
<th>Cause of Incident</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misjudgement of the target (something that turned out to be an incorrect target)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Poor visibility</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Falling, tripping</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Weapon unintentionally unsafetied</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Fault with weapon</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Dropped weapon</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>A dog caused the incident</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other (most probable cause):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Could the incident have been prevented?

<table>
<thead>
<tr>
<th>Possible Prevention</th>
<th>Incident 1</th>
<th>Incident 2</th>
<th>Incident 3</th>
<th>Incident 4</th>
<th>Incident 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>no</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

45. If you believe that the incident could have been prevented, please specify how?

Incident 1: __________________________________________________________
Incident 2: __________________________________________________________
Incident 3: __________________________________________________________
Incident 4: __________________________________________________________
Incident 5: __________________________________________________________
**Future contact?**

46. May we contact you by phone or email with additional questions if necessary?

☐ yes  ☐ no

If YES: please provide your name, telephone number and email address, and the best time to contact you:

Name:___________________________________________________
Phone number, including area code: ______________________________
Best time to contact you: ______________________________________
E-mail address (please write legibly!): ____________________________

48. We appreciate any further comments regarding this questionnaire:

________________________________________________________________________
________________________________________________________________________

THANKS FOR YOUR PARTICIPATION!