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A comparison of penetration and damage caused by different types of arrowheads on loose and tight fit clothing

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ABSTRACT

Bows and arrows are used more for recreation, sport and hunting in the Western world and tend not to be as popular a weapon as firearms or knives. Yet there are still injuries and fatalities caused by these low-velocity weapons due to their availability to the public and that a licence is not required to own them. This study aimed to highlight the penetration capabilities of aluminium arrows into soft tissue and bones in the presence of clothing. Further from that, how the type and fit of clothing as well as arrowhead type contribute to penetration capacity. In this study ballistic gelatine blocks (non-clothed and loose fit or tight fit clothed) were shot using a 24 lb weight draw recurve bow and aluminium arrows accompanied by four different arrowheads (bullet, judo, blunt and broadhead).

The penetration capability of aluminium arrows was examined, and the depth of penetration was found to be dependent on the type of arrowhead used as well as by the type and fit or lack thereof of the clothing covering the block. Loose fit clothing reduced penetration with half of the samples, reducing penetration capacity by percentages between 0% and 98.33%, at a range of 10 m. While the remaining half of the samples covered with tight clothing led to reductions in penetration of between 14.06% and 94.12%.

The damage to the clothing and the gelatine (puncturing, cutting and tearing) was affected by the shape of the arrowhead, with the least damaged caused by the blunt arrowheads and the most by the broadhead arrows. Clothing fibres were also at times found within the projectile tract within the gelatine showing potential for subsequent infection of an individual with an arrow wound.

Ribs, femur bones and spinal columns encased in some of the gelatine blocks all showed varying levels of damage, with the most and obvious damage being exhibited by the ribs and spinal column.

The information gleaned from the damage to clothing, gelatine blocks and bones could potentially be useful for forensic investigators, for example, when a body has been discovered with no weapons or gunshot residue present.

1. Introduction

A penetration injury is generally a result of sudden and forceful pressure in a small area, causing the tissues to be stretched or crushed by a projectile, such as a bullet, knife or, in the case of this study, an arrow [1]. It is estimated that archery has been used as a means of hunting and protection since the late Palaeolithic period, however interest in archery as a means of protection declined by the late 1700s later being revived, but for sport rather than protection [2]. Now in the 21st century; firearms have become increasingly popular as the weapon of choice, in warfare and law enforcement as well as crime. As a result, archery is used in the modern world for sport and recreation but is no longer used primarily for hunting and warfare with the exception of indigenous groups, such as Australian Aborigines [3]. However, it is not unheard of for a bow and arrow to be used as a weapon in place of a firearm or knife either to injure oneself or another. Cina et al. [4] describe a case of suicide, where a 17-year-old man used a compound bow held in his hands and drawn by his left foot to shoot a broadhead arrow into his chest. While Erikson et al. [5] describe a case of murder, here a foreman was found dead at his place of work with three arrows in his chest. In this case, the man had been shot by a co-worker who decided to kill someone after watching videos containing murders and purchased arrows specifically to kill the first person to enter the building after him. More recently in India Devchand and Singh [6] describe a case of a non-fatal arrow shooting following an argument between two brothers resulting in one of them being shot in the chest. Despite the fact that firearms are taking over as a weapon used in criminal activities, projectile trauma is readily observed, therefore investigators may

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Fig. 1. Left to right: bullet, blunt, judo and broadhead arrowheads used during the project.

come across a crime where a bow and arrow has been used be they cases of suicide, murder, assault or accidental as described by Paučić-Kiriňcić et al. [7]. This case involved two children (aged 9 and 17) who were playing outside with a toy bow and arrow when the arrow broke and a part struck the younger boy in his left eye. Though the boy survived this injury he lost his left eye and was left with brain damage causing weakness down the right-hand side of his body.

Although arrows can be purchased with pre-set arrowheads, many arrows are designed in such a way that the arrowheads can be interchanged. These arrowheads include but are not limited to, broadhead, judo, blunts and bullet [Fig. 1]. Broadheads are used in bow-hunting and consist of two or more blades radiating from the body of the shaft beneath a conical tip. The blades are designed to cut and tear the tissue and organs of the animal hunted [8]. The judo is designed with four spring-action arms that open out during flight; then catch onto grass or tree stumps preventing the arrow from being lost during target practice. The blunt is designed so that the tip is flat and is used mainly for field practice and stump shooting, but can also be used in bowhunting to stun smaller prey. Bullet points are mainly used for target shooting and their tip looks like that of a bullet typically fired from a firearm [9].

Arrows can cause damage to a human by puncturing, stabbing, tearing, cutting or a combination of these mechanisms depending on the arrowhead used. In the Handbook of Forensic Medicine [10], it is stated that the wounding potential of an arrow is primarily dependent on the shape of the arrowhead. For example, puncture wounds being caused by pointed or rounded tips and cuts caused by a sharp tip being forced into the body. It also states that the penetration mechanism of soft tissues uses a combination of cutting and stabbing – resulting in a deep penetration of tissues. This penetrative arrow trauma is also dependent on the draw weight of the bow, the distance the arrow is shot from and the type of tissue encountered [11]. For example, considering Newton's 2nd Law of Motion, a bow with a 20 lb draw weight will supply an arrow with less acceleration than a 24 lb. bow resulting in a lesser penetrative force applied at impact thus potentially causing less penetrative damage than that of the 24 lb bow shot over the same distance. Also, the area of injury and the type of tissue encountered are of great importance as it is usually proportional to the severity of the injury. For example, a thoracic arrow injury may result in the damage to major blood vessels or the heart (which could potentially result in death) whereas an injury to the arm can lead to a treatable bone fracture [12].

Arrows will certainly come into contact with soft tissues and are likely come into contact with bone; the damage caused will be dependent on the type of bone impacted. The arrow will impact tightly in thick bones, such as the femur, essentially penetrating deep enough into the bone to become embedded making extraction of the arrows difficult. However, with flat bones such as ribs or scapula, the arrows may perforate or fracture the bones [9]. Though skin is the most resistant of the body's soft tissues once penetrated less force is needed to penetrate further into the body [13]. Therefore once the skin is overcome the internal organs, especially those in the abdominal region, are easily incised and damaged.

Although most arrow injuries are survivable, they can potentially lead to death, such as a case reported by Hain [14] where an arrow travelled through the right bicep of the individual and entering the right side of their chest, causing rapidly fatal injuries. In some instances, death is not directly caused by the arrow injury but from a subsequent infection, such as blood loss, septicaemia, pneumonia or hypotension [12].

When arrow wounds are encountered by investigators in crime scenes, depending on the arrowhead used, the injury may be misinterpreted as a potential stab wound or gunshot wound. Randall and Newby [15] carried out a wound ballistic study observing that field tipped arrow wounds have a high resemblance to gunshot wounds both morphological and the reddish-brown abrasion rings of burned skin, surrounding the entrance wound. Therefore, in cases where no gunshot residue is detected or bullet fragments recovered, field-tip arrows could be considered as a potential murder weapon. In these types of situations, the individual will most likely be clothed; therefore ballistics studies have been carried out using ballistics ordnance gelatine covered with clothing to determine the impact of the clothing. Vennemann et al. [16] conducted an investigation into how textile fibres can be distributed along the path of a bullet into the human body. They used soft-tissue simulants including gelatine and the belly region of slaughtered pigs covered in a layer of textile material and shot at from a distance of 2 m. The study demonstrated that textile fibres from the entrance and exit areas were transferred into the bullet tract in both an anterograde and retrograde fashion – however, the distribution pattern was determined by the bullet path and the extension of the temporary cavity.

Fabric damage can occur in many different ways depending on the weapons used, such as tearing where the pulling force on the fabric causing the threads to stretch and/or break, or cutting where the fibres are forcefully severed. According to Robertson and Grieve [17], puncture damage to clothing is produced by pointed instruments without cutting edges and penetration is dependent on the shape of the tip and the force applied. Several studies have been carried out with regards to penetration capacity in firearms, air weapons and even bladed weapons. The Wightman et al. [18] study found that clothing that was in contact with the gelatine provided a reduced penetration capacity of various types of air rifle pellets, however, a greater relative standard deviation was found when the clothing was loosely wrapped around the gelatine. In the same study, it was also noted that any damage caused to clothing was dependent on the pellet shape, with the pointed pellets causing the least damage and the domed pellets causing the most damage. They also noted that the type of clothing affected the penetration capacity with jeans providing the most protection from the pellets and the T-shirt providing the least. Cuts caused by knives were examined by Johnson [19] who found that the tip of the blade engaged with the fabric, pushing into or between a yarn eventually causing the yarn to fail, resulting in cutting or tearing. The penetration capability of the blade was influenced by several factors, including blade thickness and tip radius and/or sharpness. Finding that the blunter the tip, the more difficult penetration was, resulting in more fabric distortion and frayed yarns rather than cut yarns.

This study investigated the impact and penetration of aluminium arrows, in the presence of clothing, into ballistic gelatine, to simulate soft-tissue. Four different arrowheads were used: broadhead, judo, blunt and bullet, with two clothing types tested, jeans and T-shirts. Both of the clothing types were either being loosely draped over or tightly wrapped around the gelatine in a way that a human may wear the clothing and therefore allowing to determine whether the fit of clothing contributes to penetration capacity. Bones were also added to some of the blocks to determine the impact on bones and injury caused by broadhead arrows.

It was hypothesised that loose fit clothing would provide greater resistance to arrow penetration as it would absorb energy thus reducing