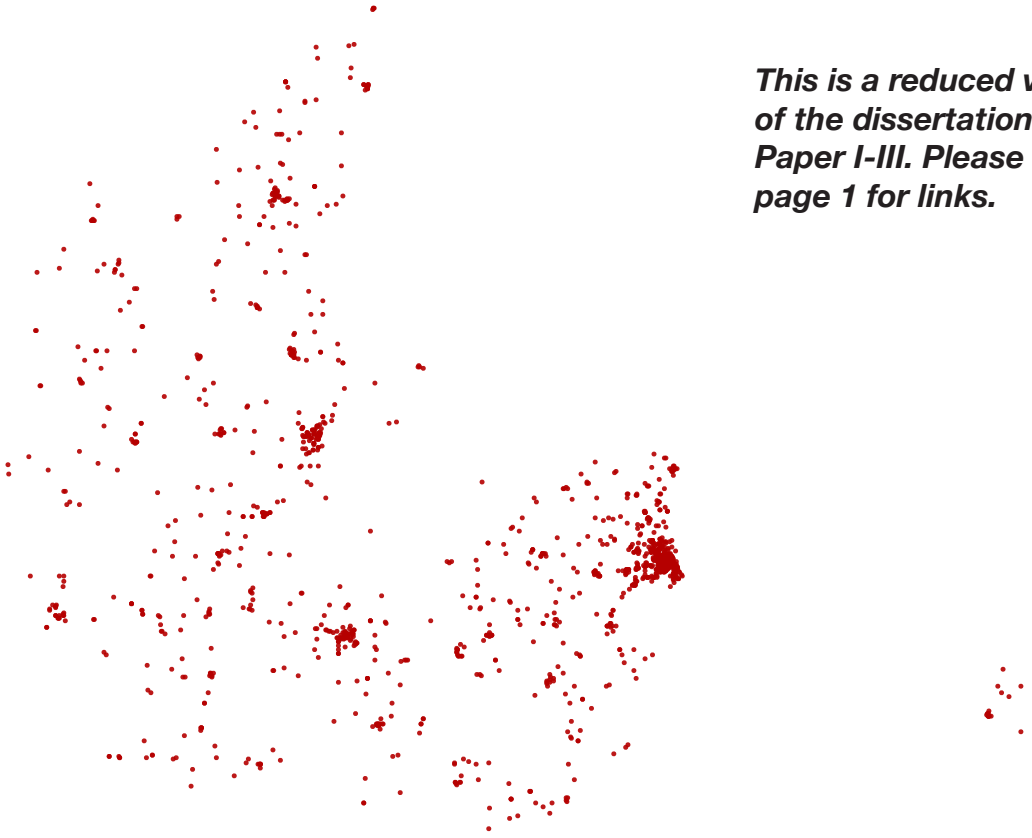
AARHUS
UNIVERSITY
DEPARTMENT OF FORENSIC MEDICINE

Homicide in Denmark 1992-2016

PhD-dissertation

Asser Hedegård Thomsen



This is a reduced version of the dissertation without Paper I-III. Please refer to page 1 for links.

Health
Aarhus University
2020

AARHUS
UNIVERSITY
DEPARTMENT OF FORENSIC MEDICINE

Homicide in Denmark 1992-2016

PhD-dissertation

Asser Hedegård Thomsen

Health

Aarhus University

2020

To my wife and my mother (two persons).

Preface

I would like to thank the mysterious heart surgeon at Aarhus University Hospital, who neglected to show up for our mandatory clinical lesson in medical school one rainy afternoon in March 2000. Because of you -and the rain- I stayed in your conference room, toying with a prostate-exam plastic-model until my fingers hurt. At 02.39 p.m., with the plastic replica still on my thumb, my life's trajectory changed. My eye caught a dusty blue book that seemed out of place, squeezed in between volumes of The Lancet and New England Journal of Medicine.

"Drab i Danmark 1946-70, J P Hart Hansen". It had an air of FBI, Clarice Starling and Hannibal Lecter to it. It smelled like an old book store and how I imagine Miggs' cell. As I opened it, the cover and spine came off, spilling more than 200 leaves with type-written text on the floor. Panic ensued, as I wrestled with the -now stuck- plastic replica in one hand, while collecting data on 25 years of homicides in Denmark off the floor with the other hand. Up until that moment, I did not know that you could collect data on homicides as a doctor. And so, it began, this journey into homicide research, often plagued with bouts of mild panic and psychological discomfort.
Thank you, mysterious heart surgeon.

My interest in research, forensic medicine and homicide started out as pure fascination. Later, I have been confronted with the harsh realities behind the stories, meeting victims of homicide, their offenders and relatives. These are real people. The front page of the dissertation you are holding features a map of Denmark, made up of 1,417 red dots. Each red dot represents a homicide location and a homicide victim. Each red dot was someone's neighbor, friend, colleague, relative, wife, husband, lover, mother, father, sister, brother, daughter or son. One thousand four hundred and seventeen red dots. As you read through the text, please take another look at the map and send the victims and those left behind a few thoughts.

Asser Hedegård Thomsen, Aarhus, June 2020

Author

Asser Hedegård Thomsen, MD
Department of Forensic Medicine
Aarhus University
Palle Juul-Jensens Boulevard 99
8200 Aarhus N
Denmark
aht@forens.au.dk

Supervisors

Ole Brink, Clinical Associate Professor
Department of Clinical Medicine, Aarhus University, Denmark

Peter M. Leth, Professor
Department of Forensic Medicine, University of Southern Denmark, Denmark

Hans Petter Hougen, Professor
Department of Forensic Medicine, University of Copenhagen, Denmark

Assessment committee

Torben Steiniche, Professor (chairman and moderator of the defence)
Department of Clinical Medicine, The Department of Pathology, Aarhus University, Denmark

Ingemar Thiblin, Professor
Department of Surgical Sciences, Forensic Medicine, Uppsala University, Sweden

Kari Ormstad, Consultant
Oslo University Hospital, Avdeling for rettsmedicinske fag, Norway

Financial support

Brødrene Hartmanns Fond
Videreuddannelsesregion Nord
Institut for Retsmedicin, Aarhus Universitet

Contents

1 Original papers

Paper I - Published [1]:
Thomsen AH, Leth PM, Hougen HP, Villesen P, Brink O.
Homicide in Denmark 1992-2016.
Forensic Sci Int: Synergy. 2019;1:275-82.
doi:10.1016/j.fsisyn.2019.07.001.

Paper II - Published [2]:
Thomsen AH, Hougen HP, Villesen P, Brink O, Leth PM.
Sharp Force Homicide in Denmark 1992-2016.
J Forensic Sci. 2020;65(3):833-9.
doi:10.1111/1556-4029.14244.

Paper III - Published [3]:
Thomsen AH, Villesen P, Brink O, Leth PM, Hougen HP.
Improved medical treatment could explain a decrease in homicides with a single stab wound.
Forensic Sci Med Pathol. 2020. Epub ahead of print.
doi:10.1007/s12024-020-00246-z.

2 Introduction

This dissertation concerns the manner of death "homicide" as seen from the perspective of forensic medicine. In three studies (**Figure 1**), homicides will be approached from the view of the forensic pathologist going from a broad overview of all homicide methods (Study I), to a narrow focus on the findings in the group of homicide victims killed by sharp force trauma (Study II), and how developments in medical treatment have impacted the group of victims killed with stab wounds (Study III). The broad overview will hopefully serve as a spark for further specific studies in forensic medicine, as well as a basis for policy development related to interpersonal violence. The specific studies of homicide by sharp force trauma should serve as a reference in death investigations and daily autopsy work, but also as a link to understand the underlying factors that direct the broader homicide statistics.

Figure 1 The three studies of this dissertation.

2.1 Manner of death: Homicide

In medicine, we use the terms "manner of death" and "cause of death" to categorize deaths [4, 5]. For most deaths this is fairly easy, but for some of the deaths encountered in forensic medicine, it can be quite a challenge [6-8]. To understand homicide research in general, and the choices made in this dissertation in particular, it is necessary to have a basic knowledge about manner of death and cause of death.

2.1.1 Manner of death and cause of death

There are four manners of death: natural, accident, suicide and homicide (**Figure 2**). To determine the manner of death, information related to the cause of death is needed.

A cause of death is simply a medical diagnosis leading to the death of a person [4, 5, 9]. Causes of death fall in two major groups; diseases and external causes [4, 5, 9] (**Figure 3**). For individual deaths a sequence of events can be stringed together from the medical history [4-9].

Example: A middle aged man has developed coronary atherosclerosis over several years, one day leading to coronary thrombosis and myocardial infarction with cardiac arrest and death. The immediate cause of death is myocardial infarction in the setting of coronary thrombosis. The underlying cause of death is coronary atherosclerosis. When the underlying cause of death is a disease, the manner of death is "natural" [4, 5, 9]. Five years later, his widow suffers a hip fracture stumbling down the stairs. She is admitted to the hospital,

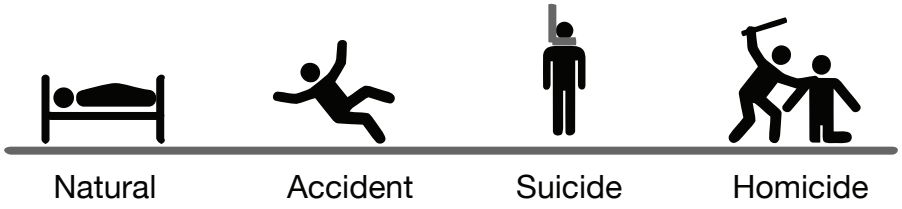


Figure 2 Manner of death.

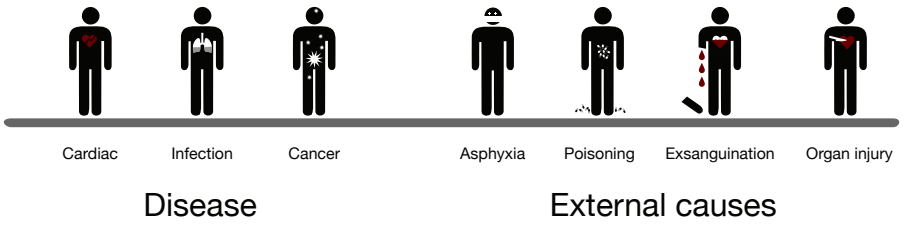


Figure 3 Cause of death.

where she develops pneumonia over five days and dies. The immediate cause of death is pneumonia. The underlying cause of death is a fall down the stairs, causing a femoral neck fracture. When the underlying cause of death is an external cause (e.g., a fall) the manner of death is non-natural, even when the immediate cause of death is a disease (e.g., pneumonia) [4, 5, 9]. It is not uncommon to have multiple factors causing death in the same person. If the widow had osteoporosis and lung disease, these could be listed as contributing causes of death, i.e., they have increased the risk of fractures and pneumonia, although they would not necessarily fit in a causal sequential chain of events [4-9].
There are three types of non-natural manner of death and the circumstances surrounding the death will determine the type [4, 5, 9]:
a) Did the widow slip in her nightgown and fall down the stairs? Manner of death: "accident".
b) Did she throw herself down the stairs with the intention of dying? Manner of death: "suicide".
c) Did her nephew push her down the stairs, to inherit money for drugs? Manner of death: "homicide".

To assign reliable cause- and manner of death, we need sufficient information obtained from the medical history, the examination of the deceased and police reports, if available [4, 5, 9]. In situations where these do not provide the manner of death with reasonable certainty, it is said to be "undetermined" [4, 5, 9]. If the manner of death is recorded on the death certificate before the police investigation in a suspicious death is complete, the manner of death is sometimes recorded as "undetermined", even though it later will be considered a homicide [10].

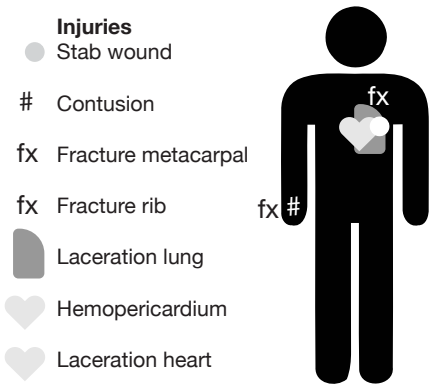


Figure 4 Example of injuries in a homicide victim (the nephew).

2.1.2 Homicide

Nine years later, the nephew is drinking with some friends in his apartment. A fight breaks out and the nephew punches his friend twice in the face. The friend grabs a kitchen knife and stabs the nephew once in the chest, penetrating a rib, the left lung and the heart (**Figure 4**). The nephew is transported to the hospital, but dies 55 minutes later on the operating table. The cause of death is exsanguination from a stab wound to the heart and the homicide method is sharp force trauma. Besides injuries caused by the stab, the nephew also has a contusion and a fracture in the right hand. These injuries add to the overall severity of his injuries, but are not part of the cause of death due to their limited severity.
When a person dies from intentional harm caused by another person, the manner of death is "homicide" [4, 5, 9]. This is a medical definition. Later, the legal system will look closer at whether there

was an intention to cause harm and to cause death. If the offender had the intention of causing death or should have known that the action would cause death it would be a homicide ("manddrab", §237 in the Danish Criminal Code)[11]. If the intention was to cause harm, but not death it would be manslaughter ("vold med døden til følge", §246 in the Danish Criminal Code) [11]. If there was no intention of using the knife to cause harm it would be involuntary manslaughter ("uagtsomt manddrab", §241 in the Danish Criminal Code), and as such an accident in legal terms as well as in medical terms [4, 5, 9, 11].

2.1.3 Borderline homicide

The International Classification of Crime for Statistical Purposes (ICCS) includes the legality of an assault in the definition of "intentional homicide": "Unlawful death inflicted upon a person with the intent to cause death or serious injury" [12]. The definition can be broken down into three elements [13]:
a) Objective element: The killing of a person by another person [13].
b) Subjective element: The intent of the perpetrator to kill or seriously injure the victim [13].
c) Legal element: The unlawfulness of the killing [13].

The medical definition of homicide does not take the legality of the homicide into consideration, and the death certificates in Denmark do not have categories beyond natural, accident, suicide, homicide and undetermined.
With respect to the medical definition used in this dissertation the various types of borderline homicides are interpreted as follows [4, 5, 9]:
a) When certain conditions are met the police in Denmark are allowed to use lethal force with firearms. Such deaths by "legal intervention" are considered homicides in the medical definition.
b) Homicides performed in self-defense can be legally excused ("nødværge", §13 in Danish Criminal Code), but are still homicides in the medical definition [11].
c) New born babies left out to die or killed immediately after birth by their mother are considered a special type of homicide ("barnedrab", §238 in the Danish Criminal Code), with reduced sentencing [11]. They are considered homicides in the medical definition.
d) The death of an unborn child from either maternal assault or direct inflicted trauma, is not considered a homicide by the medical definition, regardless of the outcome for the mother [11].
e) Under certain circumstances a simple brawl with minimal use of force, e.g., a punch, will lead to a fall, with the victim striking his head on the ground, causing death from brain trauma. Even though this will often lead to a conviction for simple assault (Danish Criminal Code §244), it is considered a homicide in the medical definition, i.e., the victim would not have suffered the brain trauma without the preceding punch [4, 5, 9].
f) A homicide committed at the request of the victim ("drab på begæring", §239 in the Danish Criminal Code) is a homicide in the medical definition [4, 5, 9].
g) A suicide committed with the help of another person ("hjælp til selvmord", §240 in the Danish Criminal Code) is not a homicide in the medical definition.

2.2 Homicide in general

The idea for this dissertation was in part brought on by a lack of recent scientific studies on homicides in Denmark from the perspective of forensic medicine, as well as difficulties in assessing changes in homicide epidemiology from more recent official statistics. Here follows brief summaries of a selection of studies and statistics on homicide in general from Denmark and internationally.

2.2.1 Homicide in Denmark 1946-1970, Hart Hansen [14]

Hart Hansen's monumental work "Drab i Danmark 1946-1970", published as a doctoral dissertation in 1977, is the latest complete review of homicides in Denmark in forensic medicine [14]. The main document is in Danish, but features a thorough English summary. The study included "all cases in which the manner of death ought to be listed as criminal homicide on the death certificate", meaning "all intentional and unintentional deaths due to premeditated violence or other deliberate injury, including injury of passive nature, i.e.

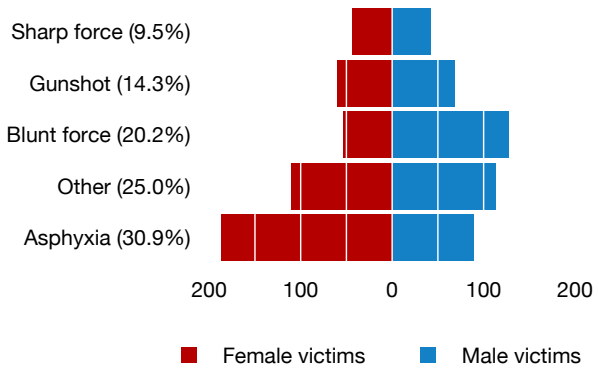


Figure 5 Homicide methods in "Homicide in Denmark 1946-1970, Hart Hansen" [14].

neglect or abandonment" [14], meaning the medical definition of homicide. It was based on data from the criminal archives as 25% of victims did not have an autopsy, most often family homicides with suicides.

The study included 892 homicide victims (439 (49.2%) males, 453 (50.8%) females), killed in 761 homicide events, with a homicide rate of 0.79 per 100,000 per year. A large part of victims (42%) were younger than 15 years. Over the 25-year period there was a decrease in the homicide rate, predominantly due to a reduction in family homicides, where a parent killed the children and committed suicide. A total of 30.0% of homicidal events were followed by suicide and 9.3% by suicide attempts. The reduction in family homicides was presumed to be because of limited availability of poisonous town gas and better social support for single mothers. Asphyxia (including drowning), poisoning and blunt force trauma were the most common homicide methods (**Figure 5**), but with a shift towards asphyxia, blunt force trauma, gunshots and sharp force trauma in the last five years of the study. Two-thirds of offenders were males. Female offenders killed mostly in family homicides, including new born babies (infanticides).

Hart Hansen's dissertation contains information of many types, including data on employment, offender upbringing and mental health, and is an interesting historical document. That things certainly have changed a lot since then is made clear in the following quote from the English summary: "In particular, the investigation of nail scrapings for blood seems superfluous, as a species determination was possible in only a few cases and blood grouping in none" [14].

2.2.2 Homicide in Southern Denmark During 25 years, Leth [15]

Leth studied all 166 homicides (82 (49.4%) males, 81 (50.6%) females) in Southern Denmark during 1983-2007, an area with approximately 13% of Denmark's population and home to the third largest city, Odense [15]. The primary case identification was via the Danish Register of Causes of Death (medical definition), but four additional cases were identified via the archives at the Institute of Forensic Medicine. The average annual homicide rate was 0.92 per 100,000 with little variation. Sharp force trauma (34.3%) was the most common homicide method, followed by asphyxia (22.9%), gunshots (20.5%) and blunt force trauma (15.1%). There were no changes in the homicide pattern over the years. Many homicide victims were socially disadvantaged and/or suffering from alcoholism: "A typical Danish homicide occurs in a private dwelling as a result of a drunken dispute between spouses, friends, or acquaintances" [15].
As there is a considerable overlap of 16 years with parts of the current study, a complete summary is unwarranted. As offspring from the study, papers have been published on intimate partner homicides, child homicides and sharp force homicides [16-18].

2.2.3 Homicides in two Scandinavian capitals, Hougen et al. [19]

As part of a joint study with the Oslo capital area (Norway), Hougen et al. studied all 275 homicides (142 males, 133 females) in the Copenhagen capital area during 1985-1994, an area with approximately 30% of Denmark's population [19]. The source of case identification was the autopsy database at the Institute of Forensic Medicine, University of Copenhagen (medical definition). The annual homicide rate was 1.6 (1.1-2.3) per 100,000 with the highest rate in 1985. The most common homicide method was sharp force trauma (36.0%), followed by strangulation (22.9%), gunshots (18.2%) and blunt force trauma (16.0%). Most homicides occurred in private homes, with the relation being family or friends. Many victims were under the influence of alcohol. The study has led to papers on homicides by sharp force trauma, gunshots, asphyxia and blunt force trauma [20-23].

2.2.4 Injuries Due to Deliberate Violence in Areas of Denmark. II. Victims of Homicide in the Copenhagen Area (1985-1986), Thomsen, J.L. et al. [24]

Thomsen, J. L. et al. studied twelve months of homicides (45 homicides, 31 (68.9%) males, 14 (31.1%) females) at the Institute of Forensic Medicine in Copenhagen (February 1985 - January 1986) as part of a larger study comparing deliberate violence in Europe and South America [24]. As this study period completely overlaps with the above study by Hougen et al. [19], the findings will not be described here.

2.2.5 Homicide in Denmark (2008-2011), The Research Office of the Danish Justice Department [25]

The Research Office of the Danish Justice Department has published data on homicides including on homicide offenders in Denmark during 2008-2011, based on the police database of reported crime [25]. The inclusion criteria were the legal definition of homicide and death from aggravated assault with exclusion of cases were the investigation or the legal process concluded that it was another manner of death. There were 168 victims of homicide and 28 victims that died from aggravated assault, totaling 196 victims. As there is complete overlap with the time period of the studies in this dissertation a further summary will not be provided. There was focus on the general circumstances surrounding homicides, demographics of victims and offenders, as well as criminal convictions. The material section is thorough and vividly demonstrates the challenges in using unfiltered data on reported crime. The study has only been published in Danish.

2.2.6 Types of homicide (2012-2016), The Research Office of the Danish Justice Department [26]

After publication of "Paper I" and "Paper II" and submission of "Paper III" for this dissertation The Research Office of the Danish Justice Department has published a study of homicides in Denmark [26]. The study is based on court verdicts for all guilty convictions of "homicide" (§237 in the Danish Criminal Code), "child homicide" (§238 in the Danish Criminal Code) and "manslaughter" (§246 in the Danish Criminal Code) [11] from late 2012 to 2017. As the study overlaps completely with the homicides in this dissertation, the findings will not be described here. The data, especially regarding mental illness and ethnicity, are a good supplement to the findings in "Study I". The study has only been published in Danish.

2.2.7 Official statistics on homicide in Denmark [27-29]

Despite the studies by Hansen [14], Leth [15-18] and Hougen [19-23], there is a gap in our knowledge from peer reviewed scientific studies of homicides in Denmark. Turning to the national statistics from the Danish Register of Causes of Death the general development for 1970-2016 can be appreciated (**Figure 6**) [27, 28]. Since 1996 there has only been published statistics on the number of homicides, and not on the various homicide methods. The statistics are based on death certificates, with the inherent disadvantage that most of these are registered before the investigation is completed and there is a final verdict in court, leaving room for misrepresentation of true homicides and vice versa [10, 30].

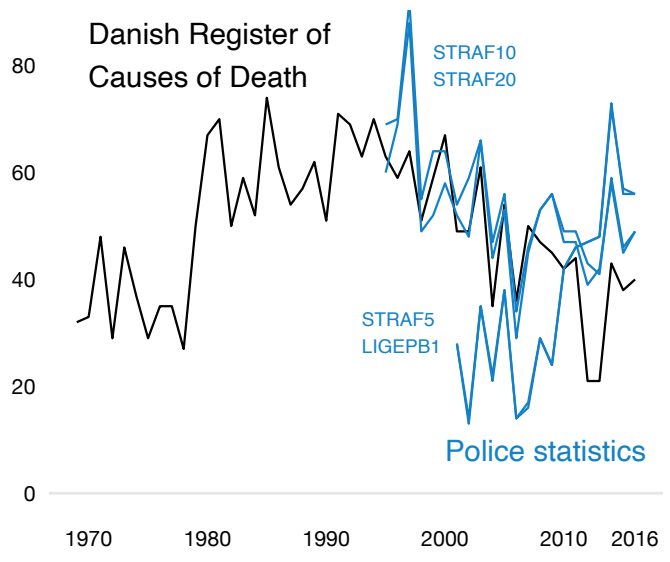


Figure 6 Official statistics on homicides in Denmark 1970-2016, from the Danish Register of Causes of Death [27, 28] and four online police databases [29].

Example: In the case with the nephew who was stabbed once in the chest during a drunken brawl, there might be initial discussions of whether the stab was intentional, which could lead to the death certificate being signed out as manner of death "accident" or "undetermined". On the other hand, the death certificate could be signed out as manner of death "homicide", but the court finding that intention of causing harm could not be proved.

There has been an increase in the number of homicides up through the 1980s with a reduction again in the 1990s until 2016. This mirrors what has happened in other countries in the Western world (see below) [13, 30-35].

The statistics from the Danish Register of Causes of Death can be supplemented with various police statistics on homicides from official online databases (STRAF 5, STRAF10, STRAF20, LIGEPB1) (**Figure 6**) [29]. It is apparent that there is considerable variation between the databases. One of the databases with a low number of homicides (STRAF5) comes with the caveat, that the number of homicides are thought to be underestimated for 2001-2009, but the other (LIGEPB1) does not. With the exception of those years the number of homicides are in general higher in the police statistics compared to the Danish Register of Causes of Death. This could be due to the above-mentioned effect of not registering "homicide" on the death certificate, when there is doubt about the manner of death. Another reason could be that if the initial investigation indicates that a death is suspicious of homicide, it will be recorded as such in the police database over reported crime, even though the following investigation shows that the manner of death is non-homicidal [30].

2.2.8 Homicide in Greenland 1985-2010 [36]

Christensen et al. studied homicides in Greenland 1985-2010 [36]. Although Greenland is part of the Kingdom of Denmark, the country has autonomy and the society is quite different from Denmark, which makes comparisons difficult. The average annual homicide rate was extremely high (16 per 100,000 by a medical definition), with a significant decrease during the period. Most victims and offenders were males. The most common homicide methods were sharp force trauma (41%), gunshots (29%), blunt force trauma (13%) and asphyxia (11%).
The study does not include specific information about sharp force homicides, survival time or medical treatment.

2.2.9 Homicide in Finland, the Netherlands and Sweden -A first Study on the European Homicide Monitor Data [30]

Ganpat et al. studied all known cases of homicides during 2003-2006 in Finland (FI), the Netherlands (NL) and Sweden (SE) as part of the European Homicide Monitor data [30]. The introduction describes an increase in the homicide rates in all three countries from the late 1960s to the 1990s, as seen in all of the Western world [31]. After this the homicide rate decreased, starting in the early 1990s in Finland and Sweden, with the Netherlands following at the turn of the century.
The data was collected from various sources, but for all three countries it included cases reported to the police and with more victims than was apparent from the cause of death registries. For Finland and Sweden there were fewer victims in the study than in the official criminal statistics, while those figures were not included for the Netherlands. The study's "Appendix A" is a great resource for understanding the complexity of homicide data when comparing official statistics internationally.
The study provides a framework for conducting similar studies in other countries, with detailed descriptions of the included variables in a "coding manual" (the study's "Appendix B"). Instead of grouping homicides by a single motive, such as jealousy, revenge or financial motivation, the study introduces a typology rooted primarily in the relationship between victim and offender. As a supplement, it provides variables for capturing multiple possible motives for each homicide, as homicides can have more than one motive. For example, an intimate partner homicide (type) can have separation, jealousy and mental illness as driving motives. Further details supplement the homicide type by including precise information about the relation between victim and offender, e.g., current intimate partner vs. former intimate partner. The homicide typology and related variables will be used in "Study I" and "Study II".

The study included 1,577 homicide victims and 1,917 homicide offenders:

- **FI)** 475 victims (30%, average annual rate = 2.34 per 100,000)
- **NL)** 760 victims (48%, average annual rate = 1.26 per 100,000)
- **SE)** 342 victims (22%, average annual rate = 0.98 per 100,000)

As opposed to the above-mentioned studies from Denmark, the definition of "homicide" only includes criminal acts of violence, meaning that deaths by legal intervention (police shootings) are not included.
Sharp force trauma, gunshots, blunt force trauma and asphyxia were the most common homicide methods, responsible for 93-94% of homicides in each country. The most apparent difference between the countries was that gunshot homicides were twice as common in the Netherlands, owing to a larger proportion of violence in criminal environments.
Two thirds of victims in all three countries were males. Two thirds of all victims were in the age group 25-64

in all three countries, but on average the victims in the Netherlands were younger (37.4 years) than in Finland (42.1 years) and Sweden (41.5 years).
Nine out of ten offenders were males in all three countries. For offenders more than 60% were in the age group 25-64, also with a younger average in the Netherlands (31.9 years) than in Finland (37.5 years) and Sweden (34.7 years). The younger average ages in the Netherlands were also due to more homicides in criminal environments.
The study does not include specific information about sharp force homicides, survival time or medical treatment.

2.2.10 Global Study on Homicide -The United Nations Office on Drugs and Crime (UNODC) [13, 32, 33]

The United Nations Office on Drugs and Crime (UNODC) has published reports on the global impact of homicides in 2011 [32], 2013 [33] and 2019 [13] with the most recent figures being from 2017. It is estimated that approximately 362,000 people were victims of "intentional homicide" globally in 1993, rising to 464,000 in 2017 [13]. In comparison 89,000 people are estimated to have died in armed conflicts in 2017 [13]. During the same period the global population increased, equating a decrease in the annual homicide rate from 7.4 per 100,000 to 6.1 per 100,000 [13].
The available data has gaps in the national availability and quality, but clearly shows differences in the regional annual homicide rates with the Americas and Africa more than four times higher than Asia, Oceania and Europe (**Figure 7**) [13]. These figures cover large differences in annual homicide rates between the nations in each region (**Figure 8**) and also within nations [13]. While the global annual homicide rate has decreased (by 38 % in Europe from 1990 to 2017) it has remained constant in the Americas with young males aged 15-29 particularly at risk (estimated annual homicide rate of 64 per 100,000) [13]. Organized crime

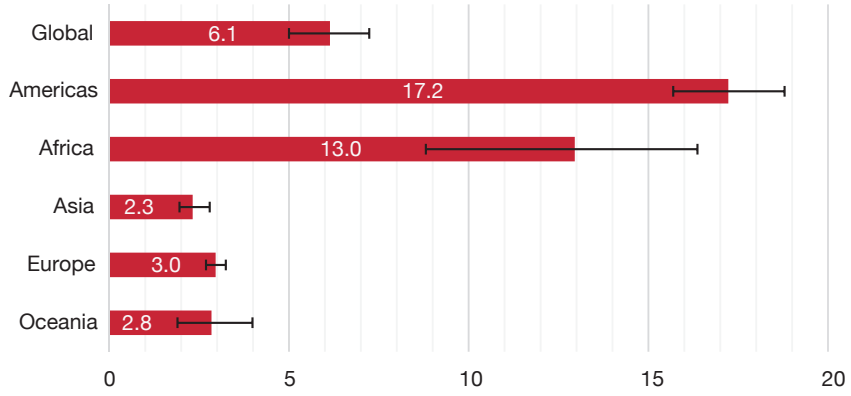


Figure 7 Global and regional homicide rates, 2017. From United Nations Office on Drugs and Crime, Global Study on Homicide 2019 [13].

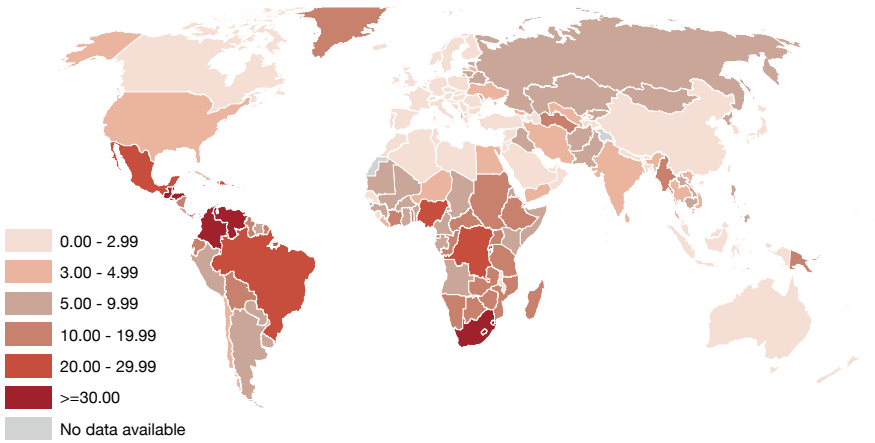


Figure 8 Homicide rate by country or territory, 2017. From United Nations Office on Drugs and Crime, Global Study on Homicide 2019 [13].

and street gangs are responsible for the high homicide rates in parts of Central America, with spikes in rates related to drug trade [13].
In 2017 firearms were used in 54% of the world's homicides with known method, while sharp objects were used in 22% and other specified methods in 24% [13]. There are indications that a high proportion of homicides by firearms is related to high homicide levels, while a high proportion of homicides by sharp objects is related to a low homicide level [13]. Of interest to the subject of this dissertation, Denmark is one of the only European countries in the report with insufficient data available on homicide methods [13].
Males dominate the global homicide statistics with an estimated 81% of victims (2017) and 90% of offenders (2014-2016) [13]. However, females make up 82% of the victims in intimate partner homicides and 56% of all female victims were killed by a member of their family [13]. The Global Study on Homicide 2019 includes separate booklets on "Gender-related killing of women and girls" and "Killing of children and young adults" that provide an extensive overview of these types of homicides, that are different to traditional adult male-on-male homicides [13].
The studies do not provide specific information on sharp force homicides, survival time and medical treatment.

2.2.11 A need for detailed studies of homicide in Denmark

The data from the Danish Register of Causes of Death [27, 28] and the police statistics [29] (**Figure 6**) are crude figures with inherent data quality issues [10, 30], so for forensic pathologists and related professionals to better understand the area, we need to look closer at each individual homicide.
In Denmark all homicide victims are required by law to undergo a medicolegal autopsy at one of the three departments of forensic medicine in Copenhagen, Odense or Aarhus (§184 in the Danish Health Care Act) [37]. This means that a study of autopsy files from these departments at the outset should include all homicide victims. The main products of a medicolegal autopsy are the autopsy report, the supplementary report (histology and toxicology) and photos, enabling a detailed registration of the circumstances of the homicide and the findings on the victim [9].
"Study I" will provide new detailed statistics on homicides in general, serving as a basis for case selection and further analysis in "Study II" and "Study III", where the focus will be on sharp force homicides.

2.3 Sharp force homicides

Injuries inflicted with a sharp object, such as a knife, are often seen in severe interpersonal trauma [38, 39]. In forensic medicine we divide the wounds from sharp force trauma into (**Figure 9**):

a) Slash wounds (cuts/incised wounds), where the sharp edge of the object has made cuts into the tissue, often relatively superficial [39, 40].
b) Stab wounds, where the sharp object has been driven into the depth of the tissue with the tip forward, frequently with resulting injuries to internal organs [39, 40].

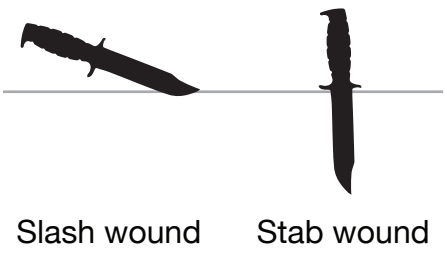


Figure 9 The two types of wounds from sharp force trauma: Slash wounds and stab wounds.

In deaths from sharp force trauma the number, location and characteristics of wounds, as well as the location of the weapon, are important for determining the manner of death. The interpretation can especially be difficult in deaths with only a few wounds, where all three non-natural manners of death are conceivable [39-47]. The trajectories of stab wounds in underlying tissue can help establish how the stabbing occurred, although a given trajectory usually can be caused in more than one way, depending on the positioning and actions of the victim and the offender (**Figure 10**) [39, 40].

Some studies on sharp force homicide do not include certain wounds on arms and hands of victims, i.e., the so-called defense wounds [42, 43, 45]. A reason for excluding these could be that the shifting grip of a victim trying to ward off a knife could lead to multiple wounds, making the attack look more brutal than was intended by the assailant. The movement of the limbs of a victim can make the interpretation of stab wounds

Figure 10 Example of similar stab wound trajectories from different situations.

vs. slash wounds difficult, so in "Study II" and "Study III" stab wounds are only reported as such for the head, neck, thorax and abdomen.

The studies from Denmark by Hart Hansen [14], Leth [15] and Hougen et al. [19] all have data or related studies on sharp force homicides. As part of a doctoral dissertation, Karlsson et. al [41-46] have written extensively on deaths from sharp force trauma in Sweden.

2.3.1 Sharp force homicides in Denmark 1946-1970, Hart Hansen [14]

A total of 85 (9.5%) victims died from sharp force trauma (49.4% males, 50.6% females) [14]. Kitchen knives were used in 41.2% of the sharp force homicides. Most victims (66 (77.6%)) had at least one stab wound, while 11 (12.9%) victims only had slash wounds. It was more common for female victims to have slash wounds. The thorax had wounds in 62.4% of victims, the neck in 41.2% and the abdomen in 16.5%. The lungs were injured in 52.9% victims, the heart in 36.5% and the large thoracic vessels in 15.3%.
For all homicides the survival time was known in 57.3%. Of those 62.2% died immediately, 11.7% survived less than 60 minutes, 11.5% 1-24 hours and 14.1% more than 24 hours, with longest survival in poisonings and blunt force trauma. Surgery, blood transfusion, etc. (unclear what "etc." entails) was performed in 13.6% of all homicide victims. It was noted that the advances in alarm systems, transport, on scene treatment and hospital treatment in the last decades of the study has led to fewer homicide victims, analogous to the hypothesis in "Study III" of this dissertation.
In victims of sharp force trauma, 79 (92.9%) had known survival time. Of those 58.2% died immediately, 21.5% survived less than 60 minutes, 15.2% 1-24 hours and 5.1% more than 24 hours. There is no data on the level of treatment specifically for sharp force homicides.

2.3.2 Sharp force homicides in Southern Denmark During 25 years, Leth [15, 18]

Kitchen knives were used in 72% of sharp force homicides [15]. The victims of sharp force homicides had injuries to the heart in 36.8%, the lungs in 63.1% and neck arteries in 31.6% [18]. The study does not provide data on survival time or medical treatment.

2.3.3 Homicides by sharp force in two Scandinavian capitals, Rogde et al. [20]

The study on homicide by sharp force only provides specific information for the complete dataset and not distinctly for the sharp force homicides in Copenhagen [20]. Most injuries were inflicted with knives. Most cases lacked information about the type of knife, but at least 21% of males and 27% of females were killed with a kitchen knife. Female victims had injuries in more body regions (the majority in 3-4 (head, neck, thorax, abdomen, upper limbs, lower limbs)) than male victims (45% in only one region). The study does not provide data on the number of wounds, organ injuries, treatment or survival time.

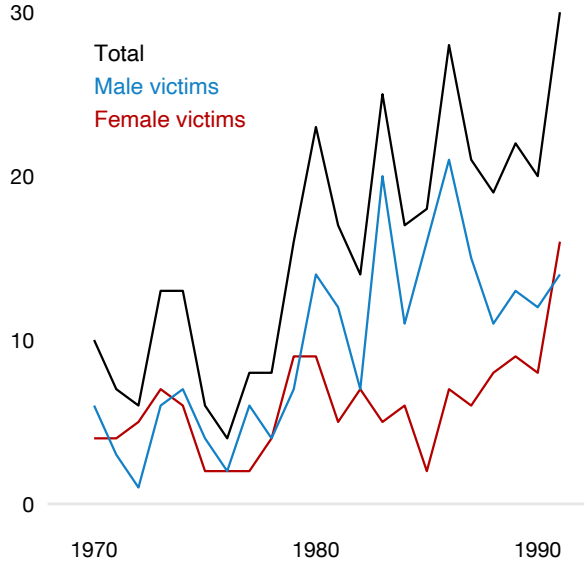


Figure 11 Official statistics on sharp force homicides in Denmark 1970-1992, from the Danish Register of Causes of Death [27, 28].

2.3.4 Official statistics on sharp force homicide in Denmark [27, 28]

The Danish Register of Causes of Death provided detailed information about homicide methods in annual publications up until 1996 [27, 28]. During 1970-1992 there was a considerable increase in the number of sharp force homicides in Denmark (**Figure 11**). The increase mostly affected male victims, with a distinct change going into the 1980s, similar to the findings in Sweden (see below) [41].

2.3.5 A multivariate approach to the interpretation of patterns in homicidal and suicidal sharp force fatalities, Karlsson et. al [41-46]

In a Swedish doctoral dissertation from 1997, Karlsson examined all suicidal and homicidal deaths in the Stockholm area for the 20-year period 1973-1992 [41]. The

dissertation includes two papers on homicidal deaths, one by Ormstad et al. from 1973-1982 (N = 142)[43], and one by Karlsson et. al 1983-1992 (N = 174) [42]. The three other papers in the dissertation concern sharp force suicides [44] and comparisons between of sharp force suicides and homicides [45, 46].
During 1973-1992 there was a significant increase in the annual number of male victims, but when split between the two studies, it was only significant for 1983-1992. There was no annual increase in female victims.
Both studies examined the number of sharp force wounds, excluding defense wounds on hands and arms.
For 1973-1982, 43.7% of victims had 1 wound, 40.1% had 2-9 wounds and 16.2% had 10 or more wounds.
For 1983-1992, 33.9% of victims had 1 wound, 42.5% had 2-9 wounds and 23.6% had 10 or more wounds.
In general, homicides with a single wound were connected to alcohol intake and involved male drinking companions, while those with 2-9 wounds often involved acquaintances or strangers under influence of narcotic compounds. The homicides with 10 or more wounds often occurred within families and often had offenders with mental illness [42].
The studies do not provide data on the precise number of wounds, average number of wounds between various groups, the number of injured regions or injured organs that can be used as direct comparison to "Study II" and "Study III". They do, however, provide lots of other detailed information about perpetrators, including injuries and earlier convictions, as well as toxicological findings and legal consequences [42, 43].

There are numerous other studies on sharp force homicides, but due to the limited space available in this dissertation, these will only be mentioned as part of the discussion of the results (see below).

2.4 Injury quantification

Autopsy reports provide detailed information about the location of wounds and related organ injuries in a somewhat standardized format, not unlike a science report. Capturing this information systematically for research is a challenge. The Abbreviated Injury Scale provides a structured framework for quantification of injuries [48, 49] and subsequent calculation of various injury scores.

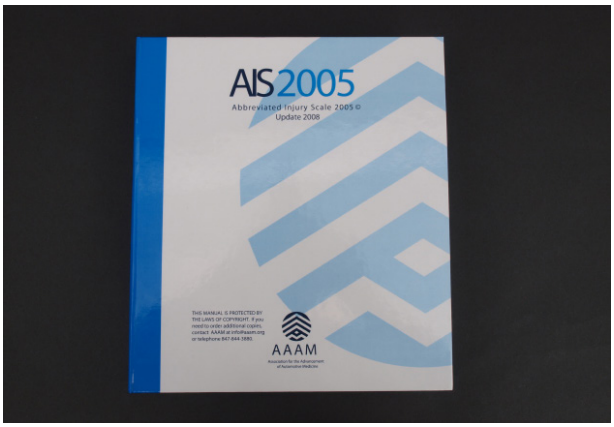


Figure 12 The Abbreviated Injury Scale manual [48].

441414.3	laceration NFS
441430.3	unilateral NFS
441431.3	minor; <1 lobe
441432.4	major; ≥1 lobe
441450.4	bilateral NFS
441451.4	minor; <1 lobe
441452.5	major; ≥1 lobe in at least one lung

Figure 13 The Abbreviated Injury Scale, categories in lung laceration [48].

2.4.1 Abbreviated Injury Scale

The Abbreviated Injury Scale (AIS) was developed in 1971 as a tool for quantifying the severity of trauma in traffic accidents [48, 49] (**Figure 12**). It has since been revised multiple times reflecting advances in trauma treatment and in order to accommodate use for other types of trauma [49-57]. The idea behind AIS is that every single injury can be given a seven-digit injury code (123456.7), reflecting the anatomical region (1xxxxx.x), anatomical structure (x2xxxx.x), injury type (xx34xx.x), injury extent (xxxx56.x) and injury severity (xxxxxx.7) (**Figure 13**). The injury severity ranges from 1 (trivial) to 6 (maximal).
There are many pitfalls in injury scoring with AIS and the use requires completion of a course with examination, provided by the organization behind AIS (see diploma in **Appendix (pg. 113)**). As a basic principle in AIS, all injuries are coded conservatively, meaning that if there is doubt about the severity of an injury, the least severe injury code in that category should be used [48]. In the example with the nephew, uncertainty about whether or not one or two lung lobes were injured (severity of 3 or 4), should lead to registration of only single lobe injury (**Figure 13**).

AIS	Supplement	Injuries
416001.**1**	02 70 83 1210	Stab wound, left front thorax (trajectory: post.-dxt.-inf.)
710402.**1**	01 65 60	Contusion, right hand
752521.**2**	01 00 60	Fracture lateral metacarpal, right
450201.**1**	02 00 83	Fracture rib, left side
441431.**3**	02 00 83	Laceration lung, one lobe, left
441603.**3**	00 00 83	Hemopericardium
441012.**5**	00 00 83	Laceration heart

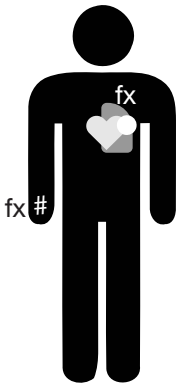


Figure 14 Injury codes (AIS) for a homicide victim (the nephew). Bold indicates severity of each injury [48].

The AIS manual comes with suggestions for optional registration of detailed information about the localization and cause of injury in supplementary digits [48]. One set of localizers is used to describe the location as to right, left, midline, bilateral, etc. (localizer 1). The other set is used for the precise anatomical region, e.g., ear, elbow, hip or toe (localizer 2). By combining the two sets of localizers, a precise registration of an injury is possible, e.g., right angle of jaw, left knee or right front of thorax. In a similar fashion there is a set of digits that describe what the cause of injury for that particular injury was. This makes it possible to discern which injuries in a victim are caused by a weapon and which are caused by beating with fists or kicking. For the current project these localizers and cause of injury codes have been adapted to better suit the needs in forensic medicine. In gunshot trauma the cause of injury information is used to describe the range of fire for each injury, in order to capture more than just a single range of fire in a victim with multiple gunshot injuries. A set of four digits has been added to register information about trajectories in penetrating injuries (stab wounds and gunshot wounds), and whether or not the projectile has exited the victim's body. The same codes are utilized in injuries from strangulation to discern marks from ligatures and fingernails. The optional registration of injuries in this project involves 10 digits, making the total for each injury 17 digits (123456.7 ab cd ef ghij).

For trauma victims, like the above-mentioned nephew with a single stab in the chest, there can be one or more AIS-codes, detailing external and internal injuries (**Figure 14**). The AIS manual is ambiguous concerning whether or not external injuries with underlying organ injuries should be registered with an injury severity [48]. As documentation and interpretation of external injuries is an important part of forensic medicine and inclusion does not influence the results of the most commonly used injury scores, these have been included for the current study [48, 49].

2.4.2 Injury Scores

From the deducted regional information (1xxxxx.x) and the injury severities (xxxxxx.7) it is possible to calculate various trauma scores (**Figure 15**-**Figure 17**), that give an impression of the overall severity of injuries in a trauma victim:

"Maximum Abbreviated Injury Scale" (MAIS): 0-6. (**Figure 15**). The highest severity in the trauma victim's injury codes [48].

AIS	Supplement	Injuries
416001.**1**	02 70 83 1210	Stab wound, left front thorax (trajectory: post.-dxt.-inf.)
710402.**1**	01 65 60	Contusion, right hand
752521.**2**	01 00 60	Fracture lateral metacarpal, right
450201.**1**	02 00 83	Fracture rib, left side
441431.**3**	02 00 83	Laceration lung, one lobe, left
441603.**3**	00 00 83	Hemopericardium
441012.**5**	00 00 83	Laceration heart
MAIS (**5** heart)		**ISS** (5^2 (heart) + 2^2 (metacarpal) + 1^2 (stab wound))
5		**30**
		NISS (5^2 (heart) + 3^2 (hemopericardium)+ 3^2 (lung))
		43

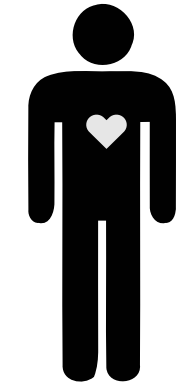


Figure 15 "Maximum Abbreviated Injury Scale" (MAIS) [48, 58].

"Injury Severity Score" (ISS): 0-75. (**Figure 16**). For each of the ISS regions (head/neck, thorax, abdomen, spine, extremities, other) the highest severity is chosen [48]. The three highest of those are squared and added. If one or more injuries have a severity of 6, the score 75 is automatically assigned. The ISS was developed to predict mortality in populations, but is also used to stratify trauma victims in research of quality of care and injury recovery [49, 58].

AIS	Supplement	Injuries
416001.**1**	02 70 83 1210	Stab wound, left front thorax (trajectory: post.-dxt.-inf.)
710402.**1**	01 65 60	Contusion, right hand
752521.**2**	01 00 60	Fracture lateral metacarpal, right
450201.**1**	02 00 83	Fracture rib, left side
441431.**3**	02 00 83	Laceration lung, one lobe, left
441603.**3**	00 00 83	Hemopericardium
441012.**5**	00 00 83	Laceration heart

MAIS (**5** heart)
5

ISS (**5**^{2} (heart) + **2**^{2} (metacarpal) + **1**^{2} (stab wound))
30

NISS (**5**^{2} (heart) + **3**^{2} (hemopericardium)+ **3**^{2} (lung))
43

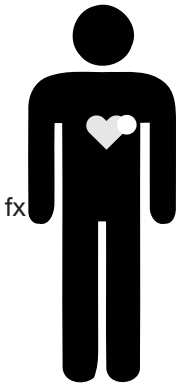


Figure 16 "Injury Severity Score" (ISS) [48, 58].

"New Injury Severity Score" (NISS): 0-75 (**Figure 17**). Same concept as ISS, but the top three severities are chosen from anywhere in the body, i.e., they can be from the same region [49, 50]. NISS was proposed to avoid underestimation of injuries in victims of penetrating trauma, such as the stabbed nephew, where ISS disregards the hemopericardium and the injury to the left lung as they are in the same region as the heart injury [49, 50, 59].

AIS	Supplement	Injuries
416001.**1**	02 70 83 1210	Stab wound, left front thorax (trajectory: post.-dxt.-inf.)
710402.**1**	01 65 60	Contusion, right hand
752521.**2**	01 00 60	Fracture lateral metacarpal, right
450201.**1**	02 00 83	Fracture rib, left side
441431.**3**	02 00 83	Laceration lung, one lobe, left
441603.**3**	00 00 83	Hemopericardium
441012.**5**	00 00 83	Laceration heart

MAIS (**5** heart)
5

ISS (**5**^{2} (heart) + **2**^{2} (metacarpal) + **1**^{2} (stab wound))
30

NISS (**5**^{2} (heart) + **3**^{2} (hemopericardium)+ **3**^{2} (lung))
43

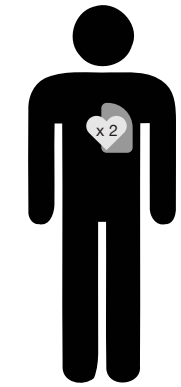


Figure 17 "New Injury Severity Score" (NISS) [48-50].

It is important to note that not all values within ISS and NISS are obtainable and they should therefore not be considered continuous variables, but rather be reported as ordered categorial variables [49]. Despite this, many studies report means and medians of ISS and NISS, which could lead to misleading interpretations [49]. As "Study III" concerns stab wounds, only NISS is reported. Traditionally ISS and NISS are categorized into "minor (1–3)", "moderate (4–8)", "serious (9–15)", "severe (16–24)" and "critical (25–75)" [49]. As homicide victims tend to have higher ISS and NISS than the general trauma population, the NISS categories in "Study III" are reported as "low (1–24)", "medium (25–44)" and "high (45–75)".

The AIS cannot be used to register long-term consequences of injuries directly, such as the pneumonia in the above-mentioned example with the widow, who stumbled down the stairs, but the risk of complications are reflected in the severity of an injury [48]. The same applies for wounds and injuries sustained during treatment and resuscitation, e.g., pneumothorax and rib fractures [48].
The AIS, MAIS, ISS and NISS are the most commonly used tools for assessing trauma victims in research. Other tools include the "Exponential Injury Severity Score" (EISS) derived from AIS, the "Trauma Score

- Injury Severity Score" (TRISS) derived from AIS as well as physiological parameters, and "International Classification of disease-9 Injury Severity Score Single Worst Injury" ($ICISS_{SWI}$) [59-63].

External injuries are important in forensic medicine and especially in homicide victims, as they can indicate the intention of the offender. Various methods have been used to capture this information and relate it to the degree of violence and victim-offender relationship.
Perhaps the simplest method is to count the total number of injuries (TNI) during external examination [64] with the caveat that each injury does not have the same severity or underlying organ injury, e.g., a bruise compared to a laceration. For the nephew the TNI would be 1 or 2, depending on inclusion of both the stab wound and the self-inflicted contusion.
The "Sum of all AIS scores" (SAIS) was proposed by Tamsen et al. as an alternative to TNI [55]. Via AIS it incorporates the severity of each injury, including injuries to internal organs and structures. For the nephew, the SAIS would be 13 or 16, depending on inclusion of the self-inflicted contusion and metacarpal fracture. A few studies have expanded on SAIS by dividing the scores according to body regions [54, 65], with special focus on victim-offender relationship.
Safarik et. al introduced the Homicide Injury Scale (HIS) with six steps of increasing severity (1-6) [66]. There are no individual registrations of each injury in HIS. Instead it requires an assessment of the overall external injury severity, signs of "overkill" and whether or not more than one homicide method was employed. It is unclear how "overkill" should be interpreted. Tamsen et al. suggested a definition involving the number of injuries, their location and involvement of underlying organs, but found the scale suboptimal compared to SAIS, although less time consuming [53, 55].

All types of injury registration-schemes come with advantages and disadvantages. AIS is by far the most comprehensive system, but is time consuming and requires completion of a course to use it properly. A challenge in determining the degree of violence from counting external injuries (TNI) is that completely different wounds will have the same impact on the score. One contusion from a punch with a fist will have the same value as one stab wound from a knife. And how close to each other should five abrasions be, to be counted as coming from the same trauma? And is it even possible to make a meaningful comparison of injury severity between different homicide methods, such as gunshots and asphyxia? It also needs to be decided whether or not to include self-inflicted injuries, like the contusion and fracture on the hand of the nephew. In studies about the brutality of assaults, the self-inflicted injuries are not relevant, but they would be relevant in studies of trends in survival and studies on the type of injuries encountered at autopsy. Dividing injuries according to lethality and type of trauma provides a way of controlling all these factors [53, 54, 64]. In an attempt to limit problems with comparability between victims, "Study II" is limited to sharp force homicides, and "Study III" to stab wound homicides.

2.5 Homicides and medical treatment

Elements before, during and after homicidal events influence the homicide rate. Unemployment, substance abuse and mental illness are some of the psychosocial factors that increase the risk of assault and homicide [31, 67-70]. The victim's physique, the assault method, severity of injuries, response from witnesses and medical personnel all determine the risk of a lethal outcome [31, 71-81]. Developments in healing technologies, such as telecommunication, transport and medical treatment are factors that are thought to be partly responsible for the recent decrease in homicide rates in the Western World [82].
Increased access to localization technology (Global Positioning System (GPS)) and mobile phones has lowered the response times for ambulance services and death rates at the scene [83, 84].
Trauma treatment in the Western world has been systematized and refined since the 1990s. Trauma victims have increased chances of survival if transferred directly to trauma centers for damage control [72, 76-78, 80]. Improvements in pre-hospital and in-hospital treatment with trauma centers at major hospitals and structured reception of multi-trauma victims have increased the survival of trauma victims [71, 74, 75, 85-88].

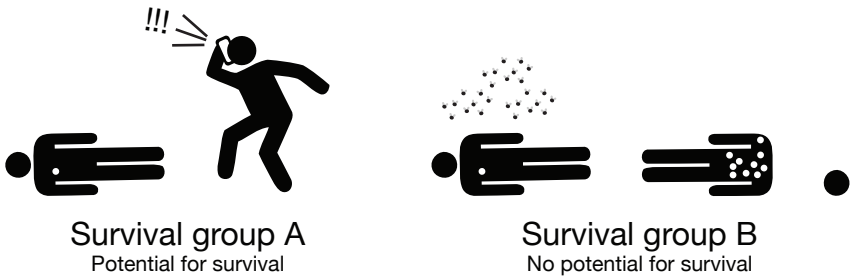


Figure 18 Survival groups [3].

Medical personnel on scene will initially assess potential homicide victims based on an evaluation of vital signs, as well as the number- and severity of injuries [71-73, 76-80]. The potential for treatment and survival in trauma victims can be divided into two groups (**Figure 18**):

Survival group A: Victims who have survivable injuries and are reached at a time where treatment is still an option and actually receive treatment. With better and faster medical treatment victims in this group will have a better chance of survival, and even for the victims who end up dying, longer survival times could be expected [3, 73, 77, 80].

Survival group B: Victims who have unsurvivable injuries, such as decapitation and complete heart laceration, or who have unmistakable signs of postmortem changes. Resuscitation and treatment are not options [3, 80].

As improved trauma response will benefit victims with less severe injuries the most, a relative increase in injury severity in non-surviving trauma victims is expected [64]. Applied to "Study III" we would expect a decrease in the number of stab wound homicides in Denmark during 1992-2016 to be coinciding with fewer single stab wound homicides (**Figure 19**). If this holds true, it should be accompanied by increased treatment of homicide victims and by differences in treatment and survival time between victims with single and multiple stab wounds.

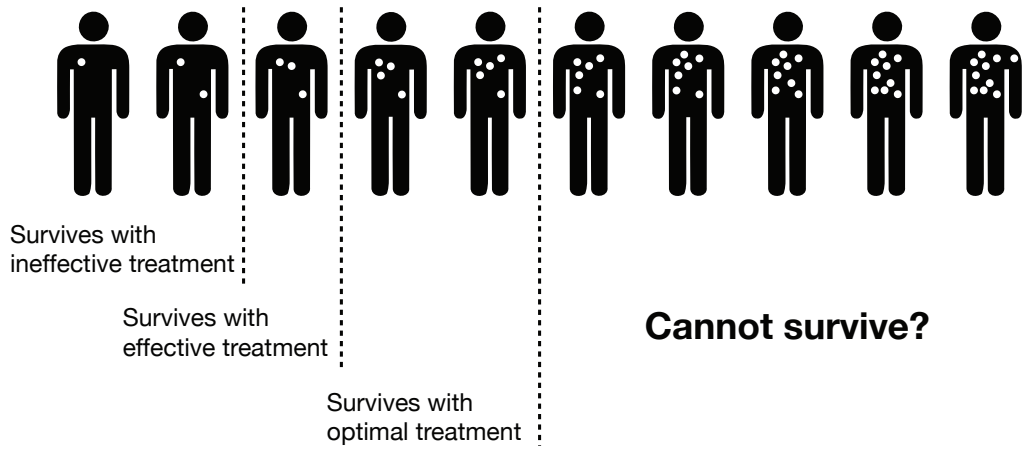


Figure 19 Better and faster medical treatment should lead to survival of the least injured victims, leading to more injuries in the group of those who die.

3 Aims

The overall aim of the studies in this dissertation is to provide evidence-based data on homicides, as seen from the point of view of the forensic pathologist.

Study I: Homicide in general

Aim: To give an overview of homicide epidemiology in Denmark 1992-2016, to be used as an anchor point for "Study II" and "Study III", as well as further studies in forensic medicine, providing an evidence-based foundation for public debate and policy development.

Paper I [1]:
Thomsen AH, Leth PM, Hougen HP, Villesen P, Brink O.
Homicide in Denmark 1992-2016.
Forensic Sci Int: Synergy. 2019;1:275-82.
doi:10.1016/j.fsisyn.2019.07.001.

Study II: Sharp Force Homicide

Aim: To give an overview of sharp force homicides in Denmark during 1992-2016, with special focus on aspects relevant to forensic pathologists, to be used as a work of reference for death investigations internationally and as a source for generation of new research hypotheses, including for "Study III".

Paper II [2]:
Thomsen AH, Hougen HP, Villesen P, Brink O, Leth PM.
Sharp Force Homicide in Denmark 1992-2016.
J Forensic Sci. 2020;65(3):833-9.
doi:10.1111/1556-4029.14244.

Study III: Stab wounds and better treatment

Aim: To explore how changes in the annual number of stab wound homicides in Denmark during 1992-2016 relate to the number of stab wounds in victims, their survival time and medical treatment.
Hypothesis: Part of the decrease in the sharp force homicide rate can be explained by better and faster medical treatment [3].

Paper III [3]:
Thomsen AH, Villesen P, Brink O, Leth PM, Hougen HP.
Improved medical treatment could explain a decrease in homicides with a single stab wound.
Forensic Sci Med Pathol. 2020. Epub ahead of print.
doi:10.1007/s12024-020-00246-z.

4 Materials and methods

4.1 Materials

4.1.1 The background population

In 1992-2016 Denmark had an average population of 5,410,573 (2,677,215 males and 2,733,358 females). The population increased from 5,162,126 in 1992 to 5,707,251 in 2016 [89].

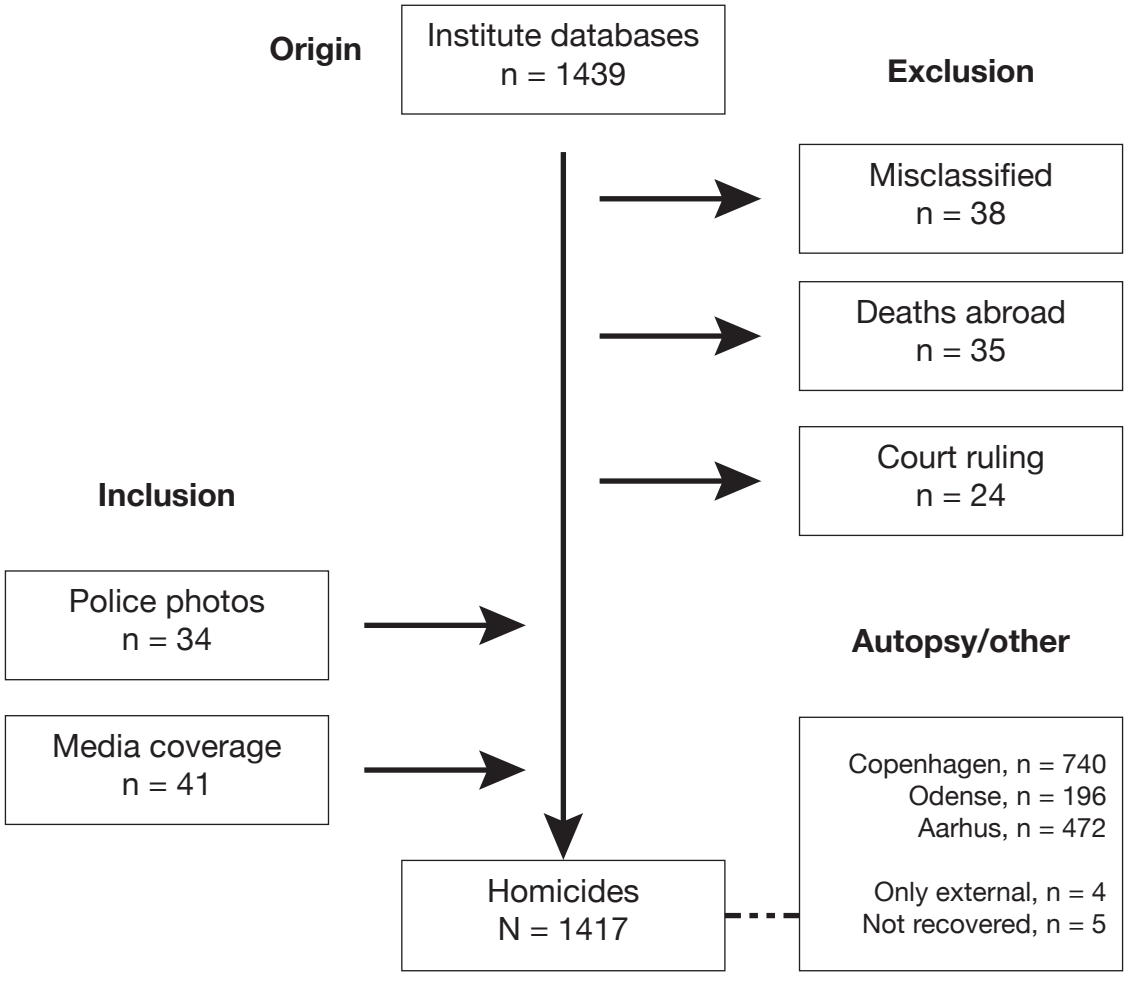


Figure 20 Inclusion and exclusion of homicide victims.

4.1.2 Inclusion and exclusion

The baseline identification of cases for the project "Homicide in Denmark 1992-2016" was via searches in the electronic databases of the departments of forensic medicine in Copenhagen, Odense and Aarhus for manner of death "homicide" committed during 1992-2016 (n = 1439) (**Figure 20**). To capture all homicides this was supplemented with a manual search in the photo archives of the departments as they contain photos where the National Danish Police has attended the autopsies, i.e., suspicious deaths, homicides and borderline cases (n = 34). Finally, a search of the media database, Infomedia (www.infomedia.dk), for annual reviews of Danish homicides in major media outlets was compared to the departments' databases to find homicides that were misclassified as another manner of death with no available police photos (n = 41) or no autopsy. The yield from media searches included 11 homicides with no autopsy, grouped into:

a) Homicides where the police, despite the legal obligation, had refrained from an autopsy, but only conducted an external examination (n = 4). One of those was a death in hospital some time after an assault by blunt force trauma, while the other three were children killed during a parent's suicide.

b) Homicides where the victim's body has not been found, but the offender was convicted in a court of law (n = 5). Three of the victims were killed in one event, the two others in separate events.

Some of the retrieved cases were excluded because of simple errors in entries of manner of death in the databases (deaths from diabetes, coronary thrombosis, etc.) (n = 38). A group of the retrieved cases were excluded, as they had occurred abroad (n = 35), most of those being Danish soldiers killed in military operations in Iraq and Afghanistan. Finally, a group of deaths were excluded because the court, after looking at the totality of evidence, had ruled the deaths as accidents (n = 24), typically involving single stab wounds or single gunshot wounds.

The last homicide victim was included in November 2018 when found after being reported missing in 2009. The project inclusion was closed on March 15, 2019, when "Paper I" was submitted. At the time of this writing (June 2020) no further victims have died from assault injuries sustained during 1992-2016 and no additional missing homicide victims have been found.

4.1.3 Available material

The primary documents in the material were the autopsy reports (including examination of the victim at the crime scene, if a forensic pathologist attended), autopsy photos and initial police reports. For about one third of the victims, additional police reports from later in the investigation and/or court documents were available. These were consulted if clarification of the primary documents was needed.

The documents were reviewed on site, at the respective departments of forensic medicine.

4.2 Methods

4.2.1 Pilot study

A pilot study served as preparation for "Study I". The study included the 29 homicides by asphyxia at the Department of Forensic Medicine in Aarhus during 2003-2012. The aim was to test the amount of information that could be gleaned from the material in the autopsy files at the department and how best to capture the data in forms for "Database A" (see below).

4.2.2 Databases

The data was registered in two main databases (**Figure 21**):

Database A) Information about the victim, the circumstances, the homicide and the offender (**Figure 22**).

Database B) Injuries in the victims via the AIS-system with localizers (**Figure 23**).

4.2.3 Data collection

The data was registered on paper forms, one for "Database A" and one for "Database B", with subsequent electronic registration in EpiData (EpiData Association, 2010, Odense, Denmark. www.epidata.dk). All data handling was done with an audit trail as advised in "An introduction to Stata for Health Researchers" [90].

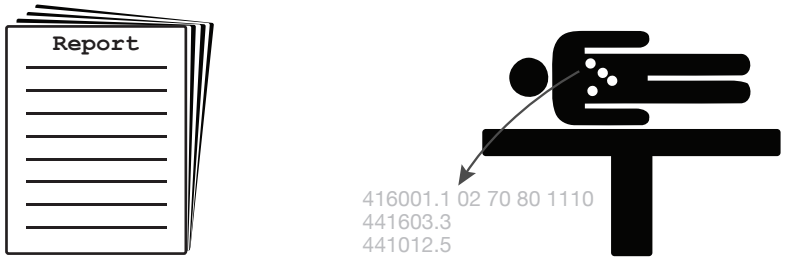


Figure 21 The two databases.

Victim	Circumstances	The homicide	Offender
Age	Time	Method	Age
Sex	Place	Motive	Sex
Health	Location	Type	Suicide
Mental health	Number of victims	Relation	*Conviction*
Substance abuse	Number of offenders	Weapon	*Mental health*
Toxicology	Survival time		*Substance abuse*
	Medical treatment		*Toxicology*

Figure 22 Information in "Database A". Italic: variables not used in "Study I-III".

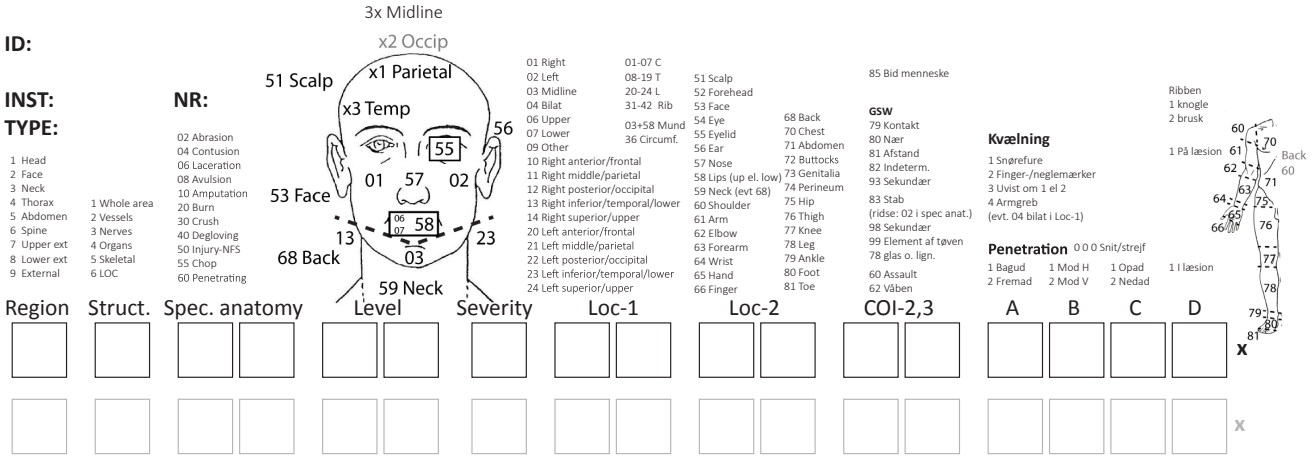


Figure 23 Injury registration in "Database B".

For "Database A" the electronic data entry in EpiData was conducted with checks between variables, to avoid entry of nonsensical data [90, 91]. Unique case identifiers (case number, police record number, autopsy number), age and sex of the victim were registered twice to avoid mismatch of cases. For each victim a short written summary was recorded with pertinent information that was compared to the form data for inconsistencies.

Summary example: "34y male with chronic alcohol abuse, stabbed once by drinking mate during argument and fight about abuse of a puppy. Dies during surgery. Prior homicide conviction (aunt)."

The AIS-data in "Database B" was registered electronically, twice (see below, "Data quality").

After completion of "Database A" and "Database B" the data was exported to Stata (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LLC.). Each variable in "Database A" was checked against other variables via cross tables in Stata, in order to find obvious inconsistencies stemming from entry errors (see below, "Data quality").

4.2.4 Data quality

There are various stages of potential data weakness, related to accuracy, completeness and capture [92].

a) Errors in inclusion of homicides (capture):

Only homicides that have been discovered are included in this project. Undoubtedly, there has been homicides in the period, that have not been discovered, either because of concealment of the victim or misdiagnosis of the manner of death during the death investigation. It is of course uncertain how large this figure is, but hopefully it is negligible.

As all homicides in Denmark are required by law to undergo autopsy [37], this material based on medicolegal autopsies, should be exhaustive. As mentioned above, the department database searches were combined with two other sources (police photos and mass media annual reviews) in order to find misclassified homicides. Via a search of mass media annual reviews, only a few homicides with no autopsy were included. Could there be more of those cases? To answer that, contact was made to the Danish Register of Causes of Death requesting data on how many death certificates they had registered for 1992-2016 with manner of death "homicide", but without any autopsy. For technical reasons they were unable to answer the question stating that a search would require a substantial amount of man hours with an unknown fee, and with uncertain results. With that in mind, the request was cancelled.

b) Errors in the original information in the studied documents, either due to misinterpretation or obvious mistakes (completeness and accuracy):

In the registration of data for this project only obvious mistakes have been corrected, and only if backed up by a secondary source, mainly photographic evidence, a police report or court document. Any interpretation made by the forensic pathologists at the time of autopsy has been registered loyally, even in the few cases where there was room for a different interpretation from the available material.

c) Errors in the transfer of data from the original documents to paper forms (completeness and accuracy):

The best way of finding these errors would be to read and register each case twice and compare. The data from the pilot study of 29 cases has been compared to the entries of "Database A" for the same cases in this study, yielding no errors in the paper forms. For that reason, there has not been any double registration of the paper forms of "Database A", as the potential yield was considered too low compared to the doubling of data collection time. As the pilot study did not have any registration in "Database B", a comparison was not possible.

d) Errors in the transfer of information from paper forms to electronic forms (completeness and accuracy):

This could have been avoided by skipping the paper forms and doing electronic entry immediately. The pilot study showed that direct electronic registration was slow and led to many entry errors, ergonomically hazardous situations and possible computer data safety issues, when registering data from the institutes in Copenhagen and Odense.

For "Database A", comparison of electronic entries with the pilot study found errors in 1.4% of entries, all leading to non-sensical data, that would have been discovered via the above-mentioned cross-tabulation. For that reason, there has not been double entry of the complete dataset in "Database A". However, as part of registering detailed offender data for a future project, data on homicide methods, typology and motives have been reentered, also leading to a few cases of nonsensical data.

Due to the numerical nature of "Database B" there was a much higher risk of entry errors. To counter this tendency, the complete database was reentered one month after being completed. The primary and secondary entries were compared via EpiData's "Data quality tool" and mismatches resolved. To get an accurate figure of the error rate, the primary and secondary entries were transferred to Stata where calculations showed a mismatch rate in AIS-lines of 3.1% (728/23,486). Most of those were switches in sequence, e.g., "02" entered as "20" in part of a line, often leading to nonsensical data.

4.2.5 Statistical methods

Statistical analyses for all three studies were made in Stata and RStudio (RStudio Team (2015). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA; www.rstudio.com/). Data visualizations were made in Adobe Illustrator and RStudio using ggplot2.

Study I: Annual data were analyzed with linear regression, using lm() in R. Models were fitted allowing for different regression lines using lm(number ~ year) and lm(rate ~ year) [1].
Seasonal and monthly variation was tested with Kruskal-Wallis rank sum test, standardized for days per month [1].
Multiple regression was performed with glm(sex ~ homicide method + . . .) in R with victim sex as response variable and homicide method, year of homicide, victim age, main homicide type (domestic, criminal milieu and non-criminal related) and time of day as predictor variables. The full model was compared with a nested model for significance of each factor [1].
A statistical significance level of 0.05 was chosen prior to all analyses in the study.

Study II: Annual data were analyzed with linear regression, using lm() in R. Models were fitted allowing for different regression lines using lm(number ~ year) and lm(rate ~ year) [2]. Multiple regression was performed with glm(sex ~ location + . . .) in R with victim sex as response variable and location (inside and outside), weapon type, main homicide type (nightlife/intoxication, partner killing, and other), and number of stabs as predictor variables. The full model was compared with a nested model for significance of each factor [2]. For differences between groups (e.g., difference in mean age between female and male victims), permutation tests of 100,000 permutations were performed. For each permutation, the sex was permuted and the mean difference between the two groups (the null) was calculated. Contingency tables were tested with χ^2-test [2].
A statistical significance level of 0.05 was chosen prior to all analyses in the study.

Study III: Annual data were analyzed with linear regression and logistic regression using lm() and glm() in R. Models were fitted allowing for different regression lines using lm(number ~ year) and glm(proportion with surgery ~ year) [3]. Contingency tables were tested with the χ^2-test [3]. For survival data, Cox proportional hazards model was used, including adjustment for single/multiple stab wounds, NISS group and first/last period of study using the "survival" package in R [3]. The annual proportion of victims having surgery was tested with the likelihood ratio test.
A statistical significance level of 0.05 was chosen prior to all analyses in the study.

5 Results and discussion

5.1 Study I - Homicide in general

5.1.1 Homicide methods

The four most common homicide methods (sharp force trauma, gunshot, blunt force trauma and asphyxia) accounted for 95.1% of all homicides (**Figure 24**). Most victims (62.2%) were male. Asphyxia was the only method with more female than male victims.

The same four homicide methods were responsible for most homicides in the study from Finland, the Netherlands and Sweden for 2003-2006 [30]. The availability of weapons in a society has an impact on the homicide methods. In countries where gun ownership -legal or illegal- is widespread, gunshot homicides are common [93]. In the United States, for example, the majority of homicides are by gunshot trauma, which explains part of the high homicide rate compared to other Western countries [13, 93].

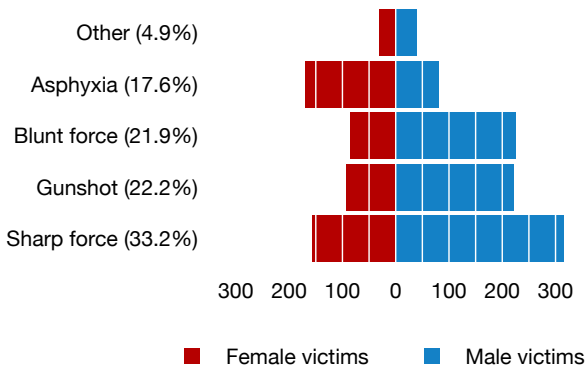


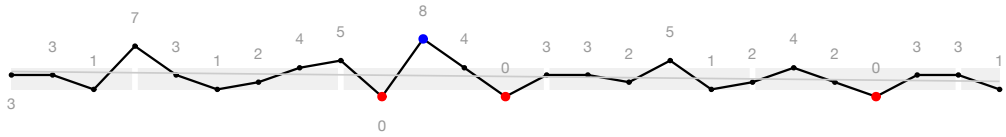
Figure 24 Homicide methods [1].

We all have easy access to knives and it requires little to no skill to inflict lethal injuries, so it is not surprising that sharp force trauma is the most common homicide method [38]. "Study II" and "Study III" will look closer at the developments in sharp force homicide.

Blunt force trauma is the most common type of violence in Denmark, both in reported violent crime and as seen in the emergency departments [94, 95]. The blunt force homicides can basically be divided into two groups: those from more or less trivial trauma that leads to a fall against an unyielding surface resulting in brain injury, and those with severe trauma from beating, kicking, stomping and use of blunt objects, often in combination. As mentioned, the legal system does not consider the deaths from trivial trauma homicides in a strict legal sense.

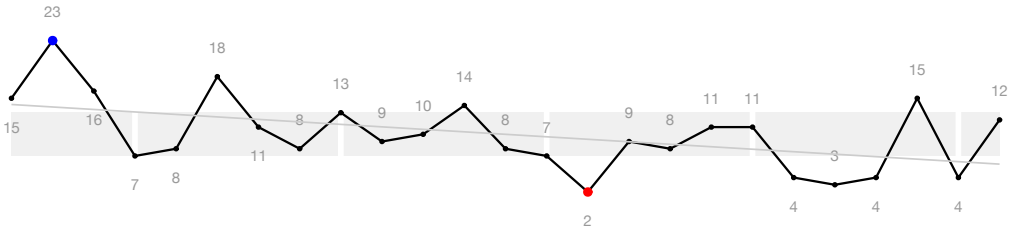
Homicide by asphyxia, such as manual strangulation, ligature strangulation and smothering requires physical dominance by the offender as a victim with equal strength will have a greater chance of escape [22]. As males in general are stronger than females, this explains why fewer males are killed by asphyxia [22]. If the victim and offender are equal in strength, it will possibly lead to some other method or termination of the assault. A large proportion of victims of asphyxial homicide were children, which also can be explained by differences in strength [96]. As seen below, the two sexes are equally distributed in child homicides, also contributing to males not being overrepresented in asphyxia as they are in other homicide methods.

The male overrepresentation in homicide victims is a change from Hansen's study of homicides in Denmark 1946-1970, where there was an equal distribution between the sexes, in part because there were many child homicides in families [14]. The current sex distribution is almost identical to the findings in Finland, the



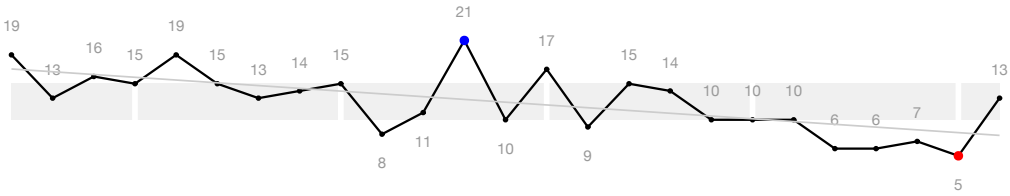
Other
70 (4.94%)
Mean: 2.8 (0-8)
Rate*: 0.05 (0.00-0.15)

Slope = -1.4 (linear regression: P = 0.32003, F = 1, R^2 = 0.04)



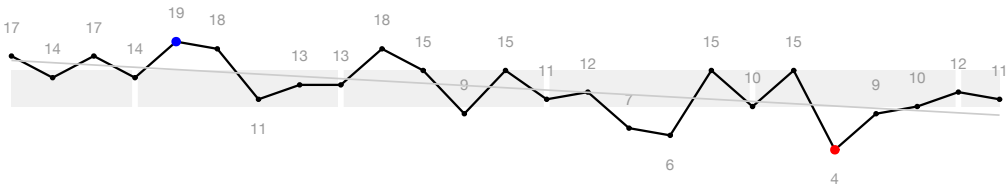
Asphyxia
250 (17.64%)
Mean: 10.0 (2-23)
Rate*: 0.18 (0.04-0.44)

Slope = -0.34 (linear regression: P < 0.05, F = 7.8, R^2 = 0.25)



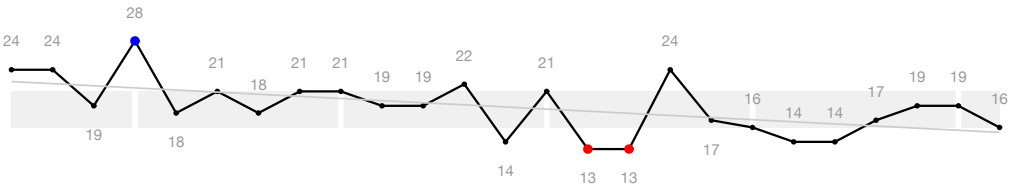
Blunt force
311 (21.95%)
Mean: 12.4 (5-21)
Rate*: 0.23 (0.09-0.39)

Slope = -0.38 (linear regression: P < 0.001, F = 17, R^2 = 0.43)



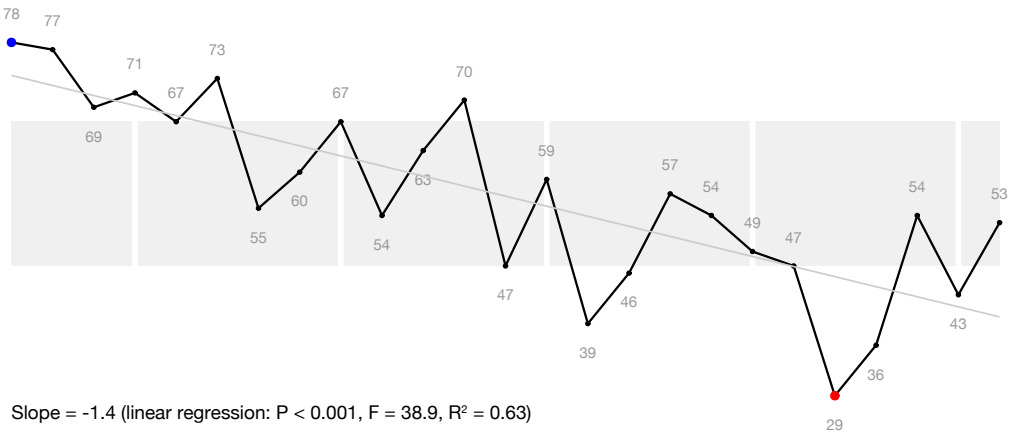
Gunshot
315 (22.23%)
Mean: 12.6 (4-19)
Rate*: 0.23 (0.07-0.36)

Slope = -0.32 (linear regression: P < 0.01, F = 12.9, R^2 = 0.36)



Sharp force
471 (33.24%)
Mean: 18.8 (13-28)
Rate*: 0.35 (0.24-0.54)

Slope = -0.29 (linear regression: P < 0.01, F = 10.6, R^2 = 0.32)



Total
1417 (100%)
Mean: 56.7 (29-78)
Rate*: 1.05 (0.52-1.51)

Slope = -1.4 (linear regression: P < 0.001, F = 38.9, R^2 = 0.63)

1995 2000 2005 2010 2015

Figure 25 Opposite: The annual number of homicides, total and by homicide method [1]. Grey areas: interquartile range. Lines: linear regression.

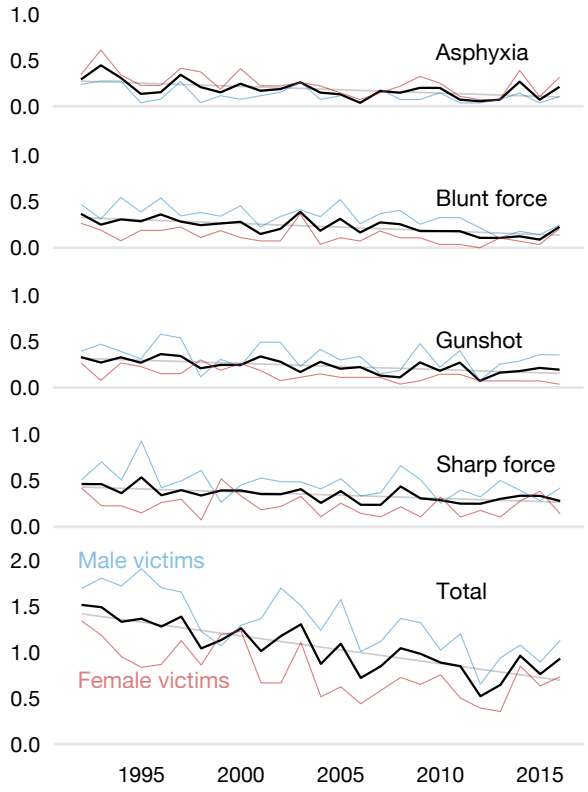


Figure 26 Annual homicide rates (per 100,000/year), total and by homicide methods [1]. Lines: linear regression.

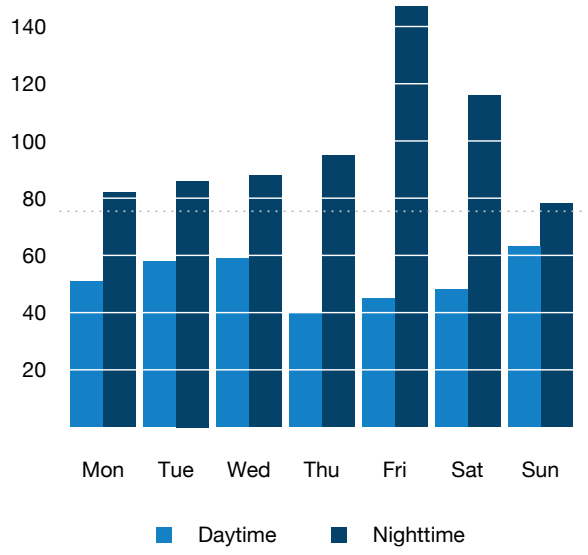


Figure 27 The time of the homicide, weekday and time of day [1]. The bars show the number of homicides for each 12-h time slot (06-18, 18-06). Dotted line: mean.

Netherlands and Sweden [30], but with a much lower proportion of male victims, than the 90% seen globally [13]. The proportion of homicides with male victims tends to follow the homicide rate, i.e. a high homicide rate in a country equals a high proportion of male victims ("Verkko's law") [13, 30].

5.1.2 The number of homicides and homicide rates

The homicide rate, total number of homicides and the number of homicides in each of the four most common homicide methods were reduced significantly during 1992-2016. (**Figure 25** & **Figure 26**). The homicide rate was 1.05 per 100,000, 1.32 per 100,000 for males and 0.78 per 100,000 for females. The highest rate was 1.51 per 100,000 in 1992, and the lowest rate was 0.52 per 100,000 in 2012 [1]. The decrease in the homicide rate and total number of homicides affected both sexes.

The homicide rate in Denmark is relatively low and the decrease since the 1990s is similar to the findings regarding homicide rates in other Western European countries [13, 30-33, 97]. There has been a great decline in the global homicide rate through historical time, which has been attributed to a civilization process in society [31, 98]. As mentioned in the introduction, the more recent decline is partly attributed to technology of healing in form of medical advances and better telecommunication [99]. During the current study period, the response times for ambulance services and the survival rates at the scene has improved due to the public's access to localization technology (Global Positioning System (GPS), etc.) and mobile phones [83, 84]. There has also been increased survival due to developments in pre-hospital and in-hospital care for trauma patients, although this has not necessarily been the case for patients reaching the hospital alive [75, 87, 88].

Many factors dictate the fluctuations in the homicide rates. Some of the variation is due to psychosocial factors such as prolonged unemployment, substance abuse and mental illness, often intertwined [67]. In substance abuse the increase in violence is enabled via proximal factors in form of increased aggression and cognitive impairment as well as distal factors such as contact with other intoxicated people and the accompanying lifestyle [69]. This increased risk is confirmed by the largest group of male victims being in the homicide type "nightlife and intoxication", often between friends/acquaintances (see below).

5.1.3 Time of homicide

The time of day and week was known in 75% of homicides. Most occurred in the nighttime, often Friday and Saturday evenings and nights, with male victims and connected to intake of alcohol and/or illicit drugs (**Figure 27**). Previous studies have found that there is an overrep-

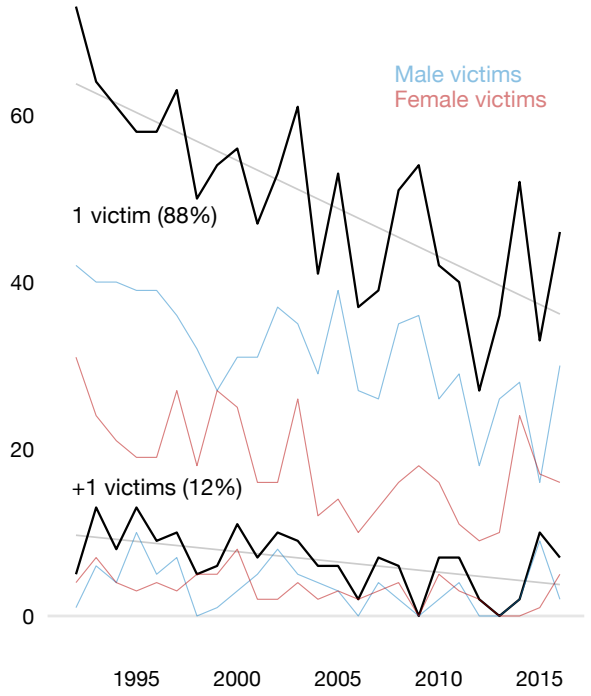


Figure 28 The annual number of homicides grouped by homicide events with one victim and multiple victims [1].

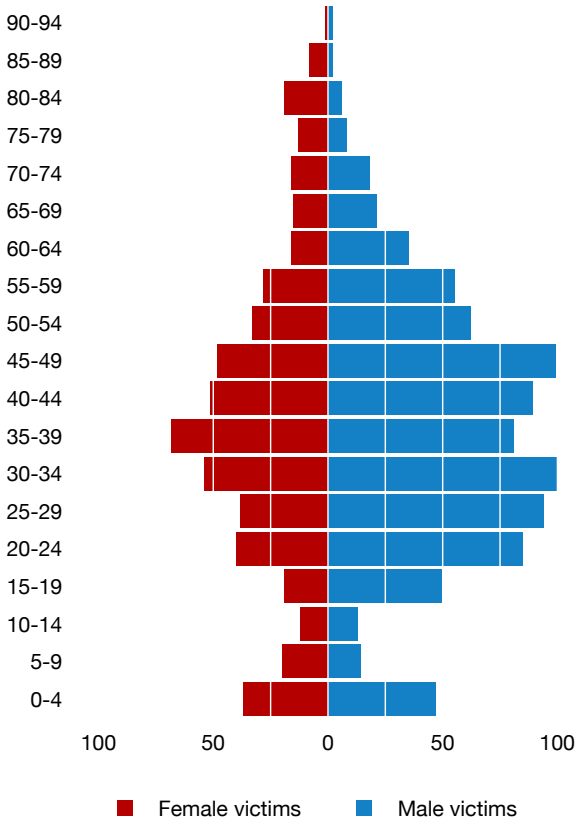


Figure 29 The age distribution of homicide victims [1].

resentation of homicides on weekends and evening/nighttime, often with intoxication by alcohol and/or illicit drugs [14, 19, 30]. Many of the nightlife/intoxication homicides had triviality as part of the motive (see below), which indicates that a reduction in alcohol intake is an obvious starting point for prevention.

5.1.4 Homicide events, single victims vs. multiple victims

The decrease in the number of homicides affected both homicidal events with a single victim (linear regression: slope = -1.25, $P < 0.01$, $F = 32.6$, $R^2 = 0.59$) and with multiple victims (linear regression: slope = -0.25, $P < 0.05$, $F = 7.9$, $R^2 = 0.26$) (**Figure 28**). 11.9% of victims were killed in homicidal events with multiple victims.

In Hart Hansen's study from 1946-1970 one quarter of the homicide victims were killed in events with multiple victims, albeit with a reduction in "family dramas" from about 30% of all homicides in the first half of the period to about 10% in the last period (exact figures for the development in multiple victim episodes are not given) [14]. To a large extent this was due to a reduction in family homicides where mothers killed their children with carbon monoxide-rich town gas, while killing themselves in the process. As mentioned in the review of the study, better social support for single mothers and the limited availability of carbon monoxide-rich town gas were thought to be the main reasons for the reduction.

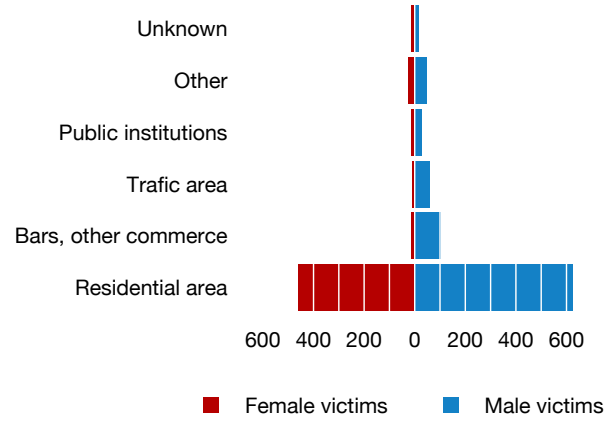


Figure 30 The location of homicides by area [1].

5.1.5 Age of victims

For 1946-1970, 42% of the victims were younger than 15 years old [14]. In the current study two thirds of victims were 25-64 years old (**Figure 29**), which is similar to the findings in Finland, Sweden and The Netherlands [30]. The age-adjusted homicide rate was highest for the first year of living, double the total homicide rate, which reflects the vulnerability of infants left to the care of other people. Infants are at risk of homicide in the newborn period, either from being born in concealment or as a result of postpartum depression, later during babysitting by inexperienced parents and as part of family homicides

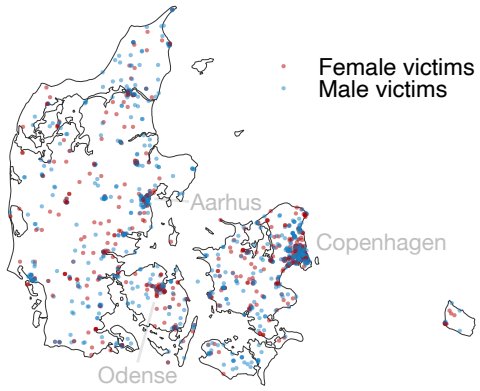


Figure 31 Map of Denmark with location of homicides [1].

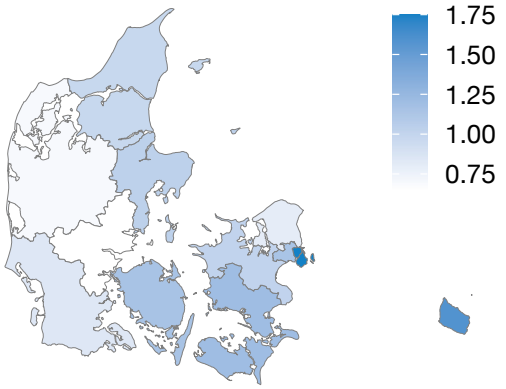


Figure 32 Map of Denmark with homicide rates (per 100,000/year) in the 12 police districts.

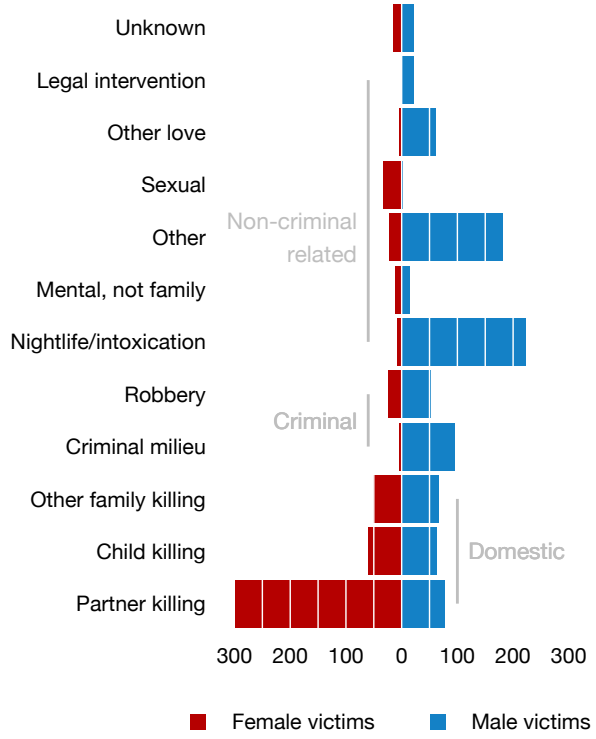


Figure 33 The type of homicide [1].

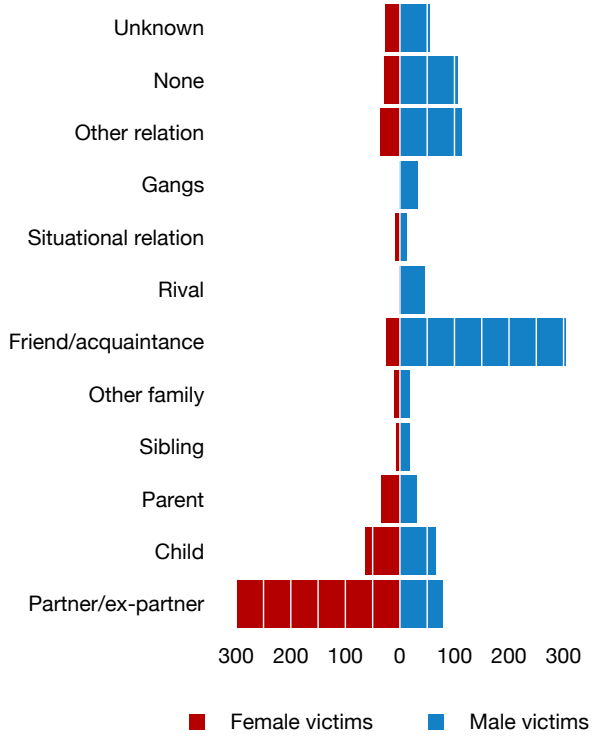


Figure 34 Relation between victim and offender [1].

where the whole family is killed.

5.1.6 Homicide location

76.6% of homicides occurred in residential areas (**Figure 30**), often inside the home of the victim and/or offender. As most victims and offenders had a relation to each other and many of the homicides were based on a personal conflict this is not surprising, and is in line with other studies [13, 30, 32, 33].
The homicides were clustered in larger cities with the highest homicide rate being in the Copenhagen area (**Figure 31** & **Figure 32**). Big cities are risk areas for violent crime, due to social and criminological factors, which could explain the high rate in the Copenhagen area, although it is relatively low compared to large cities around the world [33, 100].

5.1.7 Type of homicide, motives and relation

76.5% of female victims and 23.6% of male victims were killed within the family (**Figure 33**). The sex difference arises from intimate partner homicides (55.6% of females vs. 8.9% of males), more often motivated by

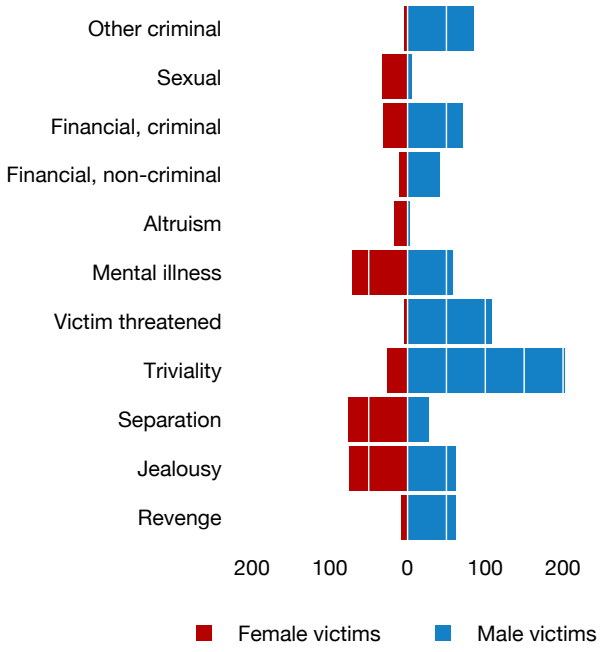


Figure 35 The homicide motives. Each homicide can be represented more than once [1].

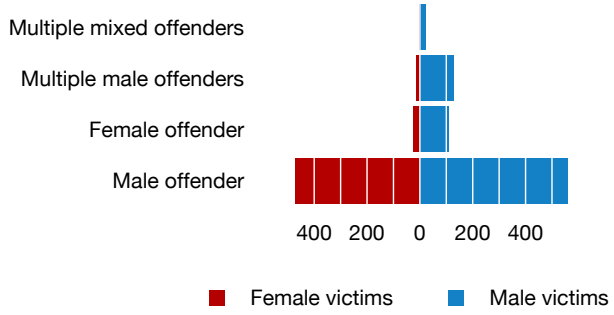


Figure 36 Offender sex related to sex of victim [1].

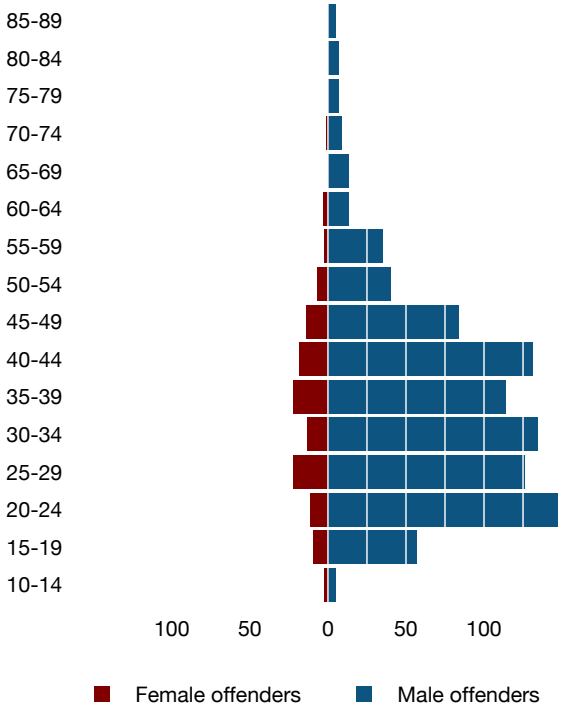


Figure 37 The age distribution of homicide offenders in homicidal events with only one offender (n=1050) [1].

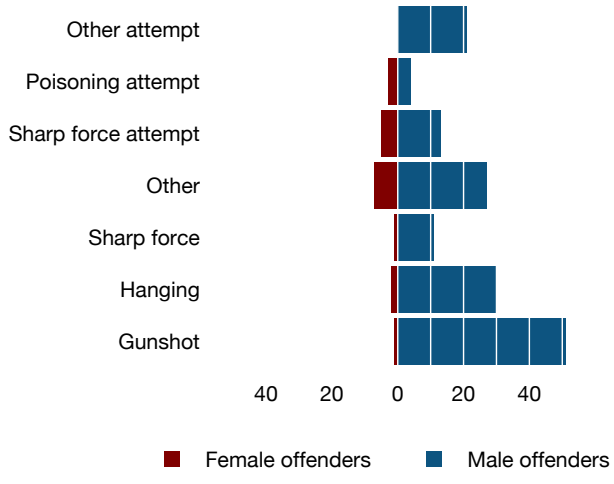


Figure 38 Offender suicide method [1].

separation and/or jealousy for female victims vs. victims threatened (violent and threatening behavior) for male victims (**Figure 33**-**Figure 35**). 75% of children killed in the family were killed by their father.
84.2% of victims in non-domestic homicides were males, 15.8% females. The largest subgroup within non-domestic homicides was in the setting of nightlife/intoxication, almost exclusively male victims and often with a trivial quarrel as motivation.
It follows that females were mostly killed by family members, while males often were killed by friends/acquaintances. Homicides in criminal environments (including criminal gangs) were relatively rare (7.1%).

It is obvious that homicides with female victims are quite different from those with male victims, as they almost exclusively take place in a domestic setting, often involving current or former intimate partners. Relatively more homicides were between intimate partners than is estimated for high-income countries in general, but the proportion is similar to data from Sweden for 1990-2013 [101, 102].
The data in "Study II" will provide more information about the sex differences in relation to homicide type and how those differences affect the injuries we see at autopsy in sharp force homicides.

5.1.8 Offenders and offender suicide

Most offenders were males (87.9% of homicides with known offenders)(**Figure 36**). 80.7% of female offenders killed within the family vs. 47.5% of male offenders. 74.6% of offenders were 25-64 years old. All offenders aged 75 years and older were males (**Figure 37**).
For 1946-1970 Hansen found that 32% of offenders were females [14], and the reduction in female perpetrated homicide since then reflects the above-mentioned reduction in domestic homicides. The current male dominance in homicide offending is a worldwide trend [13, 30], that follows a general trend in male aggression and risk taking behavior peaking at ages 18-30 [103, 104].

9.8% of homicide events were followed by offender suicide and 3.6% by a suicide attempt. Most were males, but in proportion to offender sex in general (9:1), there was no sex difference (**Figure 38**). The majority of homicide-suicides were within the family, often with multiple victims including partners and children, and occurred immediately following the homicide. Half of the completed suicides was with the same method as the homicide vs. one fifth for attempted suicides. Firearms were often used by male offenders, for both homicides and suicides.
In absolute numbers the offender suicides and suicide attempts are about half of what was seen in the 25 years Hansen studied during 1946-1970, but in relative numbers only one third [14]. Again, this is an effect of the decrease in the child family homicides. The common use of firearms in homicide-suicide, the domestic setting and multiple victims is in agreement with international studies, although the use of firearms are even more common in the U.S.A. [105-107].

5.1.9 Multiple regression

In multiple regression models, homicides with female victims were significantly different from homicides with male victims with regard to main homicide method, main homicide type (domestic, criminal milieu and non-criminal related), victim age and time of day (with interaction between homicide method and main homicide type), but not with regard to homicide year (**Table 1**).

Equation	Variable	R^2	ΔR^2	P
victim sex ~ victim age + time of day + method * homicide type	Full model	0.388	-	-
victim sex ~ year + victim age + time of day + method * homicide type	Full model + year	0.373	0.015	0.378
victim sex ~ victim age + time of day + method + homicide type	No interaction	0.373	0.015	<0.001
victim sex ~ victim age + time of day + homicide type	Method	0.379	0.009	<0.001
victim sex ~ victim age + time of day + method	Homicide type	0.175	0.213	<0.001
victim sex ~ time of day + method * homicide type	Victim age	0.375	0.013	<0.001
victim sex ~ victim age + method + homicide type	Time of day	0.362	0.026	<0.05

Table 1 Multiple regression models with victim sex as response variable [1].

5.2 Study II - Sharp force homicide

5.2.1 The number of sharp force homicides and sharp force homicide rates

There were 471 homicides that had sharp force trauma as the primary homicide method (33.2% of 1417 total homicides) (**Figure 24 (pg. 25)** & **Table 2**), distributed in 456 homicidal events with 1-3 victims (multiple victims in 29 events). In 8.1% of sharp force homicides, other homicide methods contributed to the death, typically blunt force trauma or asphyxia. In the remaining 946 homicides with non-sharp force trauma as the primary homicide method, 2.3% had sharp force trauma as a contributing homicide method. The primary homicide method in those was blunt force trauma (63.6%), asphyxia (27.3%) and gunshots (9.1%).
The average annual number of sharp force homicides was 18.8 (13-28) (**Figure 25 (pg. 27)**). There was a significant reduction of 0.29 sharp force homicides per year (linear regression: $P < 0.01$, $F = 10.6$, $R^2 = 0.32$). The sharp force homicide rate was 0.35 per 100,000 and there was a significant annual decrease of 0.007 per 100,000 (linear regression: $P < 0.001$, $F = 16.7$, $R^2 = 0.42$) (**Figure 26 (pg. 27)**). For male victims the sharp force homicide rate was 0.47 per 100,000 with a significant annual decrease of 0.010 per 100,000 (linear regression: $P < 0.05$, $F = 7.5$, $R^2 = 0.24$)). For female victims the sharp force homicide rate was 0.23 per 100,000 with a non-significant annual decrease of 0.004 per 100,000 for female victims (linear regression: $P = 0.23$, $F = 1.5$, $R^2 = 0.06$).
The sharp force homicide rate has more than tripled since Hansen's study of homicides in Denmark 1946-1970, where it was 0.08 per 100,000/year [14]. The official death statistics (**Figure 11 (pg. 11)**) showed that the largest increase in the intervening years occurred during the 1980s, mainly in male victims. The decrease during 1992-2016 is part of an overall trend for all the most common homicide methods, as described in "Study I" [1]. "Study III" will look closer at the possible effect of medical treatment on the development in homicides with stab wounds.

	All	**Males**	**Females**	**P**
Number of victims, N (%)	471 (100)	315 (66.9)	156 (33.1)	<0.001[a]
Victim age, mean, (min-max, sd)	39.3 (0-91, sd=15.8)	38.7 (2-91, sd=14.5)	40.5 years (0-88, sd=18.3)	0.23[b]
Number of sharp force lesions, mean (min-max, median)	14.0 (1-211, 7)	12.1 (1-211, 6)	17.9 (1-105, 10)	<0.01[b]
Regions with sharp force lesions, mean (median)	2.8 (3)	2.7 (2)	3.0 (3)	<0.01[b]
Victims with stab wounds, N (% within group)	428 (90.9)	294 (93.3)	134 (85.9)	<0.05[a]
Number of stab wounds, mean (min-max, median)	5.9 (1-92, 3)	5.1 (1-92, 2)	7.7 (1-75, 4)	<0.01[b]
Victims with defense wounds, N (%)	272 (57.8)	170 (54.0)	102 (65.4)	<0.05[a]
-Intimate partner homicides, N (%)	81 (55.1)	17 (28.8)	64 (72.7)	<0.001[b]
	1 stab wound	**2-9 stab wounds**	**10+ stab wounds**	**P**
Victims with defense lesions, (%)	(40.3)	(67.5)	(76.2)	<0.001[a]

Table 2 Sharp force injuries and stab wounds of victims [2].
a) $\chi 2$-test. b) Permutation test, 100,000 permutations.

5.2.2 Victim and offender characteristics

Two thirds of the victims were males (**Table 2**), as opposed to Hansen's more equal sex distribution [14]. Numerous studies have shown a proportional increase in male victims of sharp force homicides through the 1970s and 1980s [18, 20, 42, 43, 47, 108-117].

There were no significant differences in ages between male and female victims (**Table 2**). The only difference in sharp force homicide compared to the other homicide methods mentioned in "Study I" is that there are fewer children [1]. Many other studies show that the majority of victims of sharp force homicide are the age group 20-59 [14, 18, 20, 42, 110, 113, 114].

For 457 (97.0%) sharp force homicides, the offender's sex was known, with 379 (82.9%) of those having only male offenders. In 94.6% of sharp force homicides with female offenders, the victim was a male. Of those,

77.1% were intimate partner homicides vs. only 28.5% of sharp force homicides with male offenders. Hansen [14], Leth [18], Rogde et al. [20], Ormstad et al. [43] and Karlsson et al. [42] found a similar distribution in offender sex, i.e., sharp force homicides are not different from homicides in general [1]. In the study from Finland, the Netherlands and Sweden during 2003-2006, Ganpat et al. found no differences between male and female offenders of sharp force homicides [30].

5.2.3 The weapons and location

The weapon was a knife in 97.7% of sharp force homicides, most often a kitchen knife (70.8% of homicides with known weapon type) (**Figure 39**). In at least half of the homicides, the weapon was near the victim. A few (4.5%) still had the weapon placed in a wound (62.5% in thorax, 20.8% in neck, 12.5% in abdomen, and 4.2% in leg)[2]. One victim with the weapon still in place only had a single wound, the rest (91.7%) had 4 wounds or more.

It is not surprising that knives were used in the majority of sharp force homicides [38, 39]. The legislation in Denmark has been changed numerous times over the years in order to prevent stabbings among young males in the public nightlife [18]. As the group of public nightlife homicides is relatively small, the effect is uncertain. As will be discussed below and in "Study III", the victims in these homicides often have few stab wounds, which improves the chance of survival with improved medical treatment [3].

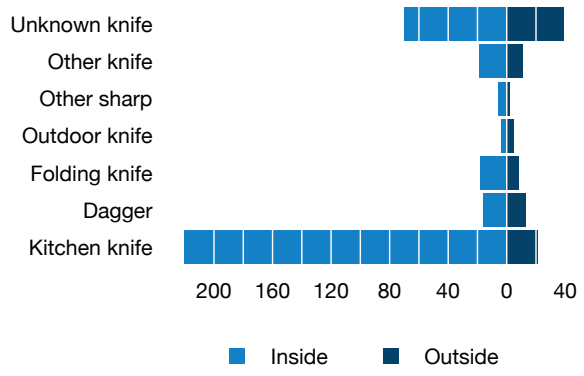


Figure 39 The type of weapon [2].

The majority (75.3%) of homicides occurred inside. Male victims made up 79.4% of victims killed in an outside location. As a large group of homicides involve offenders and victims that are either in a family relation or friends/acquaintances, and kitchen knives are available in all homes, it is hardly surprising, that many sharp force homicides occur inside [1, 18, 38]. In 2005 Hern et al. [38] suggested a sales ban on large pointed kitchen knives as an obvious measure of prevention, but the idea has not yet penetrated the Danish kitchens. At first the idea seems a bit silly, but the arguments are compelling with assistance from renowned chefs, who state that pointed ends on large kitchen knives are somewhat pointless [38].

5.2.4 The sharp force wounds

The sharp force trauma often involved the front left thorax (**Figure 40**). A minority (18.9%) of victims had only a single sharp force wound (front of body: 89.9%, left side of body: 59.6%, neck: 18.0%, thorax: 68.5) (**Figure 41**). Male victims had fewer sharp force injuries than female victims (**Table 2**). In female victims the injuries affected more regions and more often involved the neck (**Table 2** & **Figure 42**-**Figure 44**).

The front left thorax was also a common site for stab wounds as a separate entity, and the thorax in general was involved in the majority of homicides with stab wounds (**Figure 45** & **Figure 46**). More victims had stab wounds to the front of the body and the left side of the body than the back and the right side. Male victims also had fewer stab wounds than female victims (**Table 2**).

To state the obvious, all sharp force assaults start with the first wound, some then followed by additional wounds. In a study with data on single stab wound homicides, Ormstad et al. [43] found that injury to the back of the body was uncommon. No exact proportion was given, but from the provided figure it appears as if 5 out of 62 (8.1%) were in the back, which is similar to this study's findings. Burke et. al [47] studied 56 homicides with single stab injuries and found that the site of injury was the chest in 82% (72.6% in the left chest, 16.1% in the right chest), resembling this study's finding if only including stab wounds as a separate entity.

The best explanation for the predominance of single stab wounds to the front of the body is that the victim and offender are facing each other during the assault. The pervasiveness of right handedness (81.9%-90.7% [118]), community knowledge of anatomy and the odds of striking the heart and large vessels have been suggested as reasons for injuries to the left chest being common in single stab wound homicides [47]. Even

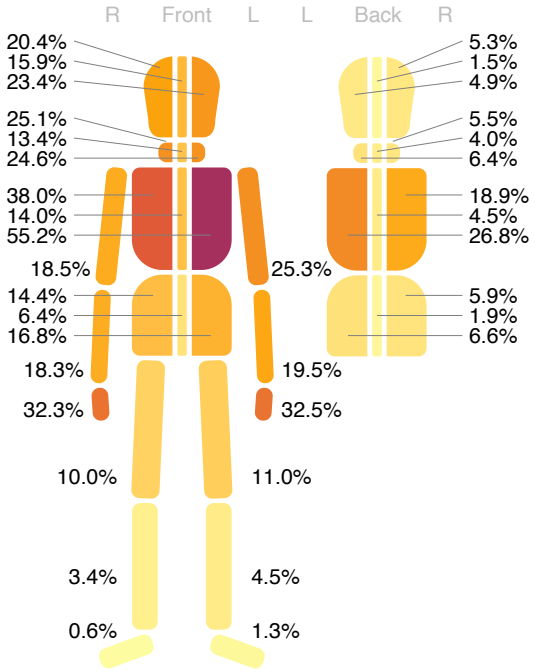


Figure 40 Distribution of sharp force injuries (stab & slash wounds) relative to all 471 sharp force homicides, that is, the percentage of victims that have at least one lesion in a given area [2].

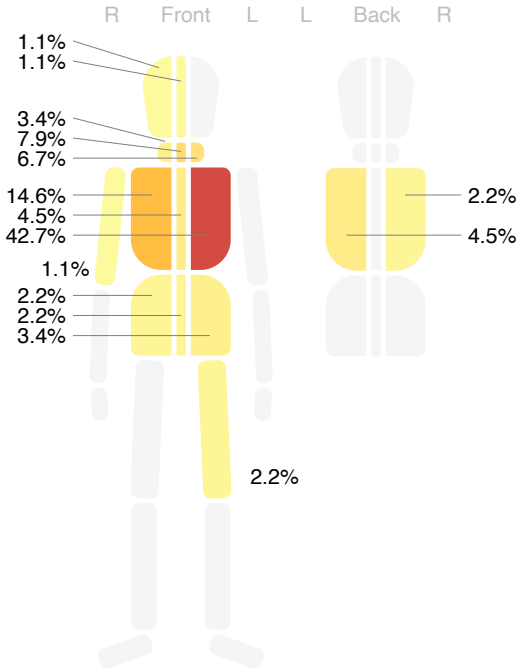


Figure 41 Distribution of sharp force injuries (stab & slash wounds) for sharp force homicides with only a single sharp force wound (n=89) [2].

in survivors of sharp force assaults, the left side is more commonly injured [119], which is an argument for right handedness in assailants, and not just the location of the heart, being an important element. The same factors must influence homicides with multiple stab wounds, with increased risk of injuries to other organs and regions with the relative movement between the offender and victim. In homicides with multiple stab wounds, the thorax, especially the front left thorax, is often injured [18, 20, 112-114, 120, 121].

At surgery and/or autopsy the most commonly observed trajectories of stab wounds were directly posterior with no deviation to the sides or up/down (25.6%) followed by directly anterior with no deviation to the sides or up/down (12.4%) (**Figure 47**). Inferior elements in the trajectories were more common than superior elements.
Descriptions of wound trajectories of stab wounds and gunshot wounds are an essential part of the autopsy report [39, 40, 122], but are oddly enough missing from the scientific literature on sharp force homicides. In court the wound trajectories can be important in determining the plausibility of statements given by various witnesses, for example in single stab wound death with a statement of "running onto a knife" [47].
As not all homicides occur with the victim standing upright in anatomical normal posture and as the relative position of offender and victim can vary extensively during a homicide, caution in interpretation is advised [39]. The wound trajectory is in part dictated by location of the stab wound, i.e., stabs to the very front of the body will result in the trajectories with at least a posterior element or else they would cause no injury. As injuries to the front of the body are the most common, it could be expected that the majority of stab wound trajectories would have a posterior element. The use of overhand thrusts by offenders, the victim being in sitting position or hunching over in standing position could possibly explain that inferior trajectories are more common than superior trajectories (**Figure 10 (pg. 11)**).

5.2.5 Defense wounds and hesitation marks

Female victims more often had defense wounds, most pronounced in intimate partner homicides (**Table 2**). The more stabs, the more often there were defense wounds (**Table 2**). When determining the manner of death, it is important to evaluate whether or not there are defense wounds [123, 124]. Depending on study size and subpopulation, defense wounds are described in 13%-78% of sharp force homicides [18, 20, 45, 108, 111-114, 123, 125-127]. The prevalence of defense wounds is correlated with the number of sharp

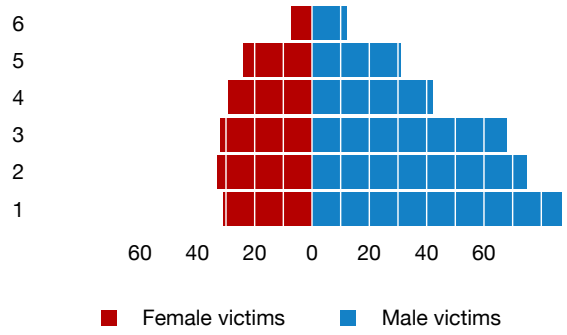


Figure 42 The total number of injured regions [2].

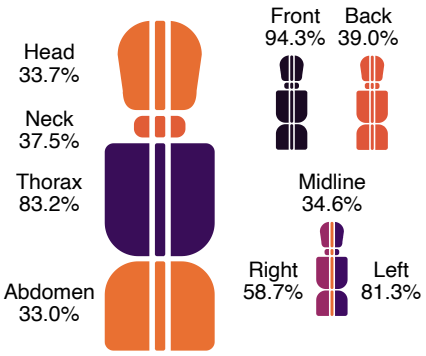


Figure 43 Regional distribution of sharp force injuries in male homicide victims [2].

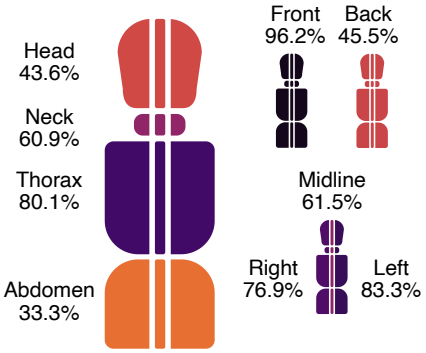


Figure 44 Regional distribution of sharp force injuries in female homicide victims [2].

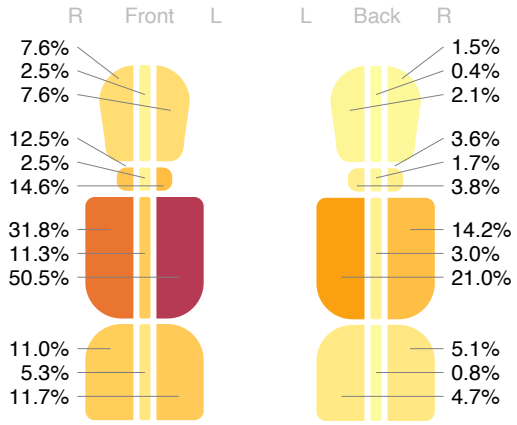


Figure 45 Distribution of stab wounds relative to all 471 sharp force homicides [2].

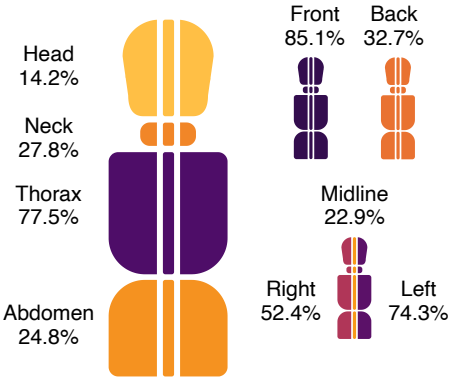


Figure 46 Regional distribution of stab wounds relative to all 471 sharp force homicides [2].

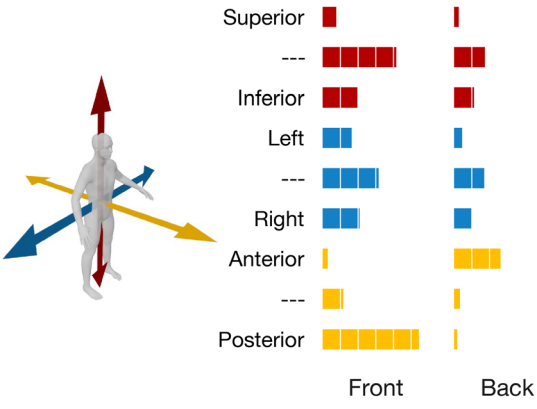


Figure 47 Stab wound trajectories, grouped by the geometrical planes [2].

force injuries, which explains why they are more common in female victims [18, 20, 108, 114, 119, 125]. Wounds with superficial parallel elements (hesitation marks), either from a sawing motion or genuine hesitation were found in 5.3% of victims (in at least one wound), almost exclusively (82.5%) on the neck. In studies of sharp force suicides, hesitation marks occur in 50%-80% of cases [108]. Tentative stab wounds are well known in suicides, but have also been described in homicides [39, 40, 45]. So, while hesitation marks and tentative stab wounds are highly suggestive of suicide, they do not exclude homicide.

5.2.6 Typology/motives/stabs

As with homicides in general, many male victims were killed in a setting of nightlife/intoxication (34.0% [7.0%/27.0%]), the majority by a few stab wounds inflicted by a friend/acquaintance (**Figure 48**). The offender was unknown to the victim before the assault in only 17 (15.9%) of males killed in nightlife/intoxication-homicides. The majority of female victims were killed in domestic homicides (73.7%), many in partner killings (56.4%). In partner killings, female victims also had more stab wounds than male victims (**Table 2**). Sharp force homicides with male victims often had triviality (wrong glance, spilled beer) as part of the motive and those had a large share of only a single stab wound (**Figure 49**). Jealousy was relatively often part of the motive in homicides with female victims (14.7% of female victims vs. 7.6% of male victims), more commonly with multiple stab wounds compared to male victims ($\chi^2 = 9.45$, df = 1, $P < 0.001$). Female victims were relatively more often represented in homicides with mental illness as part of the motive (22.4% of female victims vs 10.6% of male victims), but did not differ from male victims in prevalence of multiple stab wounds ($\chi^2 = 0.37$, df = 1, $P = 0.546$).

That the type of homicide and various motivational aspects affect the number of stab wounds is evident.

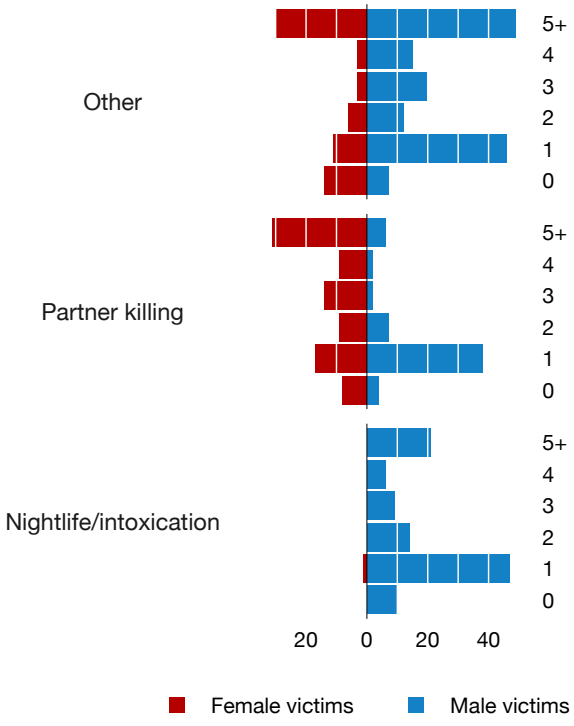


Figure 48 Homicide type related to number of stab wounds (head, neck, thorax, and abdomen) and sex of victim. 0: no stab wounds, only slash wounds [2].

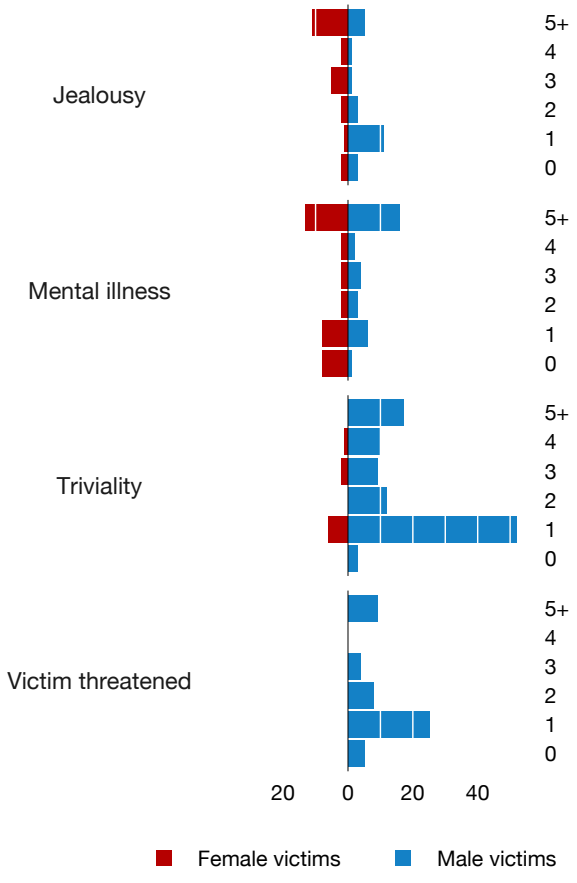


Figure 49 Motive related to number of stab wounds (head, neck, thorax, and abdomen) and sex of victim. 0: no stab wounds, only slash wounds. Each homicide can be represented more than once [2].

The current findings, namely that female victims have more sharp force injuries, involving more regions, are supported by numerous other studies [20, 43, 47, 125]. Males killed in the setting of nightlife/intoxication often have only a single stab wound [42]. Jealousy and/or separation as motives are more common in partner killings with female victims, which could explain the difference in the number of injuries. In contrast, partner killings with male victims often have the victim's threat of violence as a motive, often leading to only few injuries. Hunt [125] described that male offenders in partner killings were more "emotionally disturbed" in the act of stabbing, while female offenders acted in self-defense or after severe provocation.

5.2.7 Organ injuries and causes of death

There were injuries to the heart (including pericardium) and/or the lungs (including hemo- & pneumothorax) in 77.9% of victims (**Figure 50**). There were skeletal injuries in 53.9% of victims, most often the rib cage. In victims with no stab wounds to the head, neck, thorax or abdomen, i.e., only slash wounds, 44% had sharp force trauma to vessels in the head or neck.

Sharp force trauma to the cardiovascular system was the main cause of death in 81.3% of victims, and sharp force trauma to the lungs and/or airways in 9.8%. Most (78.1%) victims had sparse lividity, a decreased amount of blood in the vessel and/or pale organs, i.e., signs of exsanguination.

Multiple studies have shown that sharp force homicides often entail injuries to the heart, the great vessels and the lungs [14, 18, 20, 113, 128]. The lungs extend over a large area of the chest wall, so the risk of injury is high in stabs to the thorax, even if the injuries are not at critical as the ones to the heart and great vessels [48, 128, 129].

Injuries to the skeleton and cartilage can aid in identifying the weapon [130]. Furthermore, they are important indicators of the amount of force that was used in a stab, and can guide in the determination of manner of death as well as having consequences for sentencing in court [111, 123].

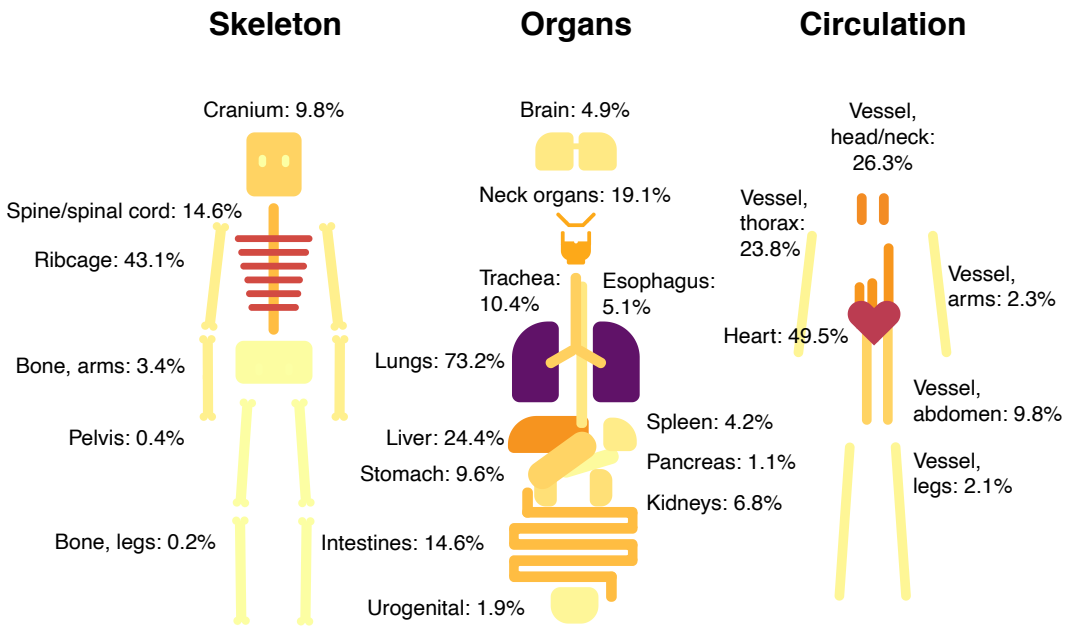


Figure 50 Distribution of injuries to organ systems [2].

5.2.8 Multiple regression

In multiple regression models, sharp force homicides with female victims were significantly different from sharp force homicides with male victims with regard to main homicide type (domestic, criminal milieu and non-criminal related) and number of stab wounds (with interaction), but not with regard to homicide location and type of weapon (**Table 3**).

Equation	Variable	R^2	ΔR^2	P
sex ~ location + weapon + homicide type * number of stabs	Full model	0.353	-	-
sex ~ location + weapon + homicide type + number of stabs	No interaction	0.340	0.013	<0.01
sex ~ weapon + homicide type * number of stabs	Location	0.353	0	0.47
sex ~ location + homicide type * number of stabs	Weapon	0.359	-0.006	0.55
sex ~ location + weapon + number of stabs	Homicide type	0.032	0.321	<0.001
sex ~ location + weapon + homicide type	Number of stabs	0.173	0.179	<0.001

Table 3 table_multi_studyII: Multiple regression models with victim sex as response variable [2].

5.3 Study III - Stab wound homicides and better treatment

5.3.1 Stab wound victims

There were 428 homicide victims who died from stab wounds (90.9% of all sharp force homicides). The average annual number of victims was 17.1, with a significant annual decrease of 0.25 victims (linear regression: $P < 0.005$, $F = 9.6$, $R^2 = 0.30$) (**Figure 51**).

5.3.2 The number of stab wounds

The mean number of stab wounds was 5.9 (1-92, median = 3) (**Table 2 (pg. 32)**) and 37.4% of victims had only a single stab wound. During 1992-2016 there was a significant annual decrease of 0.25 victims with a single stab wound (linear regression: $P < 0.001$, $F = 24.35$, $R^2 = 0.51$), but none in victims with multiple stab wounds (linear regression: $P = 0.99$, $F = 0.0003$, $R^2 < 0.001$) (**Figure 51**).

The statistics for emergency room treatment of general violence victims in Denmark has showed a decrease during 1992-2016, in part due to changes in injury registration and fewer emergency departments [131]. The police statistics on reported crime in Denmark has showed an increase in reported violence during 1992-2016, most likely reflecting an increased inclination towards reporting instead of more violence per se [94]. There were no changes in the proportion of assaults that were due to sharp force trauma, neither in the emergency room data or in data on reported crime [94, 131]. It is not clear from either datasets whether or not the severity of injuries from sharp force trauma has changed [94, 131]. The decrease in homicides with a single stab wound could be explained by assaults being more severe overall , i.e. that the offenders do not stop at the first stab. In that situation, one would expect an increase in the number of homicides with multiple stab wounds, which is not the case. From the data in "Study II" it is apparent that homicides in the set-

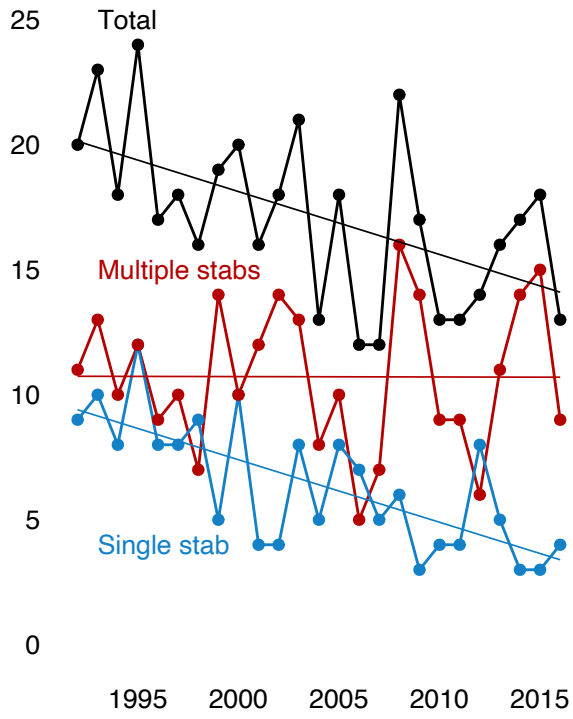


Figure 51 The total annual number of stab wound homicide victims and grouped by single and multiple stab wounds [3].

ting of nightlife/intoxication often have only a single stab wound [3]. As mentioned, changes in Danish legislation has tried to limit the availability of knives in public places, which is a common arena for nightlife violence [2, 18]. It is not possible to deduce the effect of this legislation solely by looking at lethal assaults, as these are relatively rare. A systematic study of the severity of injuries in surviving victims could help provide an answer (see "Future aspects"). In Denmark most homicides -including homicides between intoxicated males- take place in private homes, with kitchen knives readily available, unaffected by the ban on knives in public places [1, 2]. One thing that could potentially affect the outcome of assaults, regardless of setting, is the change in medical treatment of trauma victims, as described in the "Introduction". From the outset it could be expected that these improvements would impact victims with a single stab wound more than victims with multiple stab wounds, leading to relatively fewer homicide victims with single stab wounds (**Figure 19 (pg. 16)**).

5.3.3 Level of treatment and stab wounds

About a third (30.6%) of the victims were in survival group A, i.e. received treatment at the scene. About half (51.9%) of victims with a single stab wound reached the hospital and/or received surgery versus one fifth (21.6%) of victims with multiple stab wounds ($\chi^2 = 48.83$, df = 3, $P < 0.001$) (**Figure 52**).

This difference is hardly surprising and suggests that the potential for survival at the outset is better in the group with a single stab wound or at least in the eyes of the first responders [64, 73, 79, 80].

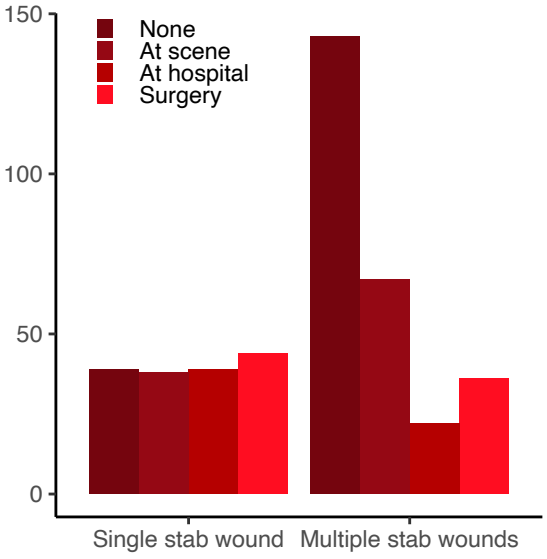


Figure 52 The number of victims ordered by treatment level in victims with single vs. multiple stab wounds [3].

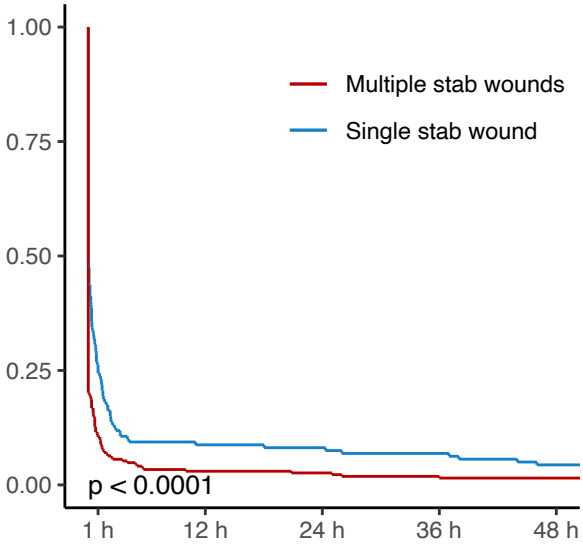


Figure 53 Survival curve for the first 48 h of victims in all stab wound homicides, single stab wound vs. multiple stab wounds [3].

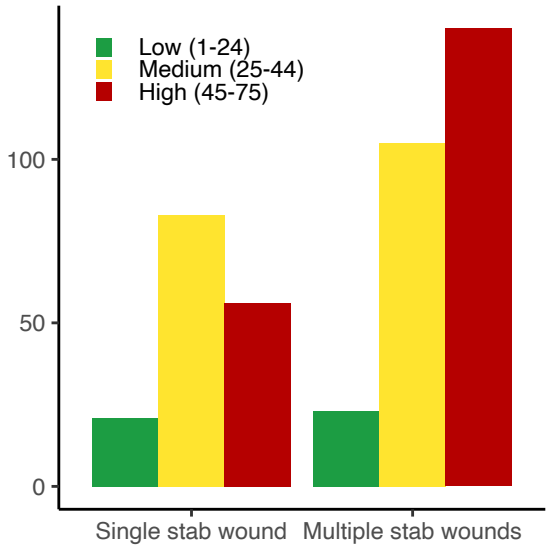


Figure 54 The number of victims ordered by NISS-group in victims with single vs. multiple stab wounds [3].

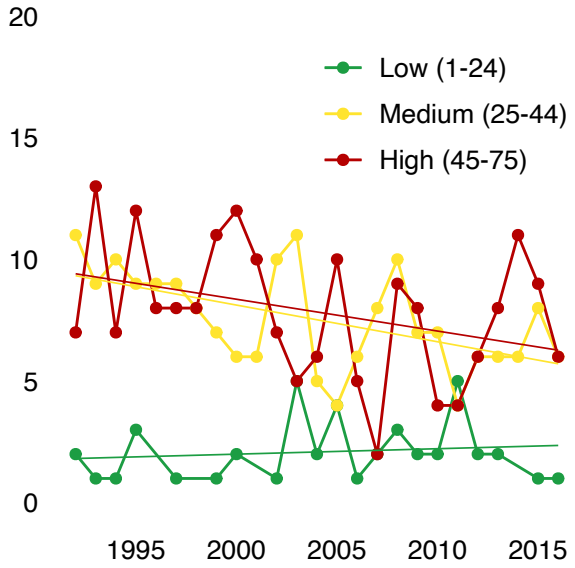


Figure 55 The annual number of sharp force homicide victims grouped by NISS groups [3].

5.3.4 Survival curves and stab wounds

The survival times showed significant differences between victims with a single stab wound and victims with multiple stab wounds in general, also pointing to the potential of survival being higher in single stab wound victims (**Figure 53** & **Table 4 (pg. 42)** & **Table 5 (pg. 42)**). For victims in survival group A, however, the differences in survival time were insignificant between single stab wound and multiple stab wound victims. This is likely due to survivor bias [132], as all victims in survival group A have been found worthy of treatment by first responders, which would tend to level out differences in severity of injuries between the two groups.

5.3.5 NISS and stab wounds

35.0% of victims with a single stab wound were in the NISS group "high (45-75)" compared to 52.2% of victims with multiple stab wounds ($\chi^2 = 12.19$, df = 2, $P < 0.001$) (**Figure 54**), confirming the intuitive as-

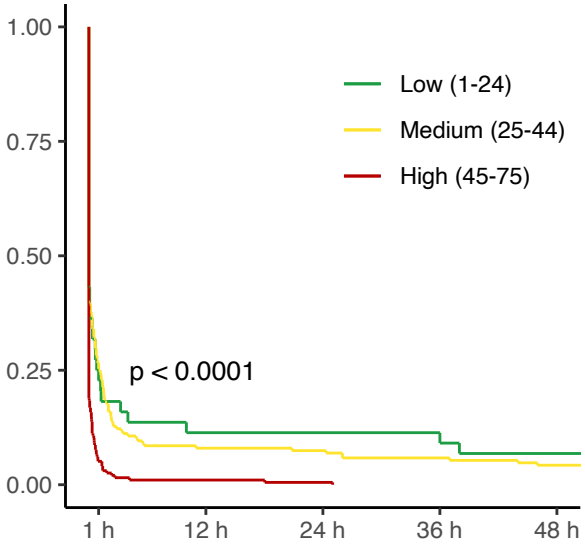


Figure 56 Survival curve for the first 48 hours of victims in all stab wound homicides, NISS groups [3].

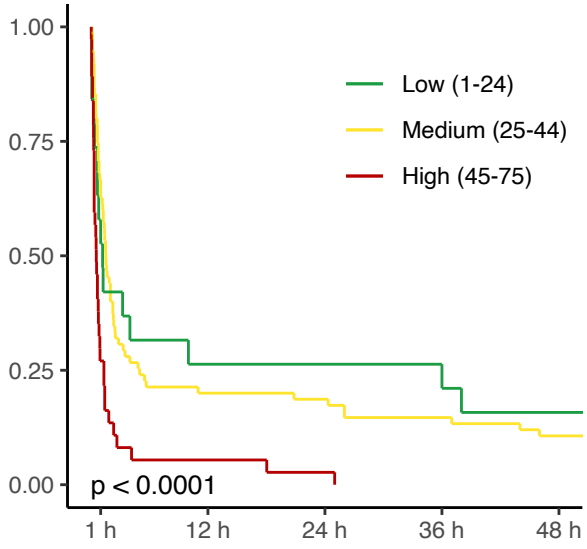


Figure 57 Survival curve for the first 48 h of victims in survival group A, NISS groups [3].

sumption that multiple stab wounds reduce the chance of survival as NISS is correlated to survival [48-51]. For survival group A, the corresponding ratio of NISS group "high (45-75)" was 27.3% in single stab wound victims and 29.6% in multiple stab wound victims ($\chi^2 = 0.56$, df = 2, P = 0.756), which points to the role of survivor bias levelling out the differences in injuries between the two groups.

Grouped by NISS (**Figure 55**) only victims in "medium (25-44)" had a statistically significant reduction over the years (linear regression: slope = −0.15, P < 0.01, F= 9.62, $R^2 = 0.29$), while "high (45-75)" had a statistically insignificant reduction (linear regression: slope = −0.13, P = 0.09, F = 3.13, $R^2 = 0.12$) and "low (1-24)" remained unchanged (linear regression: slope = 0.02, P = 0.57, F = 0.33, $R^2 = 0.02$). It is somewhat surprising that it is not in the group "low (1-24)" that there was a reduction, although there were not many homicides in the group at the outset. Victims in "low (1-24)" do not have severe injuries to larger vessels or the heart and thus have had a large potential for survival in the whole period. Deaths in victims with less severe injuries are often due to medical complications, such as infections and pulmonary embolisms, or coexisting natural disease [4-9]. It would be informative to correlate the changes in NISS during 1992-2016 with details about the level of medical facilities and comorbidity. Due to the retrospective nature of the study with inconsistencies in the available medical records, this was unfortunately not feasible.

Grouped by NISS there were statistically significant differences in the survival curves with shorter survival times for NISS group "high (45-75)" in general and for survival group A in isolation (**Table 4** & **Table 5**). The three NISS groups had statistically significant differences in survival curves in general (**Figure 56**) and for survival group A in isolation (**Figure 57**). This shows that NISS can be used in injury stratification in homicide victims, even for the victims who survive for some time.

5.3.6 Level of treatment, time period and NISS

During 1992-2016 the proportion of victims undergoing surgery increased from about 10% to about 30%, albeit with substantial year-to-year variation (likelihood ratio test: P < 0.001, Efron's pseudo $R^2 = 0.369$) (**Figure 58**). This is a clear indication of the changed practices and circumstances in trauma treatment [71, 72, 74-78, 80, 85, 86]. Even when controlling for NISS and single vs. multiple stab wounds, the survival time for victims in the first half of the period was shorter than the last half (**Figure 59**). However, the difference was only statistically significant for homicides in general and not for survival group A in isolation (**Table 4 (pg. 42)** & **Table 5 (pg. 42)**). This also suggests that stabbing victims increasingly are reached by medical per-

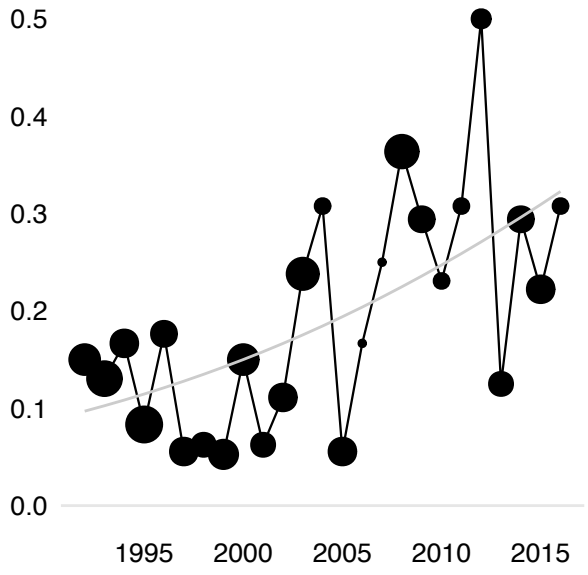


Figure 58 The proportion of victims who went into surgery. Point size reflects the total number of stab wound homicides for a given year (used for weighting) [3].

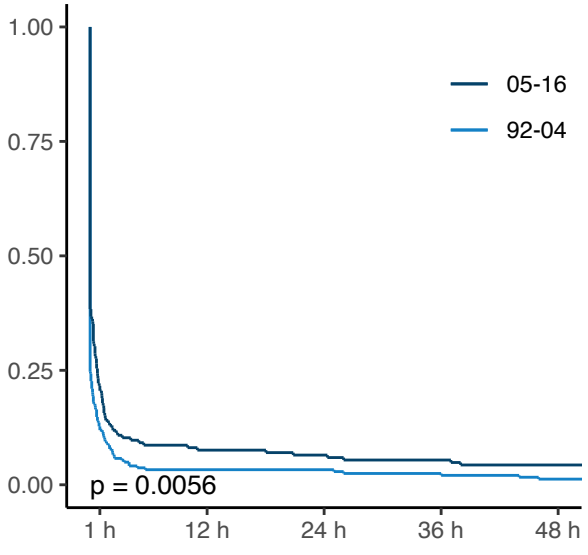


Figure 59 Survival curve for the first 48 hours of victims in all stab wound homicides, first/last period [3].

sonnel while treatment still is relevant and that they get a higher intensity of treatment [74-76, 80]. It is surprising that the difference in survival time for survival group A was insignificant. It could be due to the small sample size (60 victims for 1992–2004 and 71 victims for 2005–2016) combined with the survivor effect of improved treatment, i.e., potential homicide victims have had an increased chance of survival in the last period and consequently do not appear in the homicide statistics. A study of surviving stabbing assault victims, their injuries and related treatment could help shed light on this and aid with the above-mentioned problems of deciphering changes in stabbing assaults in regards to incidence and severity (see "Future aspects").

Dependent: Surv(time, event)		**All**	**HR (univariable)**	**HR (multivariable)**
NISS group	Low (1-24)	44 (10.3%)	-	-
	Medium (25-44)	188 (43.9%)	1.08 (0.77-1.52, p=0.647)	1.12 (0.80-1.58, p=0.502)
	High (45-75)	196 (45.8%)	1.99 (1.41-2.80, p<0.001)	1.96 (1.39-2.77, p<0.001)
Stab group	Single stab wound	160 (37.4%)	-	-
	Multiple stab wounds	268 (62.6%)	1.63 (1.33-1.99, p<0.001)	1.56 (1.27-1.91, p<0.001)
Period	92-04	243 (56.8%)	-	-
	05-16	185 (43.2%)	0.74 (0.61-0.90, p=0.003)	0.73 (0.60-0.88, p=0.001)

Table 4 Cox proportional hazards model, all stab wound homicide victims [3].

Dependent: Surv(time, event)		**All**	**HR (univariable)**	**HR (multivariable)**
NISS group	Low (1-24)	19 (14.5%)	-	-
	Medium (25-44)	75 (57.3%)	1.07 (0.62-1.85, p=0.806)	1.12 (0.64-1.95, p=0.685)
	High (45-75)	37 (28.2%)	2.59 (1.42-4.73, p=0.002)	2.77 (1.51-5.10, p=0.001)
Stab group	Single stab wound	77 (58.8%)	-	-
	Multiple stab wounds	54 (41.2%)	1.01 (0.70-1.46, p=0.941)	0.99 (0.68-1.42, p=0.946)
Period	92-04	60 (45.8%)	-	-
	05-16	71 (54.2%)	0.82 (0.57-1.17, p=0.279)	0.76 (0.53-1.09, p=0.138)

Table 5 Cox proportional hazards model, survival group A [3].

6 Conclusions

The idea for this dissertation was in part sparked by a lack of detailed official statistics on homicide in Denmark, both for forensic pathologists in their daily work, and for the general public. Without objective data we are left with anecdotes from the murky memories of forensic pathologists, and impressions from the news media and popular culture, where the facts are misrepresented towards certain types of homicide [133-135]. Anecdotal evidence is important in forensic medicine, as we often deal with rare phenomenons, but it does not have the benefit of being readily available for scrutiny. If anecdotal evidence is to be used, it should ideally be based on published case reports for all to evaluate [136]. The better we understand homicides from both a general view and in detail for each homicide method, the better we stand a chance of helping achieve justice. By collating information on homicides in general, and on each homicide method, certain patterns emerge. An experienced forensic pathologist might already know that the left chest is the most common location for lethal stabs, that killings in drunken brawls often are a result of only a single stab wound, and that homicide victims seem to have more stab wounds today, than back in the good old days, when a knife was something you used to cut homemade bread, baked in an oven that would later be used for killing the whole family with poisonous town gas. The fair and reasonable question to ask is "how do you know that?". If the answer is only related to individual experience and not scientific literature, respectful skepticism is justified [137]. The data in this dissertation and the published papers will help qualify that opinion, hopefully resulting in better service for the legal system.
Whenever I meet people with no experience in forensic medicine or death investigation, and conversation flows towards this project, I try and ask, what they know about homicides in Denmark and how they know it? The answers are varied, but many people seem to think that gang violence, serial killer-rapists and well-planned poisonings are common and things are getting worse, loosely based on news media, TV series and suspense novels. If decision makers get their information from the same sources, we risk that they fail to understand the true nature of homicide in Denmark. Therefore, I have tried my best to make the data available to the general public via the news media.

The data has been presented under the constraints of the formal requirements for a PhD-dissertation and thus only offers a limited view of homicides in Denmark. In order to demonstrate the scientific approach to a research area and to represent multiple levels of homicide research in forensic medicine, the data was subjected to three distinct levels of analysis.

Study I: I have presented an overview of the homicide epidemiology in Denmark 1992-2016, that supplements the scarse official statistics. We now have data on how the homicide methods have changed since previous studies, and detailed knowledge on homicide types. The sex differences in homicides are obvious, with males being the most common victims and offenders, but with an extreme overrepresentation of females as victims of domestic homicides, driven by intimate partner homicides. When Paper I was published as "open access" in August 2019, the data was presented to the general public in Denmark via thorough coverage in a national Danish newspaper [138, 139] leading to further dissemination in other national media, ultimately resulting in a nomination for the journalistic award "Cavlingprisen" for journalist Line Vaaben, Dagbladet Information [140]. The attention has lead to initiatives from special interest groups and has resulted in legislative proposals in the parliament regarding domestic homicides [141]. The initiatives are still ongoing, but

have been somewhat halted by the current situation with COVID-19 [142, 143]. The general homicide data has proven to be useful as an evidence-based foundation for public debate and policy development.

Study II: Moving one step closer to the details of each homicide by sharp force trauma, I have provided data on aspects that are relevant to forensic pathologists. The data is a supplement to the previous scientific literature on sharp force homicide and provides a contemporary base for interpretation and decision making in death investigations. The correlation between homicide type, victim sex and the number of stab wounds demonstrates, that the differences seen in the general homicide group permeates into how each individual homicide is committed. It indicates that intimate partner killings with female victims is a distinct entity, different from intimate partner killings with male victims and male-on-male homicides. This knowledge is useful for qualifying the public debate and for guiding preventive measures.

Study III: Stepping even closer, I have provided data on homicide victims with stab wounds and how the severity of injuries relate to medical treatment and initial survival. While the first two studies were hypothesis-generating, this study suggested that the hypothesis "part of the decrease in the sharp force homicide rate can be explained by better and faster medical treatment" is true [3]. The study underscores that homicide statistics are influenced by technical changes in society, such as advances in telecommunication and medicine.

Overall, the three studies in this dissertation have provided much needed insight into recent homicide epidemiology for both professionals and the general public, as well as a solid foundation for further studies of homicide from the perspective of forensic medicine.

7 Future aspects

Future studies

The variables used in the three studies could become part of a prospective Danish homicide database, monitoring the changes in homicide epidemiology at a closer view than the official statistics provide, and making continuous homicide research possible.
To put the findings of the three studies into context, it would be valuable to conduct similar studies with a similar time frame in the Nordic countries, Europe and the rest of the world. There are various studies underway via European Homicide Monitor [30], and hopefully it will be possible to have a common European homicide database.

The three studies in this dissertation are a small part of the project "Homicide in Denmark 1992-2016". From the collected data in the project it is possible to do numerous other studies that would expand our knowledge about homicides:

General studies of all the homicides concerning

a) Toxicological findings in victims and offenders.
b) Mental illness in victims and offenders.

Narrow studies on homicide methods similar to "Study II" & "Study III"

a) Gunshot homicides.
b) Asphyxia homicides.
c) Blunt force trauma homicides.
d) "Other" homicides.

Studies with data on subgroups of homicides

a) Intimate partner homicides.
b) Child homicides.
c) Late detected homicides.
d) Concealed homicides.
e) Sexual homicides.

Study on survivors of sharp force assaults

To respond to the questions raised in "Study III" regarding the development in stabbing attacks and severity of injuries, a closer look at survivors of stabbing assault should be undertaken. In Denmark some of the surviving victims of sharp force assault are examined at the departments of forensic medicine, presenting an avenue for further studies. In order to make inferences to homicide victims, the included group of survivors needs to be stratified according to severity of the assault, as some of the victims have insubstantial injuries. A strict legal division between attempted homicide and assault could be problematic, as it often includes an assessment of the intention of the assailant. A more medically sound stratification could be based on NISS, major surgery, blood transfusions and admittance to intensive care facilities.

Currently, a study is being conducted at the Department of Forensic Medicine, Aarhus University, looking into the injuries and medical treatment of these survivors.

Use in forensic medicine

The AIS framework has proven to be an excellent tool for registering injuries in forensic medicine. It would be fairly easy to use the nomenclature for autopsy reports in all or selected autopsy cases, thereby generating standardized data for research, but also for automatization of sketches with wounds and injuries.
The same framework could be used in clinical forensic medicine with the same results, but with the added possibility of qualifying the conclusions about the severity of injuries via relevant trauma scores, such as ISS and NISS.

8 Summary

The dissertation concerns the manner of death "homicide" as seen from the perspective of forensic medicine. In three studies, homicides are approached going from a broad overview of all homicide methods (Study I) to a narrow focus on the findings in the group of homicide victims killed by sharp force trauma (Study II) and how developments in medical treatment have impacted the group of victims killed with stab wounds (Study III). The studies are based on autopsy reports of homicide victims killed in Denmark during 1992-2016.

Study I: Homicide in general

1,417 homicide victims were included. The most common homicide methods were sharp force trauma (33.2%), gunshots (22.2%), blunt force trauma (21.9%) and asphyxia (17.6%). There was a significant decrease in the annual number of homicides in all the four most common homicide methods and for homicidal events with single and multiple victims during the period. Two thirds of the victims were male, while nine in ten offenders were male. There were clear differences between male and female victims, with a large proportion of female victims killed in a family setting and a large proportion of male victims killed by a friend/acquaintance in the setting of nightlife/intoxication.

Study II: Sharp Force Homicide

471 homicide victims were killed by sharp force trauma, the most common homicide method. Most sharp force homicides occurred inside, often committed with a kitchen knife. Female victims had more sharp force wounds, stab wounds and defense wounds than male victims. There were clear differences in the number of injuries between various homicide types and thereby between male and female victims. The thorax was the most commonly injured region, often with injuries to the lungs and heart.

Study III: Stab wounds and better treatment

428 homicide victims died from stab wounds. The decrease in the annual number of stab wound homicides only affected victims with a single stab wound and not victims with multiple stab wounds. The victims of single stab wound homicides differed from victims of multiple stab wound homicides in the severity of injuries, level of treatment and survival time. Despite the decrease in single stab wound homicides, the survival time has increased from the first to the last half of the period and the proportion of victims undergoing surgery before dying has tripled. This indicates that faster and better medical treatment could be responsible for the decrease in single stab wound homicides and thus possibly for the decrease in stab wound homicides in general.

The three studies demonstrate that homicide epidemiology is ever changing and follows general developments in society. The broad overview (Study I) will hopefully serve as a spark for further specific studies in forensic medicine, as well as a basis for policy development related to interpersonal violence. The specific studies of homicides by sharp force trauma (Study II and III) should serve as a reference in death investigations and daily autopsy work, but also as a link to understanding the underlying factors that direct the broader homicide statistics.

9 Summary in Danish / Dansk resumé

Afhandlingen omhandler dødsmåden "drab", som den tager sig ud fra et retsmedicinsk perspektiv. Gennem tre forskningsstudier undersøges drab, først med en overordnet undersøgelse af alle drabsmetoder (Studie I), derefter med en afgrænset undersøgelse af drab ved skarp vold (Studie II) og hvordan udviklingen i behandling har påvirket gruppen af drabsofre udsat for stiklæsioner (Studie III). Studierne er baseret på obduktionserklæringer fra ofre for drab i Danmark i perioden 1992-2016.

Studie I: Drab - overordnet
Der var 1.417 drabsofre. De hyppigste drabsmetoder var skarp vold (33,2%), skud (22,2%), stump vold (21,9%) og kvælning (17,6%). Der var et signifikant fald i det årlige antal drab ved alle de fire hyppigste drabsmetoder, samt i drabsepisoder med både et enkelt drabsoffer og flere drabsofre. To ud af tre drabsofre var mænd, og ni ud af ti gerningspersoner var mænd. Der var tydelige forskelle mellem mandlige og kvindelige ofre, idet en stor andel af kvindelige drabsofre blev dræbt i familien, og en stor andel af mandlige ofre blev dræbt af en ven/bekendt i forbindelse med fuldskab/i nattelivet.

Studie II: Drab ved skarp vold
471 drabsofre blev slået ihjel ved skarp vold, den hyppigste drabsmetode. De fleste drab ved skarp vold blev begået indendørs, ofte med en køkkenkniv. Kvindelige ofre havde flere skarprandede læsioner, stiklæsioner og afværgelæsioner end mandlige ofre. Der var tydelige forskelle i antallet af skader ved de forskellige drabstyper, hvilket forklarer forskellene mellem mandlige og kvindelige drabsofre. Brystkassen var den hyppigst skadede region, ofte med skade på lunger og hjerte.

Studie III: Drab ved stik vs. bedre behandling
428 drabsofre blev dræbt med stiklæsioner. Faldet i det årlige antal drab med stiklæsioner skyldtes et fald i antallet af drab med en enkelt stiklæsion og ikke drab med flere stiklæsioner. Drabsofre med en enkelt stiklæsion adskilte sig fra drabsofre med flere stiklæsioner med hensyn til alvorlighed af skader, behandlingsniveau og overlevelsestid. På trods af faldet i antallet af drab med en enkelt stiklæsion er overlevelsestiden steget fra den første halvdel af perioden til den sidste halvdel og andelen af drabsofre, der er nået på operationsbordet er tredoblet. Dette tyder på, at hurtigere og bedre lægebehandling kunne være årsag til faldet i drab med et enkelt knivstik og derfor muligt også for faldet i drab med stiklæsioner i det hele taget.

De tre studier viser, at drabsepidemiologi er foranderlig og følger den generelle samfundsudvikling. Den overordnede undersøgelse (Studie I) kan forhåbentlig give anledning til yderligere retsmedicinske forskningsstudier og danne grundlag for offentlig debat og politikudvikling relateret til vold. De afgrænsede undersøgelser (Studie II og III) kan bruges som støtte i efterforskning af dødsfald og obduktionsarbejde, men også som en uddybning af de underliggende forhold, der påvirker drabsstatistikkerne.

10 References

1. Thomsen AH, Leth PM, Hougen HP, Villesen P, Brink O. Homicide in Denmark 1992-2016. Forensic Sci Int: Synergy. 2019;1:275-82. doi:10.1016/j.fsisyn.2019.07.001.
2. Thomsen AH, Hougen HP, Villesen P, Brink O, Leth PM. Sharp Force Homicide in Denmark 1992-2016. J Forensic Sci. 2020;65(3):833-9. doi:10.1111/1556-4029.14244.
3. Thomsen AH, Villesen P, Brink O, Leth PM, Hougen HP. Improved medical treatment could explain a decrease in homicides with a single stab wound. Forensic Sci Med Pathol. 2020. doi:10.1007/s12024-020-00246-z.
4. Sundhedsdatastyrelsen. [Principles and guidelines for registering cause of death and other clinical information in the death certificate]. Principper og vejledning i registrering af dødsårsager og andre kliniske oplysninger i dødsattesten. Clinical guide in Danish. 2016.
5. Brooks EG, Reed KD. Principles and Pitfalls: a Guide to Death Certification. Clin Med Res. 2015;13(2):74-82; quiz 3-4. doi:10.3121/cmr.2015.1276.
6. Cordner SM. Deciding the cause of death after necropsy. Lancet. 1993;341(8858):1458-60. doi:10.1016/0140-6736(93)90892-k.
7. Pollanen MS. Deciding the cause of death after autopsy--revisited. J Clin Forensic Med. 2005;12(3):113-21. doi:10.1016/j.jcfm.2005.02.004.
8. Pollanen MS. On the strength of evidence in forensic pathology. Forensic Sci Med Pathol. 2016;12(1):95-7. doi:10.1007/s12024-015-9740-2.
9. Shkrum MJ, Ramsay DA. Chapter 1: The "complete autopsy". Forensic Pathology of Trauma: common problems for the pathologist. Totowa, New Jersey: Humana Press; 2007.
10. Helweg-Larsen K. The Danish Register of Causes of Death. Scand J Public Health. 2011;39(7 Suppl):26-9. doi:10.1177/1403494811399958.
11. Justitsministeriet. [The Danish Criminal Code], Straffeloven. In Danish.
12. The United Nations Office on Drugs and Crime (UNODC). International Classification of Crime for Statistical Purposes, Version 1.0.
13. The United Nations Office on Drugs and Crime (UNODC). Global Study on Homicide 2019. Vienna, 2019.
14. Hart Hansen JP. [Homicide in Denmark 1946-1970]. Drab i Danmark 1946-70. Dissertation. In Danish. 1977.
15. Leth PM. Homicides in Southern Denmark During 25 Years. Homicide Studies. 2010;14(4):419-35. doi:10.1177/1088767910384074.
16. Leth PM. Intimate partner homicide. Forensic science, medicine, and pathology. 2009;5(3):199-203. doi:10.1007/s12024-009-9097-5.
17. Christiansen S, Rollmann D, Leth PM, Thomsen JL. [Child homicide 1972-2005]. Drab på børn 1972-2005. In Danish. Ugeskrift for laeger. 2007;169(47):4070-4.
18. Leth PM. [Lethal Stabbings in Southern Denmark during the Last 25 Years]. Knivdrab i Syddanmark gennem 25 år. In Danish. Nordisk Tidsskrift for Kriminalvidenskab 2008:279-86.
19. Hougen HP, Rogde S, Poulsen K. Homicides in two Scandinavian capitals. The American Journal of Forensic Medicine and Pathology : Official Publication of the National Association of Medical Examiners. 1999;20(3):293-9.

20. Rogde S, Hougen HP, Poulsen K. Homicide by sharp force in two Scandinavian capitals. Forensic Sci Int. 2000;109(2):135-45. doi:S0379073899002303 [pii].
21. Hougen HP, Rogde S, Poulsen K. Homicide by firearms in two Scandinavian capitals. The American Journal of Forensic Medicine and Pathology : Official Publication of the National Association of Medical Examiners. 2000;21(3):281-6.
22. Rogde S, Hougen HP, Poulsen K. Asphyxial homicide in two Scandinavian capitals. The American Journal of Forensic Medicine and Pathology : Official Publication of the National Association of Medical Examiners. 2001;22(2):128-33.
23. Rogde S, Hougen HP, Poulsen K. Homicide by blunt force in 2 Scandinavian capitals. The American Journal of Forensic Medicine and Pathology : Official Publication of the National Association of Medical Examiners. 2003;24:288-91.
24. Thomsen JL, Albrektsen SB, Aalund O, Breiting VB, Danielsen L, Helweg-Larsen K et al. Injuries Due to Deliberate Violence in Areas of Denmark. II. Victims of Homicide in the Copenhagen Area. Forensic science international. 1989;40:291-7.
25. The Research Office of the Danish Justice Department. [Homicide in Denmark (2008-2011)]. Justitsministeriets forskningsafdeling. Drab i Danmark 2008-2011. In Danish. 2014.
26. The Research Office of the Danish Justice Department. [Types of homicide (2008-2011)]. Justitsministeriets forskningsafdeling. Typer af drab. In Danish. 2020.
27. Danish Health Authority. [Causes of Death in Denmark]. Dødsårsagerne i Danmark. Sundhedsstyrelsen. In Danish. 1969-1996.
28. Danish Register of Causes of Death. Dødsårsagsregisteret [database on the Internet]. Available from: https://sundhedsdatastyrelsen.dk/dar. Accessed: 21.03.2020
29. Statistics Denmark. Statistikbanken [database on the Internet]. Available from: www.statistikbanken.dk. Accessed: 21.03.2020
30. Ganpat SM, Granath S, Hagstedt J, Kivivuori J. Homicide in Finland, the Netherlands and Sweden: A first study on the European homicide monitor data. 2011.
31. Eisner M. Modernity Strikes Back? A Historical Perspective on the Latest Increase in Interpersonal Violence (1960-1990). Int J Confl Violence. 2008;2(2):288-316.
32. The United Nations Office on Drugs and Crime (UNODC). Global Study on Homicide 2011. ; Trends, Contexts, Data. vol Book, Whole. United Nations Publications; 2012.
33. The United Nations Office on Drugs and Crime (UNODC). Global study on homicide 2013: trends, contexts, data. 2013.
34. Renno Santos M, Testa A, Porter LC, Lynch JP. The contribution of age structure to the international homicide decline. PLoS One. 2019;14(10):e0222996. doi:10.1371/journal.pone.0222996.
35. Aebi MF, Linde A. The persistence of lifestyles: Rates and correlates of homicide in Western Europe from 1960 to 2010. European Journal of Criminology. 2014;11(5):552-77. doi:10.1177/1477370814541178.
36. Christensen MR, Thomsen AH, Hoyer CB, Gregersen M, Banner J. Homicide in Greenland 1985-2010. Forensic Sci Med Pathol. 2016;12(1):40-9. doi:10.1007/s12024-015-9729-x.
37. Sundheds- og Ældreministeriet. [The Danish Health Care Act], Sundhedsloven. In Danish.
38. Hern E, Glazebrook W, Beckett M. Reducing knife crime. BMJ. 2005;330(7502):1221-2. doi:10.1136/bmj.330.7502.1221.
39. Shkrum MJ, Ramsay DA. Forensic Pathology of Trauma: common problems for the pathologist. Forensic science and medicine. Totowa, N.J.: Humana Press; 2007.
40. Knight B, Saukko PJ. Knight's forensic pathology. Fourth edition. ed. Boca Raton: CRC Press, Taylor & Francis Group; 2016.
41. Karlsson T. A multivariate approach to the interpretation of patterns in homicidal and suicidal sharp force fatalities: Karolinska Institutet, Stockholm; 1997.
42. Karlsson T. Sharp force homicides in the Stockholm area, 1983-1992. Forensic Sci Int. 1998;94(1-2):129-39. doi:https://doi.org/10.1016/S0379-0738(98)00067-X.
43. Ormstad K, Karlsson T, Enkler L, Law B, Rajs J. Patterns in sharp force fatalities--a comprehensive forensic medical study. J Forensic Sci. 1986;31(2):529-42.

44. Karlsson T, Ormstad K, Rajs J. Patterns in sharp force fatalities--a comprehensive forensic medical study: Part 2. Suicidal sharp force injury in the Stockholm area 1972-1984. J Forensic Sci. 1988;33(2):448-61.
45. Karlsson T. Homicidal and suicidal sharp force fatalities in Stockholm, Sweden. Orientation of entrance wounds in stabs gives information in the classification. Forensic Sci Int. 1998;93(1):21-32. doi:https://doi.org/10.1016/S0379-0738(98)00025-5.
46. Karlson TA. Multivariate analysis ("Forensiometrics") - A New Tool in Forensic Medicine. Differentiation between Sharp Force Homicide and Suicide. Forensic science international. 1998;94:183-200.
47. Burke MP, Baber Y, Cheung Z, Fitzgerald M. Single stab injuries. Forensic Sci Med Pathol. 2018;14(3):295-300. doi:10.1007/s12024-018-9982-x.
48. Gennarelli TA, Wodzin E, Association for the Advancement of Automotive M. Abbreviated injury scale 2005 : update 2008. Barrington, Ill.: Association for the Advancement of Automative Medicine; 2008.
49. Stevenson M, Segui-Gomez M, Lescohier I, Di Scala C, McDonald-Smith G. An overview of the injury severity score and the new injury severity score. Inj Prev. 2001;7(1):10-3. doi:dx.doi.org/10.1136/ip.7.1.10.
50. Rowell SE, Barbosa RR, Diggs BS, Schreiber MA, Trauma Outcomes G, Holcomb JB et al. Specific abbreviated injury scale values are responsible for the underestimation of mortality in penetrating trauma patients by the injury severity score. J Trauma. 2011;71(2 Suppl 3):S384-8. doi:10.1097/TA.0b013e3182287c8d.
51. Peng J, Wheeler K, Shi J, Groner JI, Haley KJ, Xiang H. Trauma with Injury Severity Score of 75: Are These Unsurvivable Injuries? PLoS One. 2015;10(7):e0134821. doi:10.1371/journal.pone.0134821.
52. Cros J, Alvarez JC, Sbidian E, Charlier P, de la Grandmaison GL. Survival time estimation using Injury Severity Score (ISS) in homicide cases. Forensic Science International. 2013;233(1-3):99-103. doi:10.1016/j.forsciint.2013.08.026.
53. Tamsen F, Sturup J, Thiblin I. Quantifying Homicide Injuries: A Swedish Time Trend Study Using the Homicide Injury Scale. Scandinavian Journal of Forensic Science. 2018? doi:doi.org/10.1515/sjfs-2017-0005.
54. Tamsen F, Sturup J, Thiblin I. Homicide injury severity in association with the victim-offender relationship. Forensic Sci Int. 2019;300:151-6. doi:10.1016/j.forsciint.2019.05.012.
55. Tamsen F, Logan FK, Thiblin I. Homicide Injury Quantification: Correlations and Reliability of Injury Severity Scores Applied to Homicide Victims. Homicide Studies. 2014;19(1):88-100. doi:10.1177/1088767914558142.
56. Friedman Z, Kugel C, Hiss J, Marganit B, Stein M, Shapira SC. The Abbreviated Injury Scale. A valuable tool for forensic documentation of trauma. Am J Forensic Med Pathol. 1996;17(3):233-8.
57. Adams VI, Carrubba C. The Abbreviated Injury Scale: application to autopsy data. Am J Forensic Med Pathol. 1998;19(3):246-51.
58. Baker SP, O'Neill B, Haddon W, Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14(3):187-96.
59. Haider AH, Villegas CV, Saleem T, Efron DT, Stevens KA, Oyetunji TA et al. Should the IDC-9 Trauma Mortality Prediction Model become the new paradigm for benchmarking trauma outcomes? J Trauma Acute Care Surg. 2012;72(6):1695-701. doi:10.1097/TA.0b013e318256a010.
60. Wang MD, Fan WH, Qiu WS, Zhang ZL, Mo YN, Qiu F. The exponential function transforms the Abbreviated Injury Scale, which both improves accuracy and simplifies scoring. Eur J Trauma Emerg Surg. 2014;40(3):287-94. doi:10.1007/s00068-013-0331-1.
61. Van Belleghem G, Devos S, De Wit L, Hubloue I, Lauwaert D, Pien K et al. Predicting in-hospital mortality of traffic victims: A comparison between AIS-and ICD-9-CM-related injury severity scales when only ICD-9-CM is reported. Injury. 2016;47(1):141-6. doi:10.1016/j.injury.2015.08.025.
62. Shanti CM, Tyburski JG, Rishell KB, Wilson RF, Lozen Y, Seibert C et al. Correlation of revised trauma score and injury severity score (TRISS) predicted probability of survival with peer-reviewed determination of trauma deaths. Am Surg. 2003;69(3):257-60; discussion 60.
63. Schluter PJ. The Trauma and Injury Severity Score (TRISS) revised. Injury. 2011;42(1):90-6. doi:10.1016/j.injury.2010.08.040.
64. Ericsson A, Thiblin I. Injuries inflicted on homicide victims. A longitudinal victiminologic study of lethal violence. Forensic Sci Int. 2002;130(2-3):133-9.

65. Li F, Liu S, Lu X, Ou Y, Yip PSF. Application of the injury scales in homicides. Forensic Sci Int. 2018;292:83-9. doi:10.1016/j.forsciint.2018.09.010.
66. Safarik ME, Jarvis JR. Examining attributes of homicides - Toward quantifying qualitative values of injury severity. Homicide Studies. 2005;9(3):183-203. doi:10.1177/1088767905277144.
67. Savolainen J, Lehti M, Kivivuori J. Historical Origins of a Cross-National Puzzle:Homicide in Finland, 1750 to 2000. Homicide Stud. 2008;12(1):67-89. doi:10.1177/1088767907311850.
68. Kuhns JB, Exum ML, Clodfelter TA, Bottia MC. The prevalence of alcohol-involved homicide offending: a meta-analytic review. Homicide studies. 2014;18(3):251-70.
69. Kuhns JB, Wilson DB, Clodfelter TA, Maguire ER, Ainsworth SA. A meta-analysis of alcohol toxicology study findings among homicide victims. Addiction. 2011;106(1):62-72. doi:10.1111/j.1360-0443.2010.03153.x.
70. Kuhns JB, Wilson DB, Maguire ER, Ainsworth SA, Clodfelter TA. A meta-analysis of marijuana, cocaine and opiate toxicology study findings among homicide victims. Addiction. 2009;104(7):1122-31. doi:10.1111/j.1360-0443.2009.02583.x.
71. Seamon MJ, Fisher CA, Gaughan J, Lloyd M, Bradley KM, Santora TA et al. Prehospital procedures before emergency department thoracotomy: "scoop and run" saves lives. J Trauma. 2007;63(1):113-20. doi:10.1097/TA.0b013e31806842a1.
72. Seamon MJ, Shiroff AM, Franco M, Stawicki SP, Molina EJ, Gaughan JP et al. Emergency department thoracotomy for penetrating injuries of the heart and great vessels: an appraisal of 283 consecutive cases from two urban trauma centers. J Trauma. 2009;67(6):1250-7; discussion 7-8. doi:10.1097/TA.0b013e3181c3fef9.
73. Berg RJ, Karamanos E, Inaba K, Okoye O, Teixeira PG, Demetriades D. The persistent diagnostic challenge of thoracoabdominal stab wounds. J Trauma Acute Care Surg. 2014;76(2):418-23. doi:10.1097/TA.0000000000000120.
74. Brink O, Borris LC, Hougaard K. Effective treatment at a Danish trauma centre. Danish medical journal. 2012;59(3):A4393.
75. Mikkelsen R, Moller Hansen O, Brink O. Non-survivors after admission to trauma centre. Danish medical journal. 2014;61(10):A4928.
76. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med. 2006;354(4):366-78. doi:10.1056/NEJMsa052049.
77. Garwe T, Cowan LD, Neas BR, Sacra JC, Albrecht RM. Directness of transport of major trauma patients to a level I trauma center: a propensity-adjusted survival analysis of the impact on short-term mortality. J Trauma. 2011;70(5):1118-27. doi:10.1097/TA.0b013e3181e243b8.
78. Nirula R, Maier R, Moore E, Sperry J, Gentilello L. Scoop and run to the trauma center or stay and play at the local hospital: hospital transfer's effect on mortality. J Trauma. 2010;69(3):595-9; discussion 9-601. doi:10.1097/TA.0b013e3181ee6e32.
79. Kong VY, Sartorius B, Clarke DL. The accuracy of physical examination in identifying significant pathologies in penetrating thoracic trauma. Eur J Trauma Emerg Surg. 2015;41(6):647-50. doi:10.1007/s00068-014-0484-6.
80. Davis JS, Satahoo SS, Butler FK, Dermer H, Naranjo D, Julien K et al. An analysis of prehospital deaths: Who can we save? J Trauma Acute Care Surg. 2014;77(2):213-8. doi:10.1097/TA.0000000000000292.
81. Weile J, Nielsen K, Primdahl SC, Frederiksen CA, Laursen CB, Sloth E et al. Trauma facilities in Denmark - a nationwide cross-sectional benchmark study of facilities and trauma care organisation. Scand J Trauma Resusc Emerg Med. 2018;26(1):22. doi:10.1186/s13049-018-0486-1.
82. Harris AR, Thomas SH, Fisher GA, Hirsch DJ. Murder and medicine. Homicide Studies. 2002;6(2):128.
83. Gossage JA, Frith DP, Carrell TW, Damiani M, Terris J, Burnand KG. Mobile phones, in combination with a computer locator system, improve the response times of emergency medical services in central London. Ann R Coll Surg Engl. 2008;90(2):113-6. doi:10.1308/003588408X242079.
84. Wu O, Briggs A, Kemp T, Gray A, MacIntyre K, Rowley J et al. Mobile phone use for contacting emergency services in life-threatening circumstances. J Emerg Med. 2012;42(3):291-8 e3. doi:10.1016/j.jemermed.2011.02.022.

85. Cirocchi R, Montedori A, Farinella E, Bonacini I, Tagliabue L, Abraha I. Damage control surgery for abdominal trauma. Cochrane Database Syst Rev. 2013(3):CD007438. doi:10.1002/14651858.CD007438.pub3.
86. Funder KS, Petersen JA, Steinmetz J. On-scene time and outcome after penetrating trauma: an observational study. Emerg Med J. 2011;28(9):797-801. doi:10.1136/emj.2010.097535.
87. Lendrum RA, Lockey DJ. Trauma system development. Anaesthesia. 2013;68:30-9. doi:10.1111/anae.12049.
88. Botker MT, Bakke SA, Christensen EF. A systematic review of controlled studies: do physicians increase survival with prehospital treatment? Scand J Trauma Resusc Emerg Med. 2009;17:12. doi:10.1186/1757-7241-17-12.
89. Statistics Denmark [database on the Internet]. Population Data. http://www.statistikbanken.dk/10021. Accessed 17-12-2018.
90. Juul S, Frydenberg M. An introduction to Stata for health researchers. 3rd ed. College Station, Tex.: Stata Press; 2010.
91. Juul S. Take good care of your data. 2004. Aarhus. http://www.epidata.dk/downloads/takecare.pdf.
92. O'Reilly GM, Gabbe B, Moore L, Cameron PA. Classifying, measuring and improving the quality of data in trauma registries: A review of the literature. Injury. 2016;47(3):559-67. doi:10.1016/j.injury.2016.01.007.
93. Global Burden of Disease Injury C, Naghavi M, Marczak LB, Kutz M, Shackelford KA, Arora M et al. Global Mortality From Firearms, 1990-2016. JAMA. 2018;320(8):792-814. doi:10.1001/jama.2018.10060.
94. Pedersen A-JB, Kyvsgaard B, Balvig F. [Vulnerability to violence and other crime], Udsathed for vold og andre former for kriminalitet. Report in Danish. Justitsministeriet, 2018. Report No.: ISBN 978-87-93469-25-9.
95. Det Kriminal Præventive Råd. [Violence in Denmark 2015], Vold i Danmark 2015, report in Danish, 2016.
96. Leth PM. Homicide by drowning. Forensic Sci Med Pathol. 2019;15(2):233-8. doi:10.1007/s12024-018-0065-9.
97. Tuttle J, McCall PL, Land KC. Latent Trajectories of Cross-National Homicide Trends: Structural Characteristics of Underlying Groups. Homicide Stud. 2018;22(4):343-69. doi:10.1177/1088767918774083.
98. Netterstrøm JB. Criminalization of Homicide in Early Modern Denmark (16th–17th Centuries). Scandinavian Journal of History. 2017;42(4):459-75. doi:10.1080/03468755.2017.1349578.
99. Harris AR, Thomas SH, Fisher GA, Hirsch DJ. Murder and Medicine: The Lethality of Criminal Assault 1960-1999. Homicide Studies. 2002;6(2):128-66. doi:10.1177/1088767902006002003.
100. Briceno-Leon R. Urban violence and public health in Latin America: a sociological explanatory framework. Cad Saude Publica. 2005;21(6):1629-48; discussion 49-64. doi:/S0102-311X2005000600002.
101. Stöckl H, Devries K, Rotstein A, Abrahams… N. The global prevalence of intimate partner homicide: a systematic review. 2013. doi:10.1016/S0140-6736(13)61030-2.
102. Caman S, Kristiansson M, Granath S, Sturup J. Trends in rates and characteristics of intimate partner homicides between 1990 and 2013. Journal of Criminal Justice. 2017;49:14-21. doi:10.1016/j.jcrimjus.2017.01.002.
103. Lendrem BA, Lendrem DW, Gray A, Isaacs JD. The Darwin Awards: sex differences in idiotic behaviour. BMJ. 2014;349:g7094. doi:10.1136/bmj.g7094.
104. Archer J. Sex Differences in Aggression in Real-World Settings: A Meta-Analytic Review. Rev Gen Psychol. 2004;8. doi:10.1037/1089-2680.8.4.291.
105. Liem M, Barber C, Markwalder N, Killias M, Nieuwbeerta P. Homicide-suicide and other violent deaths: an international comparison. Forensic Sci Int. 2011;207(1-3):70-6. doi:10.1016/j.forsciint.2010.09.003.
106. Reckdenwald A, Simone S. Injury Patterns for Homicide Followed by Suicide by the Relationship Between Victims and Offenders. Homicide Studies. 2017;21(2):111-32. doi:10.1177/1088767916671350.
107. Regoeczi WC, Gilson T. Homicide-Suicide in Cuyahoga County, Ohio, 1991-2016. J Forensic Sci. 2018;63(5):1539-44. doi:10.1111/1556-4029.13729.

108. Racette S, Kremer C, Desjarlais A, Sauvageau A. Suicidal and homicidal sharp force injury: a 5-year retrospective comparative study of hesitation marks and defense wounds. Forensic Sci Med Pathol. 2008;4(4):221-7. doi:10.1007/s12024-008-9046-8.
109. Lynch M, Black M. A tale of two cities: a review of homicide in Melbourne and Glasgow in 2005. Med Sci Law. 2008;48(1):24-30. doi:10.1258/rsmmsl.48.1.24.
110. Leyland AH. Homicides involving knives and other sharp objects in Scotland, 1981-2003. J Public Health (Oxf). 2006;28(2):145-7. doi:10.1093/pubmed/fdl004.
111. Brunel C, Fermanian C, Durigon M, de la Grandmaison GL. Homicidal and suicidal sharp force fatalities: autopsy parameters in relation to the manner of death. Forensic Sci Int. 2010;198(1-3):150-4. doi:10.1016/j.forsciint.2010.02.017.
112. Ambade VN, Godbole HV. Comparison of wound patterns in homicide by sharp and blunt force. Forensic Sci Int. 2006;156(2-3):166-70. doi:10.1016/j.forsciint.2004.12.027.
113. Kemal CJ, Patterson T, Molina DK. Deaths due to sharp force injuries in Bexar County, Texas, with respect to manner of death. Am J Forensic Med Pathol. 2013;34(3):253-9. doi:10.1097/PAF.0b013e31828ced68.
114. Vassalini M, Verzeletti A, De Ferrari F. Sharp force injury fatalities: a retrospective study (1982-2012) in Brescia (Italy). J Forensic Sci. 2014;59(6):1568-74. doi:10.1111/1556-4029.12487.
115. Webb E, Wyatt JP, Henry J, Busuttil A. A comparison of fatal with non-fatal knife injuries in Edinburgh. Forensic Sci Int. 1999;99(3):179-87. doi:https://doi.org/10.1016/S0379-0738(98)00189-3.
116. Maxwell R, Trotter C, Verne J, Brown P, Gunnell D. Trends in admissions to hospital involving an assault using a knife or other sharp instrument, England, 1997-2005. J Public Health (Oxf). 2007;29(2):186-90. doi:10.1093/pubmed/fdm018.
117. Fischer J, Kleemann WJ, Troger HD. Types of trauma in cases of homicide. Forensic Sci Int. 1994;68(3):161-7. doi:https://doi.org/10.1016/0379-0738(94)90355-7.
118. Papadatou-Pastou M, Ntolka E, Schmitz J, Martin M, Munafò MR, Ocklenburg S et al. Human handedness: A meta-analysis. Psychological Bulletin. 2020;146(6):481-524. doi:10.1037/bul0000229.
119. Schmidt U, Pollak S. Sharp force injuries in clinical forensic medicine--findings in victims and perpetrators. Forensic Sci Int. 2006;159(2-3):113-8. doi:10.1016/j.forsciint.2005.07.003.
120. Park J, Son H. Weapon Use in Korean Homicide: Differences Between Homicides Involving Sharp and Blunt Instruments. J Forensic Sci. 2018;63(4):1134-7. doi:10.1111/1556-4029.13673.
121. Kitulwatte I, Edirisinghe P. Relationship of sharp force injuries to motivation. Med Leg J. 2015;83(3):159-62. doi:10.1177/0025817215580942.
122. Maiden NR, Hiss J, Gips H, Hocherman G, Levin N, Kosachevsky O et al. An Analysis of the Characteristics of Thoracic and Abdominal Injuries Due to Gunshot Homicides in Israel. J Forensic Sci. 2016;61(1):87-92. doi:10.1111/1556-4029.12901.
123. Dettling A, Althaus L, Haffner HT. Criteria for homicide and suicide on victims of extended suicide due to sharp force injury. Forensic Sci Int. 2003;134(2-3):142-6. doi:https://doi.org/10.1016/S0379-0738(03)00139-7.
124. Schmidt U. Sharp force injuries in "clinical" forensic medicine. Forensic Sci Int. 2010;195(1-3):1-5. doi:10.1016/j.forsciint.2009.10.031.
125. Hunt AC, Cowling RJ. Murder by stabbing. Forensic Sci Int. 1991;52(1):107-12. doi:https://doi.org/10.1016/0379-0738(91)90102-O.
126. Inoue H, Ikeda N, Ito T, Tsuji A, Kudo K. Homicidal sharp force injuries inflicted by family members or relatives. Med Sci Law. 2006;46(2):135-40. doi:10.1258/rsmmsl.46.2.135.
127. Hugar BS, Harish S, Girish Chandra YP, Praveen S, Jayanth SH. Study of defence injuries in homicidal deaths - An autopsy study. J Forensic Leg Med. 2012;19(4):207-10. doi:10.1016/j.jflm.2011.12.022.
128. Kristoffersen S, Normann SA, Morild I, Lilleng PK, Heltne JK. The hazard of sharp force injuries: Factors influencing outcome. J Forensic Leg Med. 2016;37:71-7. doi:10.1016/j.jflm.2015.10.005.
129. Sobotta J, Putz R, Pabst R, Taylor AN. Sobotta atlas of human anatomy. 12th English ed. Baltimore: Williams & Wilkins; 1997.
130. Love JC. Sharp force trauma analysis in bone and cartilage: A literature review. Forensic Sci Int. 2019;299:119-27. doi:10.1016/j.forsciint.2019.03.035.

131. Det Kriminalpræventive Råd. [Violence in Denmark 2017]. Vold i Danmark 2017. Report in Danish, 2018. Report No.: ISBN 978-87-92966-55-1.
132. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. 3rd ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2008.
133. Sorenson SB, Manz JG, Berk RA. News media coverage and the epidemiology of homicide. American journal of public health. 1998;88(10):1510-4.
134. Taylor CA, Sorenson SB. The nature of newspaper coverage of homicide. Injury Prevention. 2002;8:121-7.
135. Morin O, Acerbi A, Sobchuk O. Why people die in novels: testing the ordeal simulation hypothesis. Palgrave Communications. 2019;5(1). doi:10.1057/s41599-019-0267-0.
136. Cordner S, Clay FJ, Bassed R, Thomsen AH. Suicidal ligature strangulation: a systematic review of the published literature. Forensic Sci Med Pathol. 2020;16(1):123-33. doi:10.1007/s12024-019-00187-2.
137. Houck MM. Open, transparent science helps promote justice. Forensic Sci Int. 2019;1:A275-A6. doi:10.1016/j.fsisyn.2018.12.001.
138. Vaaben L. [1,417 Danish homicides in 25 years]. 1.417 danske drab i 25 år. Dagbladet Information, article in Danish, Copenhagen. 2019. https://www.information.dk/DrabIDanmark. 2020.
139. Vaaben L. »I have no desire to open up this man's skull. I do it because I have to«. Dagbladet Information, Copenhagen. 2019. https://www.information.dk/mofo/no-desire-to-open-up-this-mans-skull-do-it-because-to. 2020.
140. Journalistforbundet. [The nominated for Cavlingprisen are revealed]. Nu afsløres de nominerede til Cavlingprisen 2019. Article in Danish. Copenhagen. 2019. https://journalistforbundet.dk/nyhed/nu-afsloeres-de-nominerede-til-cavlingprisen-2019. 2020.
141. Danner. [Gender and femicide]. Køn står i vejen for kvindedrab. Blog post in Danish. https://danner.dk/blog/k-n-st-r-i-vejen-bek-mpe-kvindedrab. 2020.
142. Spiteri G, Fielding J, Diercke M, Campese C, Enouf V, Gaymard A et al. First cases of coronavirus disease 2019 (COVID-19) in the WHO European Region, 24 January to 21 February 2020. Euro Surveill. 2020;25(9). doi:10.2807/1560-7917.ES.2020.25.9.2000178.
143. Cattaneo C. Forensic medicine in the time of COVID 19: An Editorial from Milano, Italy. Forensic Sci Int. 2020;312:110308. doi:10.1016/j.forsciint.2020.110308.

11 Glossary

AIS: Abbreviated Injury Scale
FI: Finland
HIS: Homicide Injury Scale
ISS: Injury Severity Score
MAIS: Maximum Injury Score
NISS: New Injury Severity Score
NL: The Netherlands
SAIS: Sum of all AIS scores
SE: Sweden
TNI: Total number of injuries

12 Acknowledgements / Taksigelser

Den afhandling du lige har læst, eller i det mindste bladret igennem for at se om du er nævnt i taksigelserne, er resultatet af et langt sejt træk. Selv om det er mig, der har siddet krumbøjet over sagerne og statistikprogrammerne i efterhånden en del år, vil jeg ikke tage hele æren.

Tak til **Pernille, Rasmus, Anna** og **Ida** for at være utroligt søde og forstående, også når jeg har været presset og gnaven. Uden jer, var jeg enten sprunget fra eller blevet fuldstændig umulig. I er verdens bedste.
Tak til **Kristian, Signe** og **Anton** for husly alle de mange gange jeg har arbejdet i København. Hyggeligt.
Tak til **Andreas** for at drikke en enkelt øl eller to med mig i København og ikke mindst for, næsten altid, at stoppe, mens legen var god.
Tak til hele resten af **min familie** og **venner** for støtte og interesse for projektet.

Tak til mine ph.d.-vejledere **Ole Brink, Peter Leth** og **Hans Petter Hougen** for gode tips og tricks samt kommentarer til artiklerne. Tak til min uformelle vejleder **Palle Villesen** for rigtig gode forslag til figurer og databehandling til artiklerne, det var sgu et velkomment skub.
Tak til **Jytte Banner** og **Peter Leth** for at sende hele projektet min vej, midt i en barselsorlov i starten af 2006 og for støtte i den indledende fase, hvor jeg ad flere omgange var væk til turnus og speciallægeuddannelse.
Tak til **Markil Gregersen** for de små besøg på onsdage med drøftelse af nye og gamle sager. Man bliver altid en lidt klogere retsmediciner af at tale med dig.

Tak til **Brødrene Hartmanns Fond, Videreuddannelsesregion Nord** og **Institut for Retsmedicin, Aarhus Universitet** for økonomisk støtte. Uden jeres bidrag var det ikke blevet til noget.

Tak til **Line Vaaben** for det grundige og ordentlige arbejde med at formidle data fra projektet, og ikke mindst fortællingerne om menneskene bag, i **Dagbladet Information**. Ingen kan gøre det bedre end dig.

Tak til **kolleger** og **personale på de retsmedicinske institutter i Aarhus, Odense og København**. Alle tre steder har der været stor forståelse, imødekommenhed og velvilje, som har gjort det hele meget lettere.

Tak til **nuværende og tidligere ansatte i dansk politi** for at afklare tvivlspørgsmål under dataindsamlingen.

Jeg ville gerne takke endnu flere, men min frygt for at glemme blot en enkelt person, er større end tiltroen til min hukommelse. Derfor vil jeg nøjes med at takke **dig**, for vi ved begge, hvad dit bidrag har betydet: Det har været uvurderligt.

And finally, in **English**, thanks to the staff at the **Victorian Institute of Forensic Medicine, Melbourne, Australia** for having me stay for almost a half year, learning forensic medicine from the very best. I have cold stubbies and good company waiting for you all in Denmark, if you happen to swing by.

Paper I-III

This is a reduced version of the dissertation without Paper I-III. Please refer to page 1 for links.