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TECHNICAL NOTE

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Modular 12 Gauge Shotgun Beanbag Accuracy Study

ABSTRACT: As with all less-than-lethal weapons, the user is frequently left to estimate the optimum effective range of their weapon. Factory literature often exaggerates effective ranges and other features, which can be misleading and potentially dangerous in the deployment of the weapon. Using a modular combat shotgun and its three barrels, this study examined the accuracy of 12 gauge bean bag rounds in relation to barrel length. Accuracy was measured by point of impact and projectile spread in relation to the deviation from the point of aim. Our observations for the selected shotgun and bean bag rounds show that, at distances under 12 m (40 ft), the projectile was both accurate and reliable. At greater distances, both accuracy and reliability decreased. The 25 cm (10 in), 36 cm (14 in), and 46 cm (18 in) barrels can be used in close proximity from 3 m (10 ft)—15 m (50 ft) without a considerable loss of accuracy. This is of major significance as the use of shotguns during tactical room clearing is often limited by the length of barrel. These findings suggest that even the shortest length barrel tested would perform well if the targets are not engaged beyond 15 m (50 ft). Beyond this distance, the 46 cm (18 in) barrel is the most accurate performer and will reliably engage targets out to the maximum tested range of 24 m (80 ft).

KEYWORDS: ballistic, accuracy, less-than-lethal, shotgun, bean bag

Introduction

Frequently law enforcement officers are faced with armed or resisting offenders that refuse to comply with their lawful orders. Consequently, a degree of force on the part of law enforcement is necessary to bring the situation to an expedient and controlled resolution. Unfortunately, to date, there is no single less-than-lethal weapon that fits every circumstance. While some electromuscular disruption devices appears to offer the maximum in suspect compliance and a reduction in both suspect and officer injuries [1], they are limited by the range that they can reach a suspect. Accordingly, in order to use electromuscular disruption devices, it is necessary for officers to place themselves within a 6 m (21 ft) range of the suspect, creating additional risks and tactical concerns.

However, kinetic weapons such as bean bag projectiles perform quite well at distances over 6 m (21 ft) but suffer the limitation of transferring too much kinetic energy at close range. As a result of this excessive energy transfer, a number of deaths and serious injuries have been documented from these weapons at various close ranges [2–4]. It is a dangerous balancing act in determining which weapon has sufficient energy to incapacitate, while at the same time not killing the suspect. Equally problematic is creating a weapon system that is sufficiently portable for patrol officers to bring to use in the field.

Less-than-lethal impact munitions fire a projectile that will provide a transfer of kinetic energy that will impact and potentially incapacitate a suspect. There are a variety of different launchers and projectiles currently on the market that are designed to fit the specific need of the individual scenario. The 12 gauge launcher is most frequently utilized, as most agencies already possess the weapon. Currently all less-than-lethal 12 gauge munitions must be fired from a pump action shotgun in order for the ammunition to cycle correctly [5,6].

Using bean bag rounds, Mesloh and Thompson [7,8] tested the drop rates of the projectiles at distances of up to 12 m (40 ft); the drop was an acceptable 9.6 cm (3.8 in) with a projectile spread of only 14 cm (5.5 in). At distances greater than 12 m (40 ft), the accuracy of the rounds decreases significantly and their flight becomes erratic, striking objects to the right, left, or below the target, increasing the risk to innocent bystanders (Fig. 1).

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 [6]. Other significant

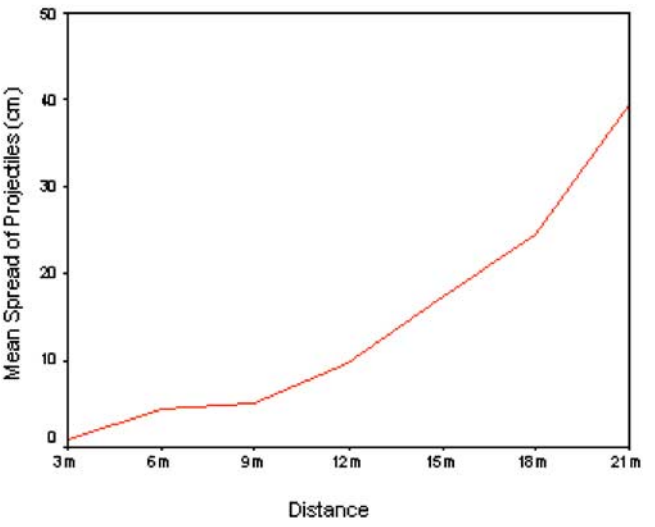

FIG. 1—*Rate of projectile drop by distance at point of aim.*

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FIG. 2—*Modular Combat Shotgun with interchangeable barrels, stocks and bean bag rounds.*

FIG. 3—*Tester firing from a fixed platform position. The bench rest is used to reduce human error while aiming.*

injury predictors are the hardness of the material being fired, e.g., wood versus rubber, and mass of the projectile. The harder projectiles and those with more mass resulted in higher injury rates in a study conducted by DuBay and Bir [8].

Methodology

This project evaluated a commonly used modular combat shotgun, with one type of bean bag round and three different barrel lengths. The weapon was purchased as part of a Bureau of Justice Assistance Grant in 2005 for the Weapons and Equipment Research Institute and was used to conduct a number of different field experiments. The shotgun used in this study is the "workhorse" shotgun for most police departments [9] and is the standard shotgun utilized to train recruits at the Federal Law Enforcement Training Center. The weapon is simple to operate and one can easily change the length of the barrel in less than a minute by simply unscrewing the end cap and exchanging a barrel. Currently, under federal law, all commercially sold shotguns must have a barrel length equal to or in excess of 46 cm (18 in). To use a shorter barrel, the owner must register the weapon with the National Firearms Act (NFA) Branch of the Bureau of Alcohol Tobacco Firearms and Explosives (ATFE).

The shotgun used in our study can be found in various configurations and barrel lengths in law enforcement inventories across the country. Prior to the 1997 North Hollywood bank robbery shootout, these shotguns were the predominate long gun found in police vehicles. Today, many agencies are also issuing center-fire rifles, mostly variants of the M16/AR15. The average patrol officer will have a 46 cm (18 in) barrel on the shotgun that is kept in the police vehicle, whereas tactical teams (i.e., SWAT) will often carry a shotgun with a short 25 cm (10 in) barrel to breach doors and locks. Nevertheless, the operation of the weapon remains the same, only the barrel length changes (Fig. 2).

The goals of this project are to quantify the accuracy of each barrel [25 cm (10 in), 26 cm (14 in), and 46 cm (18 in)] with a standard projectile at a variety of ranges.

It is commonly accepted amongst expert shooters that, typically, a longer barrel will result in increased accuracy. This increased accuracy of longer versus shorter barrels can be attributed to the energy that is imparted to the projectile (in this case a bean bag) during gas expansion being less susceptible to variations in bean bag rounds and propellant burn characteristics. In addition to this effect, when the weapon is fired, the longer distance between the front and rear sights allows shooters to make more precise shots.

In effect, shotguns act much like Civil War muskets as the majority of their barrels do not have any rifling. Modern rifling (lands and grooves cut into the barrel) spin a bullet to increase accuracy, much like a perfect football throw. Traditional shotgun barrels do not have this feature and are smoothbore, which makes them inherently less accurate than their rifled counterparts.

Ultimately, the researchers wanted to determine if the smallest configuration of the shotgun tested is sufficiently accurate for tactical deployments of less-than-lethal munitions. A linear regression of the preliminary pilot study found that projectiles could be accurately aimed and fired up to 12 m (40 ft) ($r=.90$; $df=62$) when using the standard 46 cm (18 in) barrel. However, there is no published research that addresses the effect of the barrel length on the accuracy and reliability of the less-than-lethal projectiles in flight.

This study utilized 12 gauge bean bag projectiles that were fired from a fixed platform, using each of the different barrels (Figs. 2 and 3). Accuracy was measured through the spread of all the fired projectiles at a given distance and the difference between the point of aim (POA) and the point of impact (POI) for each projectile. Accuracy is defined as the difference between the standardized point of aim and point of impact in order to assess the deviation of the projectiles. Two shooters, utilizing each of the three barrels per distance, were used to reduce the effect of an individual's skill on outcome measures and confirmed by t-tests. Linear regression was used to examine the relationship between distance and accuracy for each barrel. In order to best identify the distance at which each barrel's accuracy began to diminish, bean bags were fired at 1.5 m (5 ft) increments, from 1.5–24 m (5–80 ft) from the target. Measurements and photographs of the targets were taken after each shooter fired ten rounds at each distance. The point of aim was standardized by utilizing a neon orange paste-on target, which contrasted the rest of the target. This point of aim was not modified for either shooter or distance. A total of 480 bean bag rounds were fired in this project to determine the accuracy for each barrel length.

Findings

A t-test of each shooter's individual results indicated that no significant differences existed between their scores. Consequently, we were able to aggregate the data from both shooters without skewing the results. The results were placed into a statistical software pack-

TABLE 1—*Projectile drop from point of aim by distance and barrel length.*

Distance to target	Barrel length	Mean	N	Std. Deviation
3 meters (10 feet)	25 cm (10 in)	1.27	20	1.30
	36 cm (14 in)	1.08	20	1.25
	46 cm (18 in)	0.00	20	0.00
6 meters (20 feet)	25 cm (10 in)	0.64	20	1.05
	36 cm (14 in)	2.03	20	1.04
	46 cm (18 in)	0.06	20	0.28
	Total	0.91	60	1.19
9 meters (30 feet)	25 cm (10 in)	−0.89	20	6.54
	36 cm (14 in)	2.98	20	2.45
	46 cm (18 in)	0.57	20	1.27
12 meters (40 feet)	25 cm (10 in)	9.90	20	5.78
	36 cm (14 in)	0.64	20	2.12
	46 cm (18 in)	2.35	20	3.35
15 meters (50 feet)	25 cm (10 in)	15.75	20	5.66
	36 cm (14 in)	0.25	20	3.83
	46 cm (18 in)	6.92	20	12.60
18 meters (60 feet)	25 cm (10 in)	25.46	20	5.35
	36 cm (14 in)	8.70	20	7.36
	46 cm (18 in)	12.40	20	6.75
21 meters (70 feet)	25 cm (10 in)	25.21	20	6.95
	36 cm (14 in)	30.35	20	6.27
	46 cm (18 in)	15.51	20	6.48
24 meters (80 feet)	25 cm (10 in)	24.23	20	13.06
	36 cm (14 in)	36.65	20	11.61
	46 cm (18 in)	19.44	20	9.82
Total	25 cm (10 in)	12.70	160	12.64
	36 cm (14 in)	10.34	160	14.81
	46 cm (18 in)	7.16	160	9.74

age (SPSS 11) for quantitative analysis. Average differences between POA and POI were placed in Table 1 shown below.

The 25 cm (10 in) barrel performed well, only displaying a slight increase in deviation between the distances 12–15 m (40–50 ft) (+2.7 in spread increase). Ultimately, the accuracy of the 25 cm (10 in) barrel began to diminish at a distance of 18 m (60 ft) (10.625 in spread). The 36 cm (14 in) barrel displayed excellent accuracy until 18 m (60 ft), where the data indicated a substantial increase in deviation. The 46 cm (18 in) barrel displayed excellent accuracy throughout testing, showing little deviation (Table 1).

Additional analysis indicates that projectile drop for each of the barrels is minimal at 15 m (50 ft), but a noticeable change in accuracy for each barrel's projectiles occurs at 18 m (60 ft). Consequently, the longest barrel performs better at greater distances. Surprisingly, the 36 cm (14 in) barrel which had performed the best up to 15 m (50 ft) has a substantial increase in deviation and reduction in performance at 18 m (60 ft) (Fig. 4).

Unfortunately, the use of linear regression proved to be of little value due to the variance in projectile drop rates. Consequently, it was impossible to create a definitive predictive drop rate for two of the barrels due to only moderate correlations. This was contrary to the authors' pilot study, which identified a much stronger and more predictable relationship between distance and drop rate of bean bag projectiles. As both weapons were manufactured by the same company, fired the same bean bag projectiles, and utilized an identical barrel length (during a portion of the test), it is unclear why the results are not identical.

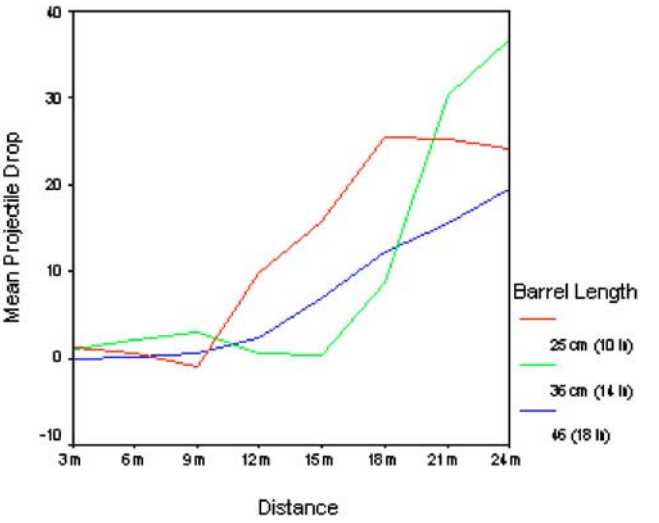

FIG. 4—*Projectile performance by barrel and distance.*

However, for the 36 cm (14 in) barrel, a much stronger correlation between distance and drop rate was observed. While up to 15 m (50 ft), it is possible to accurately deliver the projectiles on target, beyond that distance the projectiles drop rate rapidly increases. As shown below in Table 2, the linear regression indicates a strong relationship (R=0.87) and the unstandardized coefficient of the regression model indicates that at distances beyond 15 m (50 ft) the drop of the projectile will be 13.08 cm (5.15 in) for every 3 meters of distance (10 ft). Consequently, the point of aim must be elevated accordingly to compensate for projectile drop if accuracy is to be maintained at greater distances.

Conclusion

The versatility of the modular combat shotgun provides law enforcement with a less-than-lethal weapon that can be applied in various situations. Less-than-lethal bean bag munitions should not be fired at targets less than 3 m (10 ft) away or serious bodily trauma may occur. Beyond 3 m (10 ft), the officer can use the tested shotgun for breaching doors, subduing large crowds, close quarter combat, and long-range target acquisition.

The different barrels [25 cm (10 in), 36 cm (14 in), and 46 cm (18 in)] can be used in close proximity from 3–15 m (10–50 ft) without a significant loss of accuracy. This is of major significance as the use of shotguns during tactical room clearing is often limited by the length of the barrel. Frequently, officers are not able to carry these large weapons as it is difficult to navigate close-quarter environments. These findings suggest that even the smallest length barrel tested would perform well if the targets are not engaged beyond 15 m (50 ft). Beyond this distance, the 46 cm (18 in) barrel is the most accurate performer and will reliably engage targets out to a maximum range of 24 m (80 ft).

Based upon this study's findings, the 12 gauge bean bag munition has shown to be capable of delivering its payload to greater distances than most tools in the less-than-lethal arsenal. At distances less than 24 m (80 ft), an officer can reliably engage man-sized targets with reasonable accuracy. While the 12 gauge bean bag munitions may not be the most suitable for every scenario, these findings suggest that it is more versatile than many of the other less-than-lethal weapons in the law enforcement inventory.

TABLE 2—*Linear regression of 36 cm barrel beyond 15 meters.*

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.871[a]	0.758	0.755	3.29310

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2653.795	1	2653.795	244.714	0.000
	Residual	845.870	78	10.844		
	Total	3499.665	79			

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	−26.009	2.172		−11.975	0.000
	Distance to target	5.152	0.329	0.871	15.643	0.000

[a]Predictors: (Constant), distance to target.

Although predictive models were not possible for all three barrels tested, a linear regression for the 36 cm (14 in) barrel was able to identify a reliable drop rate coefficient. If greater accuracy is needed for distances exceeding 15 m (50 ft), an operator can adjust the point of aim accordingly to compensate for projectile drop. However, law enforcement end users should be aware of the limitations of this technology and be cautious when attempting to engage targets at greater distances.

Further, as this study has shown, there are substantial differences in the performance between shotguns, even those produced by the same manufacturer. The drop rates of projectiles fired through one weapon may not be identical to those fired through a similar model. Consequently, agencies should validate each weapon's performance prior to attempting an actual field deployment.

References

[1] Mesloh, C., and Hougland, S., 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, December 2004.

[2] de Britio, D., Challoner, K. R., Sehgal, A., and Mallon, W., "The injury pattern of a new law enforcement weapon: The police bean bag," *Ann. Emerg. Med.*, Vol. 38, No. 4, 2001, pp. 383–390.

[3] Nelson, C., and Winston, D., "A New Type of Shotgun Ammunition Produces Unique Wound Characteristics," *J. Forensic Sci.*, Vol. 52, No. 1, 2007, pp. 195–198.

[4] Voiglio, E. J., Frattini, B., Dorrzapf, D. D., Breteau, J., Miras, A., and Caillot, J. L., Ballistic Study of the SAPL GC27 Gun: Is It Really "Nonlethal?" *World J. Surg.*, Vol. 28, 2004, pp. 402–405.

[5] Kenny, J. M., Heal, S., and Grossman, M., "The attribute based evaluation (ABE) of less-than-lethal, extended-range, impact munitions," Applied Research Laboratory, Penn State University, 2001.

[6] Hubbs, K., and Klinger, D., "Impact munitions: Data base of use and effects," U. S. Department of Justice, National Institute of Justice. NCJ 204433, 2004.

[7] Mesloh, C., Wolf, R., Henych, M., and Thompson, F., "Less Lethal Weapons for Law Enforcement: A Performance-Based Analysis," *Law Enforcement Executive Forum 8*, (1), 2008, pp. 133–149.

[8] DuBay, D. K., and Bir, C. A., "Assessment of kinetic energy as a predictor of injury risk of less lethal munitions" (Technical Report). Springfield, VA, Department of Commerce, National Technical Information Service, 2000.

[9] Simpson, L., "Remington's Magnificent Five," Shooting Times, May 2000.