# Relationship Between Spent Shell Casing Location and the Shooter's Location

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Often times, when spent shell casings are found at a crime scene, the location of the shell casing is used to indicate the location of the shooter. The assumption is that semi-automatic rifle shell casings land to the right and in front of the shooter and that semi-automatic handgun shell casings land to the right and behind the shooter. The author of this study investigated if there is a trend between the shooter's location and the angle and/or distance of a spent shell casing for both a semi-automatic rifle and semi-automatic handgun. Each firearm was fired ninety times, ten trials, each with nine rounds, from the same distance from the target, same surface and same shooting form. The results emphasized a consistency with the assumptions that semi-automatic rifle shell casings land to the right and in front of the shooter and that semi-automatic handgun shell casings land to the right and back of the shooter. The results also draw attention to the fluctuating distances and angles of the spent shell casings. These results demonstrate that determining a shooter's location solely on the location of spent shell casings can only lead to a cautious location of the shooter.

## Introduction

The intent of the experiment was to determine if there was a sure way to determine the location of a shooter based on the location of spent shell casings. When analyzing a crime scene, spent shell casings can be used to get an approximate area of where the shooter was. These results are then usually used to help reconstruct the scene and is then typically presented to the court. Therefore, it is important to test how accurately the results could determine the location of the shooter.

Ammunition contains the projectile (bullet), case, propellant (powder), and primer which contains a small amount of explosive material detonated by the firing pin. (Giannelli, 2007) Once a bullet is propelled out of the gun from the reaction, the casing is ejected from the gun using an ejector and extractor. This allows for the next round to be loaded and ready to fire with the pulling of the trigger. When a semi-automatic firearm is fired, the cartridge case (shell casing) is automatically ejected from the gun and if it is found, can possibly identify the firearm that fired it. Forensic laboratories can use the firing pin markings on the shell casing to potentially trace it back to a list of manufacturers and models (Miller, 2013). However, one of the issues forensic scientists are encountering today is the use of reloaded cartridges due to the lack of research (Wang, 2016). The firing pin is used to hit the rim of

the ammunition, crushing the folded rim causing the primer to explode igniting the powder. However, different manufacturers and models use different firing pins because the shape of the firing pin changes where the pin hits the casing and in turn changes how the primer ignites. (House, 2016).

During investigations, it can be crucial to know the location of the shooter to help understand what has occurred. Often, behavior in high-stress situations, which can include pointing and shooting a gun, is likely to not be stored in the shooter's memory (Lewinski, 2008). Therefore, the shooter may not be able to accurately and honestly report the exact location or way they fired the gun. However, shooting-scene reconstruction, enhanced by a firearm expert (for a purely forensic standpoint, a person with an in-depth knowledge of all varieties and types of firearms (Walker, 2013) began to place an emphasis on the location of spent shell casings. This emphasis assumes that the shell casing had been undisturbed after being ejected from the firearm. However, this is extremely difficult to account for due to the shooting factors, including hand-hold, body position, or movement, the environmental factors, the surface that shell casings are landing on, the rain or wind, and the alteration factors, being kicked or stepped on, or being moved by someone on the scene. (Miller, 2016)

Reconstructionist can take different approaches to their reconstructions. Reconstruction is different from re-creation or re-enactment, it is based on the ability to make observations at the scene, the scientific ability to examine physical evidence, and the use of logical approaches to theory formulations. A forensic reconstruction takes many forms, from analyzing the trajectories to determining how certain evidence would impact the crime, in order to build a case that will be withheld in court (Claridge, 2016). The simplistic approach to reconstructing the scene, based on shell casings, is to know the general direction of where spent shell casings land. Therefore, they state that with a handgun the shells will land to the right and rear of the shooter and with rifles the shells will land to the right and front of the shooter. (Lewinski, 2010) The other approach is more to account for many factors that could alter the way a spent shell casing lands. Edward Hueske stated that reconstruction should account for eight different factors: weapon design, weapon condition, ammunition type, position the weapon was held when fired, movement of the weapon when fired, how tightly the weapon was held when fired, type of terrain where the weapon

was fired, and the presence of obstacles (Hueske, 2006).

In this study, a simplistic approach to reconstruction efforts is studied to determine if there is a relationship and the precision that could be reached between the angle and distance a shell casing lands from the shooter. The researcher used one semi-automatic handgun and one semi-automatic rifle with one test position for each gun and one subject firing the firearm. The study demonstrated that the distance of the shell casing was variable with no significant trend, and the angle was closer together but still remained variable. The variability factors were then limited to the ejector, but still had significant variability in the relationship between distance and angle of the shooter's location.

**Materials and Methods**

The experiment was conducted at 30º12'33.4"N, 97º57'20.2"W on 14-15 October 2017. The surface of the site contained patchy turf grass on a relatively level plot of land. The grass was able to slightly reduce the bounce factor of the shell casing, but still allowed the shell casings to bounce. The experimental site had an average temperature of 79.5ºF on Oct. 14 and 64ºF on Oct. 15 with no significant wind speed to factor into our test results. Four quadrants were marked off using colored string with the origin being where the subject stood when firing the gun. Once the quadrants were set up, the subject was instructed to stand at the origin and fire nine rounds at the target. After the subject fired nine rounds, strings were extended from the origin to the shell casing which was then labeled, measured and recorded. The distance from the parallel boundary, in relation to the target, to the shell casing and the distance from the origin were measured which then were also used to calculate the angle of the shell casings.

The subject was standing at a height of 6' and at a distance of 25', making the height of the gun off of the ground roughly 5' and the end of the barrel of the handgun at roughly 22' and the barrel of the rifle at roughly 23'. The experiment tested a Taurus Millennium G2 9mm semi-automatic handgun and a Mossberg International 702 Plinkster .22 LR semi-automatic rifle. Both firearms, at the end of the test firings, end in a slide lock. Every round, which was the same brand and type of ammunition, was fired by the same subject, at the same target, and from the same location. Each round of the same ammunition, .22 copper-plated bullet Aguila Ammunition for the rifle and SIG SAUER 9mm for the handgun, was from the

same lot allowing for the least amount of variability caused by variable pressure due to the crimping of the cartridge onto the bullet, seating, amount of grains and composition of gunpowder.

Prior to running the experiment a few observation tests were conducted involving angle of firing and distance from the target. In the observation tests it was observed that rifle shell casings land to the right and in front of the shooter at an average of nine feet and that handgun shell casings land to the right and behind the shooter at an average of six feet. The general direction that shell casing eject is also the general assumption, so the experiment was designed to determine if there was a trend between a shooter's location and the location of the spent shell casing. The trends that were looked for were distance and angle.

To determine a trend, the angle of the shell casing, with the path from the gun to the target as 0º, and the distance of the shell casing to the shooter was observed. The same subject fired both the rifle and the handgun with an angle slightly lower than parallel to the horizon. The subject tested ten trials for each firearm with nine rounds fired in each trial. All ten trials using the handgun were conducted after each other, followed by all ten trials using the rifle. The measurements were then used to run statistical analysis on the values. The statistical analysis of the experiment allowed us to see the distribution of the angle measurements and distances of the shell casings, calculate a median value, the interquartile range, and determine if there were any outliers.

**Results**

The results of this study emphasized a consistency with the assumptions that rifle shell casings land to the right and in front of the shooter and that handgun shell casings land to the right and back of the shooter when fired from a standard standing shooting position. A total of 180 bullets were fired, 90 with the handgun and 90 with the rifle, in the course of the experiment. Shell casing locations are illustrated with pictures of each trial containing string that stretches from the origin to the shell casing. The results will also reference angle measures with 0º and 180º being perpendicular to the target and 90º and -90º being parallel to the target. Negative angle measures are found to the left of the shooter and positive angle measures are found to the right of the shooter. The zero reference is located at the shooter's location.

***Figure 1:*** *Location of spent shells traced using yellow string. Shows the variability in case location.*

Statistical analysis was used to determine the mean, median, interquartile range, and outliers of the experiment for the distances and angle measurements. When dealing with the handgun, the data helped us determine that the mean distance was 333.0345694 cm and the median distance of the shell casing from the shooter was 310.8325 cm. The interquartile range (IQR) was 162.8775 allowing us to see that the middle values spanned 162.8775 cm apart with a standard deviation of 119.5027105 cm. It was also determined that two outliers were observed at 693.57875 cm and 722.3125 cm. The mean angle measure was 123.7848717º and the median angle measure was 120.03415º. The IQR allowed us to see that the middle angle values spanned 16.5575º apart from each other with a standard deviation of 15.16292522. There were three outliers at 166.9410º, 159.0907º, and 176.0431º.

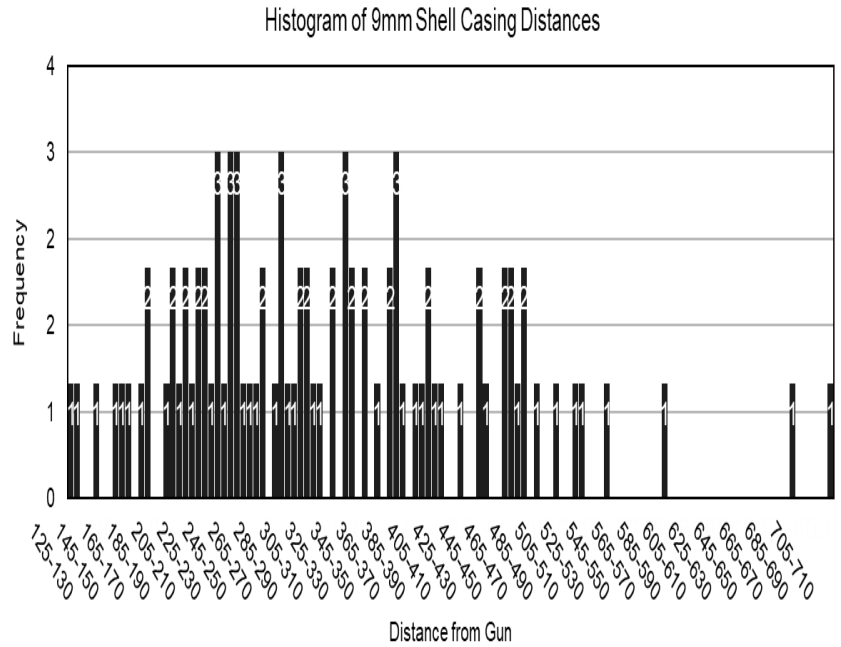


***Figure 2****: Distance of 9mm casing from shooter's location. Bars represent the frequency of a case landing at a specific interval of distance measured in cm.*

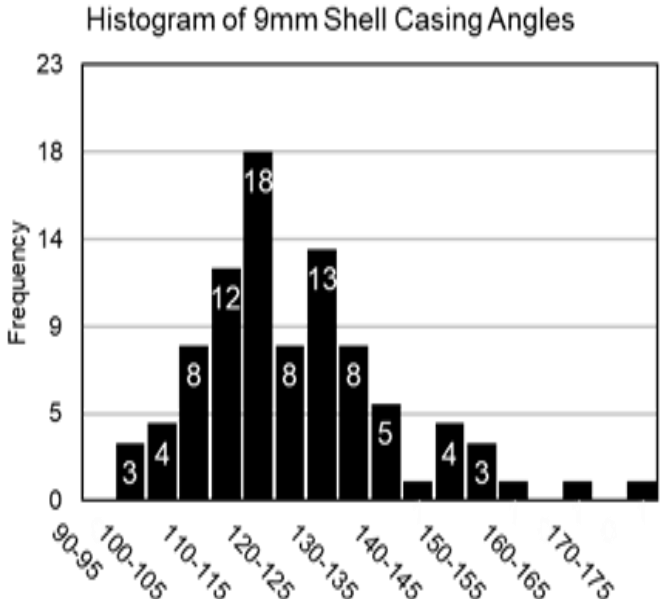


***Figure 3:*** *Angle of 9mm casing relative to the shooter's location. Bars represent the frequency of casing landing at certain angle intervals.*

***Tables 1-10:*** *The angle that the 9mm casing formed with the shooter was used to form a right triangle. All sides of the triangle were recorded using both cm and in. this was performed nine times within each trail to have a sufficient amount of data.*

Pistol Trial 1

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| Round 1 | 91.5000 | 232.4100 | 34.2500 | 86.9950 | 111.982 |
| Round 2 | 103.7500 | 263.5250 | 35.2500 | 89.5350 | 109.862 |
| Round 3 | 214.7500 | 545.4650 | 128.7500 | 327.0250 | 126.8366 |
| Round 4 | 90.5000 | 229.8700 | 22.2500 | 56.5150 | 104.232 |
| Round 5 | 117.2500 | 297.8150 | 63.3125 | 160.81375 | 122.6822 |
| Round 6 | 99.7500 | 253.3650 | 90.0000 | 228.6000 | 154.4562 |
| Round 7 | 150.6250 | 382.5875 | 61.5000 | 156.2100 | 114.0980 |
| Round 8 | 114.7500 | 291.4650 | 57.6250 | 146.3675 | 120.1442 |
| Round 9 | 152.7500 | 387.9850 | 99.3125 | 252.25375 | 130.5539 |

Pistol Trial 2

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| Round 1 | 82.6250 | 209.8675 | 40.5625 | 103.02875 | 119.4013 |
| Round 2 | 49.5000 | 125.7300 | 33.5625 | 85.24875 | 132.6899 |
| Round 3 | 63.3750 | 160.9725 | 26.5000 | 67.3100 | 114.718 |
| Round 4 | 98.5000 | 250.1900 | 49.0625 | 124.61875 | 119.8741 |
| Round 5 | 94.2500 | 239.3950 | 91.8125 | 233.20375 | 166.9410 |
| Round 6 | 91.6250 | 232.7275 | 39.1250 | 99.3775 | 115.278 |
| Round 7 | 65.8750 | 167.3225 | 38.2500 | 97.1550 | 125.496 |
| Round 8 | 112.2500 | 285.1150 | 55.0625 | 139.85875 | 119.3757 |
| Round 9 | 170.1250 | 432.1175 | 125.0625 | 317.65875 | 137.3175 |

Pistol Trial 3

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| Round 1 | 99.2500 | 252.0950 | 55.1250 | 140.0175 | 123.7393 |
| Round 2 | 95.375 | 242.2525 | 59.875 | 152.0825 | 128.8869 |
| Round 3 | 121.7500 | 309.2450 | 68.2500 | 173.3550 | 124.0956 |
| Round 4 | 135.2500 | 343.5350 | 62.8750 | 159.7025 | 117.7024 |
| Round 5 | 135.2500 | 343.5350 | 66.2500 | 168.2750 | 119.3296 |
| Round 6 | 122.5000 | 311.1500 | 60.1250 | 152.7175 | 119.3943 |
| Round 7 | 95.6250 | 242.8875 | 44.6250 | 113.3475 | 117.8181 |
| Round 8 | 118.6250 | 301.3075 | 73.0625 | 185.57875 | 128.0182 |
| Round 9 | 190.3750 | 483.5525 | 67.3750 | 171.1325 | 110.7265 |

Pistol Trial 4

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| Round 1 | 130.6250 | 331.7875 | 35.5000 | 90.1700 | 105.770 |
| Round 2 | 157.9375 | 401.16125 | 100.0000 | 254.0000 | 129.2838 |
| Round 3 | 184.5000 | 468.6300 | 83.3750 | 211.7725 | 116.8655 |
| Round 4 | 187.1250 | 475.2975 | 23.1875 | 58.89625 | 97.11807 |
| Round 5 | 67.6250 | 171.7675 | 56.4375 | 143.35125 | 146.5706 |
| Round 6 | 148.3750 | 376.8725 | 109.1250 | 277.1775 | 137.3467 |
| Round 7 | 109.0000 | 276.8600 | 32.7500 | 83.1850 | 107.463 |
| Round 8 | 51.2500 | 130.1750 | 47.8750 | 121.6025 | 159.0907 |
| Round 9 | 233.5625 | 593.24875 | 112.0625 | 284.63875 | 118.67212 |

Pistol Trial 5

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 74.1875 | 188.43625 | 12.8750 | 32.7025 | 99.9941 |
| **Round 2** | 163.0625 | 414.17875 | 85.4375 | 217.01125 | 121.59796 |
| **Round 3** | 150.1250 | 381.3175 | 109.0000 | 276.8600 | 136.5572 |
| **Round 4** | 122.2500 | 310.5150 | 65.9375 | 167.48125 | 122.6405 |
| **Round 5** | 101.2500 | 257.1750 | 62.3750 | 158.4325 | 128.0282 |
| **Round 6** | 179.0000 | 454.6600 | 109.1250 | 277.1775 | 127.5633 |
| **Round 7** | 193.6250 | 491.8075 | 95.8125 | 243.36375 | 119.6589 |
| **Round 8** | 175.8750 | 446.7225 | 77.5625 | 197.00875 | 116.1683 |
| **Round 9** | 141.5000 | 359.4100 | 57.5000 | 146.0500 | 113.9764 |

Pistol Trial 6

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 176.0625 | 447.19875 | 111.1875 | 282.41625 | 129.16257 |
| **Round 2** | 189.1250 | 480.3775 | 130.3750 | 331.1525 | 133.5794 |
| **Round 3** | 159.8750 | 406.0825 | 79.4375 | 201.77125 | 119.7933 |
| **Round 4** | 141.5625 | 359.56875 | 36.8125 | 93.50375 | 105.0727 |
| **Round 5** | 187.0000 | 474.9800 | 76.5000 | 194.3100 | 114.1477 |
| **Round 6** | 284.3750 | 722.3125 | 121.1875 | 307.81625 | 115.2237 |
| **Round 7** | 97.0000 | 246.3800 | 50.8125 | 129.06375 | 121.5902 |
| **Round 8** | 127.6875 | 324.32625 | 98.5000 | 250.1900 | 140.4811 |
| **Round 9** | 124.1875 | 315.43625 | 42.3750 | 107.6325 | 109.9511 |

Pistol Trial 7

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 165.0625 | 419.25875 | 50.3750 | 127.9525 | 107.7694 |
| **Round 2** | 101.0625 | 256.69875 | 66.3125 | 168.43375 | 131.00716 |
| **Round 3** | 88.3750 | 224.4725 | 73.5000 | 186.6900 | 146.2720 |
| **Round 4** | 57.7500 | 146.6850 | 40.3750 | 102.5525 | 134.3576 |
| **Round 5** | 85.1250 | 216.2175 | 34.0625 | 86.51875 | 113.5874 |
| **Round 6** | 104.8750 | 266.3825 | 104.6250 | 265.7475 | 176.0431 |
| **Round 7** | 84.3750 | 214.3125 | 70.0000 | 177.8000 | 146.0607 |
| **Round 8** | 151.1250 | 383.8575 | 35.7500 | 90.8050 | 103.684 |
| **Round 9** | 198.9375 | 505.30125 | 74.1250 | 188.2775 | 111.8763 |

Pistol Trial 8

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 159.5000 | 405.1300 | 47.7500 | 121.2850 | 107.4200 |
| **Round 2** | 136.5000 | 346.7100 | 103.5000 | 262.8900 | 139.3094 |
| **Round 3** | 115.1250 | 292.4175 | 46.1250 | 117.1575 | 113.6189 |
| **Round 4** | 208.6250 | 529.9075 | 121.2500 | 307.9750 | 125.5340 |
| **Round 5** | 273.0625 | 693.57875 | 168.4375 | 427.83125 | 128.08617 |
| **Round 6** | 183.5000 | 466.0900 | 71.7500 | 182.2450 | 113.0172 |
| **Round 7** | 145.1875 | 368.77625 | 94.2500 | 239.3950 | 130.4783 |
| **Round 8** | 88.7500 | 225.4250 | 22.0000 | 55.8800 | 104.353 |
| **Round 9** | 121.0000 | 307.3400 | 23.8750 | 60.6425 | 101.380 |

Pistol Trial 9

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (º) |
|---|---|---|---|---|---|
| **Round 1** | 140.0000 | 355.6000 | 58.0625 | 147.47875 | 114.5024 |
| **Round 2** | 74.2500 | 188.5950 | 39.6250 | 100.6475 | 122.2538 |
| **Round 3** | 149.0000 | 378.4600 | 49.3125 | 125.25375 | 109.3268 |
| **Round 4** | 135.3750 | 343.8525 | 85.0625 | 216.05875 | 128.9283 |
| **Round 5** | 130.0000 | 330.2000 | 116.2500 | 295.2750 | 153.4098 |
| **Round 6** | 80.8750 | 205.4225 | 68.2500 | 173.3550 | 147.5537 |
| **Round 7** | 86.5625 | 219.86875 | 55.0000 | 139.7000 | 129.4481 |
| **Round 8** | 108.1250 | 274.6375 | 64.2500 | 163.1950 | 126.4570 |
| **Round 9** | 94.5000 | 240.0300 | 43.6250 | 110.8075 | 117.4930 |

Pistol Trial 10

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (º) |
|---|---|---|---|---|---|
| **Round 1** | 71.1250 | 180.6575 | 35.1875 | 89.37625 | 119.6518 |
| **Round 2** | 101.0000 | 256.5400 | 76.3750 | 193.9925 | 139.1293 |
| **Round 3** | 118.7500 | 301.6250 | 15.2500 | 38.7350 | 97.3784 |
| **Round 4** | 136.0625 | 345.59875 | 67.6250 | 171.7675 | 119.8027 |
| **Round 5** | 156.3750 | 397.1925 | 62.3750 | 158.4325 | 113.5082 |
| **Round 6** | 185.7500 | 471.8050 | 88.6875 | 225.26625 | 118.5194 |
| **Round 7** | 108.3750 | 275.2725 | 73.9375 | 187.80125 | 133.0187 |
| **Round 8** | 114.3750 | 290.5125 | 103.6250 | 263.2075 | 154.9598 |
| **Round 9** | 206.5000 | 524.5100 | 139.3125 | 353.85375 | 132.4260 |

When dealing with the rifle, it was determined that the mean distance was 276.4301264 cm and the median distance of the shell casing from the shooter was 276.06625 cm. The IQR allowed us to see that the middle values spanned 71.59625 cm apart and there was a standard deviation of 63.64663549 cm. It was also determined that three outliers were observed at 76.67625 cm, 443.2300 cm and 486.7275 cm. The mean angle measure was 34.16262645º and the median angle measure was 30.84º.

The IQR allowed us to see that the middle angle values spanned 30.2215635º apart from each other with no outliers and a standard deviation of 19.9541985º.

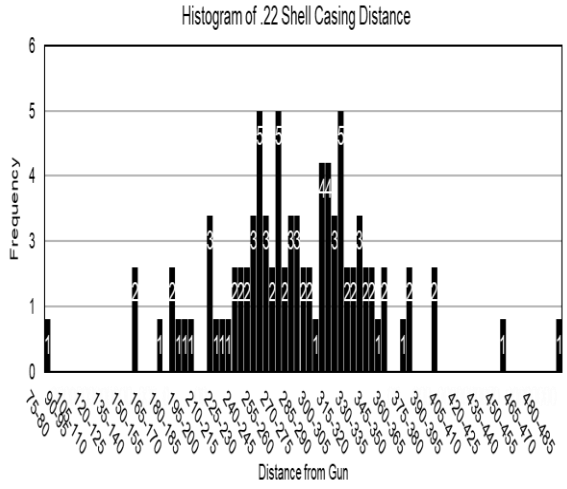


***Figure 4:*** *Distance of .22 shell from shooter's location. Bars represent the frequency of a case landing at a specific interval of distance measured in cm.*

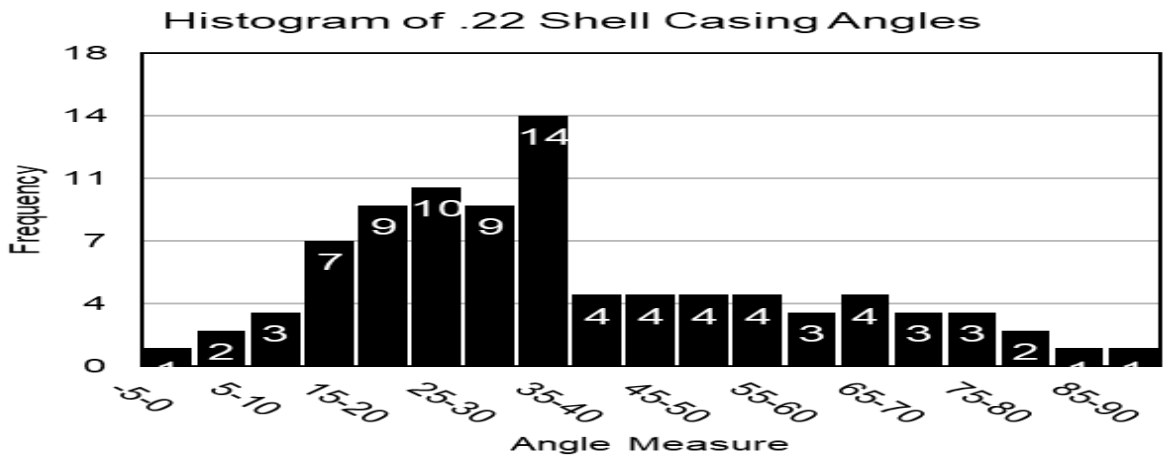


***Figure 5****: Angle of .22 shell casing relative to the shooter's location. Bars represent the frequency of casing landing at certain angle intervals*

***Table 11-20:*** *The angle that the .22 shell formed with the shooter was used to form a right triangle. All sides of the triangle were recorded using both cm and in. this was performed nine times within each trail to have a sufficient amount of data.*

Rifle Trial 1

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (º) |
|---|---|---|---|---|---|
| **Round 1** | 57.1250 | 145.0975 | 26.7500 | 67.9450 | 62.0779 |
| **Round 2** | 81.7500 | 207.6450 | 70.1875 | 178.27625 | 30.84442 |
| **Round 3** | 135.3125 | 343.69375 | 108.5625 | 275.74875 | 36.648790 |
| **Round 4** | 97.6250 | 247.9675 | 6.3750 | 16.1925 | 86.2559 |
| **Round 5** | 83.6250 | 212.4075 | 23.1250 | 58.7375 | 73.9467 |
| **Round 6** | 98.0625 | 249.07875 | 83.3750 | 211.7725 | 31.76406 |
| **Round 7** | 120.5000 | 306.0700 | 49.0000 | 124.4600 | 66.00612 |
| **Round 8** | 119.8750 | 304.4825 | 108.0000 | 274.3200 | 25.71830 |
| **Round 9** | 122.0625 | 310.03875 | 103.2500 | 262.2550 | 32.23386 |

Rifle Trial 2

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (º) |
|---|---|---|---|---|---|
| **Round 1** | 104.2500 | 264.7950 | 88.2500 | 224.1550 | 32.16454 |
| **Round 2** | 73.9375 | 187.80125 | 62.4375 | 158.59125 | 32.385529 |
| **Round 3** | 97.1250 | 246.6975 | 89.6875 | 227.80625 | 22.56819 |
| **Round 4** | 131.0000 | 332.7400 | 119.1250 | 302.5775 | 24.58416 |
| **Round 5** | 65.0625 | 165.25875 | 31.0625 | 78.89875 | 61.48260 |
| **Round 6** | 128.4375 | 326.23125 | 121.4375 | 308.45125 | 19.003483 |
| **Round 7** | 132.3750 | 336.2325 | 83.5625 | 212.24875 | 50.85716 |
| **Round 8** | 102.6250 | 260.6675 | 69.2500 | 175.8950 | 47.56240 |
| **Round 9** | 105.6250 | 268.2875 | 97.5625 | 247.80875 | 22.53155 |

Pistol Trial 3

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 99.2500 | 252.0950 | 55.1250 | 140.0175 | 123.7393 |
| **Round 2** | 95.375 | 242.2525 | 59.875 | 152.0825 | 128.8869 |
| **Round 3** | 121.7500 | 309.2450 | 68.2500 | 173.3550 | 124.0956 |
| **Round 4** | 135.2500 | 343.5350 | 62.8750 | 159.7025 | 117.7024 |
| **Round 5** | 135.2500 | 343.5350 | 66.2500 | 168.2750 | 119.3296 |
| **Round 6** | 122.5000 | 311.1500 | 60.1250 | 152.7175 | 119.3943 |
| **Round 7** | 95.6250 | 242.8875 | 44.6250 | 113.3475 | 117.8181 |
| **Round 8** | 118.6250 | 301.3075 | 73.0625 | 185.57875 | 128.0182 |
| **Round 9** | 190.3750 | 483.5525 | 67.3750 | 171.1325 | 110.7265 |

Rifle Trial 4

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 122.3125 | 310.67375 | 119.3750 | 303.2125 | 12.58242 |
| **Round 2** | 106.2500 | 269.8750 | 60.0000 | 152.4000 | 55.61813 |
| **Round 3** | 95.8125 | 243.36375 | 52.6875 | 133.82625 | 56.639700 |
| **Round 4** | 135.8750 | 345.1225 | 126.2500 | 320.6750 | 21.69531 |
| **Round 5** | 89.5000 | 227.3300 | 80.2500 | 203.8350 | 26.27909 |
| **Round 6** | 30.1875 | 76.67625 | 30.1810 | 76.6597 | 1.1863 |
| **Round 7** | 131.8750 | 334.9625 | 112.3750 | 285.4325 | 31.55560 |
| **Round 8** | 125.7500 | 319.4050 | 56.6875 | 143.98625 | 63.20528 |
| **Round 9** | 128.6250 | 326.7075 | 108.6250 | 275.9075 | 32.38061 |

Rifle Trial 5

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 100.1875 | 254.47625 | 97.6250 | 247.9675 | 12.98652 |
| **Round 2** | 116.5000 | 295.9100 | 97.6250 | 247.9675 | 33.07228 |
| **Round 3** | 122.7500 | 311.7850 | 119.3750 | 303.2125 | 13.46678 |
| **Round 4** | 120.3125 | 305.59375 | 87.5000 | 222.2500 | 43.34176 |
| **Round 5** | 72.1875 | 183.35625 | 53.8750 | 136.8425 | 41.72737 |
| **Round 6** | 126.7500 | 321.9450 | 89.1875 | 226.53625 | 45.27950 |
| **Round 7** | 118.8125 | 301.78375 | 111.6250 | 283.5275 | 20.03132 |
| **Round 8** | 129.0000 | 327.6600 | 121.8750 | 309.5625 | 19.13175 |
| **Round 9** | 119.375 | 303.2125 | 118.7500 | 301.6250 | 5.865575 |

Rifle Trial 6

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 95.0625 | 241.45875 | 90.7500 | 230.5050 | 17.32420 |
| **Round 2** | 106.5000 | 270.5100 | 0.4615 | 1.17221 | -0.248282 |
| **Round 3** | 110.3750 | 280.3525 | 100.8750 | 256.2225 | 23.94580 |
| **Round 4** | 119.3125 | 303.05375 | 112.4375 | 285.59125 | 19.545141 |
| **Round 5** | 76.3125 | 193.83375 | 21.8125 | 55.40375 | 73.39146 |
| **Round 6** | 99.1250 | 251.7775 | 74.4375 | 189.07125 | 41.32763 |
| **Round 7** | 102.9375 | 261.46125 | 88.5625 | 224.94875 | 30.643854 |
| **Round 8** | 116.1875 | 295.11625 | 111.1875 | 282.41625 | 16.869912 |
| **Round 9** | 98.2500 | 249.5550 | 84.7500 | 215.2650 | 30.39074 |

Rifle Trial 7

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 117.8750 | 299.4025 | 117.5000 | 298.4500 | 4.571488 |
| **Round 2** | 104.0000 | 264.1600 | 99.3750 | 252.4125 | 17.15140 |
| **Round 3** | 151.6875 | 385.28625 | 145.8125 | 370.36375 | 15.998470 |
| **Round 4** | 152.9375 | 388.46125 | 129.2500 | 328.2950 | 32.31558 |
| **Round 5** | 132.1875 | 335.75625 | 109.1875 | 277.33625 | 34.309512 |
| **Round 6** | 109.1250 | 277.1775 | 107.3750 | 272.7325 | 10.27488 |
| **Round 7** | 96.6875 | 245.58625 | 90.6875 | 230.34625 | 20.290837 |
| **Round 8** | 116.3750 | 295.5925 | 109.3125 | 277.65375 | 20.06357 |
| **Round 9** | 101.5000 | 257.8100 | 85.4375 | 217.01125 | 32.67475 |

Rifle Trial 8

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 191.6250 | 486.7275 | 87.1875 | 221.45625 | 62.93570 |
| **Round 2** | 111.8750 | 284.1625 | 100.0625 | 254.15875 | 26.56682 |
| **Round 3** | 87.1250 | 221.2975 | 77.0625 | 195.73875 | 27.80933 |
| **Round 4** | 122.1875 | 310.35625 | 119.4375 | 303.37125 | 12.178912 |
| **Round 5** | 101.0625 | 256.69875 | 100.0625 | 254.15875 | 8.0668015 |
| **Round 6** | 81.7500 | 207.6450 | 71.3125 | 181.13375 | 29.27014 |
| **Round 7** | 99.1875 | 251.93625 | 92.4375 | 234.79125 | 21.259609 |
| **Round 8** | 123.5625 | 313.84875 | 23.8750 | 60.6425 | 78.8591 |
| **Round 9** | 92.0625 | 233.83875 | 86.7500 | 220.3450 | 19.55945 |

Rifle Trial 9

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | Misfire | ⚠ | Misfire | ⚠ | Misfire |
| **Round 2** | 92.1250 | 233.9975 | 82.1875 | 208.75625 | 26.85783 |
| **Round 3** | 84.8750 | 215.5825 | 68.0625 | 172.87875 | 36.68668 |
| **Round 4** | 106.8750 | 271.4625 | 56.4375 | 143.35125 | 58.12484 |
| **Round 5** | 142.0000 | 360.6800 | 100.3125 | 254.79375 | 45.05513 |
| **Round 6** | 108.6875 | 276.06625 | 82.4375 | 209.39125 | 40.669454 |
| **Round 7** | 69.0625 | 175.41875 | 54.1250 | 137.4775 | 38.39844 |
| **Round 8** | 113.9375 | 289.40125 | 89.9375 | 228.44125 | 37.874425 |
| **Round 9** | 94.1250 | 239.0775 | 33.1250 | 84.1375 | 69.3949 |

Pistol Trial 10

| | Hypotenuse (in.) | Hypotenuse (cm.) | Leg (in.) | Leg (cm) | Angle (°) |
|---|---|---|---|---|---|
| **Round 1** | 71.1250 | 180.6575 | 35.1875 | 89.37625 | 119.6518 |
| **Round 2** | 101.0000 | 256.5400 | 76.3750 | 193.9925 | 139.1293 |
| **Round 3** | 118.7500 | 301.6250 | 15.2500 | 38.7350 | 97.3784 |
| **Round 4** | 136.0625 | 345.59875 | 67.6250 | 171.7675 | 119.8027 |
| **Round 5** | 156.3750 | 397.1925 | 62.3750 | 158.4325 | 113.5082 |
| **Round 6** | 185.7500 | 471.8050 | 88.6875 | 225.26625 | 118.5194 |
| **Round 7** | 108.3750 | 275.2725 | 73.9375 | 187.80125 | 133.0187 |
| **Round 8** | 114.3750 | 290.5125 | 103.6250 | 263.2075 | 154.9598 |
| **Round 9** | 206.5000 | 524.5100 | 139.3125 | 353.85375 | 132.4260 |

**Discussion**

From the results, a definite relationship between the shooter's location and the shell casing's distance and angle is not possible. However, it is possible to determine a cautious idea of where the shooter was positioned based on the location and angle of the shell casings. However, this test did not account for other variability that could be possible, including the way the gun was held or if the shooter was moving when he fired the gun. A study done by Lewinski in 2010 did account for these factors including firearm design, firearm condition, ammunition type, the position firearm is held when fired, movement of the firearm and person during firing, and grip factors, and found that there was still significant variability in the results. Therefore, even when eliminating as many factors as possible, determining a shooter's location based on shell casings should be a cautious determination.

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