Feasibility of using damage to body armour as evidence to prove the degree of intent of wounding

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Abstract

It has become standard practice for Police Authorities to issue stab resistant body armour to all officers who are placed at risk of knife assault. Subsequently if the officer is subjected to a knife attack it has been difficult to prove the degree of intent of wounding by a suspect. Arguments that no real harm could be intended, as the officer was protected by armour, are presented in court to mitigate any sentence of intent to wound. Several Police Forces have requested that damaged armour from attacks be forensically examined to determine the extent of damage and directly relate this damage to the forces of the impacts in an attack.

This paper assesses the feasibility of using damage to body armour worn during an incident as evidence to prove the degree of intent of wounding. The study compares the different weapons used, variation in damage caused by blades of different dimensions and damage related to tip and blade sharpness. The relationships between force, energy and damage, the effect of armour construction and how all these factors effect the type of damage expected are also investigated. This work highlights the fundamentals necessary for the development of a forensic protocol to investigate damage to stab resistant armours so that the results could be accepted in evidence.

Keywords: Forensic, Body Armour, Knife Attack

Threat Analysis

Officers are regularly threatened with a variety of edged weapons. So to determine the range of weapons, a knife analysis was conducted by the Metropolitan Police Service[1] (MPS) on prisoner property collected over a period of two months across all of London. The information gathered included the types and description of weapons used in attacks or confiscated from individuals. The knives were grouped and categorised as follows: Knuckle dusters and throwing knives, Combat knives, Ceremonial/sheath knives/daggers, Swords, Batons/hatchets, Multi-purpose tools, Flick /switch /butterfly knives, Razor blades/Stanley/craft knives, pen knives, lock knives and kitchen implements. Enquiries were also made to other Police Forces [2,3] into the types of weapons encountered by officers on a routine basis. It was reported that vegetable or carving knives were by far the most common weapons followed by Stanley knives, penknives and screwdrivers.
Most of the knife blades collected could be classified as blunt along the edges and many had sustained damage. The tips of larger blades had mostly remained sharp and when measured were comparable to a newly purchased carving knife. Smaller blades

were more variable in their sharpness with better quality knives sharper than the larger blades. However, many that had been used in attacks were bent or damaged at the tip. When tested, the sharpness of some of the pocket, flick and pen knives were as sharp as the sharpness specified for the tip of the Home Office Scientific Development Branch (HOSDB) P1 test blade.

The knife analysis highlighted the difference in dimensions between knives intended for the same purpose. The size and shape of the handles, the weight of the knife and the materials used may all have an influence on the scale of the damage created. However previous research by Horsfall *et al*[4]had found that handle shape had little effect on the energies delivered by the volunteers as long as a finger guard was in place. A finger guard provided greater confidence and could double the energy of the delivered stab. As the handle became less comfortable to hold, the energy of the stab decreased.

Weapons

Following this threat analysis the weapons chosen for the assessment were: a PSDB P1 test blade, vegetable knife, carving knife, paring knife, flat-edged screwdriver/ as new and sharpened and a Phillips style screwdriver/as new and sharpened.

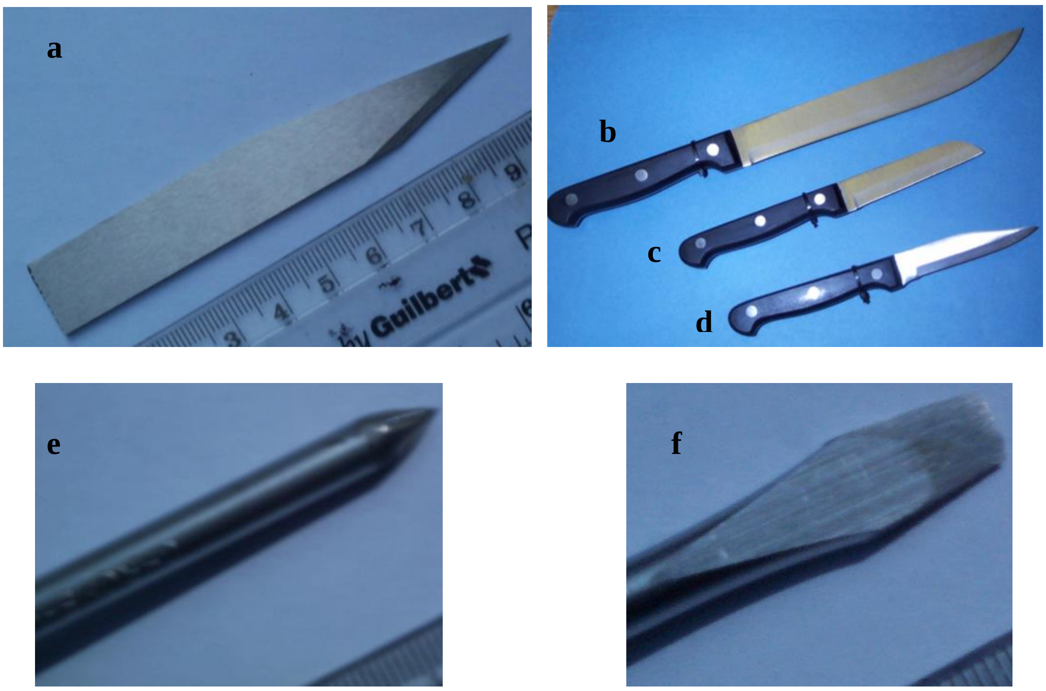

Fig 1. Test Weapons a) HOSDB P1, b)Carving, c) Paring, d) Vegetable, e)Sharpened Phillips Style Screwdriver, f) Sharpened Flat-edged Screwdriver

To establish if a direct relationship between back face damage to the armour and the energy applied could be found. Tests were carried out with the HOSDB[8,9] drop tube equipment using the weapons listed above to assess the variation of damage (cut length) to the back face of an armour with respect to tip and blade sharpness and to investigate the difference in damage caused by blades of different dimensions. It has been reported that the most important factor in causing penetration by a stabbing is the sharpness of the tip of the knife [4,5,6,7]. The method of tip sharpness measurement developed by Horsfall *et al*, described in the HOSDB test standards[8,9] for knife and spike resistant armour was used for this work. Tip sharpness is measured in modified Rockwell hardness C values where a high value denotes a blunt tip and a low value a sharp tip. The dimensions of the blades used are given below the width and tip thicknesses were measured at 5mm from the point.

Table 1. Dimensions of weapons used

Weapon Type	Blade Length (mm)	Thickness (mm)	Width (mm)	Cross-sectional area mm^2	Average tip sharpness HRC
Vegetable	77	0.8	5.00	4.0	-114
Carving	171	1.91	7.90	15.1	-18
Paring	82	1.03	8.51	8.8	-20
HOSDB	100	1.91	3.62	6.9	120
Flat screwdriver	75	1.78	7.30	13	+75
Phillips screwdriver	70	5.41	5.41	29.3	+40

Armour Constructions

A selection of armour constructions were chosen from a range of HOSDB protection levels to assess the amount of damage the weapons would cause to real systems. Typical protection levels and constructions of two of the armours used are listed below.

Table 2. Constructions of armour vests

Vest Number	Protection Level	Construction Strike face to wear face
2	KR2 HG1/A	6mm diameter chain mail 10 layers quilted fine weave Kevlar 12 layers quilted fine weave Kevlar stitched to 2 layers thick weave Kevlar Nylon cover, Synthetic covert carrier
3	KR1 HG1	6 layers quilted thick weave Kevlar stitched to 2 layers coated Kevlar 16 layers coated Kevlar 6 layers quilted thick weave Kevlar stitched to 1 layer thick coated Kevlar Nylon cover, Cotton covert cover

Current Standards

The HOSDB Body Armour Standard for UK Police, (2007) part 3, Knife and Spike protection[9] define the protection grades to which body armours can be certified. The different levels of protection within the standard allow the correct armour to be worn to defend against a variety of expected threat levels. Knife resistant armours are graded by the amount of penetration of the blade at different energy levels.

Table 3. HOSDB Knife Protection Levels

Protection Level	Lower Energy Level (J)	Acceptable Penetration (mm)	Higher Energy Level (J)	Acceptable Penetration (mm)
KR1	24	7	36	20
KR2	33	7	50	20
KR3	43	7	65	20

KR3 is the highest protection level and is designed for use in high threat situations. KR2 is a general level of protection chosen by most of the UK police forces, as the protection level should defend against a serious attack whilst still allowing good movement and comfort to the officers. KR1 is the lowest level of protection and is designed for use in a low risk situation.

Human performance vs HOSDB standard drop tube tests

Horsfall et al[4] developed an instrumented knife to assess the human performance in stabbing. The study investigated the energy values achieved by 500 volunteers in order to provide a realistic scale for use in the HOSDB test standard. The knife calculated impact energy from force and acceleration measured during the event. This instrumented knife was also used for this study fitted with carving, vegetable and HOSDB blades and two types of screwdriver. The damage to body armour and any penetration was measured.

Vest 2, KR2 chain mail overt armour, was chosen to assess the damage caused by the different weapons. The handles were all cut from the knife blades and screwdrivers so they could fit easily into the fixings on the drop tube sabot. The tip sharpness of the implements was tested using the method described in The HOSDB Body Armour Standard for UK Police, (2007) part 3, Knife and Spike protection[9] the sharpness values recorded are given below. The HOSDB drop tube was used for one drop of each of the knives listed above onto the armour at KR2 E1 (33J). It was expected that the armour would show some measurable damage, but not necessarily total penetration.

Results

The carving knife produced cuts to both the inner and outer covers but did not break any rings. The paring knife bent on impact with the armour and caused minor fraying of the fibres on the outer jacket. The screwdrivers produced very little damage apart from a few damaged fibres on the outer cover of the armour. Only the sharpened screwdriver perforated the outer jacket and no damage was visible to the inner cover. It was found that the HOSDB blade damaged the outer cover and caused some bending and stretching of the rings in the mail. The vegetable knife broke two rings of the mail and fully penetrated the armour at 33J. A second test was performed on a different area of the vest and again caused a ring to be broken at 23J and a penetration of 8mm.

Table 4. Cut damage to vest 2 from various types of weapons fitted to drop tube.

Weapon Type	Tip Sharpness HRC	Energy (J)	Velocity m/s	Comments on damage
PSDB P1	-137	34	5.99	4mm cut
Vegetable 2	-123	23	4.87	8mm cut length
Carving	-51	33	5.86	10mm cuts to cover
Paring	-20	34	5.92	Slight splitting of fibres
Flat-edged Screwdriver	+87	34	5.91	No visible damage, dent in fabric no perforation
Phillips style Screwdriver	+78	35	6.08	Fraying fibres on outer cover, no perforation
Sharpened Flat-edged screwdriver	+49	34	5.90	Fraying of fibres. No perforation of outer cover
Sharpened Phillips style screwdriver	+8	33	5.9	Hole in outer cover 3mm diameter, no damage to inner cover

This mode of failure is typical of chain mail systems, when the knife blade strikes the centre of a link the diameter of link allows some penetration of the blade. As the increase in cross-sectional area of the blade becomes greater than the diameter of the link the high stresses imparted by blade on the circumference of the link cause it to deform and break. Once a link has broken there is less resistance to penetration and the knife is able to cut through the armour. The severity of the vegetable knife at 33 and 23 joules is primarily due to its cross-sectional area, table 1 which is much less than the other weapons and was about 0.6 of an HOSDB blade. This means that for the same input energy the amount of energy per mm^2 at the tip will be greater than that of weapons with larger cross-sections and consequently the armour system will have to resist higher stresses.

Vest 2 and the instrumented knife were used to compare damage from hand stabs using the weapons that had caused significant damage during the drop tube tests. All hand stabs were under arm, the volunteer was a male of average height (5’ 9”) and weight (75Kg). The volunteer rested for 5 minutes between stabs but attempted to perform the hand stabs in exactly the same way to give some repeatability. The results of the hand stab tests are given in Table 5 .

When compared these results show that no relationship could be established between the amount of cut damage caused by drop tube tests and damage caused by hand stabs. However the results from the vegetable knife blade were more consistent so this blade was chosen for further tests with the volunteer performing stabs at a range of energies. The cut lengths from these stabs are compared in figure 1 with a range of cut lengths and energies from the drop tube. The drop tube data shows cut lengths increasing linearly with increasing energy. In this test the knife is guided and always impacts the armour at 90^0. In this test the relaxation of the muscles of the wrist and arm is simulated by foam dampers which give a repeatable consistent response. However the human response is inherently more variable as it is not always possible to repeat each stab exactly and generally the cut lengths achieved in human stabs were much less severe than those from the drop tube test.

Table 5. Cut damage to vest 2 from hand stabs

Weapon Type	**Tip Sharpness**	**Energy J**	**Velocity m/s**	**Comments**
Veg 1	-126.1	8	2.88	4.5mm cut length
Veg 2	-109.5	20	4.63	7mm cut length
Carving 1	-72.9	14	3.18	1mm cut
Carving 2	-71.1	14	3.75	1mm cut
Carving 3	-70.9	21	3.46	1.5mm cut
Sharpened Flat-edged screwdriver	+48	14	4.29	Frayed fibres no perforation
Sharpened Phillips style screwdriver	+9	15	4.30	Puncture hole approx. 0.5mm diameter

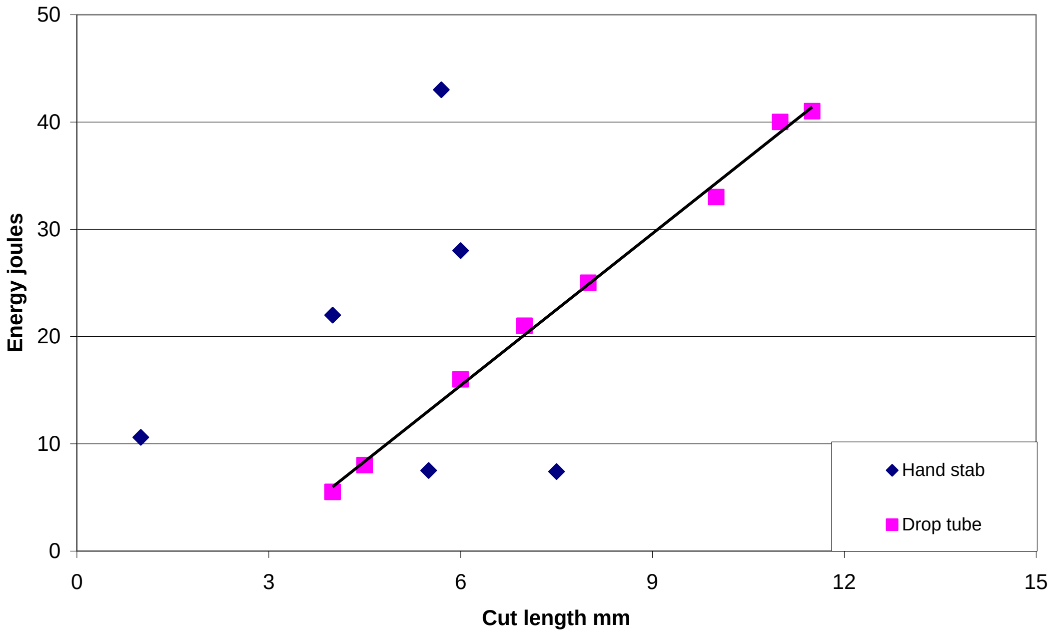

Figure 2. Comparison of drop tube and hand stab results from vest 2

Further drop tube tests to examine cut damage were carried out on vest 3, a KR1 textile only dual-purpose armour. The drop tube results followed the trend of the previous tests on vest 2 and showed that the vegetable knife was more penetrative than the test blade. Hand stabs were also performed on vest 3 , table 6 to confirm that it would be possible to achieve the same result in an actual stabbing. The damage done to the armour by the vegetable knife blade was more severe than that done by the PSDB blade. This result was expected as the profile and cross-sectional area of the vegetable knife blade was the smallest in the group. The influence of the increased confidence of the volunteer as the testing progressed was also difficult to assess. The instrumented knife has a sabre guard around the hilt to protect the volunteers' hand and this may have resulted in higher energies being applied.

Table 6. Hand stab damage to Vest 3 with vegetable and HOSDB P1 knives

Weapon Type	Tip Sharpness	Energy (J)	Velocity (m/s)	Comments
Veg 18	-113	20.0	4.56	31mm penetration, 16mm cut length
Veg 19	-107	16	4.05	8.5mm cut length
Veg 20	-113	20.8	4.59	23mm penetration
Veg 21	-120	24.7	5.05	40mm penetration
PSDB 1	-129	18.5	4.39	4mm cut length
PSDB 2	-129	23.8	5.00	6mm cut length,
PSDB 3	-128	21.5	4.06	7mm cut length,

Hand stabs were also performed on a ballistic aramid, a KR2 level plated and a KR2 wire mesh armour. Only the KR2 plated armour was able to defeat the vegetable knife. Plated armour is very stiff and this is very effective against the initial high stresses applied by the tip of a sharp knife. In the instances where penetration was observed, the blade had slid between the gaps in the plates and cut the fibres beneath. As with the previous armour systems no relationship between damage and energy for a hand stab attack was established. Any damage was caused mainly by the edge of the blade cutting the material as it was dragged through the fabric. In almost all the cases where large cut lengths were seen, there was very little damage done to the actual armour.

All the armours tested for this study provided the necessary protection against the vegetable blades at the energies specified in the PSDB standards for which they were certified. This means that although some of the penetrations seem severe, the armour would still be life saving. Vest 3 was certified to KR1 but failed at low energies against the vegetable blade. Had a reconstruction been required on this armour, it would be extremely difficult to give an indication of the energy used. The profile of the blade reduced the minimum energy required to fully penetrate this armour to 20J. Therefore they could be no means to prove if the energy used by an attacker was higher than this.

Conclusions

The results of the tests showed that a simple relationship, such as cut damage vs energy, cannot be used to analyse the cut damage caused during a knife attack by an assailant. The drop tower produces a linear scale which could be indicative of the potential amount of energy that caused damage but the hand stab trials were so variable that the two tests were not directly comparable. For forensic purposes the inability to prove beyond reasonable doubt that the link between damage and energy from hand stabs can be quantified and replicated by a drop tube test would exclude the use of drop tower data as evidence to establish intent to wound.

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