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REVIEW

Edged weapons awareness

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Abstract
Edged weapons (sometimes referred to as sharp weapons or blades) are an increasing threat to military personnel, the blue light community (police, ambulance, firefighters, other first responders) and the general public worldwide. The use of edged weapons in criminal and terrorist incidents internationally means the forensic community needs an awareness of the technology of edged weapons, how they are used, the damage (clothing and wounding) that might be caused and any other forensic implications. In this paper, the magnitude of the problem is presented, prior research summarised and implications for forensic investigations discussed.

Keywords Weapon types · Concealment · Use · Textile damage · Injuries · Forensic implications

What is an edged weapon?

Edged weapons, sometimes referred to as sharp weapons or blades, are any object that can be used to puncture or cut. Examples include knives (e.g. kitchen, combat, hunting, cleavers, box cutters), scissors, screwdrivers, machetes and swords, axes, razor blades, shards of glass and broken or sharpened credit cards. Edged weapons are a threat and therefore of interest to the military, blue-light community (police, ambulance, firefighters, other first responders) and the general public worldwide. The use of edged weapons in criminal and terrorist incidents internationally means the forensic community needs an awareness of the technology of edged weapons, how they are concealed and used, the damage (clothing and wounding) that might be caused and any other forensic implications. Knives are the most common edged weapon used in crimes and consist of a blade (with a tip and one or two sharp edges; edge characteristics include smooth, serrated, scalloped) connected to a handle. Knives and their blades can be made of diverse materials (metallic, ceramic, polymeric). The anatomy of a typical knife is shown in Fig. 1. Kitchen knives tend to have blunter tips and thinner spines than hunting or combat knives. Hunting knives generally have a straight edge but can vary in size and shape. Combat knives (sometimes referred to as daggers) often have two sharpened edges (double edged) although there are many different designs including those with false edges (partially sharp) [1]. Handles may have a guard to stop the hand sliding down the blade on impact with a target.

The threat

Police recorded crime in England and Wales involving a knife or other sharp instrument[1] states there were 36,598 incidents in the year ending December 2017, a 22% increase compared to the previous year [2]. In England and Wales to the year ending March 2018, there were 13,144 possession offences involving items with a blade or point[1], up approximately 9% compared to the previous year [3]. In 2011, 24% of injuries treated in the emergency department at a major trauma centre in the UK were caused by knives [4]. Of these injuries, 44% were self-reported as being due to assaults. The use of edged weapons against individuals in criminal and terrorist incidents means that practitioners within the forensic community will

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[1] knife or other sharp instrument – terminology used in the report

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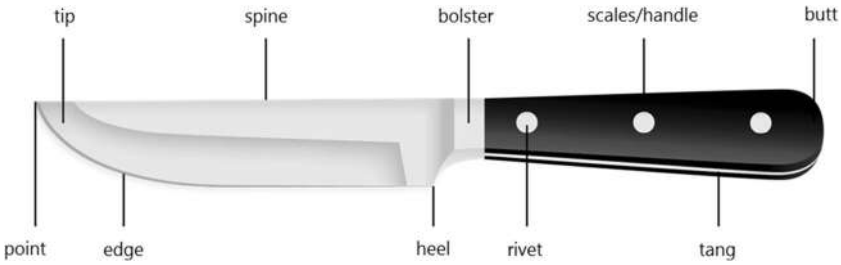

Fig. 1 General anatomy of a knife. Image by CDS Learning Services, Cranfield University - reproduced with permission from Carr, D.J. Ed. 2017. Forensic Textile Science. Cambridge; Elsevier

routinely examine damaged clothing and injuries caused by edged weapons.

Illegal and disguised knives

In the UK, it is illegal to carry a knife in public that has a blade longer than 76.20 mm (3 in.) [5]. There are also a number of banned knife types and other sharp weapons, including disguised knives and concealable knives [5]. There are a number of exclusions e.g. religious purposes, transporting to a museum for exhibition and transporting to work if required for work [5]. In 2018, the definition of flick knives was updated, carrying knifes in education institutions was banned, checks around the online purchase of knives were tightened and the possession of certain types of knives by individuals was banned [6]. Knives cannot be legally bought by under 18-year olds in England and Wales. In Scotland, knives for domestic use can be purchased by those over 16-years old.

Knives can be disguised in belts, combs, pens and lipsticks; concealable knives can be hidden in and under clothing (e.g. Figure 2) [7]. An edged weapon can be concealed in various ways. In palming, the digits and palm of the hand are used to conceal the weapon [7]. The weapon may be holstered using a custom-made sheath under clothing, typically on the belt, in a pocket, around the neck or in a boot [7]. A third method of concealment includes hiding weapon with other objects, for example within a newspaper/magazine, under a seat or above a door.

Use of edged weapons

The majority of incidents are spontaneous, they occur in the home and in public and use an edged weapon of convenience, typically a kitchen knife [8, 9]. These incidents may be defensive or offensive in origin. However, in premeditated attacks, the purchase of a specific weapon may occur and that weapon may be used by someone with a level of expertise. The training received by these individuals affects how the weapon is used, how long an attack might take and the area of the body targeted [7, 10–12]. A trained attacker will use different edged weapons in particular ways influenced by the design of the weapon. Typical grips a trained attacker might use for different attacks are shown in Fig. 3.

The technique and force used by an untrained user during an attack is higly variable [13, 14]. Untrained users will typically use an underarm stabbing or a slashing motion, less commonly an overarm stab and may deliver single or prolonged multiple untargeted attacks usually of the same nature. Both Miller and Jones (1996) and Horsfall (2005) comment on the effect of technique and knife handle and the importance of the follow-on the mechanics of the impact event. An attack by a trained user takes only a

Fig. 2 Examples of disguised and concealed knives, plus safety equipment. 1. Belt knife: buckle conceals a blade; 2. Folding push dagger-can be concealed in the palm; 3. Sheaths for boot knives; 4. Polymer blades designed to avoid metal detectors; 5. Folding blade designed for rapid draw and deployment from clothing; 6. Neck knife-worn on cord around neck under clothing; 7. Pen concealing a blade; 8. Comb concealing a blade; 9. Essential safety equipment (gloves and eye protection) used when working with blades

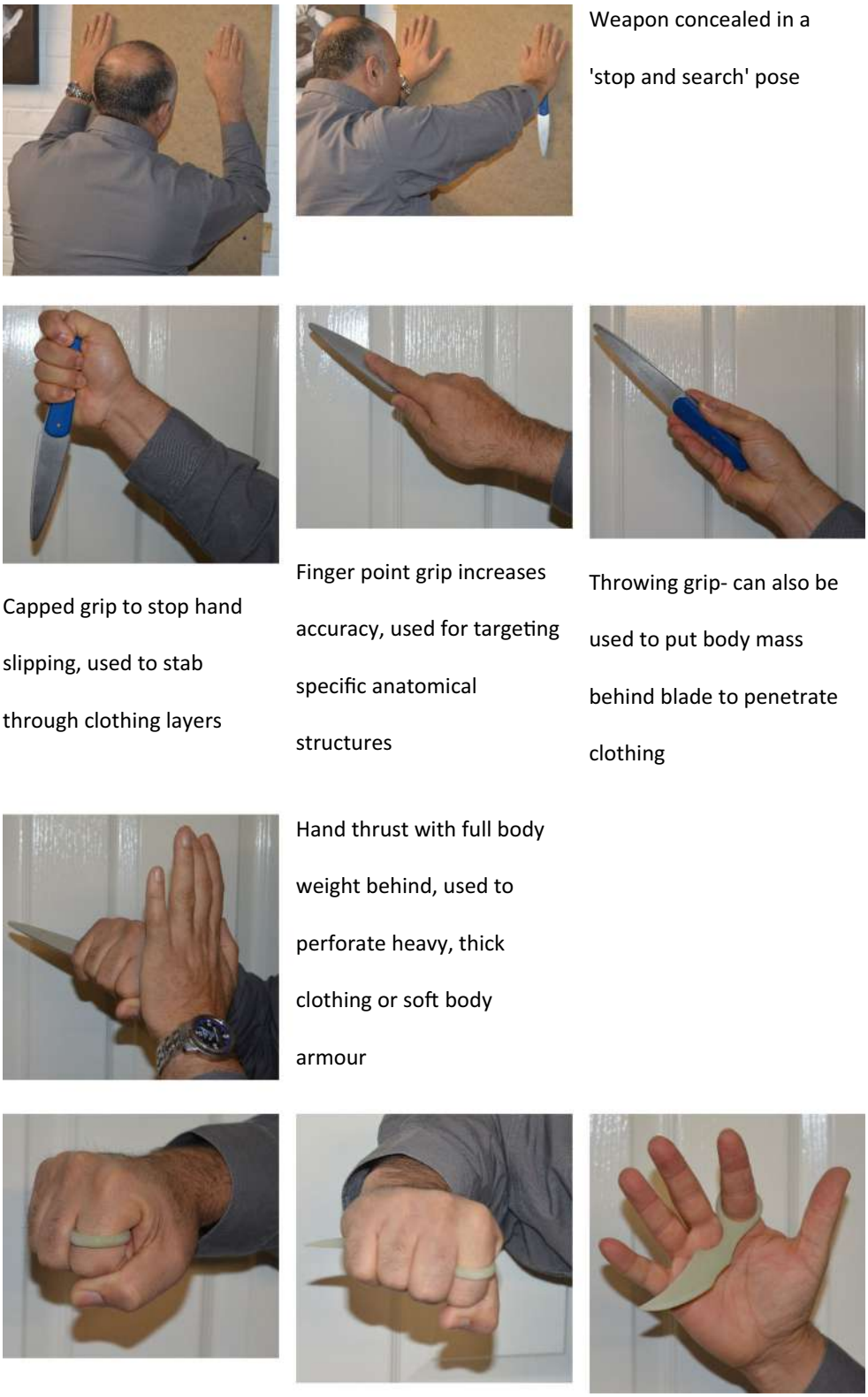

Fig. 3 Examples of grips used by a trained attacker

few seconds and results in targeted damage (to clothing and people) that might combine multiple slash and stab type impacts. A single attack may therefore result in different types of textile damage and underlying wounds and vary when different weapons are used (e.g. Figure 4) [11].

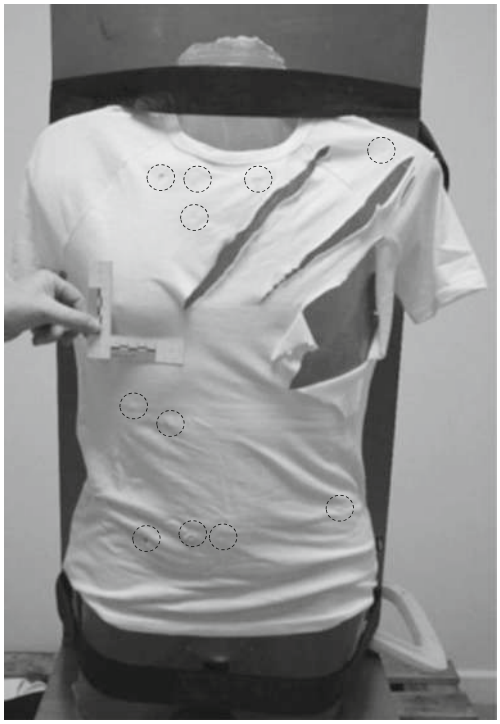

Fig. 4 Post-attack analysis of an attack by an expert user on a PermaGel™ torso wearing a white 100% cotton T-shirt (small impacts made with weapon tip are circled). Cowper, E., Mahoney, P.F., Godhania, K., Carr, D.J. and Harrison, K., A pilot study examining garment severance damage caused by a trained sharp-weapon user, Textile Research Journal, 87, 1287–1296. Copyright © 2017 (Sage Publications). Reprinted by permission of SAGE Publications

Edged weapons can be used in a number of ways (Table 1). The injuries caused are affected by the type of weapon used, how the weapon is used, the expertise of the user, how the injured person(s) reacts and what clothing they are wearing. The above factors result in different types of textile damage and wounding to the victim.

A mechanism which is rarely commented on in the forensics literature is throwing knives or other sharp objects. Sterzik et al. (2010) reported an interesting case study involving consideration of whether a glass shard impacted a victim's neck due to another person falling on a glass-top table or whether a shard of glass was used as a weapon during a fight. The work concluded that a blade shaped glass fragment had been used to stab the victim resulting in the fatal wound [15]. In an experiment that considered whether or not an 18 mm (wide) × 30 mm (deep) neck wound was caused by a thrown knife or a knife that slipped from a hand; seven participants performed trials using a pig carcass [16]. The work concluded that it was likely the wound could have been caused by a thrown knife (for 6 out 7 participants) but not likely to have been caused by a knife slipping from a hand. The effect of different throwing techniques with three different knives and a pair of scissors has been reported with ten participants ($n = 5$ male, $n = 5$ female) [17]. The depth of penetration (DoP) from 2 to 4 m into a target consisting of 10% (by mass) gelatine covered by a synthetic skin was reported. Using the heaviest weapon (chef's knife) resulted in a higher hit probability (0.167 at 4 m) and larger DoPs (mean = 44.2 mm at 4 m) than the lightest weapon (scissors) (0.067 at 2 m and 26.9 mm at 2 m respectively).

There is a vast array of books published on knives and knife fighting and the majority are easily accessible from mainstream online retailers. Additionally, on-line material is available. Some discuss military combative systems e.g. [18], or are closely allied to them e.g. [19, 20]. A range of books look at defence against knives and 'street survival' [21] whilst others based on prison experiences emphasise rapid offensive action and anatomical targeting [22] for lethal effect. Anatomical targeting also features in military systems [18] and more traditional martial arts books [23].

Grosz and Janich [20] take this concept further and attempt to match vascular injury with likely time to incapacitation, challenging the earlier work of Fairburn [18]. La Fonde [24] analysed knife attacks and found most were over in a matter of minutes or seconds—an observation in line with our study on time taken to draw a blade and cut a target [7].

Anatomical targets

Targets within the human body can be grouped as psychological (e.g. face, genitalia, buttocks), structural (e.g. tendons, ligaments), vascular (e.g. arteries and veins) and organs (e.g. heart, lungs, kidneys, spleen, liver, intestines, eyes) [10]. These targets differ in terms of response when struck; some will produce an immediate effect, whilst effects with others will be more gradual.

A survey of injured persons who reported to the Accident and Emergency Department at Glasgow Royal Infirmary between 1993 and 1996 suggested that 431 people had wounds caused by edged weapons (94% male) [25]. The total number of wounds was 1037. Slash wounds accounted for 63% of all wounds and were predominately located on the head ($n = 203$) and the arms ($n = 167$) [25]. The major areas suffering stab wounds were the chest ($n = 172$) and the abdomen ($n = 80$) [25]. More recent data regarding 938 incidents presented to a UK Emergency Department suggested key target areas were the limbs (71% of incidents), the thorax (20% of incidents) and the abdomen (15% of incidents) [4]. It is worth noting that both of these studies concentrate on injuries rather than injuries and fatalities.

Considering the expertise of the weapon user is important and recent work has highlighted how weapons are used by a trained user [7, 11]. Larkin (2017) describes reviewing a surveillance video taken in an American prison of inmates working out the correct cutting angles to use for attacking staff wearing body armour; they had staged a riot previously with

Table 1 Use of edged weapons

Type of action	Characteristics of striking mechanism	Comments	Example weapons
Slash	Speed and power	Cuts through an intended anatomical target	Knives, swords
Slice	Characterised solely by speed	Soft tissue lacerations	Razor blades, crushed tin cans, sharpened credit/phone cards
Hack	Powerful	Retracts on the same trajectory from which the strike began	Machetes, axes, meat cleavers
Stab	Singular or multiple; a series of attacks can be delivered at speed	With or without a twisting action	Knives, swords, broken bottles, sharpened tooth brush, scissors, screwdrivers, pens/pencils

the sole intention of getting eyes on a newly issued personal armour system [26].

Attacks by terrorists are increasingly involving edged weapons as the primary or a secondary weapon. In a study of 1615 patients who presented with intentional (terror-related) knife injuries between January 2013 and March 2016 in Israel, several important differences were noted compared to non-terror related incidents [27]. Key differences with terror-related incidents were more elderly, female victims with attacks occurring more typically in daylight hours mid-week. Head, face and neck injuries dominated and clinical outcomes were typically worse in terror incidents [27].

Impact force

The force used during an attack is of interest as it may help establish the underlying intent behind an observed wounding pattern. A number of studies have been reported that measure force during a stab or slash event using human participant trials. These studies have been conducted with reference to the dynamics of an attack, biomechanical properties of the human body, the design of body armour and the force required to perforate clothing layers e.g. [28–37]. In human participant trials, force is typically measured with an instrumented knife or by using a force plate located behind the target. The measured force is affected by the target, the edged weapon, the type of attack and the assailant (Table 2 [38]). Other work has been reported which uses commercially available instrumented laboratory equipment or equipment developed specifically for such testing. Studies including such equipment are not included in this review.

Offensive vs. accidental vs. self-inflicted incidents

A number of authors have considered the cause of injuries and fatalities due to edged weapons, classifying them as offensive, accidental or self-inflicted. A study of twenty-one fatalities (Institute of Forensic Medicine, University of Udine, Italy, 1993–2002) concluded there were nine self-inflicted cases, eight homicides, two accidental deaths and two cases that were uncertain [41]. Self-inflicted cases were characterised by injuries to the wrist or neck; homicides were more likely to feature multiple impacts and the two accidental fatalities were due to incidents involving glass. The predominance of glass injuries in accidental incidents was also discussed by Karger (2001) who reported various forms of glass (primarily people falling into and through windows) as the mechanism of death in 15 out of 18 accidental deaths from a total of 799 autopsies conducted in Münster and Berlin between 1967 and 1996 [42]. Of interest to the forensic examiner is that Rothschild et al. (2001) noted that wounds caused by glass can be mistaken for those caused by knives [43]. A retrospective analysis of 24 patients with abdominal stab wounds presenting at Angers University Hospital in France between January 2001 and January 2011 identified nine patients with self-inflicted wounds and 15 patients who were victims of an assault from patient histories [44]. Differences in the cause and outcome between the two groups were limited; patients with self-inflicted wounds were more likely to injure themselves in the home during the day. In comparison, assaults were more likely to occur during the night and in a public place. The authors concluded that care was required by forensic examiners when attempting to distinguish between self-inflicted and assault cases.

Textile damage

Humans injured in an edged weapon attack are rarely naked at the time of the attack and therefore clothing is usually damaged. A Swedish study suggested that 79% of incidents involved damaged clothing [45]. As well as variables involved in the actual attack, the textile damage observed in clothing is affected by fabric variables including, but not limited to, fabric structure

Table 2 Examples of studies that have measured force during human performance edged weapon research

Study details	Force reported (N)
Sharp-weapon resistant body armour mounted on a mannequin, dagger, $n = 50$ participants [33]	
Overarm	mean = 545
Thrust	mean = 528
Underarm	mean = 465
Stab-resistant composite mounted on Plastilina, $n = 20$ participants [34]	474–2261
Instrumented Stanley blade, slash, $n = 87$ participants [39]	mean = 107 max = 212
Effect of knife handle, Kevlar®-rubber composite mounted on a block of Plastilina, $n = 11$ participants [14]	1500–2000
Apparel fabrics mounted on foam, bread and hunting blades plus screwdriver, $n = 10$ participants [31]	mean = 314 (±133)
Skin simulant, swine leg and ribs, two screwdrivers and two knives, $n = 10$ participants [40]	35–372

(fibre and yarn types, knit/woven/non-woven, mass per unit area, thickness, sett/fabric density), clothing layers, fit and whether the garment was laundered before and/or after the attack and before examination. Therefore, specialist textile science knowledge is required when assessing these specimens.

There are a number of studies that have considered the effect of different variables on textile damage caused by an edged weapon e.g. [11, 31, 32, 38, 46–49]. That different damage is observed when all variables are controlled excluding knife type is recognised [11, 31, 32]. Knives with sharp (not shaped or damaged) tips and edges leave cleaner looking severances in fabrics. Knives with scalloped (e.g. bread knives) or blunt edges e.g. (hunting knives with a square spine) leave evidence of their shape in a fabric as long as that fabric is relative stable in structure (e.g. more obvious in a low extensible tightly woven fabric compared to a knit fabric) [11, 31, 32, 46, 50]. Garment fit may affect the textile damage observed [46, 50, 51] although a study using not-extended and extended knit fabrics suggested little difference in textile damage due to extension [32].

Severances appear different in laundered (or otherwise degraded) fabrics and if the fabric is laundered after the severance is formed [31, 32, 49]. Laundering before severance formation reportedly affects the high magnification appearance of the fibre ends and increased variability in fibre end failure types observed [31]. Laundering after severance formation typically disrupted the planar array of severed fibre ends and resulted in a more macro-frayed appearance [31, 49]. Degradation due to laundering also reportedly reduces the force required to penetrate a fabric [31]. Severance appearance may also vary with time, particularly in the case of fabrics that recover (e.g. knit fabrics) or are disturbed during the removal, transport and examination phases of a forensic investigation [31, 32, 46, 50]. If the attack results in full penetration of the weapon blade into the body the bolster or guard (if there is one) may leave a blunt impact mark on clothing [31].

User experience has been discussed and multiple types of textile damage noted as being possible due to an individual using a single weapon; an inexperienced examiner might conclude multiple attackers using different weapons were involved [11, 32]. Blood reportedly affects textile damage, but little research has been published in this area [50, 52].

Clinical damage

Assuming an edged weapon perforates clothing layers during an attack, damage will be observed on the body. This may include relatively minor lacerations to the skin (and immediate underlying soft tissue layers) caused by slash or stab attacks as well as damage to deeper structures including bones and organs. Minimum depths of organs[2] under the skin have been reported using CT as for the femoral artery 13 mm, thoracic aorta 31 mm [53] and using ultrasound for the kidneys as 12 mm, spleen 9 mm, liver 10 mm and pleura 10 mm [54].

A number of authors have reported damage observed on human and animal (usually swine) cadavers or tissue and synthetic surrogates of tissue. Rarely do these experiments include clothing layers; some reported work uses isolated bones. Practitioners should consider of potential differences in the damage reported in these results when compared to cases involving clothed (living) humans. A number of studies have considered the force to penetrate human skin with edged weapons using human cadavers e.g. [28, 55], and a number of texts exist describing wounds from a forensic pathology approach e.g. [56, 57]. Edged weapon damage to bone has been reported and includes the force to damage bone [36] and the effect of burning on (impact stab) damage to bones [58]. The effects of various types of degradation on striations caused by the use of serrated knives on swine belly sections (excluding bone) has been reported [59]. The subjective assessment of the force required to cause ‘mild’, ‘moderate’ and ‘severe’ wounding has recently been re-evaluated [60]. The work proposed that attack variables should be considered in the assessment of forces occurring during an edged weapon attack.

Conclusions

The aim of this paper was to gather information regarding edged weapons that might be of value to forensic practitioners.

[2] Depths to other organs and structures are given in the two papers, these values are selected by the authors

The paper provides information on knife types and design and quotes crime statistics to show how important understanding this area is for the forensic practitioner. In addition, the paper explains how edged weapons may be used in an opportunistic crime or by a trained expert, and summarises literature on textile damage and clinical injuries.

There are several areas of research that are not extensively considered in the literature and that have been higlighted in this paper. These include distinguishing between self-harm and other types of incidents, considering the effect of different mechanisms of injury e.g. thrown vs. stab, understanding differences between the general public and trained assailants, considering the effects of different types of weapons and identifying damage to clothing layers and the underlying torso. What is clear is that there are no firm patterns. The publication of case studies from both forensic examiners' and pathologists' perspectives would allow for a database of information to be available in the peer-reviewed literature. No doubt much of this information currently resides with individuals and organisations.

References

1. Capwell T. (2014) The illustrated encyclopedia of knives, Daggers & Bayonets Anness Publishing Ltd / Southwater Publishing Leicester, UK
2. Office for National Statistics (2018) Crime in England and Wales: year ending December 2017 (released: 26 April 2018)
3. Ministry of Justice. (2018) Knife and offensive weapon sentencing: January to March 2018 (published 14 June 2018)
4. Pallett JR, Sutherland E, Glucksman E, Tunnicliff M, Keep JW (2014) A cross-sectional study of knife injuries at a London major trauma centre. Ann R Coll Surg Engl 96:23–26
5. H.M. Goverment (2018) Selling, buying and carrying knives
6. Home Office (2018) Government introduces new Offensive Weapons Bill to tackle serious violence. Available at https://www.gov.uk/government/news/government-introduces-new-offensive-weapons-bill-to-tackle-serious-violence. Accessed 17 Nov 2018
7. Mahoney PF, Godhania K, Carr DJ (2017) Investigating the use of concealable and disguised knives. The Police Journal: Theory, Practice and Principles 91:139–149. https://doi.org/10.1177/0032258X17694176
8. Hunt AC, Cowling RJ (1991) Murder by stabbing. Forensic Sci Int 52:107–112
9. Hern E, Glazebrook W, Beckett M (2005) Reducing knife crime. Br Med J 330:1221–1222
10. Godhania K (2010) Eskrima: Fillipino Martial Art. Crowood Press Limited Ramsbury, UK
11. Cowper E, Mahoney PF, Godhania K, Carr DJ, Harrison K (2016) A pilot study examining garment severance damage caused by a trained sharp-weapon user. Text Res J 87:1287–1296. https://doi.org/10.1177/0040517516651107
12. Carr DJ, Mahoney PF, Godhania K, Malbon C. (2017) Victim's posture and protective clothing changes the approach in an edged-weapon attack. International Symposium on Ballistics Long Beach, CA, USA
13. Miller SA, Jones MD (1996) Kinematics of four methods of stabbing: a preliminary study. Forensic Sci Int 82:183–90
14. Horsfall I, Watson CH, Champion SM, Prosser PD, Ringrose T (2005) The effect of knife handle shape on stabbing performance. Appl Ergon 36:505–511
15. Sterzik V, Kneubuehl B, Rupp W, Bohnert M (2010) Stab or throw? Biomechanical studies on the injuring potential of glass fragments. Forensic Science International 199:e1–e4.
16. Muggenthaler H, Drobnik S, Hubig M, Niederegger S, Mall G (2013) Experiment throws with a knife to clarify a case of domestic violence. Archiv fur Kriminologie 231:46–54
17. Schaerli S, Schulz R, Gascho D, Enders M, Baumann S, Thali MJ, Bolliger SA (2018) Injury potential of thrown sharp kitchen and household utensils. Forensic Sci Med Pathol 14:31–41
18. Fairbairn WE. (1942) All-in fighting. The naval and military press Ltd Uckfield, East Sussex, UK
19. Janich MD (1993) Knife fighting: a practical course. Paladin Press Boulder, Colorado, USA
20. Grosz C, Janich MD. (2006) Contemporary knife targeting; modern science vs. W.E. Fairbairn's timetable of death. Paladin Press Boulder, Colorado, USA
21. MacYoung M. (1990) Knives, knife fighting, and related hassles. Paladin Press Boulder, Colorado, USA
22. Pentecost D. (1988) Put 'em down: take' em out. Paladin Press Boulder, Colorado, USA
23. Sanchez J (1980) Slash and thrust. Paladin Press US
24. LaFond J (2001) The logic of steel: a fighter's view of blade and shank encounters. Paladin Press US
25. Bleetman A, Watson CH, Horsfall I, Champion SM (2003) Wounding patterns and human performance in knife attacks: optimising the protection provided by knife resistant body armour. J Clin Forensic Med 10:243–248
26. Larkin T (2017) When violence is the answer. Little Brown and Company New York, USA
27. Rozenfeld M, Givon A, Peleg K (2017) Violence-related versus terror-related stabbings significant differences in injury characteristic. Ann Surg. https://doi.org/10.1097/SLA.0000000000002143
28. Knight B (1975) The dynamics of stab wounds. Forensic Sci 6: 249–255
29. Horsfall I, Prosser PD, Watson CH, Champion SM (1999) An assessment of human performance in stabbing. Forensic Sci Int 102: 79–89
30. Bleetman A, Hughes H, Gupta V (2003) Assailant technique in knife slash attacks. J Clin Forensic Med 10:1–3
31. Kemp SE, Carr DJ, Kieser J, Niven BE, Taylor MC (2009) Forensic evidence in apparel fabrics due to stab events. Forensic Sci Int 191: 86–96. https://doi.org/10.1016/j.forsciint.2009.06.013
32. Cowper EJ, Carr DJ, Horsfall I, Fergusson SM (2015) The effect of fabric and stabbing variables on severance appearance. Forensic Sci Int 249:214–224. https://doi.org/10.1016/j.forsciint.2015.01.024
33. Fenne P, Kemp M. (1998) Metropolitan Police Service Covert Body Armour Development. Personal Amour Systems Symposium 1998. Defence Clothing and Textile Agency Colchester, United Kingdom
34. Chadwick EKJ, Nicol AC, Gray TGF (1999) Biomechanics of stab attacks. Forensic Sci Int 105:35–44
35. Nolan G, Hainsworth SV, Rutty GN (2012) Forces required for a knife to penetrate a variety of clothing types. J Forensic Sci 58:372–379
36. Bolliger SA, Kneubuehl BP, Thali MJ, Eggert S, Siegenthaler L (2016) Stabbing energy and force required for pocket-knives to pierce ribs. Forensic Sci Med Pathol 12:394–398
37. Parmar K, Hainsworth SV, Rutty GN (2012) Quantification of forces required for stabbing with screwdrivers and other blunter instruments. Int J Legal Med 126:43–53

38. Kemp SE. (2017) Forensic analysis of sharp weapon damage to textile products. In: Carr DJ, ed. Forensic textile science. Elsevier Cambridge
39. Watson CH, Horsfall I, Champion SM, Harrod IC. (2000) Hum Perform in slash attacks. Personal Armour Systems Symposium 2000. Defence Clothing and Textiles Agency Colchester. United Kingdom
40. Nolan G (2014) Quantification of forces involved in stabbings. University of Leicester
41. Mazzolo GM, Desinan L (2005) Sharp force fatalities: suicide, homicide or accident? A series of 21 cases. Forensic Science International 147 Supplement: S33–S5
42. Karger B, Rothschild MA, Pfeiffer H (2001) Accidental sharp force fatalities - beware of architectural glass, not knives. Forensic Sci Int 123:135–9
43. Rothschild MA, Karger B, Schneider V (2001) Puncture wounds caused by glass mistaken for with stab wounds with a knife. Forensic Sci Int 121:161–5
44. Venara A, Jousset N, Airagnes G, Arnaud J-P, Rougé-Maillart C (2013) Abdominal stab wounds: Self-inflicted wounds versus assault wounds. J Forensic Legal Med 20:270–3
45. Karlsson T (1998) Homicidal and suicidal sharp force fatalities in Stockholm, Sweden. Orientation of entrance wounds in stabs gives information in the classification. Forensic Sci Int 93:21–32
46. Adolf F-P, Hearle J (1998) Textile damage in forensic investigations. In: Hearle JWS, Lomas B, Cooke WD (eds) Atlas of fibre fracture and damage to textiles, 2nd edn. Woodhead Publishing Limited Cambridge
47. Johnson N, Stacy A (1991) Forensic textiles: the morphology of stabbed textiles. Australas Text Fash 11:32–33
48. Taupin JM (1999) Comparing the alleged weapon with damage to clothing- the value of multiple layers and fabrics. J Forensic Scie 44:205–207
49. Wells SL, Laing RM, Carr DJ, Niven BE (2013) Effect of laundering on visible damage to apparel fabric caused by sharp force impact. Forensic Sci Int 233:283–287. https://doi.org/10.1016/j.forsciint.2013.09.025
50. Taupin JM, Cwiklik C (2010) Scientific protocols for forensic examination of clothing. CRC Press
51. Costello PA, Lawton ME (1990) Do stab cuts reflect the weapon that made them? J Forensic Sci Soc 30:89–95
52. Carr DJ, Featherstone M, Malbon C, Miller D, Teagle M (2018) Preliminary development of a bleeding layer to assess the effect of a ballistic impact on textile damage. Forensic Sci Int 288:169–172
53. Connor SE, Bleetman A, Duddy MJ (1998) Safety standards for stab-resistant body armour: a computer tomographic assessment of organ to skin distances. Injury 29:297–299
54. Bleetman A, Dyer J (2000) Ultrasound assessment of the vulnerability of internal organs to stabbing: determining safety standards for stab resistant body armour. Injury Int J Care Injured 31:609–612
55. O'Callaghan PT, Jones MD, James DS, Leadbeatter S, Holt CA, Nokes LDM (1999) Dynamics of stab wounds: force required for penetration of various cadaveric human tissues. Forensic Sci Int 104:173–178
56. Ormstad K, Karlsson T, Enkler L, Rajs J (1986) Patterns in sharp force fatalities - a comprehensive forensic medical study. J Forensic Sci 31:529–542
57. Payne-James J, Jones R, Karch SB, Manlove J (2011) Simpson's forensic medicine. 13th ed. CRC Press
58. Macoveciuc I, Márquez-Grant N, Horsfall I, Zioupos P (2017) Sharp and blunt force trauma concealment by thermal alteration in homicides: an in-vitro experiment for methodology and protocol development in forensic anthropological analysis of burnt bones. Forensic Sci Int 275:260–271
59. Stanley SA, Hainsworth SV, Rutty GN (2017) How taphonomic alteration affects the detection and imaging of striations in stab wounds. Int J Legal Med 132:463–475. https://doi.org/10.1007/s00414-017-1715-2
60. Nolan G, Hainsworth SV, Rutty GN (2018) Forces generated in stabbing attacks: an evaluation of the utility of the mild, moderate and severe scale. Int J Legal Med 132:229–236