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Effects of Range, Caliber, Barrel Length, and Rifling on Pellet Patterns Produced by Shotshell Ammunition

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ABSTRACT: The effects of range, caliber, barrel length, and rifling on the scatter of shotshell ammunition were investigated. A series of shots was fired from three .22-caliber weapons and two .38-caliber weapons at six ranges varying from 0.3 to 6.1 m (1 to 20 ft). The spread of each shotshell pattern was measured by taking the square root of the area of the smallest rectangle that would just enclose the pellet pattern. Regression analysis was applied to the variation of pattern spread as a function of range. A linear relationship was found to represent adequately the variation of pattern spread with range. Of the handguns tested, the weapons with the shorter barrel lengths produced the larger pellet patterns, and when the barrel lengths were similar, the larger caliber handguns produced the larger pellet patterns. The competing effects of barrel length and muzzle velocity are also discussed.

KEYWORDS: criminalistics, ballistics, wound ballistics

Shotshell ammunition in .22 caliber has been available for use with both handguns and rifles for many years. Recently, .38 special and .44 magnum shotshell ammunition for handguns has also been marketed. These cartridges are commonly referred to as "snake shot" or "rat shot" and are quite effective for close-range extermination of pests.

The wounding effects of these types of rounds on human targets have been described in reports of suicides [*1,2*] and more recently in reports of homicides [*3,4*]. In those cases where the shotshell was the cause of death, the round was fired at fairly close range. The lethality of this type of ammunition diminishes rapidly with increased range. In some of the reported homicide cases [*3,4*] this type of round was fired in conjunction with a single projectile that was the actual cause of death.

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If shotshell ammunition behaves ballistically in a manner similar to shotgun ammunition, there are several variables that may affect the shot patterns produced by shotshell ammunition. Shotgun pellet patterns increase in size as the muzzle-to-target distance increases. The length of the shotgun barrel also affects the pellet pattern [5,6]. Since shotshell ammunition may be fired from a variety of weapons having different barrel lengths, the barrel length of the firing weapon may have a profound effect on the shot pattern produced. The caliber of the rifled firearm used to fire shotshell ammunition may also influence the resulting shot pattern. An additional variable that may influence the shot pattern of shotshell ammunition is the degree of twist of the rifling of the firearm barrel. Because shotguns are smoothbore weapons, there is no basis for predicting the effects of the degree of twist of the rifling on the shotshell pattern.

To explore the effects of range, barrel length, and caliber we fired shotshell ammunition from a variety of rifled firearms at targets placed at six different ranges. Unfortunately, it was impossible to test the effect of different degrees of twist of the rifling because weapons with rifling of widely varying degrees of twist were not available.

Experimental Procedure

Five different weapons were used to fire shotshell ammunition at paper targets:

(1) .22-caliber Smith & Wesson revolver, model 34-1, with a 5.1-cm (2-in.) barrel, right-twist rifling, degree of twist = 37.9 cm (14.9 in.) per complete turn;

(2) .22-caliber Hi-Standard "Double-Nine" revolver with a 14.0-cm (5½-in.) barrel, right-twist rifling, degree of twist = 40.6 cm (16 in.) per complete turn;

(3) .22-caliber Remington Match-Master rifle, model 513-T, with a 61.0-cm (24-in.) barrel, right-twist rifling, degree of twist = 40.6 cm (16 in.) per complete turn;

(4) .38 Special Colt Cobra revolver with a 5.1-cm (2-in.) barrel, left-twist rifling, degree of twist = 35.6 cm (14 in.) per complete turn; and

(5) .357 magnum Smith & Wesson revolver, model 13-1, with a 10.2-cm (4-in.) barrel, right-twist rifling, degree of twist = 47.6 cm (18¾ in.) per complete turn.

The .22-caliber ammunition used was CCI Mini-Mag .22-caliber long rifle shotshells manufactured by Omark Industries. The cartridge case of this type of round is a standard .22 long rifle case; however, instead of a single projectile, this cartridge case is fitted with a plastic capsule containing approximately 165 pellets of No. 12 shot. The .38 Special ammunition used was Speer Lawman Ammunition Shotshell. This cartridge case is fitted with a plastic capsule containing approximately 150 pellets of No. 9 shot.

Three shots were fired with each weapon at each of six ranges: 0.3 (1), 0.8 (2.5), 1.5 (5), 3.0 (10), 4.6 (15), and 6.1 m (20 ft).

The shot spread was measured by calculating the square root of the area $\sqrt{A}$ of the smallest rectangle that just enclosed the entire shot pattern. Heaney and Rowe [7] found that this measurement of the shot spread was a linear function of range for cylinder-bore shotguns. All target perforations, including flyers (single perforations outside the main pattern area in a given target), were included. The mean and standard deviations of the mean were calculated by standard statistical methods [8].

Muzzle velocity was determined using the ECI Model 7893 Chronograph (Electronic Counters, Inc., Englewood, NJ) with two screens placed 0.3 m (1 ft) apart to measure the velocity of five test shots fired from each weapon.

Regression Analysis

Linear regressions were performed on the data obtained from the test-fired pellet patterns. The model used was

$$y = a + bx$$

where x is the range, y is $\sqrt{A}$, a is the intercept, and b is the slope. Since the standard deviations of the ys are variable (Table 1), a weighted least squares method was used [8], with the weighting factor 1/(standard deviation)^2 used for each point. The regression coefficients a and b were calculated by standard methods. In addition, the linear correlation coefficient r was also calculated. The original data, rather than the means and standard deviations in Table 1, were used in these calculations.

Results and Discussion

The spreads of the test-fired shotshell patterns for the .22 and .38 shotshell ammunition are shown in Table 1. In Figs. 1, 2, and 3, $\sqrt{A}$ for both types of shotshell ammunition is plotted as a function of range, with the appropriate error limits indicated. As may be seen, $\sqrt{A}$, over the ranges considered, is adequately represented as a linear function of the range. Table 2 presents the regression coefficients and correlation coefficients for all the test-fired patterns. Since the size of the shotshell patterns should equal the barrel diameter at zero range, these linear relationships fail at very short ranges.

As discussed by Wray et al [9], the confidence interval for range-of-fire estimates may be obtained by the following expression:

$$\hat{x} = \frac{\bar{y}' - a}{b} \pm \frac{t_s}{|b|}\left[\frac{c_0}{m} + \frac{1}{k} + \frac{(\bar{y}' - a - bx)^2}{b^2 \sum_{i=1}^{k} \frac{(x_i - \bar{x})^2}{c_i}}\right]^{1/2} \tag{1}$$

where $\hat{x}_0$ is the estimated range of fire, $\bar{y}'$ is the mean of $\sqrt{A}$s for m pellet patterns fired at the same range, c_0s^2 is the square of the standard deviation of the ys at $\hat{x}_0$, the x_is are the ranges at which k patterns were test-fired to establish the regression line, the c_is are the weighting factors, and $\bar{x}$ is the weighted mean of the x_is. The expressions necessary for the evaluation of Eq 1 were also calculated and are included in Table 2.

For purposes of comparison, the confidence intervals for the estimated range of 3.0 m (10 ft) were calculated. An estimated standard deviation at this range was obtained from a linear regression on the standard deviation as functions of range of fire. Table 3 shows the confidence intervals at 3.0 m (10 ft) for each weapon, calculated at a 99% confidence level. These confi-

TABLE 1—*Spread of shotshell pellet patterns.*

Weapon	Range, ft[a]					
	1	2.5	5	10	15	20
.22-caliber Smith and Wesson revolver	2.3[b] ± 0.2[c]	3.9 ± 0.5	7.1 ± 0.5	12.4 ± 0.5	19.5 ± 1.6	26.9 ± 1.2
.22-caliber Hi-Standard "Double Nine" revolver	1.2 ± 0.2	4.6 ± 0.7	6.5 ± 0.9	9.7 ± 0.2	16.8 ± 1.0	20.7 ± 0.9
.22-caliber Remington Match-Master rifle	1.1 ± 0.2	2.8 ± 0.5	5.7 ± 0.5	11.0 ± 0.7	19.1 ± 2.1	24.0 ± 1.2
.38-caliber Colt Cobra revolver	2.1 ± 0.3	3.8 ± 0.3	7.5 ± 0.3	16.0 ± 1.4	24.7 ± 3.8	33.9 ± 2.4
.357 magnum Smith and Wesson revolver	1.4 ± 0.2	2.5 ± 0.2	5.1 ± 0.2	12.1 ± 0.7	21.0 ± 2.6	25.2 ± 1.0

[a] 1 ft = 0.3 m.
[b] $\sqrt{A}$ in inches. 1 in. = 25.4 mm.
[c] Standard deviation in inches.

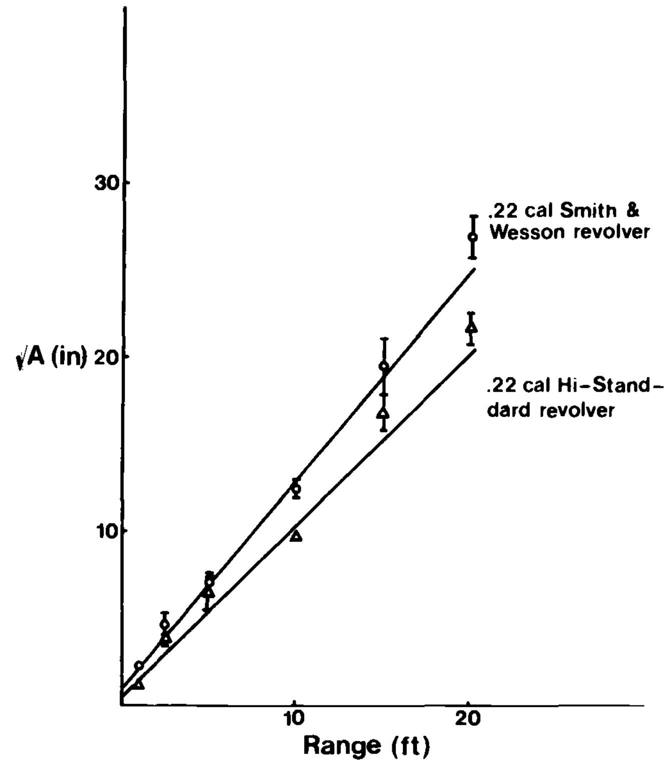

FIG. 1—*Spread of shotshell pellet pattern versus range of fire for .22-caliber handguns firing CCI Mini-Mag .22-caliber long rifle shotshells. Means ± one standard deviation are shown; lines are appropriate regression lines. 1 in. = 25.4 mm and 1 ft = 0.3 m.*

TABLE 2—*Results of weighted linear regression.*

Weapon	Regression Coefficients[a] a, in.	b, in./ft	Linear Correlation Coefficient	s^2	$\bar{x}$, ft	$\frac{1}{b^2 \sum_{i=1}^{k} \frac{(x_i - \bar{x})^2}{c_i}}$, in.^{2}
.22-caliber Smith and Wesson revolver	1.1	1.2	0.996	0.053	1.7	0.0064
.22-caliber Hi-Standard "Double Nine" revolver	0.4	1.0	0.993	0.106	5.8	0.0023
.22-caliber Remington Match Master rifle	−0.1	1.2	0.996	0.055	1.5	0.0088
.38-caliber Colt Cobra revolver	0.0	1.6	0.989	0.25	3.1	0.0039
.357-caliber magnum Smith and Wesson revolver	−0.3	1.2	0.985	0.039	2.9	0.010

[a]Model: $y = a + bx$ when $y = \sqrt{A}$ in inches and x = range in feet. 1 in. = 25.4 mm and 1 ft = 0.3 m.

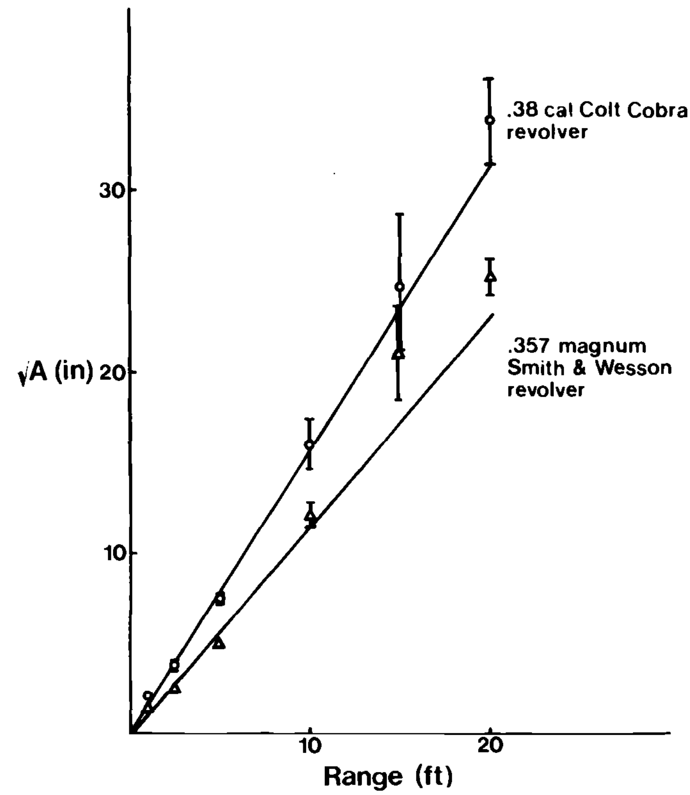

FIG. 2—*Spread of shotshell pellet pattern versus range of fire for .38-caliber handguns firing Speer Lawman Ammunition Shotshell. Means ± one standard deviation are shown; lines are appropriate regression lines. 1 in. = 25.4 mm and 1 ft = 0.3 m.*

TABLE 3—*Confidence intervals for estimated range of fire (range = 3.0 m [10 ft]).*

Weapon	Confidence Interval[a]
.22-caliber Smith and Wesson revolver	0.6 m (2.0 ft)
.22-caliber Hi-Standard "Double Nine" revolver	0.6 m (2.0 ft)
.22-caliber Remington Match Master rifle	0.7 m (2.3 ft)
.38-caliber Colt Cobra revolver	0.9 m (2.9 ft)
.357 magnum Smith and Wesson revolver	0.7 m (2.3 ft)

[a]Calculated for 99% confidence interval and 18 − 2 = 16 degrees of freedom.

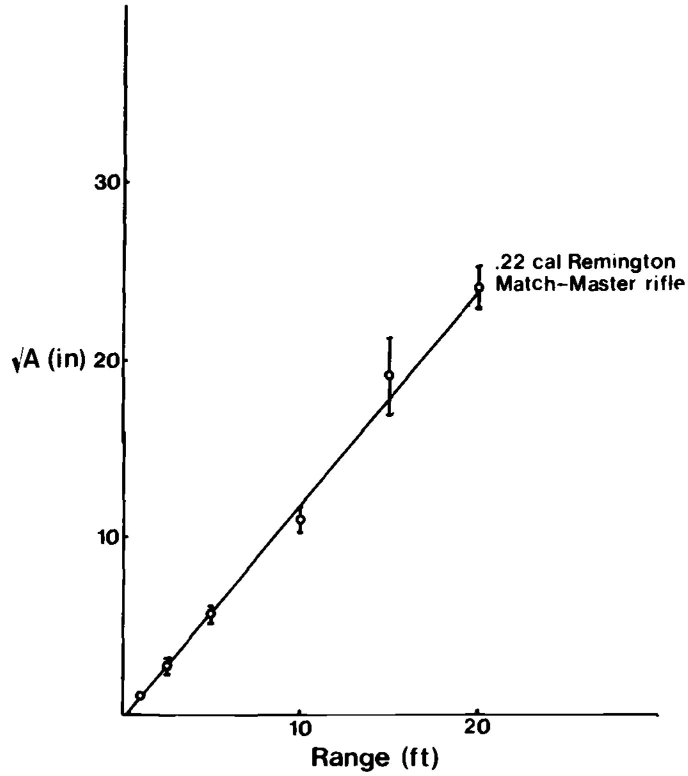

FIG. 3—*Spread of shotshell pellet patterns versus range of fire for .22-caliber rifle firing CCI Mini-Mag .22-caliber long rifle shotshells. Means ± one standard deviation are shown: line is appropriate regression line. 1 in. = 25.4 mm and 1 ft = 0.3 m.*

dence intervals are all less than the confidence interval at 0.9 m (3.0 ft) determined by Heaney and Rowe [7] to be the optimal 95% confidence interval for a cylinder-bore shotgun firing No. 2 shot cartridges.

For the purpose of assessing the effect of caliber, barrel length, and rifling, the data obtained by test firing the four handguns will be compared. The data obtained for the rifle will be discussed later and related to the data obtained for handguns. Table 4 shows the muzzle velocities of the firearms used in these experiments. Using the number of inches per turn of rifling, the rate of rotation of the capsule as it emerges from the muzzle may be calculated as follows:

$$\text{rate of rotation} = \text{muzzle velocity/distance per turn of rifling}$$

The calculated rates of rotation for the firearms used in this study are also given in Table 4. The rates of rotation of the capsules affect the outward velocities of the spreading pellets: the higher the rates of rotation, the higher the outward velocity components of the pellets.

The data for the .22-caliber handguns permit assessment of the effects of barrel length on the spread of the pellets because the muzzle velocities and rates of capsule rotation are very similar for these two weapons. Clearly, decreasing the barrel length causes an increase in the size of the shotshell pattern (Fig. 1). This effect is also seen in a comparison of the .38 and .357 handguns (Fig. 2). Also, note that for comparable barrel lengths, the larger caliber ammunition produced larger pellet patterns. This may, however, be the result of the difference in sizes and numbers of the pellets used in .22- and .38-caliber shotshell ammunition.

TABLE 4—*Muzzle velocities and rates of capsule rotation.*

Weapon	Muzzle Velocity, ft/s	Rate of Capsule Rotation (Calculated), rev/s
.22-caliber Smith and Wesson revolver	1061(21)[a]	854(16)
.22-caliber Hi-Standard "Double Nine" revolver	1130(51)	848(38)
.22-caliber Remington Match-Master rifle	1304(63)	978(47)
.38-caliber Colt Cobra revolver	1368(50)	1173(43)
.357 magnum Smith and Wesson revolver	1297(2)	772(1)

[a]Mean (standard deviation). 1 ft/s = 0.3 m/s.

At first glance, the .22-caliber rifle (Fig. 3) seems to occupy an anomalous position. Its greater barrel length would be expected to produce smaller pellet patterns than either of the .22 caliber handguns. A compensating effect, however, is also present: the rate of rotation of the capsules emerging from the .22-caliber rifle is higher than the rates of rotation for the two handguns. The net effect of the greater barrel length and the higher rate of rotation is a ballistic performance similar to the shorter of the two .22-caliber handguns.

Conclusion

Three .22-caliber weapons and two .38-caliber weapons were used to fire shotshell patterns at ranges varying from 0.3 (1) to 6.1 m (20 ft). Regression analysis was applied to the measurements of the spreads of the pellet patterns. It was found that a linear relationship adequately described the variation of pattern spread with increasing range. It was noted that range-of-fire estimates for shotshell patterns should be more precise than similar estimates for cylinder-bored shotguns. Of the two handguns used in this study, the weapon with the shorter barrel (51-mm [2 in.]) fired the larger shotshell patterns at all ranges. The size of the patterns fired by the .22-caliber rifle used in this study were, however, only slightly smaller than those fired by the .22-caliber revolver with the 51-mm (2-in.) barrel. This was attributed to the higher muzzle velocity of the rifle, which results in the shotshell capsule attaining a high rate of rotation and the pellets attaining a greater outward velocity.

References

[1] DiMaio, V. J. M. and Spitz, W. U., "Injury by Birdshot," *Journal of Forensic Sciences*, Vol. 15, No. 3, July 1979, pp. 396-402.

[2] DiMaio, V. J. M., Minnette, L. J., and Johnson, S., "Three Deaths Due to Revolver Shotshell Cartridges," *Forensic Science*, Vol. 4, 1974, pp. 247-251.

[3] Zumwalt, R. E., Campbell, B. A., Balraj, E., Adelson, L., and Fransioli, M., "Wounding Characteristics of 'Shotshell' Ammunition: A Report of Three Cases," *Journal of Forensic Sciences*, Vol. 26, No. 1, Jan. 1981, pp. 198-205.

[4] Leffers, B. and Jeanty, D., "Handgun Pellet Ammunition ('Snake Shot') Wounds: Report of Three Cases," *Journal of Forensic Sciences*, Vol. 27, No. 2, April 1982, pp. 433-437.

[5] Kamaka, S. K., "Sawed-Off Shotgun and Shot Patterns," *AFTE Journal*, 1970, pp. 26-32.

[6] Moreau, T. S., Wray, J. L., and Rowe, W. F., "Shotgun Pellet Patterns From Sawed-Off Shotguns," paper presented at 34th Annual Meeting of the American Academy of Forensic Sciences (Colorado Springs, CO), Orlando, FL, 1982.

[7] Heaney, K. D. and Rowe, W. F., "The Application of Linear Regresson to Range-of-Fire Estimates Based on the Spread of Shotgun Pellet Patterns," *Journal of Forensic Sciences*, Vol. 28, No. 2, April 1983, pp. 433-436.

[8] Brownlee, K. A., *Statistical Theory and Methodology in Science and Engineering*, Wiley, New York, 1961.

[9] Wray, J. L., McNeil, J. E., Jr., and Rowe, W. F., "Comparison of Methods for Estimating Range of Fire Based on the Spread of Buckshot Patterns," *Journal of Forensic Sciences*, Vol. 28, No. 4, Oct. 1983, pp. 846-857.

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