

Less Lethal Weapons for Law Enforcement: A Performance-Based Analysis^{1, 2}

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Introduction

The terms *less-than-lethal*, *less lethal*, and *non-lethal* are frequently and inappropriately used interchangeably. Almost anything can become lethal if used improperly or if circumstances are extremely unlucky; weapons that are considered to be of less-than-lethal force only decrease the odds of deadly injury. The court in *Graham v. Conner* (1986) addresses the use of less lethal force in the “objective reasonableness standard,” where questions regarding excessive use of force are to be judged from the perspective of a reasonable officer coping with a tense, fast-evolving situation. This revised standard alleviates some of the “Monday morning quarterbacking” that would otherwise result and respects that officers possess sound judgment skills.

The public, raised on science fiction like *Star Trek*, expects phaser-like weapons that can incapacitate without causing permanent harm or death (Heal, 1999). This phenomena has created what Surette (1998) termed a *weapons cult* within the entertainment media, “with weapons made increasingly more technical and sophisticated but less realistic” (p. 43). The entertainment industry tends to display deadly force in black and white; the evil doer misses or inflicts minor wounds while heroes are incredibly accurate and kill painlessly and from great distances.

Less lethal weapons in the entertainment arena can be viewed through a similar lens. The recipient is usually rendered unconscious from a single application and recovers almost immediately. This creates a massive discrepancy between reality and the portrayal of less lethal weapons in popular media. In reality, they are as their name reflects: less than lethal. While they have the potential to cause death or serious injury, these weapons are considerably less harmful than the projectiles fired from firearms.

At the core of this current review is the premise that law enforcement officers use the right tool for the right job. That is, in any given scenario, an officer is conditioned to react appropriately and to use the techniques acquired during training and the tools issued by the agency. Clearly, the most socially desirable outcome of these conflicts between law enforcement and the public is one in which the disturbance is quelled and no one is injured.

This paper addresses the various less lethal technologies available to law enforcement, and it provides technical data and analysis of weapon performance

and testing outcomes. Where prior research on police use of force has attempted to shed light on the specific circumstances and situations where force is used, this current study intends to provide the reader with information about the weapons systems that may be beneficial in determining the strengths and weaknesses of each system. The paper is organized to first provide an overview of each weapon system tested, then an overview of the most current testing methodologies and results.

Weapons and Equipment Research

In spring 2004, at Florida Gulf Coast University, the Weapons and Equipment Research Institute was created through a grant from the Bureau of Justice Assistance to test and evaluate less lethal weapons. Since that time, additional projects funded through the National Institute of Justice and Florida Gulf Coast University have allowed the comprehensive review of equipment currently available in the law enforcement marketplace. A series of research trials and experiments were conducted to evaluate the accuracy and performance of the TASER, chemical agents, 12-gauge beanbag munitions, FN303, and PepperBall. Ballistic accuracy testing of the weapons was conducted on an outdoor range and utilized a laser rangefinder to verify distance accuracy. Further, weapons were fired from a commercial firearms resting platform to reduce the effect of individual shooter accuracy. The point of aim was identified by a neon orange paste-on target, which contrasted with the rest of the target. Accuracy was measured as the difference between point of aim and point of impact.

As data was collected, it was entered into *SPSS 11.0* for statistical analysis. A *t*-test of each shooter's individual scores indicated that no significant differences existed, allowing the data to be aggregated. Although originally collected for unpublished technical reports that have been disseminated to the law enforcement community, this data has not been previously published in a peer-reviewed forum. The authors of this manuscript have provided the data from each evaluation, conducted over a three-year period, in abbreviated form.

Weapon Systems

Conducted Energy Weapons

Obviously the "hot" topic in discussions about police use of force today, these devices are the closest technology available today to the fictional "phaser on stun." Conducted Energy Weapons (CEWs) are less-than-lethal weapons designed to deploy an electric current through the body of the target to temporarily cause loss of muscle control. Throughout the history of law enforcement in America there have been many devices that may fit this description such as "cattle prods" or "stun guns." Devices such as these allow electricity to be deployed on contact with the skin or within close distances. Over the past several years, the technology for these devices has become more user-friendly than the original, more rustic devices, allowing the user to apply the device from greater distances, with more accurate application. As a result, the deployment and use of these devices has grown exponentially in policing.

TASER International is the company best known today for producing CEWs. Their product has become so well-known that the name "TASER" has become synonymous with "CEW," much like the name "band-aid" is to a plastic

bandage. The TASER (so named after the inventors' science fiction interests as the "Thomas A. Swift's Electric Rifle") is currently being tested or is used in over 7,200 law enforcement, military, and correctional agencies throughout the United States and abroad (U.S. Government Accountability Office, 2005). TASER International continues to advertise their device as among the safest and most effective less-than-lethal force choices available, claiming that TASER use reduces officer shootings and suspect injuries (TASER International Inc. [TASER], 2004).

Early studies indicated this weapon's effectiveness ranged from 50 to 85% (Donnelly, 2001) when deployed. In a pilot study examining a random selection of 400 deployments, the TASER was found to be immediately successful in 68% of the cases (Mesloh, Henych, Houglund, & Thompson, 2005); this rate is refuted in a second study by White and Ready (2007) who found that 68.6% of suspects continued to resist after a TASER deployment. Some literature shows that since the TASER's deployment in 2000, the use of deadly force by officers and the number of officers injured during arrest confrontations has been dramatically reduced (Hopkins & Beary, 2003; Mesloh & Houglund, 2004).

Powered by high-pressure air, the darts fired from the TASER are tethered on wire that can reach from 15 feet (civilian model) to 31 feet (law enforcement model). However, in order for the TASER to be effective in gaining compliance, both probes must strike the target, preferably with a spread of about one foot between the probes. Despite the length of the wire, recent best practices guides by the Police Executive Research Forum (PERF) (2004) suggest restricting targeting to less than 15 feet. This is consistent with other studies, which indicate that beyond 15 feet, accurate placement of probes is difficult (Mesloh et al., 2005). Reviewing a random sample of 50 cases where the TASER was found to be ineffective, 38% could be explained by the fact that both probes missed the target (Mesloh et al., 2005).

A recent study conducted by Mesloh and Thompson (2005) on the spread rates of the TASER probes found that probes separated at a rate of approximately two inches for every foot of distance between the TASER and the suspect. Again in support of the PERF guidelines, this study found that the maximum feasible distance was 15 feet as any distance beyond that, even though the probes are capable of traveling further, results in too great of a spread between probes. At 15 feet, the probe spread is approximately 30 inches, which is pushing the envelope on the dimensions of a person's torso. Consequently, ineffective TASER deployments are more related to distance factors than the suspect's ability to fight through the electricity (Mesloh & Thompson, 2005). Other failures were explained by a suspect wearing baggy clothing or by a number of weapon malfunctions.

TASER Reliability and Accuracy Testing

The researchers conducted research on the TASER, the most commonly used CEW in the police market today, by test firing 200 (N = 200) cartridges. The TASER device was fired at a Numb John™ target from a fixed platform at distances of 5-, 10-, 15-, and 20-foot intervals. At each predetermined distance, 50 shots were fired at the target. The impact points of the probes were analyzed, and their distance from the point of aim was recorded. With the exception of two cartridges that did not deploy properly, all of the TASER cartridges behaved as advertised and as expected. The probe spread (1.77 in/ft) was predictable and the weapon was

consistent in its operation. The following details the TASER's probe spread at the various respective distance intervals.

Table 1. TASER Probe Spread

Distance	TASER Projected	TASER Actual
5 feet	0.85 in	9.42 in
10 feet	17.70 in	18.45 in
15 feet	26.55 in	25.93 in
20 feet	35.40 in	34.92 in

Chemical Agents

In their simplest form, chemical agents are a type of irritant that attacks the eyes, nose, and skin, which disables or significantly impairs the recipient's ability to function (Lumb & Friday, 1997). The use of chemical agents can be found throughout history. In China during 178 AD, a peasant revolt was quelled through the use of lime dust, a severe irritant, which was used to create an early form of tear gas (Mayor, 2003). Quicklime projectiles, creating a suffocating cloud that blinded the enemy, continued in the Byzantine war in 941 AD (Partington, 1999). Noxious smoke from poisonous plants was also propelled from a smoke machine to repel attempts of the Roman invaders who were tunneling under the city of Ambracia's walls (Mayor, 2003). Leonardo da Vinci later created a similar poison smoke machine in the late 1400s (Partington, 1999). Ancient Chinese writings contain literally hundreds of recipes for creating chemical agents that were able to disable or even kill enemy troops. The earliest form of pepper spray appears in the 16th and 17th centuries from the Caribbean and Brazilian Indians who burned hot pepper seeds to create an irritant cloud that was used against Spanish conquistadors (Mayor, 2003).

Prior to the development of oleoresin capsicum (OC), agencies relied on tear gas grenades, which dispersed the chemicals o-chlorobenzal malononitrile and 2-chloroacetophenone (abbreviated as "CS/CN" gas), but problems existed due to the delivery system's propensity to start fires (Miller, n.d.). Most agencies have transitioned from the use of CS/CN gas to pepper spray, an irritant spray that can disable a suspect. Most of these products are made with OC oil from selected hot peppers.

The strength of pepper spray is related to the heat rating and quality of the source peppers. The Scoville Heat Rating, created in 1912, assigns a value to each pepper. Pure capsaicin has a rating of 15 million, while typical police pepper spray has a rating of 5.3 million. For comparison purposes, the bell pepper has a rating of zero, the jalapeno pepper a rating of 5,000, and the habanera pepper a rating of 300,000. Recovery time after exposure is based on the percentage of capsaicin in the formulation. A 15% solution may require one and a half to two hours to recover, while 2% may require only 15 to 30 minutes. The added benefit of lower solutions is that the solution much more easily penetrates mucus membranes and skin pores and thus acts faster.

When compared with impact weapons as a less lethal force alternative, OC spray was found to be at least as effective in stopping subject resistance, with the added benefit that the majority of suspects sprayed did not require medical treatment

(Rogers & Johnson, 2000). OC was on the cutting-edge of less-than-lethal weapon systems in the 1990s as it incapacitated suspects by “causing the eyes to tear and swell shut, mucus to drain profusely from the nasal passages, bronchial passages to constrict, and [make] breathing become more labored” (Morabito & Doerner, 1997, p. 681). Prior literature suggests that many law enforcement agencies believed pepper spray to be the “magic bullet” to reduce officer and suspect injury as well as citizen complaints (Kaminski, Edwards, & Johnson, 1998; Rogers & Johnson, 2000). However, a review of the literature indicates some issues regarding the use of pepper spray as it relates to the eyes and corneas of affected persons. The alcohol carrier and the force at which the liquid is expelled have been known to cause damage to suspects.

Ocular injuries are almost unheard of in the extant literature regarding pepper spray. In one study by Zollman, Bragg, and Harrison (2000), 47 subjects were sprayed with OC to evaluate the effect on the human cornea. Visual acuity was unaffected, and corneal sensitivity had returned to normal within a week (which is consistent with the findings of Stopford, 1996). In itself, corneal sensitivity is not an injury, but it can place the individual at greater risk of a future trauma as the blink reflex is affected. Repeated exposures to OC spray was found to damage the sensory nerves that initiate protective reflexes (Cohen, 1997).

Additional studies examined corneal epithelial defects after exposure to chemical agents. Das, Chohan, Snibson, and Taylor (2007) found that this injury healed after two weeks of treatment, and visual acuity returned in six weeks. Epstein and Majmudar (2000) suggested that “prompt ocular irrigation might be very important to avoid potentially permanent injury” (p. 1712). In another study, Brown, Takeuchi, and Challoner (1997) suggest that corneal abrasions and defects might be explained by suspects rubbing their eyes, and may not be the result of the chemical agent itself. This theory was supported by Zollman et al. (2000) in their response to Epstein and Majmudar’s study, where they stated that “[t]he handcuffs used may have kept the patient from rubbing her eyes and inadvertently inducing a larger epithelial defect” (p. 1713).

Issues regarding cross-contamination of back-up officers and a growing number of reports that suspects were able to fight through the burning pain of the spray illustrate a few of the weaknesses of chemical agents. Additionally, a limited range of less than eight feet for most models places the officer well within the reactionary gap, and the number of uses per canister can vary depending upon the duration of each spray. Firing at a suspect at greater distances consumes a greater portion of the canister as it takes longer for the spray to reach the target, which is necessary for the officer to adjust his or her aim.

In a recent study, researchers found that the use of chemical agents was rapidly declining at the Orange County (FL) Sheriff’s Office as officers instead chose to deploy the TASER (Hougland, Mesloh, & Henych, 2005). While the American Civil Liberties Union has stated that at least 30 fatalities have occurred as a result of TASER use (Mesloh et al., 2005), studies have shown similar deaths by OC deployments. Bowling, Gaines, and Petty (2003) examined 63 deaths after OC deployments and found that the overwhelming majority were due to the arrestee’s drug use, disease, positional asphyxiation, or a combination of these factors, similar to recent claims about TASERS (see also Granfield, Onnen, & Petty, 1994).

Chemical Agent Deployment Testing

Research has focused upon the difference between dominant (strong) hand and reactionary (weak) hand deployment of chemical agents. A public perception has emerged that an officer should be able to deploy a chemical agent against a subject armed with an edged weapon while still having the ability to use deadly force by also having a gun drawn. In this scenario, the officer would have his or her service weapon drawn in the dominant hand, while deploying the chemical agent with the reactionary hand. Basic field trials indicated that accuracy was not only negatively impacted, but the risk of "blow-back" contamination from the chemical agent was significant.

Eighteen subjects (N = 18) were trained in the use of chemical agents and then asked to fire five bursts of pepper spray from both their dominant and reactionary hands. In this study, accuracy performance dropped by approximately 50%. The dominant hand accuracy (M = 4.39, SD = 1.04) was significantly better than the reactionary hand (M = 2.22, SD = 1.52). Further, 67% of the dominant hand deployments struck the target in comparison with only 11% for the reactionary hand. Consequently, officers attempting to fire chemical agents from their reactionary hand and without additional training are much less likely to strike their intended target.

Less Lethal Munitions

Less lethal impact munitions fire a projectile that will provide a transfer of kinetic energy that will impact and potentially incapacitate a suspect. Different launchers and projectiles are on the market, with many projectiles existing to fit the specific need of individual scenarios. Currently, all 12-gauge munitions must be fired from a pump action shotgun in order for the ammunition to cycle correctly, and the 37/40-mm launchers are available in single shot and six chamber designs (Hubbs & Klinger, 2004; Kenny, Heal, & Grossman, 2001).

There are a wide range of launched munitions of a variety of compositions, each with different accuracies and a maximum effective range. The 12-gauge launcher is most frequently utilized as most agencies already possess a ready supply and the user requires minimal additional training. For these, beanbag type projectiles tend to be the ammunition of choice. However, there are many other options available that include chemical agents; rubber buckshot; and solid, rubber-finned projectiles. The only caveat with using a shotgun launching system is that it must be manually operated (e.g., pump-action) as the reduced powder loads in the beanbag prohibit a semi-automatic shotgun from cycling properly.

For those agencies that utilize the 37- or 40-mm grenade launcher, even a greater number of munitions choices become available. These munitions can be direct-fired or skip-fired depending upon the specific need or desired effect. A degree of accuracy is lost with some of these munitions, but it is made up by the ability to saturate an area with projectiles. As the accuracy decreases, the chance of hitting bystanders increases. Launched munitions include rubber buckshot, sand-filled beanbags, and foam or rubber batons. A key factor with these munitions is that at close range they have the ability to inflict severe injury or death, but as the range increases, the rate of injury drops off sharply (Hubbs & Klinger, 2004).

Other significant injury predictors are the hardness of the material being fired (e.g., wood versus rubber) and the mass of the projectile. Both harder projectiles and those with more mass resulted in higher injury rates in a study conducted by DuBay and Bir (2000). Kenny et al. (2001) found that engagement methods influenced the effectiveness of the munitions—for example, baton rounds were more effective when skip-fired, while beanbags and airfoils performed better when fired directly at the subject.

While there are certainly other types of less lethal weapons, both mainstream and not so mainstream, the types of weapons described in this manuscript are most often found in the “tool belt” of a local, county, or state police agency officer. Weapon choice certainly has an effect on subject injuries, and not every less-than-lethal weapon is appropriate for all circumstances. Each weapon has different potential to result in injury, in addition to appropriate officer-suspect distances for use.

12-Gauge Beanbag Testing

A research design was created to measure the accuracy of the 12-gauge beanbag less-lethal munitions. For testing purposes, the researchers utilized the Remington 870 pump-action shotgun with an 18-inch barrel as it is considered the workhorse weapon for most law enforcement agencies. A total of 100 ($N = 100$) rounds were used in the initial stages of testing. The drop rates of the projectiles are acceptable up to 40 feet; however, beyond 40 feet, the accuracy of the rounds decreases significantly and their flight becomes erratic, increasing the risk to bystanders. A linear regression of distance and projectile drop revealed 3.78 inches of drop for every ten feet of distance ($r = 0.90$), with a spread of 5.5 inches. When confirming the results of this study with a second weapon (FN tactical police shotgun), however, it became clear that the accuracy of the beanbag projectiles was affected greatly by the launching system.

A second study utilizing the modular Remington 870 with three different barrel lengths (14 inch, 16 inch, and 18 inch) was constructed to determine the feasibility of their use in tactical deployments. Clearly, shorter barrels create smaller weapons that are easier to maneuver in close quarter environments. Accuracy was measured as the difference between point of aim (POA) and point of impact (POI) in order to assess the deviation of the projectiles. A total of 480 ($N = 480$) beanbag rounds were fired in this project to create a predictive model of the projectile trajectory for each barrel length.

The 10-inch barrel performed well, only displaying a slight increase in deviation between the distances 40 to 50 feet (+ 2.7-inch spread increase). Ultimately, the accuracy of the 10-inch barrel leveled off at the distance of 60 feet (10.625-inch spread). The 14-inch barrel displayed excellent accuracy until 60 feet, where the data indicates a substantial increase in deviation. The 18-inch barrel displayed excellent accuracy throughout testing, showing little deviation.

Additional analysis indicates that the projectile drop for each of the different length barrels is minimal at 50 feet, but a noticeable change in accuracy for each barrel's projectiles occurs at 60 feet. Consequently, the longest barrel performs better at greater distances. Surprisingly, the 14-inch barrel which had performed the best up to 50 feet had a substantial increase in deviation and reduction in performance at 60 feet.

Utilizing data from Table 2, a reliable predictive model can be structured for law enforcement application. The 10-, 14-, and 18-inch barrels can be used in close

proximity from 10 to 50 feet without loss of accuracy. This is of major significance as the use of shotguns during tactical room clearing is often limited by the size of the weapon. Frequently, officers are not able to carry these large weapons as it is difficult to navigate around close quarters. These findings suggest that even the smallest length barrel tested would perform well if the targets are not engaged beyond 50 feet. For the 10-inch barrel, it is not uncommon for entry teams to carry these as secondary weapons specifically for door breaching. This same technique could be used to carry the 10-inch as a less lethal option for when deadly force is not an option.

Table 2: Beanbag Round Performance, Projectile Drop

Distance to Target	Barrel Length	Mean	N	SD
10 feet	10 inch	0.5000	20	0.51299
	14 inch	0.4250	20	0.49404
	18 inch	0.0000	20	0.00000
	Total	0.3083	60	0.46113
20 feet	10 inch	0.2500	20	0.41359
	14 inch	0.8000	20	0.41039
	18 inch	0.0250	20	0.11180
	Total	0.3583	60	0.47023
30 feet	10 inch	-0.3500	20	2.57570
	14 inch	1.1750	20	0.96348
	18 inch	0.2250	20	0.49934
	Total	0.3500	60	1.70816
40 feet	10 inch	3.9000	20	2.27457
	14 inch	0.2500	20	0.83509
	18 inch	0.9250	20	1.32064
	Total	1.6917	60	2.23814
50 feet	10 inch	6.2000	20	2.22663
	14 inch	0.1000	20	1.50962
	18 inch	2.7250	20	4.96163
	Total	3.0083	60	4.07503
60 feet	10 inch	10.0250	20	2.10560
	14 inch	3.4250	20	2.89862
	18 inch	4.8800	20	2.65565
	Total	6.1100	60	3.81535
70 feet	10 inch	9.9250	20	2.73513
	14 inch	11.9500	20	2.47035
	18 inch	6.1050	20	2.55250
	Total	9.3267	60	3.52775
80 feet	10 inch	9.5375	20	5.14080
	14 inch	14.4300	20	4.57086
	18 inch	7.6550	20	3.86604
	Total	10.5408	60	5.32388
Total	10 inch	4.9984	160	4.97725
	14 inch	4.0694	160	5.83076
	18 inch	2.8175	160	3.83449
	Total	3.9618	480	5.01889

Impact Weapons

All impact weapons can find their basis in the club, the least technologically advanced type of weapon system in use by police, other than hand-to-hand combat. Historically, it was probably the first human weapon as a piece of wood was used to bludgeon its victim somewhere around 10,000 BC (Meltzer, 1996). The police impact weapon's primary function is to strike specific target areas of resisting offenders to cause dysfunction or pain and gain control or compliance (Mesloh et al., 2005). Billy clubs, truncheons, and straight wood batons have been utilized for hundreds of years by police officers around the world. While most hard handheld objects are capable of being used in this fashion, law enforcement has tended to utilize impact weapons specifically designed for ease of carry and the most effective use of physics. The faster the baton is swung and the heavier its weight, the greater its kinetic energy potential will be. However, heavy objects tend to move slower than light ones. The velocity of the end of the baton is multiplied in proportion to the increase in its distance from the pivoting body parts such as the pelvis, shoulder, elbow, and wrist (Crosby, 2002). Similar to a golf swing, proper form and execution play a major part in the creation and transfer of kinetic energy from the baton to the suspect. In order to be effective, the baton must also be swung to strike with a large force and with a fast delivery (Gervais, Baudin, Cruikshank, & Dahlstedt, 1998).

As technology has advanced, this weapon type has evolved to meet specific needs. The blackjack and sap, which are made of a spring-loaded lead weight encased within a leather handle, were quickly adopted by police officers as they allowed both plainclothes and uniformed officers to conceal an effective impact weapon. The side-handled baton offered the ability to add mechanical advantage and leverage to take-down techniques. The expandable baton allowed the officer the ability to carry a full-size baton on their duty belt in a low-profile manner (Johnson, 1996). The newest generation batons have now added an enlarged plastic tip, which creates a larger amount of kinetic energy in the strike (Mesloh et al., 2005).

Highly visible nightsticks and side-handled batons carried on the police officer's belt seem to have gone out of style and have been replaced with smaller, collapsible straight batons which have a more positive public perception and are easier to carry (Johnson, 1996). These new batons have also increased their effectiveness. Gervais et al. (1997) found that a 26-inch ASP expandable baton created more impact pressure than a traditional full-size baton. The ASP collapsible baton is much lighter and easier to carry than the traditional baton. In addition to the velocity created by swinging the weapon, additional factors, such as an officer stepping into the swing or a suspect moving towards the officer, also generate increased velocity. This type of impact weapon is the most commonly used in law enforcement today due to the fact that it can be carried on the belt.

Smaller and lower profile impact weapons such as the yawara and kubaton, which can be carried in a pocket, are frequently marketed as self-defense keychains and can be used to deliver pinpoint force to nerve centers (Monadnock Lifetime Products, 1968). In addition to impact strikes, the yawara has the ability to supplement close quarter take-down techniques through joint locks and pressure point compressions. The family of yawara-type products can be found in a variety of designs, which may contain finger grooves to reduce slipping or sharp inserts

to discourage the suspect from attempting to wrestle it from an officer's hand (Monadnock Life Products, 1968). The inherent weakness of the yawara weapons system is the fact that the officer and suspect are within extremely close proximity, increasing the potential that the encounter will escalate into grappling or ground fighting. Despite the fact that many officers have martial arts training, almost one-third feel that defensive tactics training is insufficient and ineffective against combative suspects (Kaminski & Martin, 2000).

While an agency may take a "one size fits all" approach in issuing impact weapons, it is truly a very individual science to determine the baton that best fits the specific user by generating the greatest amount of energy. The primary approved target areas are large muscle masses, and the ability of an officer to hit these targets is directly related to their success in an encounter (Gervais et al., 1997). However, saps and blackjacks, due to their size and potential reach, were commonly used to strike the head. Serious injuries are a likely result if the head is targeted for an impact weapon strike (Cox, Buchholz, & Wolf, 1987).

A study of impact weapon kinetic energy is scheduled for spring 2008. This project will evaluate the amount of force generated across a range of straight, side-handled, and expandable batons of varying length, weight, and composition. Further, it will examine the smallest impact weapons, such as the yawara or kubaton, since their size is likely to produce significant amounts of energy density.

Compressed Air Weapons

The need to project a chemical agent at greater distances has led to the development of compressed air weapons. While similar weapon systems are produced for consumer use for the sport of paintball, police compressed air weapons fire projectiles loaded with chemical agents. An adapter allows air bottles or reservoirs on this type of weapon to be quickly refilled from a standard SCUBA tank, and a full tank will provide 20 to 30 refills for most air bottles. Compressed air is significantly cheaper than using CO² and allows refilling of the SCUBA tank at a local dive shop for less than five dollars. Two less lethal compressed air launchers are examined here: the "FN303" and "PepperBall."

FN303 Less Lethal Launcher

The FN303 is built by FNH USA and utilizes fin-stabilized plastic projectiles to deliver paint-marking rounds and OC rounds on target. Since FNH USA also manufactures the M16 family of weapons for the U.S. military, many of the components on the weapon should be familiar to anyone who has handled an M16 or AR15. The pistol grip is identical to the M16, and the iron sights are from the M16A2. In addition, the launcher has a picatinny rail for mounting optics, and the upper receiver of the launcher can be mounted beneath the M16 in place of the M203 grenade launcher. Independent tests by Bertomen (2005) found the FN303 to be accurate to over 50 yards, shooting four-inch steel plates; however, the weapon's sights are set at 30 yards. The primary drawback is the launcher's 15-round magazine capacity.

The ammunition for the FN303 is a proprietary fin-stabilized .68 caliber round that has a muzzle velocity of 280 to 300 feet per second. The weapon should not

be used at distances closer than three feet; at distances up to 12 feet an operator should only target the thighs as strikes to the center mass may cause serious injury or death (FN Herstal, 2002). Beyond 12 feet, the torso is the POA. The manufacturer’s literature states that the air reservoir will allow 110 firings before the air tank must be refilled; however, FN303 representatives place the number of shots at approximately 79 before a refill is necessary (pers. comm.).

FN303 Testing

A research design was created to measure the accuracy of the FN303 less lethal launcher. Ten projectiles were fired at each distance, which were in ten-yard increments ($n = 60$). Accuracy was measured as the difference between POA and POI. At distances of 30 yards and closer, the difference between POA and POI is less than four inches, indicating that there is very little drop and the weapon can be consistently and accurately fired on target. Beyond 30 yards, a substantial deteriorating effect is noted. However, while the projectiles were falling below the POA, they remained in a relatively tight pattern.

A linear regression was conducted to measure the strength of the relationship between distance from the target and the drop of the projectile from the POA. As shown below, an almost perfect relationship exists. However, when the data was plotted, it became clear that at distances closer than 30 yards there was a very small amount of drop, which impacted the perceived strength of the model ($r = 0.909$).

While the correlation between distance and spread from POA is 0.901 for the entire dataset, there is obviously more activity beyond 30 yards. Consequently, a second regression model was used to examine these greater distances, excluding distances closer than 30 yards. The strength of the model increases as shown in the $r = 0.96$. Past 30 yards, an actual relationship between distance and projectile drop emerges compared to the extreme flat shooting at distances under 30 yards (Mesloh & Thompson, 2006a).

Table 3. FN303 Mean Scores by Distance

Distance to Target	Mean	N	SD
10 yards	1.9500	10	1.03950
20 yards	3.0250	10	1.03950
30 yards	3.9500	10	2.72285
40 yards	16.7000	10	3.35162
50 yards	27.5250	10	3.56380
60 yards	46.0750	10	7.20922

The overall goal of this project was to create a predictive model that would allow an FN303 user to determine where the projectile would strike given a known distance. The unstandardized coefficient of the regression model indicates that at distances of 40 yards and greater, the drop of the projectile will be 13.72 inches for every ten yards of distance beyond 40 yards. Testers were able to effectively correct their fire based on observations of projectile impact and were capable of achieving tight groupings at distances well over 60 yards during additional test sessions.

PepperBall

The PepperBall family of launchers is designed around Tippmann paintball markers and operates in the same fashion. The stated muzzle velocity for the PepperBall launcher is 300 to 380 feet per second, and the projectiles have 8- to 12-foot pounds of kinetic energy. The standard air system for the PepperBall utilizes a 13 cubic-inch bottle, and when charged to 3,000 psi, it can launch 130 projectiles. A larger 47 cubic-inch bottle exists that can launch 450 projectiles. A 68 cubic-inch bottle exists and is capable of launching 850 projectiles. The hopper on the PepperBall launcher can hold 180 projectiles. According to the PepperBall system instructor-training manual, "PepperBall operators must understand that thirty feet is the farthest distance to target individual suspects. The lightness of the projectiles makes the ballistic accuracy fall off dramatically past thirty feet" (Bedard & Cole, 2003, p.24); however, the manufacturer claims that it is safe to engage a target at point blank range with the PepperBall system.

The PepperBall launchers fire a .68 projectile modeled off of a traditional paintball round; the primary payloads are PAVA, glass shattering rounds, paint marking rounds, inert training rounds, and an anti-freeze round for use in colder climates. PAVA is the abbreviation for pelargonyl vanillylamide, and is a synthetic form of OC. The PepperBall manual (Bedard & Cole, 2003) states that subject compliance is brought on by a combination of the three factors of shock (associated with being struck with an object), pain (resulting from impact), and the chemical irritant in the payload. The PepperBall launcher's best attribute is in the incapacitation effect of their PAVA (a synthetic OC) rounds. Mesloh and Thompson (2006b) found the effects of PAVA to be "immediate and incapacitating" and that they created a burning sensation to any exposed skin surface.

PepperBall Testing

A research design was created to test the accuracy of the Pepperball launcher. Utilizing the same methodology used in the 12-gauge beanbag and the FN303 studies, 15 projectiles were fired from each position ($n = 90$). Beginning at five feet and increasing in 5-foot increments, the study continued to 30 feet, which was the maximum recommended distance for a direct fire target.

Up to 20 feet, deviation from POA to POI is approximately five inches or less. The relationship between dispersion (difference in POA to POI) is moderately correlated. A linear regression indicates that dispersion increases 1.5 inches for every five feet of distance. However, at greater distances, the projectiles seem much less accurate and tend to "float" with little discernible pattern, unlike the traditional "drop" seen in other weapons' projectiles.

As the dispersion results indicate that the projectiles travel in no consistent, discernible pattern, a second test was conducted to determine the spread of the projectiles—that is, the distance between the two projectiles furthest away from each other in each string. First, the projectile spreads for each shooter were plotted in a table correlated to the shooter's distance from the target. As shown in Table 3, at the furthest distance of 30 feet, the average spread was less than 15 inches. The relationship between PepperBall projectile spread and distance is highly correlated ($r = 0.94$). A simple linear regression indicates that projectile spread increases an

average of 2.68 inches for every five feet of distance between target and shooter ($t = 11.07$, $df = 17$).

Table 4. PepperBall Distance Dispersion Table

Distance	Mean	N
5 feet	0.8833	15
10 feet	2.2833	15
15 feet	4.3333	15
20 feet	5.0833	15
25 feet	6.2833	15
30 feet	9.0500	15
Total	4.6528	90

While the PepperBall system is capable of producing a high rate of fire and delivering an extremely effective chemical agent payload, its accuracy and reliability hinder the effectiveness of the weapon. Unlike other compressed air weapons where the projectiles travel in a predictable pattern and POA can be corrected to achieve proper aim, this does not seem possible with the PepperBall S200 launcher. While 21 feet is considered a critical distance to law enforcement, and the PepperBall can strike a target at that range, it is frequently necessary to engage targets at much longer distances. At any distance beyond ten yards, the PepperBall launcher is unable to accurately strike a point target and can only be used for area saturation with PAVA. Therefore, successful PepperBall deployments will most likely occur within enclosed areas or in tandem with an additional less lethal launcher capable of long-range engagements.

Conclusion

Through the procurement of different less lethal weapon systems, an agency provides each officer with a range of options to overcome suspect resistance. Each agency controls and guides its personnel through its policies and the placement of the individual's less lethal weapon within the force continuum. Despite this guidance, a great deal of discretion is left to the officer on the street. While an officer may have a fraction of a second to make a choice, it is clear that that decision may be scrutinized for years to come.

After deciding which weapons to carry on their person, either for a particular incident or consistently, each officer is burdened with deciding upon his or her response to the suspect's resistance. In some cases, this decision is limited by the actions of the suspect who may flee or fight, and the officer must respond accordingly. However, in some cases, the suspect may resist, and the officer has a broad range of discretion in determining his or her response.

While less-than-lethal technology continues to evolve in modern policing, there is no perfect weapon currently in existence that will immediately stop unlawful resistance yet will cause absolutely no harm to the receiver. Certainly, there are many different manufacturing companies each vying for the potential to create a new, better, less-than-lethal weapon that could be utilized in the field as such a perfect weapon. Use of force continuums, once relied upon as the best way to train

officers on the correct application of force, are slowly being removed from agency policies across the country as a result of fear of litigation when an officer works outside of the printed standards but still within reasonable guidelines.

Endnotes

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References

- Bedard, R., & Cole, D. (2003). *Pepperball instructor training manual*. Jacksonville, FL: RRB Systems International.
- Bertomen, L. (2005). Launching less lethal rounds. *Law Enforcement Technology*, 32(2), 112-119.
- Bowling, M., Gaines, M., & Petty, C. (2003). *Effectiveness and safety of pepper spray*. Washington, DC: U.S. Department of Justice, National Institute of Justice.
- Brown, L., Takeuchi, D., & Challoner, K. (2000). Corneal abrasions associated with pepper spray exposure. *American Journal of Emergency Medicine*, 18, 271-272.
- Cohen, M. (1997). The human health effects of pepper spray: A review of the literature and commentary. *Journal of Correctional Health Care*, 4(1), 73-88.
- Cox, T., Buchholz, D., & Wolf, D. (1987). Blunt force head trauma from police impact weapons: Some skeletal and neuropsychological considerations. *Journal of Police Science and Administration*, 15(1), 56-62.
- Crosby, A. (2002). *Throwing fire*. Cambridge, UK: Cambridge University Press.
- Das, S., Chohan, A., Snibson, G., & Taylor, H. (2007). Capsicum spray injury of the eye. *International Ophthalmology*, 26, 171-173.
- Donnelly, T. (2001) *Less lethal technologies: Initial prioritization and evaluation*. London: Police Scientific Development Branch, Home Office Policing and Crime Reduction Group.
- DuBay, D. K., & Bir, C. A. (2000). *Assessment of kinetic energy as a predictor of injury risk of less lethal munitions* (Technical Report). Springfield, VA: U.S. Department of Commerce, National Technical Information Service.

- Epstein, R., & Majmudar, P. (2001). Pepper spray in the eye. *Ophthalmology*, 108, 1712.
- FN Herstal. (2002). *FN303 less lethal launcher instructor/armorer training manual*. Herstal, Belgium: Author.
- Gervais, P., Baudin, P., Cruikshank, B., & Dahlstedt, D. L. (1997). Comparative analysis between police batons. *Forensic Science International*, 91, 7-17.
- Graham v. Connor*, 490 U.S. 386 (1986).
- Granfield, J., Onnen, J., & Petty, C. S. (1994). *Pepper spray and in-custody deaths* (Executive Brief). Alexandria, VA: International Association of Chiefs of Police.
- Heal, S. (1999). *Nonlethal options: Failures and futures*. Paper presented at the Urban Operations Conference, Washington, DC.
- Hopkins, P., & Beary, K. (2003). *TASER use and officer/suspect injuries*. Orlando, FL: Orange County Sheriff's Office.
- Houglund, S., Mesloh, C., & Henych, M. (2005). Use of force, civil litigation, and the taser: One agency's experience. *The FBI Law Enforcement Bulletin*, 74(3), 24-30.
- Hubbs, K., & Klinger, D. (2004). *Impact munitions: Data base of use and effects*. Washington, DC: U.S. Department of Justice, National Institute of Justice.
- Johnson, J. (1990). *A.S.P. tactical baton assessment technical memorandum*. Vancouver: Canadian Police Research Centre.
- Johnson, J. (1996). Police impact weapons: An expanding future. *Gazette: A Royal Canadian Police Publication*, 58(1), 12-15.
- Kaminski, R., Edwards, S., & Johnson, J. (1998). The deterrent effects of oleoresin capsicum on assaults against police: Testing the velcro-effect hypothesis. *Police Quarterly*, 1(2), 1-20.
- Kaminski, R., & Martin, J. (2000). Analysis of police office satisfaction with defense and control tactics. *Policing*, 23(2), 132-153.
- Kenny, J. M., Heal, S., & Grossman, M. (2001). *The attribute based evaluation (ABE) of less-than-lethal, extended-range, impact munitions*. State College: Applied Research Laboratory, Penn State University.
- Lumb, R. C., & Friday, P. C. (1997). Impact of pepper spray availability on police officer use-of-force decisions. *Policing: An International Journal of Police Strategy and Management*, 20(1), 136.
- Mayor, A. (2003). *Greek fire, poison arrows, and scorpion bombs: Biological and chemical warfare in the ancient world*. New York: Overlook Press.

- Meltzer, M. (1996). *Weapons and warfare: From the stone age to the space age*. New York: HarperCollins Publishers.
- Mesloh, C., Henych, M., Hougland, S., & Thompson, F. (2005). TASER and less lethal weapons: An exploratory analysis. *Law Enforcement Executive Forum*, 5(5), 67-79.
- Mesloh, C., & Hougland, S. (2004, December). *TASER deployments and injuries: Analysis of current and emerging trends*. Presented as a workshop at the International S.W.A.T. Round-Up, Orlando, Florida.
- Mesloh, C., & Thompson, L. F. (2005). *TASER probe spread technical report*. Fort Myers: Florida Gulf Coast University, Weapons and Equipment Research Institute.
- Mesloh, C., & Thompson, L. F. (2006a). Evaluation of the FN 303 less lethal projectile. *Journal of Testing and Evaluation*, 34(6), 1-3.
- Mesloh, C., & Thompson, L. F. (2006b). *Pepperball ballistic accuracy technical report*. Fort Myers: Florida Gulf Coast University, Weapons and Equipment Research Institute.
- Miller, S. (n.d.). *O.C./Powder—The future of riot control*. Presentation at the meeting of the National Defense Industrial Association, "Lethal Defense III."
- Monadnock Lifetime Products, Inc. (1968). *Clubs: Clubs in self defense and mob control*. Fitzwilliam, NH: Author.
- Morabito, E. V., & Doerner, W. G. (1997). Police use of less-than-lethal force: Oleoresin capsicum (OC) spray. *Policing: An International Journal of Police Strategy and Management*, 20(4), 680-697.
- Partington, J. (1999). *A history of Greek fire and gunpowder*. London: Johns Hopkins Press.
- Police Executive Research Forum (PERF). (2004). *PERF conducted energy device policy and training guidelines for consideration*. Washington DC: PERF Center on Force and Accountability.
- Rogers, T., & Johnson, S. (2000). Less than lethal: An analysis of the impact of oleoresin capsicum. *International Journal of Police Science and Management*, 3(1), 55-67.
- Stopford, W. (1996). *Statement concerning pathophysiology of capsaicin and risks associated with oleoresin capsicum exposure*. Durham: NC: Division of Occupational and Environmental Medicine, Duke University Medical Center.
- Surette, R. (1998). *Media, crime and criminal justice* (2nd ed.). New York: Wadsworth.
- TASER International, Inc. (2004). *Facts about taser*. Retrieved June 8, 2005, from www.taser.com/facts.

U.S. Government Accountability Office. (2005). *Taser weapons: Use of tasers by selected law enforcement agencies*. (Publication No. GAO-05-464). Washington, DC: U.S. Government Printing Office.

White, M., & Ready, J. (2007). TASER as a less lethal force alternative. *Justice Quarterly*, 10(2), 170-191.

Zollman, T., Bragg, R., & Harrison, D. (2000). Clinical effects of oleoresin capsicum (pepper spray) on the human cornea and conjunctiva. *Ophthalmology*, 107, 2186-2189.

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