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Biomechanics of stabbing knife attack for trauma surgeons in Korea: a narrative review

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The aim of this paper was to review the biomechanics of knife injuries, including those that occur during stabbing rampages. In knife stab attacks, axial force and energy were found to be 1,885 N and 69 J, respectively. The mean velocity of a stabbing motion has been reported to range from 5 to 10 m/sec, with knife motions occurring between 0.62 and 1.07 seconds. This speed appears to surpass the defensive capabilities of unarmed, ordinarily trained law enforcement officers. Therefore, it is advisable to maintain a minimum distance of more than an arm's length from an individual visibly armed with a knife. In training for knife defense, particularly in preparation for close-quarter knife attacks, this timing should be kept in mind. Self-inflicted stab wounds exhibited a higher proportion of wounds to the neck and abdomen than assault wounds. Injuries from assault wounds presented a higher Injury Severity Score, but more procedures were performed on self-inflicted stab wounds. Wound characteristics are not different between nonsuicidal self-injury and suicidal self-wrist cutting injuries. Consequently, trauma surgeons cannot determine a patient's suicidal intent based solely on the characteristics of the wound. In Korea, percent of usage of lethal weapon is increasing. In violence as well as murders, the most frequently used weapon is knife. In the crimes using knife, 4.8% of victims are killed. Therefore, the provision of prehospital care by an emergency medical technician is crucial.

Keywords: Biomechanical phenomena; Stab wounds; Crime victims; Police

INTRODUCTION

There has recently been a surge in stabbing rampages in Korea, making knife crime a significant public health concern. To address this issue and lessen its impact, it is crucial to understand the biomechanics of penetrating knife injuries. The aim of this paper was to review the biomechanics of knife injuries, including those that occur during stabbing rampages.

STABBING FORCES OF KNIVES

The penetration force of a knife is primarily influenced by the characteristics of its tip, including the sharpness of the apex area, the angle, and the geometry of the wedges behind it. Conversely, the sharpness of the blade appears to play a less significant role in the knife's penetrability [1].

In the literature, it is noted that an unrestrained stabbing force

exerted by a man using his dominant hand generates a mean peak force of approximately 150 N when applied to pork thigh [2]. In a separate experiment that utilized a model of knife stab attacks, the 95th percentile values for axial force and energy were found to be 1,885 N and 69 J, respectively [3].

Recently, a series of stabbing tests were conducted using 12 different weapons, including various types of knives, a pair of scissors, a fork, several screwdrivers, a rasp, a corkscrew, and a utility knife blade [1]. The maximal force (F_{max}) observed during these tests varied significantly. For the various knives, F_{max} ranged from 159.80 to 212.07 N (average), 30.56 to 30.58 N (moderately sharp), and 168.99 to 185.48 N (extremely sharp). The pair of scissors demonstrated a F_{max} between 171.39 and 190.43 N, while the fork had a F_{max} of 233.6 N. The screwdrivers showed a wider range of F_{max} values, from 370.31 to 562.65 N. The utility knife, when used to stab pork loin, had a F_{max} between 44.14 and 56.62 N. It was found that skin penetration could be easily achieved using standard knives. The force required to penetrate skin with a pair of scissors was found to be comparable to that of knives. However, a greater force was required when stabbing with screwdrivers than with knives. The greatest force during a stabbing is exerted at the point of penetration, after which the depth of the wound is not indicative of the strength of the stabbing (Table 1) [1,4].

Among soft tissues, the skin requires the greatest force for penetration. Penetrating bone necessitates a significantly larger force; for instance, a minimum force of 906 to 1,196 N is required to penetrate a rib with a knife (Table 1) [1,4].

STABBING VELOCITY AND TIME OF KNIFE ATTACKS

The mean velocity of a stabbing has been reported to range between 5 and 10 m/sec: 5.01–5.63 m/sec [5], 9.2–9.6 m/sec [3], and 6.6–12.3 m/sec [6] (Table 2). When law enforcement officers (LEOs) are confronted with a knife attack, the field manual emphasizes the importance of swift reaction. It is crucial for them to protect themselves by creating barriers between themselves and the attacker, engage in hand-to-knife combat if necessary, and then gain control of the assailant. These steps are critical for ensuring knife safety [7].

In a recent experiment [8], 20 active-duty LEOs performed various knife motions (Table 2). The time taken to complete each motion was as follows: thrust, 0.61 ± 0.15 seconds; overhead, 0.68 ± 0.14 seconds; figure-eight, 1.07 ± 0.21 seconds; and reverse, 0.62 ± 0.11 seconds. Among these, the figure-eight motion was the slowest, while the thrust motion was the fastest. Notably, the figure-eight motion was significantly slower than the other three motions.

Given the findings that knife movements occurred in 0.62 to 1.07 seconds, it is advisable to maintain a minimum distance of more than an arm's length from an individual visibly carrying a knife. In training for knife defense, particularly in preparation for close-quarter knife attacks, this timing should be kept in mind.

STAB-RESISTANT BODY ARMOR

In a study [9], computed tomography scans were used to measure the shortest distance from the skin to the vital organs. It was found that no organ would be compromised with a knife penetration depth of 5 mm beneath body armor. However, at a depth of 20 mm, 41% of pleurae, 61% of livers, 64% of femoral arteries, 25% of spleens, and 6% of hearts would be compromised.

Currently, materials such as Kevlar (DuPont) and polyethylene are utilized in the construction of armor designed to guard against knife attacks. Additional materials, including ceramic and steel, can also offer a degree of protection. Level II body armor is designed to be lightweight and still very protective. The panels protect from 9 mm submachine guns, 44 Magnums, and even 9

Table 1. Reported stabbing forces of knives

Variable	Value (range)
Maximal force (N) [1]	
Screwdriver	370.31–565.65
Fork	233.66
Pair of scissors	171.39–190.43
Knife	
Extremely sharp	168.99–185.48
Average	159.80–212.07
Moderately sharp	30.56–30.58
Utility knife	44.14–56.62
Minimum force required to penetrate a rib [4]	
Transverse	Approximately 11 J or exceeding 906 N
Longitudinal	Between 11–16 J or exceeding 1,196 N

Table 2. Reported stabbing velocity and time of knife attacks

Variable	Value
Mean velocity of a stabbing (m/sec) [3,5,6]	5–10
Time taken to complete each motion (sec) [8]	
Thrust	0.61±0.15
Reverse	0.62±0.11
Overhead	0.68±0.14
Figure-eight	1.07±0.21

Values are presented as range or mean±standard deviation.

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mm handguns. The body armor is made of multiple layers of Kevlar. The Kevlar provides a very lightweight protection option that can be worn in many different types of carriers. The level III armors are made of hard material. The hard body armor that is used to make the level III body armor can be used on the outside of the softer options to provide maximum protection [10].

Level III armor is significantly more robust than level II, capable of shielding the wearer from multiple rounds fired from a handgun or submachine gun. Level II armor also provides protection against bullets and is primarily tested against the 357 Magnum bullet.

SISW VS. ASW, FATAL VS. NONFATAL WRIST CUTTING

Studies have compared the severity and injury patterns between self-inflicted stab wounds (SISWs) and assault wounds (ASWs). SISWs exhibited a higher proportion of wounds to the neck (44% vs. 11%, P < 0.01) and abdomen (34% vs. 26%, P = 0.02). Overall, injuries from ASWs presented a higher Injury Severity Score, but more procedures were performed on SISWs (46% vs. 34%, P < 0.01). Patients with SISWs experienced longer hospital stays and incurred higher hospital charges, despite having a lower overall injury severity [11].

A study in Korea [12] was conducted to compare the demographic and wound characteristics of nonsuicidal self-injury and suicidal self-wrist cutting injuries. The nonsuicidal self-injury group was found to be younger (33.9 years vs. 40.9 years, P < 0.01), predominantly female, and less compliant with psychiatric treatment compared to the suicide attempt group. When compared to the suicide attempt group, a smaller percentage of nonsuicidal self-injury patients had a history of psychiatric issues (26.1% vs. 45.7%, P < 0.01). A higher percentage of nonsuicidal self-injury patients declined psychiatric counseling (30.4% vs. 9.9%, P < 0.01) and follow-up appointments at the psychiatric outpatient department (8.0% vs. 17.3%, P < 0.01). Interestingly, there were no significant differences in wound characteristics between the two groups.

A study in Edinburgh [13] compared fatal knife injuries (20 individuals) with nonfatal ones (100 individuals). The risk of death seems to primarily hinge on the severity of the injuries sustained, with other factors such as alcohol consumption and the presence of a bystander capable and willing to summon emergency medical assistance playing a lesser role. The potential to save lives through enhanced hospital treatment did not appear to be significant.

CRIME OF VIOLENCE USING LETHAL WEAPON IN KOREA

Percent of usage of lethal weapon is increasing (2019, 14.1%; 2020, 14.5%; 2021, 16.0%) in Korea. In 2021, number of crime of violence was 232,018. Among them, 37,017 (16.0%) were crime of violence using lethal weapon [14].

Among the 209,289 crimes of violence occurred in 2022, 39,807 (19.0%) had weapons and the remaining 169,982 (81.0%) did not. The most frequently used weapon was knives (n = 7,424, 18.6%) followed by glass bottles (n = 3,680, 9.2%), tools (n = 3,655, 9.2%), stones (n = 1,546, 3.9%), clubs (n = 1,058, 2.7%), axes or sickles (n = 419, 1.1%), and ropes (n = 79, 0.2%).

Among the 681 murders occurred in 2022, 533 (78.3%) had weapons and remaining 148 (21.7%) did not. The most frequently used weapon were knives (n = 355, 66.6%) followed by tools (n = 48, 9.0%), clubs (n = 14, 2.6%), ropes (n = 14, 2.6%), axes or sickles (n = 12, 2.3%), and glass bottles (n = 10, 1.9 %) [15]. In 2022, among the 7,424 crimes using knife, 533 victims (4.8%) were killed.

FLORA IN KNIFE WOUNDS

Gram-positive bacteria were found to be predominant in wounds caused by butcher's knives, whereas wounds inflicted by other sharp objects were primarily colonized by gram-negative flora. Both groups exhibited similarly low concentrations of colonizing bacteria [16]. For knife cuts, appropriate antibiotics should be administered.

CONCLUSIONS

The penetration force is primarily influenced by the sharpness of the tip, rather than the sharpness of the blade. The force required for stabbing varies depending on the weapon used. While skin penetration can be readily achieved with standard knives, screwdrivers necessitate a greater force [1]. Prior to examining the victim in the trauma bay, it is advisable to gather information about the weapon used and the mechanism of injury.

The mean velocity of a stabbing motion has been reported to range from 5 to 10 m/sec, with knife motions occurring between 0.62 and 1.07 seconds [8]. This speed appears to surpass the defensive capabilities of unarmed, ordinarily trained LEOs. Therefore, it is advisable to maintain a minimum distance of more than an arm's length from an individual visibly armed with a knife (Fig. 1).

Fig. 1. The need to maintain a distance of more than an arm's reach. Illustration by Hye Won Hu.

Wound characteristics are not different between nonsuicidal self-injury and suicidal self-wrist cutting injuries [12]. Consequently, trauma surgeons cannot determine a patient's suicidal intent based solely on the characteristics of the wound. In stabbing incidents, the risk of mortality primarily hinges on the severity of the injuries incurred. Secondary factors, such as alcohol consumption and the presence of a bystander who is both able and willing to call for emergency medical assistance, also play a role.

In Korea, percent of usage of lethal weapon is increasing. In violence as well as murders, the most frequently used weapon is knife. In the crimes using knife, 4.8% of victims are killed. Therefore, the provision of prehospital care by an emergency medical technician is crucial.

ARTICLE INFORMATION

Author contributions

Conceptualization: CYP; Data curation: CYP; Funding acquisition: KH; Methodology: KH; Project administration: KH; Visualization: KH; Writing–original draft: KH; Writing–review & editing: CYP. All authors read and approved the final manuscript.

Conflicts of interest

Kun Hwang and Chan Yong Park are Editorial Board members of the *Journal of Trauma and Injury*, but were not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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Data availability

Data sharing is not applicable as no new data were created or analyzed in this study.

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