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Fatal and non-fatal strangulation in Sweden: A retrospective analysis of injury patterns and forensic implications

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ABSTRACT

Background: Strangulation is a gendered and under-recognized form of violence often linked to intimate partner violence (IPV) and sexual assault, predominantly affecting women. Understanding injury patterns in non-fatal (NFS) and fatal strangulation (FS) is essential for diagnosis, prosecution, and prevention.
Objective: This study examines injury patterns and forensic characteristics in NFS and FS cases in Sweden, contributing evidence to support clinical and forensic assessments.
Methods: This retrospective study analyzed 617 NFS cases from 2022 and 139 FS cases from 2003–2022, sourced from the Swedish National Board of Forensic Medicine. Chi-square and Fisher's Exact Test assessed associations between strangulation method and injury patterns.
Results: Manual strangulation predominated in NFS (96 %), while FS cases had a near-equal distribution of manual and ligature methods. Petechiae were much more common in FS (91 %) than in NFS (4 %), but no significant differences were observed in the occurrence of petechiae between the different types of strangulation. Fractures of neck structures were more frequent in older FS victims compared to younger. IPV was the primary context in both NFS (67 %) and FS (43 %) cases, with a majority of victims being female.
Conclusions: Distinct injury patterns were observed in NFS and FS emphasizing the need for thorough forensic assessments. The findings underscore the importance of clinical vigilance and standardized documentation of injuries in suspected strangulation cases to support legal investigations and prevent future violence.

1. Introduction

Strangulation is defined as asphyxia caused by external pressure on the neck, resulting in the obstruction of airflow or blood circulation through the neck vessels. The subtypes of strangulation are classified according to the type of external compression that causes oxygen deprivation. Manual strangulation involves the use of hands or arms, while ligature strangulation refers to the use of a cord, rope, chain, or similar object. Hanging is a form of strangulation that occurs when a constricting band around the neck is tightened by the gravitational weight of the body [1].

Both fatal (FS) and non-fatal strangulation (NFS) are recognized as gendered forms of violence, most commonly perpetrated by a man to exert power and control over a female intimate partner [2]. The reported prevalence rates of NFS in intimate partner violence contexts range from 27 % to 68 % [3,4], with its occurrence linked to a seven-fold increased risk of future lethal violence [3].

Strangulation is also a common method of homicide, particularly in cases of femicide [5,6]. In Sweden, asphyxia homicide – including strangulation – is the second most frequent method men use to kill women [7]. Women aged 15–25 are at twice the risk of strangulation compared to older women [8]. Additionally, strangulation is frequently linked to sexual assaults [9], sexually motivated homicides [10–12], and sadistic crimes [11]. There is also growing concern about the normalization of NFS as part of sexual practices among young adults, often referred to as "breath play," "erotic choking", or "sexual asphyxiation" [13].

Non-fatal strangulation (NFS) is a potentially life-threatening form of

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violence that can have severe psychological, physical, and neurological consequences [4,14–17]. The level of severity outcome depends on the duration of oxygen deprivation to the brain. Symptoms may be acute, long-term, and/or develop over time. In a study of 300 women who survived NFS, Strack et al. found that nearly 85 % out of the victims reported immediate symptoms, including neck and throat pain, hoarseness, headaches, and changes or loss of voice [14]. Life-threatening or potentially permanent conditions may manifest acutely or with delay and include carotid artery dissection, seizures, stroke, brain injury and brain death [14,18]. For many women, strangulation is not an isolated incident. In a study by Wilbur and coworkers, each woman had experienced an average of 5.3 such assaults in her intimate relationship(s) [4]. Repeated strangulation is associated with a significantly increased rate of medical sequelae as well as a suspected risk of long term neurological effects, such as memory loss, early-onset dementia, and traumatic brain injury (TBI) [16,19,20]. Cognitive and psychiatric long term conditions include post traumatic stress (PTSD), depression and anxiety [4,15,16,19]. Furthermore, strangulation is often associated with other forms of violence, such as physical or sexual assault, which can lead to additional negative health consequences [4,21,22]. Visible external signs of strangulation may include petechiae, bruising, abrasions on the neck, or ligature marks [4,14,23]. However, a complicating factor in the prevention and investigation of strangulation incidents is that this type of violence often leaves little to no visible evidence but may still be potentially lethal [15,24,25]. In the previously mentioned study by Strack and coworkers, only around half of NFS-victims displayed external signs of injury, and only 15 % present with injuries noticeable enough to be photographed [14].

Furthermore, injuries may not become apparent until hours, days, or even months after the incident, even injuries which may be potentially life threatening, such as carotid artery dissection and stroke [18,23]. In other words, in the absence of visible injuries, victims may downplay the severity of the violence or hesitate to seek medical help. In a literature review by Patch and fellow researchers, it was found that 5–69 % of strangled women sought health care [26].

Healthcare professionals, in turn, may fail to recognize or investigate NFS in the absence of visible injuries, especially if the victim does not disclose strangulation. This lack of recognition is compounded by a lack of awareness of the clinical signs and dangers of strangulation among medical professionals [27]. Similarly, law enforcement may dismiss cases without clear signs of violence, leading to failures to prosecute serious crimes [28].

Successful prosecution and conviction of strangulation offenses depend heavily on evidence collected from the victim, the crime scene, witnesses and others. These evidence categories include: emergency call recordings, photographs, physical evidence, medical evaluation forms, and expert testimony [29]. Medical evidence that might contribute to effective prosecution includes a comprehensive documentation of injuries, including high-quality photographs, detailed descriptions of the injuries, and specific questioning to identify symptoms associated with strangulation [28,30,31]. These can be used by a forensic medical doctor to issue a forensic medical certificate that includes an interpretation of the injuries [2], and to declare whether the violence was life-threatening or not, in accordance with national guidelines [32]. In a previous study, forensic medical evidence were found to lead to prosecution in 58 out of 63 cases (92 %) [31]. The crime scene and the parties may also harbor trace evidence such as blood spatter, fingernail markings and skin cells from the offender on the neck of the victim [33–35].

In fatal strangulation cases, autopsy plays a crucial role in evidence collection, enabling a thorough examination and detection of injuries to the neck tissues [21,31]. Even when external injuries are absent, internal findings related to mechanical compression and cranial congestion may be present [36].

Over the past decade, multiple studies have highlighted the severity of strangulation, its connection to IPV, and its associated physical and psychological health consequences [19,37]. However, while research on injury patterns and forensic aspects of strangulation has made some progress, the systematic investigation of NFS and FS remains notably underdeveloped. Existing studies have predominantly relied on post-mortem data related to FS, leaving significant gaps in the understanding of NFS [2,38]. Other key gaps include understanding the mechanisms of injury and distinguishing factors between fatal and non-fatal outcomes such as injury types and injury severity. Thus, this study aims to address these critical gaps by examining injury types, injury patterns and identifying factors that may influence outcomes in fatal and non-fatal strangulation. By providing a comprehensive understanding of strangulation violence, this research seeks to aid in clinical diagnostics, treatment, and documentation, while also improving prevention strategies, forensic investigations and legal responses.

2. Materials and methods

2.1. Study design, selection of cases and data sources

The study is retrospective in nature and includes victims of non-fatal strangulation (NFS) who were subject to a clinical forensic report issued by the National Board of Forensic Medicine in Sweden, and victims of fatal strangulation (FS) autopsied by the same institution. Due to an uneven prevalence of NFS versus FS, the study periods differed: the year of 2022 for the NFS-population and cases of fatal strangulation covered the study period between 2003–01–01 and 2022–12–31.

Ethical approvals were granted by the Swedish Ethical Review Authority (No 2023–05130–01, 2024–02393–02 and 2024–05436–02).

2.2. Non-fatal strangulation (NFS)

Cases of non-fatal strangulation were retrieved by free text searching clinical forensic reports for relevant expressions for strangulation. The overall analysis included cases where the forensic medical certificate was based on the forensic pathologist's direct examination of the victim, as well as those relying on external sources such as patient records, photos, police reports, or victim-provided documentation (Table 1). However, since certificates based on external sources often lack comprehensive injury documentation for strangulation (e.g., it is unclear if the presence of petechiae was assessed), only cases involving direct examination by a forensic pathologist were included in the injury analysis.

2.3. Fatal strangulation (FS)

Fatal cases of strangulation were identified by using a primary code of diagnosis defined as "Assault by hanging or strangulation" (E963), according to the International Classification of Disease, version 9 (ICD-9). Cases with primary cause of death being "hanging or strangulation" and manner of death homicide as assessed by the forensic pathologist, were included ($n = 323$). Cases where asphyxia was caused by other mechanisms, i.e. suffocation due to external covering of the air ways (choking, smothering), internal obstruction of the airways by a foreign object, compression of the thorax, or drowning, were excluded.

Table 1
Basis for clinical forensic medicine report in non-fatal strangulation.

Basis for certificate	Total 617 (100 %)	Males 99 (16 %)	Females 518 (84 %)
Forensic medical examination	149 (24 %)	16 (16 %)	133 (26 %)
Patient records	395 (64 %)	80 (81 %)	314 (61 %)
Photos taken by police	390 (63 %)	61 (62 %)	328 (63 %)
Photos taken by hospital staff/ care giver	195 (32 %)	31 (31 %)	164 (32 %)
Photos taken by victim	117 (19 %)	17 (17 %)	100 (19 %)

For each FS-case, autopsy reports, police reports and photographs were reviewed. In addition, court judgments were retrieved from the digital database JUNO which contains Swedish laws, regulations and judgments.

For both groups (NFS and FS), demographic information (year of incident, victim sex, victim age, offender sex) as well as contextual data (offender-victim relation, crime scene location, motive), information related to strangulation characteristics (type of strangulation, type of ligature) and sustained injuries (internal, external) was compiled. Some additional information specific to each group (FS and NFS) was collected for both groups.

2.4. Statistical/data analysis

Demographic data for both groups were summarized using descriptive statistics in Microsoft Excel 2019. Categorical variables were analyzed using Chi-square Test and Fisher's Exact Test to assess associations between groups. All statistical analyses were conducted using IBM SPSS software, version 26.

3. Results

The NFS group included 617 cases, with a median age of 31.0 years (mean age 32.8 years, range 4–96 years) and a sex distribution of 16 % male and 84 % female. The FS group comprised 139 cases, with a median age of 40.5 years (mean age 40.4 years, range 0–89 years) and a sex distribution of 35 % male and 65 % female.

3.1. Incidence of non-fatal and fatal strangulation violence in Sweden

In 2022, 4895 clinical forensic reports were issued by the Swedish National Board of Forensic Medicine as part of criminal investigations, of which 12.6 % ($n = 617$) concerned non-fatal strangulation (NFS). Over the 20-year study period of fatal strangulation (FS), 1968 homicidal autopsies were conducted, with strangulation identified as the primary cause of death in 139 cases (7 %).

The number of strangulation homicides remained stable over time, with females representing the majority of victims (66 %, $n = 91$), whereas other homicides fluctuated and showed an overall increase. The annual average of strangulation homicides was 6.95 cases, with a slight 9 % increase in the second decade (65 versus 74 cases). In all but four cases (3 %), a perpetrator had been identified, and the case was considered resolved, either through police action or by legal proceedings (Fig. 1).

Fig. 2 illustrates the trends in strangulation homicides over time, stratified by gender, expressed per 100,000 inhabitants. While the rates for females show greater variability, particularly in earlier years, male trends indicate a slight increase and female a slight decline over the studied period. Linear regression analysis reveals however that the slope for males (slope = 0.0005, p = 0.356, $R^2 = 0.048$) and females (slope = −0.0006, p = 0.535, $R^2 = 0.022$) are not statistically significant, suggesting no clear temporal pattern for either group. When combining data for both genders, the overall slope (-0.0001, p = 0.942, $R^2 = 0.001$) remains non-significant, reinforcing the conclusion of minimal or no discernible change in strangulation homicide rates over time (Fig. 2).

3.2. Victim and offender demography

The age and sex distribution of non-fatal strangulation (NFS) victims showed a clear gender disparity, with females significantly outnumbering males across all age groups, altogether comprising 84 % of the cases ($n = 518$). The highest incidence occurred in young adulthood, peaking in the 20–34 age range with 51 % of the cases ($n = 315$). Among children (0–14 years), cases were rare but more evenly distributed between the sexes. In older age groups (50 + years), NFS cases declined, though women remained the majority. Fig. 3.

Strangulation homicides (FS) exhibited a distinct age and sex pattern, with female victims overwhelmingly outnumbering males across most age groups (65 % female in strangulation homicides vs 25 % in all other homicides). This trend was particularly pronounced in young adulthood, where women aged 20–29 accounted for the highest number of cases (81 %, $n = 73$). In contrast, male strangulation victims were relatively rare, with only small clusters across various age groups. The number of strangulation homicides decreased with age, but female victims remained prevalent even in older populations, and the highest number of strangulation homicides were found around 50 years of age. Among children (0–14 years) however, a different pattern emerged: boys were more frequently victims of strangulation homicides than girls.

When comparing strangulation homicides to all other homicides, males accounted for 72 % of the victims and predominated across nearly

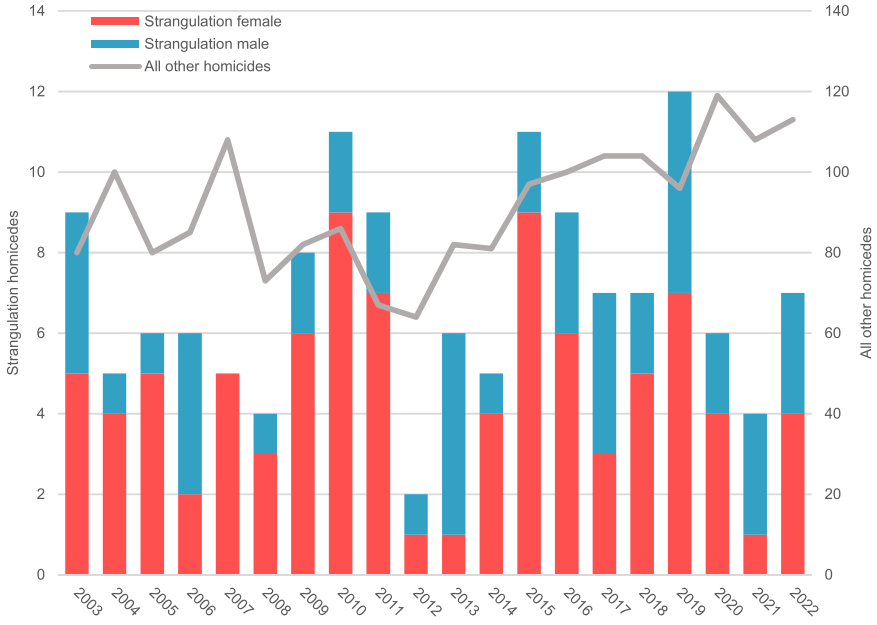

Fig. 1. Strangulation homicides ($n = 139$) compared to all other homicides ($n = 1968$) over time (2003–2022), highlighting stability in strangulation cases and variability in other homicides.

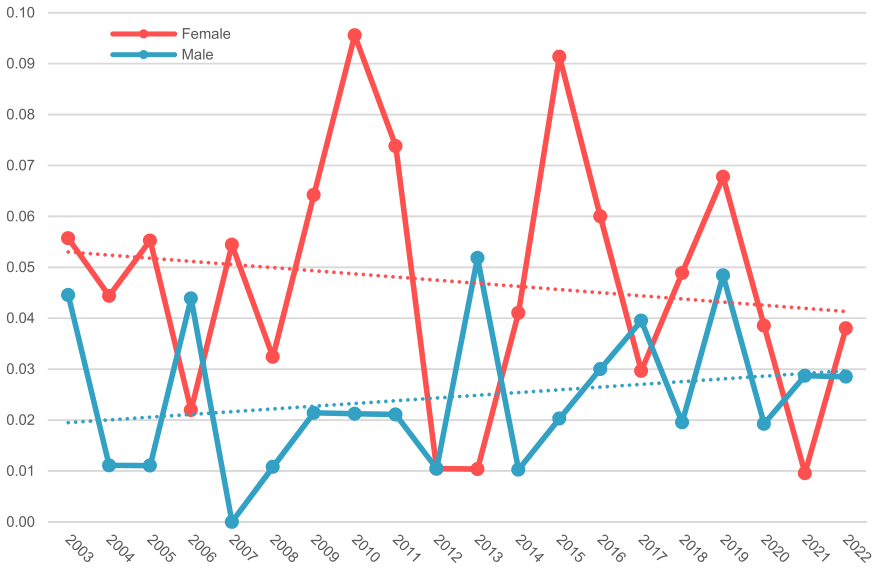

Fig. 2. Strangulation homicide rates over time per 100,000 inhabitants.

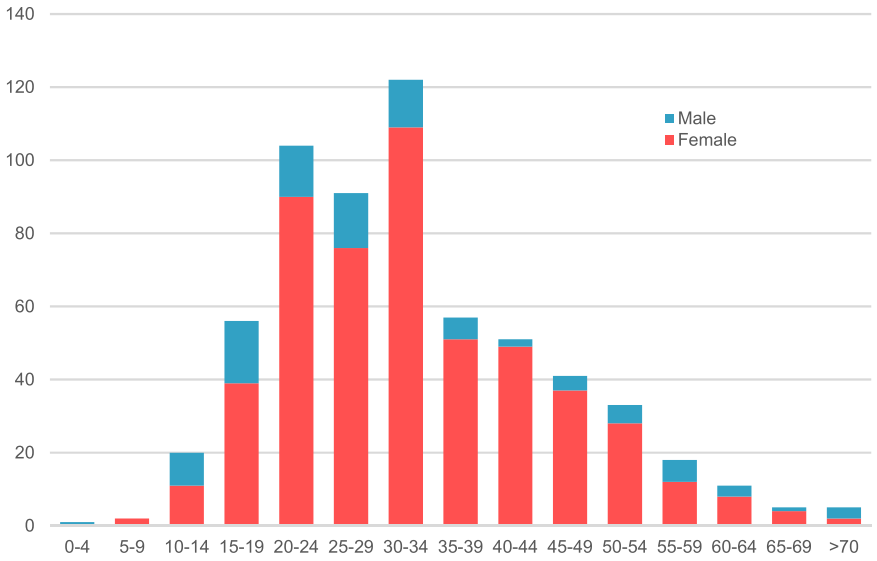

Fig. 3.. Age and sex distribution in victims of non fatal strangulation.

all age groups. Female homicide victims in other forms of homicide were fewer and more evenly distributed across age groups, Fig. 4.

Among the offenders, there was clear gender skewness with a preponderance of males, both in the NFS-group (males 97 %, females 3 %) and in the FS-group (males 86 %, females 14 %). In 5 % ($n = 7$) of the homicide cases, more than one perpetrator was involved in the crime, which resulted in a higher number of offenders compared to cases. In four cases the offender sex was not known.

Male offenders of FS most commonly victimized female victims and included 82 cases (59 %). Among FS-cases involving female offenders ($n = 20$), 15 victims were male, while the rest were female on female events. In four of these cases, a female acted as a co-offender together with a male. Female offenders more often killed a family member ($n = 10$) or an acquaintance ($n = 5$) than a partner or ex-partner ($n = 4$).

3.3. Offender-victim relationship

The most common relationship between offender and victim was partner or ex-partner, 67 % ($n = 413$) of NFS and 43 % ($n = 60$) of FS cases. Female victims in both groups were most often assaulted by male partners or ex-partners (78 % and 59 %, respectively), while male victims were more often subjected to NFS (7 %) and FS (19 %) by an acquaintance, which was also the second most common relationship between offender and victim in both groups (16 % for NFS and 29 % for FS). Stranger offending constituted 11 homicide-cases (8 %). Additional 61 victims had been subjected to NFS by a stranger evenly distributed among male and female victims. When looking exclusively at victims below 18 years of age it was revealed that children subjected to NFS ($n = 48$) were most often victimized by an acquaintance (44 %) followed by a stranger (23 %) and a parent (17 %). Child victims of FS were predominantly killed by their parents (78 %, $n = 7$) (Table 2).

3.4. Contextual factors

Contextually, intimate partner violence (i.e., all cases where strangulation was inflicted by a partner or former partner, regardless of other possible motives) accounted for 67 % (n = 412) of non-fatal cases and 42 % (n = 59) of fatal cases. Family violence, including offenses

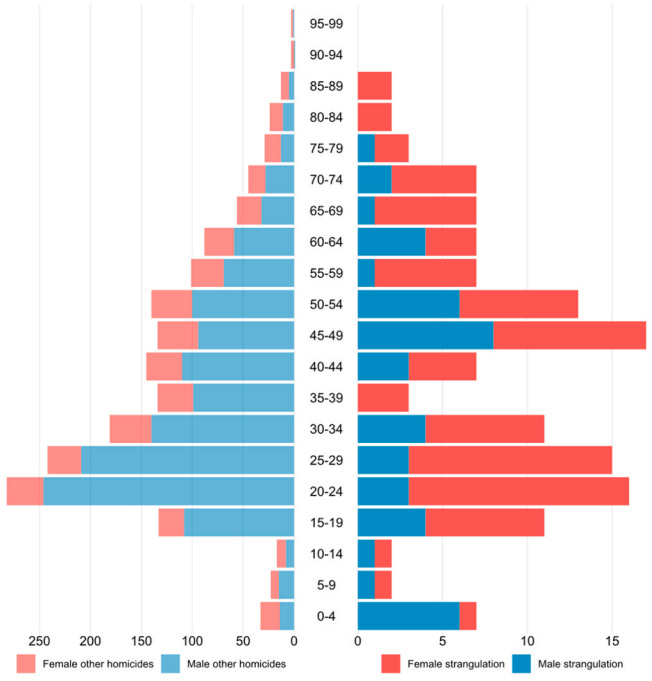

Fig. 4. Age and sex distribution in strangulation homicides (right) compared to all other homicides (left).

committed by siblings, offsprings, or other family members, accounted for 6 % (n = 35) of NFS cases and 14 % (n = 20) of FS cases.

Rape was the primary motive in 6 % of the FS cases and 8 % of the NFS cases. In addition, 12 % of the intimate partner violence cases occurred in a sexual context—for example, unwanted strangulation during consensual sex. Altogether, 8 % of FS and 17 % of NFS cases occurred in some kind of sexual context.

Alcohol induced brawls were more common in altercations leading to fatal strangulation compared to non-fatal cases (8 %, $n = 11$ vs 1 %, $n = 8$). Less common motives included financial disputes and personal conflicts. Nine cases, all of which were FS (6 %) and linked to either intimate partner violence ($n = 4$) or family violence ($n = 5$), were followed by the offender committing suicide.

An analysis of offender gender in relation to context revealed that male offenders were predominantly involved in intimate partner violence (NFS 68 %, FS 37 %), with most cases involving female victims (99 % and 90 % respectively). Among the 20 female offenders in FS cases, the most common motive was family violence (35 %), followed by intimate partner violence (20 %) and homicide-suicide (15 %) (Table 2).

Fig. 5a and b illustrate motives for non-fatal and fatal strangulation, categorized by victims' age groups and sex. In non-fatal cases (Fig. 5a), intimate partner violence dominated as the motive across all age groups, particularly among females aged 20–39 years. For males, personal conflicts and financial-related crimes (e.g., robbery) were more prominent motives.

In fatal cases (Fig. 5b), intimate partner violence remained a predominant motive for female victims, especially those aged 20–29 years. Among male victims, personal conflict and family-related motives were more prevalent. Notably, rape as a motive was observed exclusively among female victims, predominantly in younger age groups (15–29 years). Among the youngest victims of fatal strangulation (aged 0–14 years), family-related violence was the most common motive (Fig. 5a and b).

3.5. Crime scene locations

Crime scene data was collected only for fatal strangulations where the vast majority (79 %, $n = 110$) occurred in the victim's home, with females more likely to be killed at home (86 %) compared to males (67 %). Public areas and wooded areas were less common locations, accounting for 6 % and 7 % of cases, respectively, with a slightly higher proportion of male victims in these settings. Fatal strangulations in health care facilities were rare and exclusively involved male victims (8 %) (Table 3).

3.6. Methods of strangulation

In non-fatal cases, manual strangulation overwhelmingly dominated (96 %, $n = 592$), while ligature and mixed methods were rare (3 % and 1 %, respectively). In fatal cases, manual strangulation was the most

Table 2
Relationships between offenders and victims, offender sex, motives, and contextual characteristics in non-fatal and fatal strangulation cases.

	Fatal strangulation						Non fatal strangulation					
	Total Total 139 (100 %)		Males Males 48 (35 %)		Females Females 91 (65 %)		Total Total 617 (100 %)		Males Males 99 (16 %)		Females 518 (84 %)	
Relationship offender to victim												
Partner or expartner	60	43 %	6	13 %	54	59 %	412	67 %	6	6 %	406	78 %
Parent	10	7 %	7	15 %	3	3 %	13	2 %	6	6 %	7	1 %
Offspring, grandchild	10	7 %	0	0 %	10	11 %	13	2 %	5	5 %	8	2 %
Sibling	2	1 %	2	4 %	0	0 %	9	1 %	3	3 %	6	1 %
Acquaintance	42	30 %	27	56 %	14	15 %	101	16 %	46	46 %	55	11 %
Stranger	11	8 %	6	13 %	5	5 %	61	10 %	31	31 %	30	6 %
Unknown	4	3 %	0	0 %	4	4 %	8	1 %	2	2 %	6	1 %
Offender sex												
Male	119	86 %	37	77 %	82	90 %	599	97 %	91	92 %	508	98 %
Female	20	14 %	15	31 %	5	5 %	16	3 %	6	6 %	10	2 %
Unknown	4	3 %	0	0 %	4	4 %	2	0 %	2	2 %	0	0 %
Context												
Intimate partner violence	59	42 %	6	13 %	53	58 %	412	67 %	6	6 %	406	78 %
Family violence	25	18 %	11	23 %	14	15 %	35	6 %	14	14 %	21	4 %
Whereof homicide- suicide	9	6 %	3	6 %	6	7 %	-			-		
Rape	8	6 %	0	0 %	8	9 %	52	8 %	1	1 %	51	10 %
Financial gain, robbery	6	4 %	2	4 %	4	4 %	26	4 %	19	19 %	7	1 %
Personal conflict	13	9 %	11	23 %	2	2 %	32	5 %	21	21 %	11	2 %
Alcohol induced brawl	11	8 %	11	23 %	0	0 %	8	1 %	4	4 %	4	1 %
Other/unknown	17	12 %	7	15 %	10	11 %	52	8 %	34	34 %	18	3 %

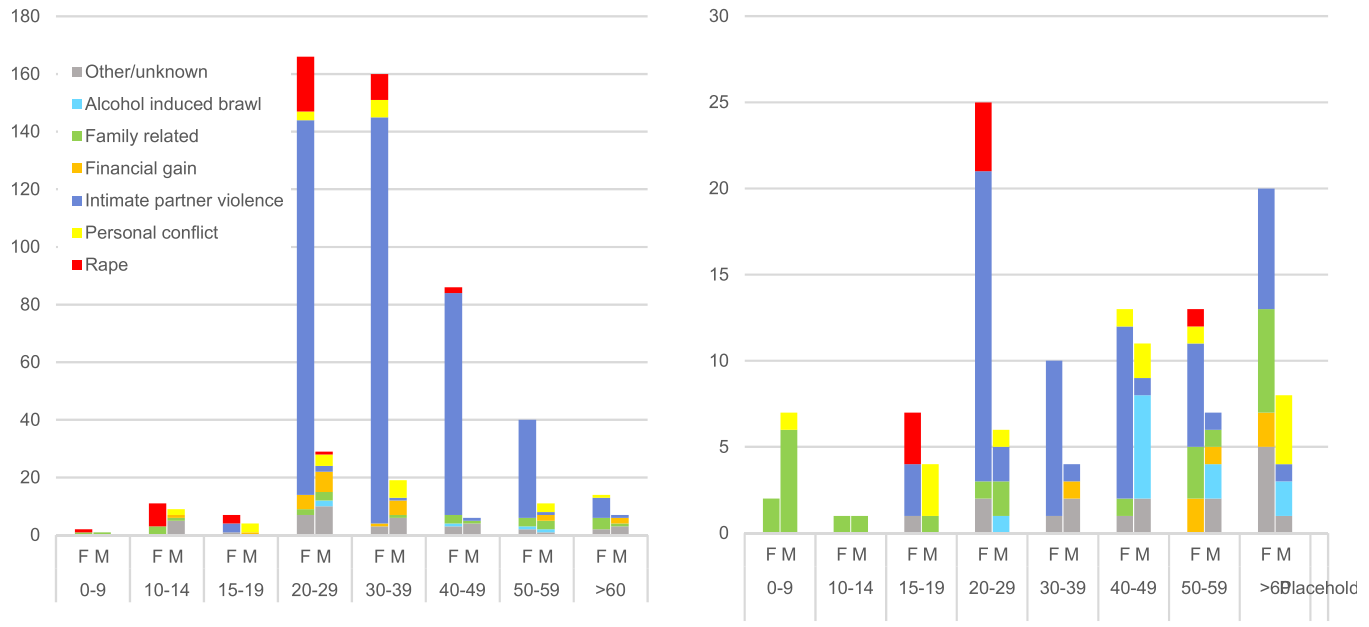

Fig. 5. a and 5b. Motives for non-fatal (a) and fatal (b) strangulation by victims' age groups and sex. F= female, M= male.

Table 3
Crime scene locations by gender among victims of fatal strangulation.

Crime scene location	Total (139) 100 %		Males (48) 35 %		Females (91) 65 %	
Home	110	79 %	32	67 %	78	86 %
Health care facility	4	3 %	4	8 %	0	0 %
Public area	8	6 %	4	8 %	4	4 %
Wooded area	10	7 %	5	10 %	4	4 %
Other	6	4 %	3	6 %	3	3 %
Unknown	1	0 %	0	0 %	1	1 %

common method (51 %, $n = 71$), followed by ligature strangulation (39 %), and a combination of both manual and ligature strangulation, classified as "mixed" (3 %). An analysis of strangulation methods in relation to the perpetrator's gender showed that women more often used ligature strangulation than manual strangulation (50 % vs. 40 %). In three cases where women were the perpetrators of manual strangulation, a male co-offender was present. Among the 119 male perpetrators of fatal strangulation, 55 % strangled their victim manually, while 36 % used a ligature.

In cases of ligature homicidal strangulation ($n = 57$), the most commonly used items were textile objects (28 %), such as scarves or fabric belts, followed by electrical cords and cables (21 %). In 29 of these 57 fatal ligature cases, the ligature was still attached to the body when discovered.

3.7. External and internal injuries and findings, non-fatal strangulation

The analysis of injuries in NFS victims was conducted exclusively on those examined by a forensic medical doctor ($n = 149$). External injuries were generally less severe than i FS cases, with contusions and abrasions on the neck being the most common injuries (65 %). Only 4 % exhibited petechial hemorrhages. Five NFS-victims (3 %) displayed both petechiae and contusions/abrasions.

No internal injuries were found among the NFS victims examined by a forensic medical doctor, and 52 individuals (35 %) showed no visible injuries or findings at all (Table 4). However, it should be noted that out of the total 617 victims of NFS, 10 who had been evaluated in a hospital setting exhibited internal injuries in the neck region, such as fractures, swelling, hemorrhages in soft tissues, or stroke.

3.8. External and internal injuries and findings, fatal strangulation

Due to postmortem decomposition or deliberate actions by the offender, 28 FS-cases could not be fully assessed. However, at least one external or internal autopsy finding was present in all but four individuals (97 %). Petechial hemorrhages were the most common trait, observed in 91 % of the assessable victims, primarily in the conjunctivae (80 %).

Statistical analyses did not reveal a significant association between the presence of petechiae and the type of strangulation method. Manual strangulation was associated with a high prevalence of external injuries, such as contusions/abrasions to the neck (76 %) and petechial hemorrhages (89 %). In 47 % of FS-victims, both petechial hemorrhages and contusions/abrasions were detected. Of these victims, 68 % had been subjected to manual strangulation, 18 % to ligature strangulation and 3 % by a mixed mode. 36 FS-victims (26 %) presented both petechiae, contusions/abrasions and fractures with manual strangulation as the most common mode (67 %). Ligature strangulation similarly resulted in frequent petechial hemorrhages (94 %) but also had a notable prevalence of ligature marks (90 %) while contusions/abrasion to the neck were less prevalent (25 %) compared to manual strangulation.

Hemorrhages in subcutaneous tissue and muscles of the neck were detected in 78 % of FS-victims and were almost as common in manual as in ligature strangulation. Tongue hemorrhages were observed in 25 % of strangulation victims, occurring more frequently in ligature strangulation cases (33 %) than in manual strangulation (20 %). Congestion of the head was seen in 42 % of 111 cases where it was possible to evaluate (Table 4).

Over half (52 %) of all strangulation homicide victims exhibited fractures in the larynx, most commonly of the thyroid cartilage (42 %), followed by the hyoid bone (23 %). Fractures were slightly more common among manually strangled victims (54 %) compared to those strangled with a ligature (48 %). The age range among those with fractures was 17–87 years, compared to 1–84 years among those without fractures. Fractures were absent in victims aged 0–14 years but increased with age, peaking at 71 % in the 40 years and above age groups (Fig. 6).

3.9. Blood alcohol concentrations

Of the FS victims 15 years and above of age ($n = 126$), 41 individuals

Table 4
External and internal injuries, their locations, and methods of strangulation in fatal and non fatal cases, highlighting injury patterns by strangulation method.

	Fatal strangulation										Non fatal strangulation							
	Total		Manual		Ligature		Mixed		Unknown		Total		Manual		Ligature		Mixed	
Total	139	100 %	71	51 %	54	39 %	3	2 %	11	8 %	149	100 %	142	95 %	4	3 %	3	2 %
External injuries																		
Petechial hemorrhages	116/128	91 %	58/65	89 %	45/48	94 %	3/3	100 %	10/11	91 %	6	4 %	5	4 %	1	25 %	0	0 %
Conjunctivae	103/128	80 %	53/65	82 %	39/49	80 %	3/3	100 %	8/11	73 %	3	2 %	2	1 %	1	25 %	0	0 %
Skin, eyelids	33/124	27 %	18/65	28 %	12/45	27 %	0/3	0 %	3/11	27 %	1	0 %	0	0 %	1	0 %	0	0 %
Skin, face	73/124	59 %	39/65	60 %	30/45	67 %	1/3	33 %	3/11	27 %	4	3 %	3	2 %	1	25 %	0	0 %
Skin, behind ears	14/124	11 %	7/65	11 %	5/45	11 %	0/3	0 %	2/11	18 %	0	0 %	0	0 %	0	0 %	0	0 %
Oral mucosa	55/127	43 %	28/65	43 %	21/48	44 %	3/3	100 %	3/11	27 %	0	0 %	0	0 %	0	0 %	0	0 %
Skin, neck	26/124	21 %	10/65	15 %	12/45	27 %	0/3	0 %	4/11	36 %	0	0 %	0	0 %	0	0 %	0	0 %
Congestion of head	47/111	42 %	25/59	42 %	17/39	44 %	1/3	33 %	4/10	36 %	0	0 %	0	0 %	0	0 %	0	0 %
Contusions, abrasions neck	73/129	57 %	51/67	76 %	12/48	25 %	2/3	67 %	8/11	73 %	97	65 %	92	65 %	3	0 %	2	67 %
Ligature marks	-	-	-	-	47/52	90 %	1/3	33 %	0/11	0 %	0	0 %	-		2	50 %	2	60 %
Tongue hemorrhage	32/127	25 %	13/65	20 %	16/48	33 %	0/3	0 %	3/11	27 %	0	0 %	0	0 %	0	0 %	0	0 %
Internal injuries of the neck																		
Fractures total	72/139	52 %	38/71	54 %	26/54	48 %	1/3	33 %	7/11	64 %	-	-	-	-	-	-	-	-
Hyoid	32/139	23 %	16/71	23 %	11/54	20 %	1/3	33 %	4/11	36 %	-	-	-	-	-	-	-	-
Thyroid cartilage	60/139	43 %	32/71	45 %	22/54	41 %	0/3	0 %	6/11	55 %	-	-	-	-	-	-	-	-
Cricoid	6/139	4 %	6/71	8 %	0/54	0 %	0/3	0 %	0/11	0 %	-	-	-	-	-	-	-	-
Muscle/subcutis hemorrhage	108/139	78 %	57/71	80 %	42/54	78 %	2/3	67 %	7/11	64 %	-	-	-	-	-	-	-	-
No injuries or findings	4/139	3 %	2/71	3 %	2/54	4 %	0/3	0 %	0/11	0 %	52	35 %	50	35 %	1	25 %	1	33 %
No internal	11/139	8 %	4/139	3 %	6/139	4 %	1/3	33 %	0/11	0 %	-		-		-			
No external	10/139	7 %	7/71	10 %	3/54	6 %	0/3	0 %	0/11	0 %	52	35 %	50	35 %	1	25 %	1	33 %

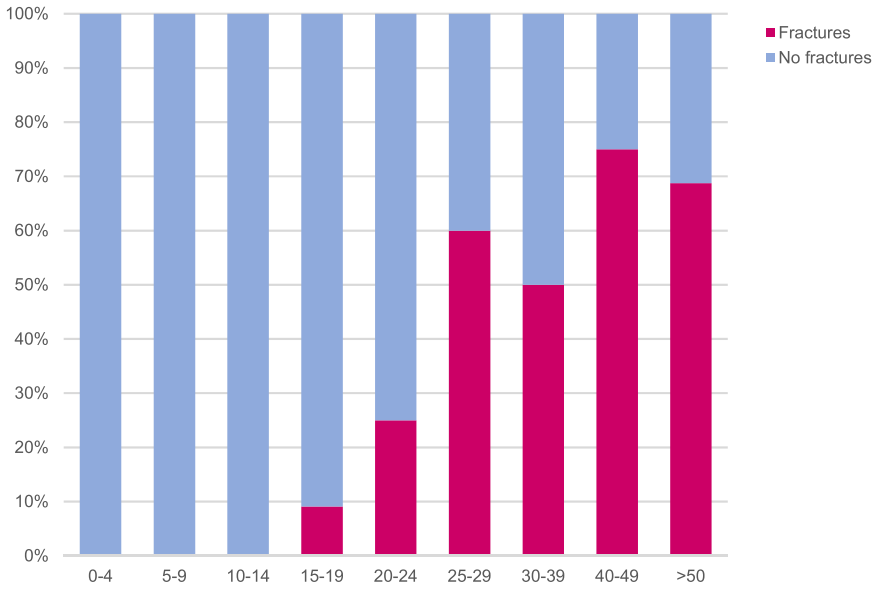

Fig. 6. Fatal strangulation, presence of fractures on hyoid bone, thyroid cartilage or cricoid cartilage related to different age groups.

(17 men and 24 women) had blood alcohol levels exceeding 0.2 g/L at the time of autopsy. Of these, 18 individuals (11 men and 7 women) exhibited blood alcohol levels over 2 g/L (Fig. 7).

4. Discussion

This study sheds light on the forensic and epidemiological characteristics of both non-fatal and fatal strangulation in Sweden, particularly in relation to gender, injury patterns, and context of violence.

4.1. Incidence, victim-offender demography and contextual findings

The study design provided a clear overview of the incidence of fatal strangulation and its trends over time. The proportion of strangulation homicides among all homicides during the study period was 7 %, which is relatively close to the reported figures from Finland (10 %) [21] but lower than Denmark 18 [39]. No clear explanation for this discrepancy has been identified, but it could be hypothesized that differences in methodological approaches or varying rates of IPV in these countries are contributing factors.

In this study, the most common case profile featured a female victim strangled manually in her own home by a partner or ex-partner, with intimate partner violence (IPV) as the predominant contextual factor. IPV accounted for 67 % of non-fatal cases and 42 % of fatal cases. These findings align with previous research that highlights strangulation as a gendered form of violence, strongly associated with IPV[3,4,14], commonly performed manually [21] in the victiḿs domestic environment [22]. The high proportion of IPV as a motive and the established association between NFS and an increased risk of subsequent lethal violence, underscores the importance of forensic assessments as well as lethality risk assessments in IPV-cases, where strangulation should always be considered [17].

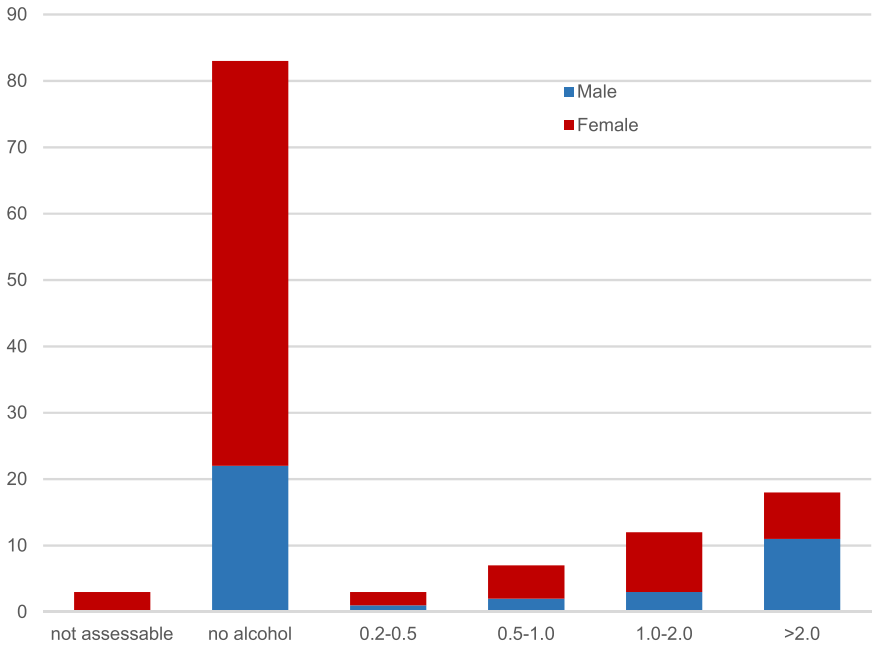

Fig. 7. Fatal strangulation, presence of blood alcohol, g/L. Subjects > 15 years of age, $n = 126$.

When specifically analyzing female perpetrators of homicide by strangulation, we found that ligature strangulation was the most commonly used method, whereas men more often resorted to manual strangulation. This difference may be explained by variations in physical strength, as using a ligature requires less direct physical engagement, reducing the risk of resistance or injury to the perpetrator. Additionally, it may provide a tactical advantage for women, enabling them to exert lethal force with less reliance on upper body strength.

Given the growing debate and concern about strangulation becoming a normalized and increasingly common, yet dangerous practice in young people's sexual behaviors [13,40,41], it was important to examine the prevalence of sexual motives in our study population. Cases where sex was the primary alleged motive (sexual assault) or part of the violence (e.g., consensual sex where the victim was subjected to non-consensual strangulation), were more common in non-fatal cases (17 %) compared to fatal cases (8 %). These numbers are higher than in previous studies. Wahlsten and Eriksson found a sexual motive in 5.5 % of all victims of asphyxia homicides in Finland where the substantial part of the victims (83 %) had died from strangulation [21]. Furthermore, strangulation is an acknowledged characteristic factor in Swedish male on female sexual homicides [12].

In a study by White in 2021 where 2206 adult victims of sexual assault was reviewed, 204 (9 %) had also experienced NFS and the highest percentage was found in the age group 21–25 years [9]. This correlates with our data where most victims of sexually motivated NFS occurred in the age span 20–29 years. Notably, in the present study we did not collect data on concurrent genital injuries or the detection of semen, which might have revealed cases not disclosed by the victim or evident from the circumstances leading to the police report. Moreover, it is a well-known fact that sexual violence is highly underreported [5].

Alcohol induced brawls as a contextual factor to altercations that led to strangulation was more prevalent in fatal strangulation cases than in non-fatal cases (8 % vs 1 %). When examining blood alcohol levels, which routinely had been assessed for FS-victims only, it was found that 33 % of victims $>$ 15 years had consumed alcohol close to the strangulation event. Of these, 18 exhibited blood alcohol levels over 2 g/l. This proportion is lower compared to a similar study that included all asphyxial homicides in Finland where the reported rate was 73 % [21]. There is a well confirmed link between alcohol and violence, with a reported annual frequency of alcohol attributed deaths of 248,000 [42]. Alcohol intoxication is an independent risk factor for homicidal strangulation and other forms of asphyxia, increasing the likelihood of respiratory depression, aspiration, cardiac failure, and the overall risk of severe injury or death [43] In the context of strangulation, whether consensual or not, intoxication may exacerbate these risks by impairing the awareness of its lethality and reducing the victim's ability to defend themselves, making them more vulnerable.

The levels of alcohol and drugs found in victims of homicidal strangulations and other asphyxial deaths are difficult to correlate with specific degrees of incapacitation. Nonetheless, intoxication remains a risk factor in homicidal strangulations. A study of 19 strangulation cases in Finland found that most offenders were under the influence of alcohol or drugs, with at least 11 victims also intoxicated [44]. In Johannesburg, 33 % of male and 18 % of female FS-victims had blood alcohol levels above 0.5 g/L. This supports the notion that intoxication impairs judgment in offenders and heightens the vulnerability of victims, thereby influencing the dynamics of violent encounters like strangulation [45]. It also highlights the need for forensic and medical professionals to assess alcohol levels in suspected cases, as intoxication may affect both clinical presentation and risk assessment.

4.2. Injury patterns and forensic implications

It has been repeatedly reported that strangulation victims may show no objective evidence of strangulation, even if the violence has been fatal [25,36]. This lack of visible injuries in NFS and FS presents a significant challenge for clinical recognition and legal prosecution. In the present study, 65 % of the NFS-victims and 97 % of FS-victims exhibited external and/or internal findings compatible with strangulation. In a 10-year review of 102 NFS-cases, 85 % of the victims displayed external injuries to the neck [17]. Strack and coworkers found that 50 % of their 300 NFS victims had visible injuries of which only 15 % were judged as distinct enough to be documented and used in court [14]. Injuries resulting from fatal strangulation often resemble those seen in non-fatal cases [25]. However, studies directly comparing the injury patterns between these two forms of violence are extremely limited.

In the present study, a more detailed qualitative analysis, including photographic documentation, the thoroughness of examinations, or the specific questions asked regarding associated symptoms (e.g., breathing difficulties, hoarseness, memory loss etc), was not conducted. However, it is important to note that the assessment of injuries in NFS victims in this study was carried out by trained forensic medical doctors which may have contributed to a relatively high proportion of registered injuries compared to the one performed by Strack where assessment was made from police and medical records. In fact, lack of training on the symptomology of strangulation has been proposed to be a factor that may contribute to strangulation being overlooked and under reported in the absence of visible injuries [14]. Key takeaway messages from these findings are that 1); the absence of physical injuries or symptoms does not rule out the occurrence of strangulation [17], not even in fatal cases [25], and 2); Strangulation events that leave minimal external signs, such as slight redness on the neck or solely a verbal account, might be underestimated or underreported, highlighting the need for improved recognition and documentation of NFS [14].

Petechial hemorrhages, commonly associated with strangulation, are non-specific in nature and can occur as a result of various forms of asphyxia or natural causes. On the other hand do their absence not rule out the possibility of strangulation [46]. Hence, a potential pitfall from a forensic medical perspective, is that cases with petechiae may be more readily classified as strangulation deaths, while those with subtle injuries and no petechiae are assigned a different or unknown cause of death. In our study, petechial hemorrhages were observed in 91 % of FS cases, slightly more often in ligature strangulation indicating, as stated previously, that petechiae is a diagnostic indicator in fatal strangulation cases when present [36]. The occurrence of petechiae in homicidal strangulation cases in our study was notably higher than in the study by Wahlsten and Eriksson [21], where only 65 % of 318 victims exhibited petechiae, but closely aligned with the findings reported by DiMaio (2000), who observed petechiae in 86 % of ligature strangulation cases and 89 % of manual strangulation victims [47]. The difference compared to the findings of Wahlsten and Eriksson [21] may, at least in part, be explained by differences in methodology. In our study, the percentage was calculated only for cases where a reliable assessment of petechiae was feasible - excluding individuals with advanced decomposition, severe burns, or other conditions that prevented proper evaluation.

Among NFS-victims, petechiae were significantly less common (4 %), suggesting that NFS is associated with shorter duration and reduced compressive force, conditions that often are insufficient to produce the intravascular pressure necessary for petechial formation.

Contusions and abrasions have repeatedly been reported as common injuries in strangulation victims [17,25]. In our sample, 65 % of our living victims of strangulation and 75 % of the FS-victims displayed contusions or abrasions. Even though contusions and abrasions of the skin are non-specific injuries that can result from various causes, in cases of strangulation, a forensic examination may provide crucial evidence of their nature. According to Gill et al. an abraded furrow or a linear contusion can suggest ligature strangulation, while vertically dispersed abrasions and contusions are more indicative of manual strangulation [36]. Contusions on the neck can also appear as finger pads marks where a thumbprint more often is visible than the whole grasp [25]. Additionally, abrasions on the neck may be self-inflicted as victims attempt to

free themselves [36] and sometimes show up like fingernail impressions [25]. The proportion of cases with both petechiae and contusions differed significantly between the two methods of strangulation (manual and ligature), indicating that the type of strangulation method may influence the likelihood of those injuries occurring. Out of the 71 victims (66 FS and 5 NFS) who displayed both petechiae and contusions/abrasions, 70 % had been strangled manually. Tongue hemorrhages were observed in 25 % of the FS victims, which aligns with previous studies reporting an incidence ranging from 5 % to 37 % [48]. Bleedings of the tongue seemed to be somewhat more common in ligature strangulation than in manual, which is in accordance with previous studies [21].

Laryngohyoid fractures are commonly associated with strangulation and can serve as indicative evidence of fatal neck compression [49]. Although laryngohyoid fractures are primarily associated with fatal strangulation, fractures can sometimes be seen in NFS victims, including those subjected to consensual strangulation [45]. Among our FS-victims, fractures were present in 52 % of the fatal cases and were slightly more common in manual strangulation than in ligature, findings in accordance with Wahlström and Erikssons study [21]. However, they found that hyoid fractures were most common in cases of manual strangulation, followed by fractures of the thyroid horn, whereas we observed the opposite—thyroid fractures were nearly twice as common as hyoid fractures in cases of both manual strangulation and ligature strangulation. Fractures were more common among older victims, likely due to the decreased flexibility and resilience of older bone and cartilage structures, which make them more prone to fractures than those of younger individuals as suggested by others [50].

A limitation of this study is that the information regarding the occurrence of NFS is primarily based on the victim's own account. It is possible that the absence of injuries, in some cases, may be due to the fact that strangulation did not actually occur. It is more likely however, that the absence is due to the application of less force in non-fatal cases, resulting in minimal visible trauma. Petechiae, for instance, were observed in only 4 % of NFS cases, and no internal injuries, such as fractures or muscle hemorrhages, were identified. Notably, as a secondary finding, we observed that among the 617 NFS victims, 10 exhibited internal injuries in the neck region, including fractures, swelling, hemorrhages in soft tissues, or stroke. These cases were evaluated in a hospital setting and not by a forensic medical doctor. This suggests that a subset of victims with potentially serious internal injuries may not undergo specialized forensic assessment, emphasizing the need for integrated protocols between hospital care and forensic evaluations to ensure thorough documentation and support for legal investigations. Another possible explanation is that forensic medical doctors, unlike hospital physicians, lack access to internal airway examinations, limiting their ability to detect strangulation-related injuries.

This study highlights significant differences in injury patterns between fatal and non-fatal strangulation, underscoring variations in severity and mechanism of injury. The substantially lower proportion of injuries among NFS cases compared to fatal strangulation (FS) reinforces the assumption that fatal neck violence involves greater force or prolonged pressure on the structures of the neck. Petechiae, fractures and internal hemorrhages were almost exclusively observed in fatal cases, further supporting this distinction.

Although concurrent injuries were not the focus of this study, further research on associated trauma could enhance our understanding of injury mechanisms in strangulation cases and contribute to the identification of a typical injury profile.

4.3. Preventive measures and legal implications

Strangulation is by its very nature life-threatening, with potential loss of consciousness within ten seconds of constant pressure [51], followed by irreversible brain death occurring within 4–5 min of sustained pressure [52]. Hence, the distinction between NFS and FS may lie in a matter of minutes, underscoring the lethality of this form of violence, even in the absence of visible injuries [14]. Given the high risk of repeated strangulation and its severe long-term consequences such as an increased morbidity, including neurological disorders, traumatic injuries and psychological symptoms, urgent preventive measures are crucial. Furthermore, research on recurrent strangulation remains limited, and future studies should explore whether a dose-response relationship exists, as suggested by Smith et al. [15].

Considering the associated health risks and lethality, strangulation should be treated and prosecuted as a serious violent offense rather than a minor assault [3]. However, successful prosecution remains challenging, particularly in the absence of visible injuries. This often results in reduced charges or even dismissal due to lack of evidence [53].

A comprehensive assessment of NFS-victims should include a detailed clinical examination, high-quality photographic documentation, thorough written reporting, and adherence to standardized forensic protocols [30,54]. Key elements to document include external signs such as bruising, abrasions, petechiae, and ligature marks; internal findings such as voice changes, swallowing difficulties, or airway injury; and reported symptoms like dizziness, incontinence, or loss of consciousness [32,54]. When combined with a structured approach and close coordination between healthcare providers and forensic experts, such documentation greatly enhances the accuracy of victim identification and strengthens the evidentiary basis for prosecution in both NFS and FS cases [2]. Beyond legal considerations, early recognition and documentation are also critical for preventing escalation to more severe or fatal violence [3].

Due to the frequent absence of visible external injuries in non fatal strangulation victims, supplementary diagnostic tools are often necessary to detect internal trauma [49]. Proposed methods include chest radiography, fiberoptic laryngoscopy, and MRI of the neck, which have shown potential in detecting mucosal hemorrhages, edema, and internal airway trauma in cases of non-fatal strangulation (NFS) [32,54]. Ruder et al. found that while over 70 % of NFS patients had normal MRI findings, potentially serious injuries such as fractures of the hyoid-larynx complex and cerebral vascular injuries were detected in 7 %, with MRI showing substantially higher sensitivity (80 %) than CT (30 %) [55]. Christe et al. similarly reported a diagnostic accuracy around 70 %, supporting the value of MRI in assessing injury severity in survivors [56]. Gascho et al. reviewed 195 NFS cases and concluded that MRI may aid in identifying soft tissue injuries – particularly in cases lacking visible trauma – though findings such as lymph node hemorrhage require further validation [57]. In fatal cases, autopsy remains the gold standard, but postmortem CT and MRI can add diagnostic value. Gascho et al. found CT to be as or more sensitive than autopsy for skeletal injuries, while MRI was nearly as effective for detecting soft tissue hemorrhages [58]. Both modalities may also reveal gas accumulations missed at autopsy. Deininger et al. confirmed the utility of MRI for soft tissue injury and CT for detecting fractures in six cases of fatal strangulation, including one without external marks [59]. Together, these findings suggest that while MRI and CT each have distinct strengths, their combined use can enhance diagnostic accuracy in both clinical and forensic settings. However, broader international validation and standardized imaging protocols are still needed to clarify their roles and optimize medico-legal outcomes.

Alternate light sources (ALS) have shown promise in detecting subcutaneous injuries, such as bruising and petechial hemorrhages not visible under normal lighting. Although early results are encouraging, the specificity and diagnostic reliability of ALS in the forensic evaluation of strangulation still require further validation [60]. In fatal cases, autopsy is considered the gold standard, but postmortem CT has also proven valuable, particularly for identifying strangulation-related fractures [49]. Further research is needed to refine these diagnostic tools and forensic protocols to enhance the identification of strangulation injuries and support more robust legal outcomes.

5. Limitations of the study

The retrospective nature of this study limits causal inferences and is relies on the accuracy of recorded data. In addition, the lack of previous studies comparing injury patterns between NFS and FS limited the possibilities of comparing our results with others.

Data were obtained from various sources and had been compiled by two different individuals with varying levels of expertise regarding what signs and injuries to look for and how to document them. Consequently, the data exhibited varying levels of quality in terms of photographs and descriptions of injuries. Another limitation is that data on non-fatal strangulation were collected for only a single year. This restricts the ability to assess changes over time or to generalize across different time periods. However, the substantial number of cases included provides a robust basis for the current analysis.

Despite these limitations, the study has notable strengths that contribute to its validity and reliability. One of the key strengths is that all FS cases included in the study were examined by physicians specialized in forensic medicine. This ensures a high degree of consistency and expertise in the documentation and evaluation of these cases, which enhances the reliability of the findings related to FS. In contrast, the NFS cases were derived from highly heterogeneous data, with substantial variation in the quality and comprehensiveness of the documentation. This variability likely reflects differing levels of knowledge and awareness regarding NFS among those responsible for collecting and documenting the data. While this heterogeneity poses challenges for the study's reliability and validity, it also highlights an important area for improvement in training and standardization in the recognition and documentation of NFS cases.

6. Conclusions

This study underscores the critical need for preventive measures, thorough forensic evaluations, and legal frameworks to address the severe consequences of strangulation. The distinct injury patterns observed between fatal and non-fatal cases emphasize the importance of recognizing the lethality of strangulation even when physical evidence is absent. By addressing these challenges through multidisciplinary collaboration, improved training, and standardized protocols, we can better identify, manage, and prosecute cases of strangulation-related violence, ultimately reducing the impact and burden of this dangerous form of violence.

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CRediT authorship contribution statement

Anna Jinghede Sundwall: Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Shilan Caman:** Writing – review & editing. **Brita Zilg:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

References

[1] A. Sauvageau, E. Boghossian, Classification of asphyxia: the need for standardization: classification of asphyxia, J. Forensic Sci. 55 (5) (2010) 1259–1267.
[2] A.J. Pritchard, A. Reckdenwald, C. Nordham, Nonfatal strangulation as part of domestic violence: a review of research, Trauma Violence Abus. 18 (4) (2017) 407–424.
[3] N. Glass, K. Laughon, J. Campbell, C.R. Block, G. Hanson, P. Sharps, et al., Non-fatal strangulation is an important risk factor for homicide of women, J. Emerg. Med. 35 (3) (2008) 329–335.
[4] L. Wilbur, M. Higley, J. Hatfield, Z. Surprenant, E. Taliaferro, D.J. Smith, et al., Survey results of women who have been strangled while in an abusive relationship, J. Emerg. Med. 21 (3) (2001) 297–302.
[5] S.B. Sorenson, M. Joshi, E. Sivitz, A systematic review of the epidemiology of nonfatal strangulation, a human rights and health concern, Am. J. Public Health (1971) 104 (11) (2014) e54–e61.
[6] Smailes H., McGowan M. An analysis of Domestic Homicide Reviews with fatal strangulation. https://ifas.org.uk/wp-content/uploads/2024/08/Domestic-Homicide-Review-Analysis-Fatal-Strangulation-_final-August-2024.pdf: Institute For Adressing Strangulation; 2024.
[7] K.H. Selin, A. Skarp, A. Repo, Dödligt våld I sverige sedan 1990. Omfattning, uveckling och karaktär, The Swedish National Council for Crime Prevention, Stockholm, 2024. Report No.: 2024:6.
[8] S. Caman, S. Skott, Youth intimate partner femicide: identification of factors specific to femicide against adolescent and young adult victims, J. Fam. Violence (2024).
[9] C. White, G. Martin, A.M. Schofield, R. Majeed-Ariss, I thought he was going to kill me': analysis of 204 case files of adults reporting non-fatal strangulation as part of a sexual assault over a 3 year period, J. Forensic Leg. Med. 79 (2021) 102128.
[10] M. Pettigrew, The preference for strangulation in a sexually motivated serial killer, Int. J. Offender Ther. Comp. Criminol. 63 (5) (2019) 781–796.
[11] A. Kim, E. Beauregard, J. Chopin, Strangulation in sexual homicide: is it opportunity, victim's vulnerability or sadism? J. Forensic Leg. Med. 94 (2023) 102488.
[12] J. Sturup, S. Rodre, D. Karlberg, E. von Vogelsang, M. Rying, S. Caman, Male-on-Female sexual homicides in Sweden, 1990 to 2013: a population-based controlled study of incidents, victims, and offenders, Int. J. Offender Ther. Comp. Criminol. 63 (9) (2019) 1557–1574.
[13] D. Herbenick, T.-c Fu, C. Patterson, Y.R. Rosenstock Gonzalez, M. Luetke, D. Svetina Valdivia, et al., Prevalence and characteristics of choking/strangulation during sex: findings from a probability survey of undergraduate students, J. Am. Coll. Health 71 (4) (2023) 1059–1073.
[14] G.B. Strack, G.E. McClane, D. Hawley, A review of 300 attempted strangulation cases part I: criminal legal issues, J. Emerg. Med. 21 (3) (2001) 303–309.
[15] J. De Boos, Review article: Non-fatal strangulation: hidden injuries, hidden risks, Emerg. Med. Australas. 31 (3) (2019) 302–308.
[16] D.J. Smith, T. Mills, E.H. Taliaferro, Frequency and relationship of reported symptomology in victims of intimate partner violence: the effect of multiple strangulation attacks, J. Emerg. Med. 21 (3) (2001) 323–329.
[17] L.B.E. Shields, T.S. Corey, B. Weakley-Jones, D. Stewart, Living victims of strangulation: a 10-year review of cases in a metropolitan community, Am. J. Forensic Med. Pathol. 31 (4) (2010) 320–325.
[18] A.M. Malek, R.T. Higashida, V.V. Halbach, C.F. Dowd, C.C. Phatouros, T. E. Lempert, et al., Patient presentation, angiographic features, and treatment of strangulation-induced bilateral dissection of the cervical internal carotid artery: report of three cases, J. Neurosurg. 92 (3) (2000) 481–487.
[19] S.P. Adhikari, J.C. Daugherty, N. Quiroz Molinares, N. Maldonado-Rodriguez, C. Wallace, J. Smirl, et al., A four-country study of strangulation-related alterations in consciousness in women who have experienced intimate partner violence: Co-Occurrence with traumatic brain injuries and measures of psychological distress, J. Neurotrauma 41 (13-14) (2024) e1666–e1677.
[20] A.J. Pritchard, A. Reckdenwald, C. Nordham, J. Holton, Improving identification of strangulation injuries in domestic violence: pilot data from a researcher–practitioner collaboration, Fem. Criminol. 13 (2) (2018) 160–181.
[21] P. Wahlsten, A. Eriksson, Asphyxia homicides in Finland, 1983–2012, J. Forensic Sci. 65 (5) (2020) 1548–1556.
[22] S. Rogde, H.P. Hougen, K. Poulsen, Asphyxial homicide in two scandinavian capitals, Am. J. Forensic Med. Pathol. 22 (2) (2001) 128–133.
[23] M. Joshi, K.A. Thomas, S.B. Sorenson, "I didn't know I could turn colors": health problems and health care experiences of women strangled by an intimate partner, Soc. Work Health Care 51 (9) (2012) 798–814.
[24] D.W. Sadler, Concealed homicidal strangulation first discovered at necropsy, J. Clin. Pathol. 47 (7) (1994) 679–680.
[25] D.A. Hawley, G.E. McClane, G.B. Strack, A review of 300 attempted strangulation cases part III: injuries in fatal cases, J. Emerg. Med. 21 (3) (2001) 317–322.
[26] M. Patch, J.C. Anderson, J.C. Campbell, Injuries of women surviving intimate partner strangulation and subsequent emergency health care seeking: an integrative evidence review, J. Emerg. Nurs. 44 (4) (2018) 384–393.
[27] G.B. Strack, C. Gwinn, On the edge of homicide- strangulation as a prelude, Crim. Justice 26 (3) (2011).
[28] L.S. Sharman, R. Fitzgerald, H. Douglas, Medical evidence assisting non-fatal strangulation prosecution: a scoping review, BMJ Open 13 (3) (2023) e072077-e.

[29] B.P. Volochinsky, Obtaining justice for victims of strangulation in domestic violence: evidence based prosecution and Strangulation-Specific training, Inq. J. /Stud. Pulse 4 (10) (2012). Available from: ⟨http://www.inquiriesjournal.com/a?id=706⟩.
[30] A. Reckdenwald, K.M. Powell, T.A.W. Martins, Forensic documentation of non-fatal strangulation, J. Forensic Sci. 67 (2) (2022) 588–595.
[31] A. Reckdenwald, A. Szalewski, C.L. Mandes, C. Peebles, Factors associated with legal decisions of nonfatal strangulation cases with forensic evidence, Crim. Justice Policy Rev. 35 (5-6) (2024) 273–294.
[32] C. Bruguier, P. Genet, J.-B. Zerlauth, F. Dédouit, J. Grimm, R. Meuli, et al., Neck-MRI experience for investigation of survived strangulation victims, Forensic Sci. Res. 5 (2) (2020) 113–118.
[33] P. Wiegand, M. Kleiber, DNA typing of epithelial cells after strangulation, Int. J. Leg. Med. 110 (4) (1997) 181–183.
[34] A.J. Cartwright, Degrees of violence and blood spattering associated with manual and ligature strangulation: a retrospective study, Med. Sci. Law 35 (4) (1995) 294–302.
[35] J.A. Perper, M.N. Sobel, Identification of fingernail markings in manual strangulation, Am. J. Forensic Med. Pathol. 2 (1) (1981) 45–48.
[36] J.R. Gill, D.P. Cavalli, S.F. Ely, J. Stahl-Herz, Homicidal neck compression of females: autopsy and sexual assault findings, Acad. Forensic Pathol. 3 (4) (2013) 454–457.
[37] E.M. Valera, J.C. Daugherty, O.C. Scott, H. Berenbaum, Strangulation as an acquired brain injury in Intimate–Partner violence and its relationship to cognitive and psychological functioning: a preliminary study, J. Head. Trauma Rehabil. 37 (1) (2022) 15–23.
[38] G.E. McClane, G.B. Strack, D. Hawley, A review of 300 attempted strangulation cases part II: clinical evaluation of the surviving victim, J. Emerg. Med. 21 (3) (2001) 311–315.
[39] A.H. Thomsen, P.M. Leth, H.P. Hougen, P. Villesen, Asphyxia homicides in Denmark 1992–2016, Int. J. Legal Med. 136 (6) (2022 Nov) 1773–1780.
[40] H. Douglas, L. Sharman, R. Fitzgerald, Domestic violence, sex, strangulation and the 'Blurry' question of consent, J. Crim. Law 88 (1) (2024) 48–66.
[41] D. Herbenick, L. Guerra-Reyes, C. Patterson, Y.R. Rosenstock Gonzalez, C. Wagner, N. Zounlome, It was scary, but then it was kind of Exciting": young Women's experiences with choking during sex, Arch. Sex. Behav. 51 (2) (2022) 1103–1123.
[42] J. Rehm, R. Room, M. Monteiro, G. Gmel, K. Graham, N. Rehn, et al., Alcohol as a risk factor for global burden of disease, Eur. Addict. Res. 9 (4) (2003) 157–164.
[43] H. Druid, Intoxication as a risk factor. Asphyxiation, Suffocation, and Neck Pressure Death, first ed., CRC Press, 2020, p. 7.
[44] H. Hakkanen, Homicide by ligature strangulation in Finland: offence and offender characteristics, Forensic Sci. Int. 152 (1) (2005) 61–64.
[45] R. Marr, L. Bugeja, Hyoid fracture: consensual sex-play or non-consensual nonfatal strangulation: a case report, Int. J. Leg. Med. 139 (2) (2025) 837–842.
[46] S.F. Ely, C.S. Hirsch, Asphyxial deaths and petechiae: a review, J. Forensic Sci. 45 (6) (2000) 1274–1277.
[47] V.J. DiMaio, Homicidal asphyxia, Am. J. Forensic Med. Pathol. 21 (1) (2000) 1–4.
[48] B. Bockholdt, H. Maxeiner, Hemorrhages of the tongue in the postmortem diagnostics of strangulation, Forensic Sci. Int. 126 (3) (2002) 214–220.
[49] M. Kempter, S. Ross, D. Spendlove, P.M. Flach, U. Preiss, M.J. Thali, et al., Post-mortem imaging of laryngohyoid fractures in strangulation incidents: first results, Leg. Med. 11 (6) (2009) 267–271.
[50] M.S. Pollanen, D.A. Chiasson, Fracture of the hyoid bone in strangulation: comparison of fractured and unfractured hyoids from victims of strangulation, J. Forensic Sci. 41 (1) (1996) 110–113.
[51] H. Kabat, J.P. Anderson, Acute arrest of cerebral circulation in man: LIEUTENANT RALPH ROSSEN (MC), U.S.N.R, Arch. Neurol. Psychiatry 50 (5) (1943) 510–528.
[52] G.B. Strack, G.E. McClane (Eds.). How to Improve Your Investigation and Prosecution of Strangulation Cases. 1999..
[53] A. Reckdenwald, D.J. King, A. Pritchard, Prosecutorial response to nonfatal strangulation in domestic violence cases, Violence Vict. 35 (2) (2020) 160–175.
[54] M. Armstrong, G.B. Strack, Recognition and documentation of strangulation crimes: a review, JAMA Otolaryngol. Head Neck Surg. 142 (9) (2016) 891–897.
[55] T.D. Ruder, A. Gonzenbach, J. Heimer, L. Arneberg, J. Klukowska-Rötzler, S. Blunier, et al., Imaging of alert patients after non-self-inflicted strangulation: MRI is superior to CT, Eur. Radiol. 34 (6) (2024) 3813–3822.
[56] A. Christe, H. Thoeny, S. Ross, D. Spendlove, D. Tshering, S. Bolliger, et al., Life-threatening versus non-life-threatening manual strangulation: are there appropriate criteria for MR imaging of the neck? Eur. Radiol. 19 (8) (2009) 1882–1889.
[57] D. Gascho, J. Heimer, M.J. Thali, P.M. Flach, The value of MRI for assessing danger to life in nonfatal strangulation, Forensic Imaging 22 (2020) 200398.
[58] D. Gascho, J. Heimer, C. Tappero, S. Schaerli, Relevant findings on postmortem CT and postmortem MRI in hanging, ligature strangulation and manual strangulation and their additional value compared to autopsy – a systematic review, Forensic Sci. Med. Pathol. 15 (1) (2019) 84–92.
[59] E. Deininger-Czermak, J. Heimer, C. Tappero, M.J. Thali, D. Gascho, Postmortem magnetic resonance imaging and postmortem computed tomography in ligature and manual strangulation, Am. J. Forensic Med. Pathol. 41 (2) (2020) 97–103.
[60] A. Tyr, N. Heldring, B. Zilg, Examining the use of alternative light sources in medico-legal assessments of blunt-force trauma: a systematic review, Int. J. Leg. Med. 138 (5) (2024) 1925–1938.