

FIRED CARTRIDGE CASE EJECTION PATTERNS FROM SEMI-AUTOMATIC FIREARMS

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Abstract

During testimony, “experts” often cite that spent cartridge case ejection locations from a semi-automatic firearm indicate the location of the shooter based on the assumption that most spent cartridge cases land to the right and rear of the shooter. The authors of this study investigated whether spent cartridge case ejection locations are an accurate indicator of a shooter’s location. Eight different semi-automatic weapons most frequently used by police officers were used to collect data from eleven different shooting positions. The results highlighted the significant inconsistency of the spent cartridge case ejection locations that occurred across test positions even when several factors including firearm type, firearm position, and ammunition were accounted for. Of 7,670 bullets fired, over 25 percent of the spent cartridge casings landed somewhere other than to the right and rear of the shooter where it is commonly accepted they should land. That pattern inconsistency is significant and demonstrates that determining shooter location from the spent cartridge case alone leads to only a tentative estimate of the shooter’s location.

Keywords: ejection patterns; scene reconstruction; semi-automatic firearm; fired cartridge case(s); spent bullet casings; spent cartridges; fired cartridge case location

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Introduction

The authors of this research project intended to determine the level of precision that can be reached and the significance that should be given to a spent cartridge case location alone as a method of determining shooter location when unknown variables include how the firearm is held and/or manipulated. Shooter location is often used in the process of homicide reconstruction and other shooting-related cases, the results of which typically are submitted to the justice system during the course of criminal or civil cases. Therefore, it is imperative to obtain the most accurate shooter location that can be determined from the evidence. Until recently, the impact of human factors, such as stance, firearm motion, firearm position and grip have not been given proper analytical consideration when attempting to determine the shooter's location from the final resting location of a spent cartridge case.

During the investigation of officer-involved shootings and some homicide incidents, knowing the shooter's location can be a vital piece of information in understanding the dynamics of the encounter. Often officers in a complex, rapidly unfolding, life-threatening event of very short duration will not be able to report on their precise or even approximate location because of their intense focus on the threat and their attempts to cope with it (Lewinski, 2008). They may later attempt to "figure out" their location but this can be recognized as the officer's "best guess." However, if for some reason, the officer was attending to or cognizant of his/her location, such as when he/she had used an obstacle for tactical cover, then of course the officer is better able to determine his/her shooting location. In an attempt to more accurately determine a shooter's location, some reconstructionists ("experts who use and analyze physical evidence at a scene, deriving inferences from that data to test theories about prior events" (Garrison, 2003)) began to place a heavy weight on the location of the spent cartridge casing(s). This emphasis assumes the reconstructionist can confirm that the spent cartridge case was undisturbed from the time it landed until its final location; was accurately marked for evidence; and did not encounter factors, such as walls and hard or bumpy surfaces at the landing site, that impacted significantly on it while arriving at its location.

Some reconstructionists engage in a very simplistic analysis, for instance, they may state that the firearm the officer fired ejected its spent cartridge cases to the right and the rear when the firearm was fired on the range. Therefore, they continue further with their analysis by asserting that when the officer fired, and when the spent cartridge cases were ejected, he/she had to be to the left and to the front of the placement of the spent cartridge cases. However, other reconstructionists understanding the effects of weapon manipulation, shooter movement, bounce factors, and other elements, began to list and accommodate for some of them. For example, Edward Hueske has said that reconstruction of an equivalent shooting environment should take into account the following eight variables: weapon design, weapon condition, ammunition type, position weapon was held when fired, movement of weapon during firing, how tightly the weapon was held during firing, type of terrain where shooting occurred, and the presence of obstacles (Hueske, 2006).

Some of this information can be determined quite empirically. For example, the markings found on spent cartridge cases help to illustrate the firearm condition variable. Semi-automatic weapons can leave magazine lip marks, chambering marks, and extractor override marks. Any atypical markings or occurrences might be attributed to the same mechanism that also creates differences in spent cartridge case patterns. The mechanism of the ejector and extractor affects the firearm condition variable, as well as the weapon design variable (Haag, 2006). The purpose of the ejector and extractor in all semi-automatic weapons is the same: to eject the spent cartridge case from the weapon. Literature about semi-automatic firearms reveals that Glock, Sig Sauer, Smith and Wesson, and the Berretta ejector and extractor mechanisms are in many cases similar. However, wear, slight damage, and alignment all seem to be plausible justification for variability/diversity in spent cartridge casing ejection (Ayoob, M 2004; Ayoob, 2005; Sweeney, 2003; Sweeney, 2004). Other elements of the reconstruction such as the grip factors or weapon manipulation, although apparently reasonable, have not been subject to the scrutiny of research to determine their impact on final spent cartridge case location. This study attempts to perform that research.

The placement and reproducibility of spent cartridge case locations from eight semi-automatic firearms is the focus of this study. Much of the literature on spent cartridge cases primarily describes techniques and measurement methods for determining ejection patterns (Garrison, 2003; Hueske, 2006). Less research has been conducted on the impact that human performance factors such as the shooter's grip on the weapon and the weapon's left-right cant or incline/decline (firearm's axes) at the time it was fired has on the location of spent cartridge cases. Similarly, little research has been conducted and published on the impact of firearm position, ammunition, shooter movement, firearm type, and grip on the ability to indicate the shooter's actual location at the time the shot was fired. The authors could only find two studies published in the Journal of Forensic Identification that utilized more than two weapons and looked at different variables such as stance (Sims & Barksdale, 2005; Pepper & Bloomer, 2006).

In this study the researchers used eight different semi-automatic handguns, eleven test positions, and three major weapon gripping techniques/styles with 45 shooters. The study demonstrated that even when done in a controlled environment with several variables accounted for, the ejection patterns of spent cartridge cases remain "trendable" at best. This study has also demonstrated that weapon motion, weapon position, and the grip on the firearm have profound effects on spent cartridge case ejection patterns. Each of the variables previously mentioned is attributable to the human factors in shooting situations, for it is humans who hold, manipulate, and fire the weapon. The weapon design and weapon type variables were accounted for by using weapons in good firing condition and by separating the data depending on weapon type. Even when these factors remain constant, significant variability, and in some cases dramatic variability, has been found in the landings of the spent cartridge cases. Specifically, this study is intended to determine the level of precision that can be reached and the significance that should be given to location of spent cartridge cases alone as a method of determining shooter location when firearm position and manipulation are unknown or not accounted for.

Experimental Design

Study Participants

The 45 participants in this study were fully certified Los Angeles Sheriff's Department (LASD) Deputies. They were all full-time deputies whose time on the job ranged from 2 months to 28 years and were 22 to 50 years old. There was nothing to indicate that any of the participants was more or less skilled than the average officer. They had all participated and qualified in the required training, including the firearms component, to become a certified peace officer in the State of California, and all were current in their certification requirements.

Experimental Site

The experimental site was located at the LASD north shooting range in Los Angeles, California. It consisted of a 30 foot by 30 foot, or 900-square foot, area that had been dug, tilled, and then loosely covered with fine-grain river sand to a depth of three inches. The whole experimental site was then leveled. A smart level was used to confirm this process. This preparation significantly reduced the bounce factor of the spent cartridge casings to nearly zero.

A grid was then constructed over the area using colored string. To further illustrate the grid structure, the experimental site picture, located below, contains some enhanced lines. This split the 900- square foot area into one foot sections in both the x and y direction. A 1-ft/sq transparent plastic template with one-inch grid marks was then constructed. When this was inserted into each square foot that had a spent cartridge casing land in it, it allowed further precise position determination (to the square inch) of the spent cartridge casings. The officers were instructed to shoot from a stake that was driven into the ground at the center of the test site. Each of the officers was told to enter into the grid from the rear and to fire 10 rounds from each of the test positions with the weapon at the center of the grid (zero point). All the test firings end in a slide lock. This has been known to produce aberrant spent cartridge locations on the last casing in some weapons. This was not observed or accounted for in this study. After each officer fired ten rounds from a specified test position, the ten ejected spent cartridge casings were measured and recorded, the casings were then removed and the sand was raked back to a relatively smooth, level surface that had a minimum of three inches of fine sand on top of the tilled soil. (Experimental Site & Pilot Site picture below)

The experimental site was located in a small sheltered valley that was hot and still each testing day, therefore wind speed was not a significant factor on our test results. Wind speed, while possibly a factor in spent cartridge casing ejections patterns, has not been specifically studied by any researcher.



Experimental Site With Enhanced



Experimental Site: Pilot Study Illustration

Firearms and Ammunition

The experiment used eight different types of semi-automatic weapons. The weapons used include: Smith and Wesson 5906, Glock 21, Glock 23, Glock 17, Sig Sauer 226, Sig Sauer 229, H&K USP, and a Berretta 9mm. Weapon type, as well as ammunition type, has said to affect the ejection of spent cartridge casings. In this study the Los Angeles County Sheriff's Department donated all 9mm ammunition, however only the 9 mm ammunition produced by Winchester was used. Federal Ammunition donated the 40-caliber ammunition and Federal also manufactured the 45-caliber ammunition purchased by the researchers. The 40 and 45-caliber ammunition were from the same Federal lot of ammunition. The 9mm ammunition from the LASD cannot be guaranteed to have come from the same lot. However, ammunition manufacturers allow for an approximate three percent (3%) variability between lots of ammunition, based on the manufacturing process (Speer Ammo, personal communication, June, 2004). This can be due to variable pressure resulting from the crimping of the cartridge onto the bullet, the seating and type of primer used, the number of grains and composition of the gunpowder, etc. Therefore the reader should take this three percent variability into account when reviewing the data on 9mm weapons. The reader should also consider applying the single digit variability from lot to lot to all ammunition.

Multiple pilot studies conducted by these researchers on the Glock 9mm, involving test firings with the weapon as it had been held and manipulated by officers in a real life shooting encounter, produced spent shell ejections from 13 feet to the right and rear to 13 feet to the left and front. As noted in the following section, some of the research subjects found some of the actual firing positions, involving movement and firing, difficult to reproduce and subsequently the data from this study on some of the positions has been moderated to some degree in comparison to our pilot studies. For example an officer engaged in a real world encounter might be both rapidly turning and shooting simultaneously as he/she tracked an assailant. Deputies in our study found this difficult to do when we were requiring them to turn and shoot as they passed a specific location. Often they would turn until they reached the assigned direction to shoot towards then stop and shoot. Subsequently there would be little or no motion of the firearm at the time of discharge and ejection of the spent cartridge casing.

Firearm Position, Motion, and Handling

Each officer performed the eleven test conditions in a random order. Prior to each test the officers were directed to hold the weapon in a particular way or to hold it and then move it through a prearranged motion. A smart level was used to help confirm angular positions. Unless otherwise stated the tests have the weapon positioned such that the plane of the weapon is vertical and the weapon is aimed parallel to the horizon. The eleven tests were:

(1) Two handed firm, regular, proper grip on the weapon that places the weapon parallel with or horizontal to the ground and held at eye level with the arms extended.



Position 1: Beginning and End

(2) Two handed regular shooting position, using an improper grip (a side-by-side grip representing the hand position of officers when hurrying to get their gun in position on target from a holster draw).



Position 2: Beginning and End

(3) One handed grip with the firearm parallel with or horizontal to the ground.



Position 3: Beginning and End

(4) One handed grip, with the arm extended at eye level, but the firearm is canted inward at 45 degrees. All of the inward cants, although unusual for a trained officer, have occurred while an officer is engaged in shooting and turning and his/her elbow rotates outward in conjunction with his/her turning. This inward cant occurs most frequently when officers hold the weapon in one hand and have not been taught how to correctly align and fire when turning, such as might occur in simulation training.



Position 4: Beginning and End

(5) Two handed regular grip, with the arms extended and the weapon declined downward 22 degrees from the horizon.



Position 5: Beginning and End

(6) One handed grip, with the weapon held at arms length and the weapon and arms are declined downward 22 degrees from the horizon and the weapon canted inward at 45 degrees.



Position 6: Beginning and End

(7) Two handed regular grip at eye level with weapon horizontal to the ground at arms length. The shooter starts rotated 45 degrees to his/her right and away from the center of the grid and then rotates counterclockwise 45 degrees toward the target zone while firing the weapon. The shooter was to carry out his or her shot while moving to and through the target zone.



Position 7: Beginning



Position 7: End

8) Two handed regular grip, arms extended, with the firearm declined downward 22 degrees from the horizon and the shooter again rotating his/her body 45 degrees to his/her left toward the target zone.



Position 8: Beginning



Position 8: End

(9) One handed grip, arm extended, with the firearm canted inward 45 degrees and the shooter again rotating his/her body 45 degrees toward the target zone.



Position 9: Beginning



Position 9: End

10) One handed grip from a close contact position. In the close contact position the shooter's elbow was tucked in and rearward against the body and the firearm was held just off of the hip and horizontal to the ground.



Position 10: Beginning and End

(11) Two handed regular grip with the firearm inclined upward 45 degrees from the horizon, as though the officer was shooting into the second story of a building. The testing site was at the base of high bluff, and when firing, the officers arm positions were static and measured with the smart level to ensure safe placement of the bullet into the bluff.



Position 11: Beginning and End

All firearm positions and movements studied were discerned from 30 years of investigation of officer-involved shootings by the lead investigator. Each position and movement had been performed by police officers in dynamic, rapidly unfolding life and death shooting situations.

A note must be added here to further clarify the results from some of the test positions so as to better interpret them. Some of the officers involved in this study were unable to correctly perform some of the test conditions (tests 7, 8, & 9) as asked by the researchers. The test conditions called for the shooters to fire while they were in motion not after they had completed the motion. The shooters who did not perform the test conditions correctly did not spin and shoot, instead they spun, stopped, and then shot. Preliminary testing indicates a dramatic change in spent cartridge casing placement when the firearm is fired while being moved rapidly. Therefore, the authors believe the data presented in these tests (7-9) significantly understates the distance and variability of the ejection pattern.

Results

The results of this study demonstrated how unpredictable spent cartridge casing ejection patterns are even when many variables are controlled. A total number of 7,670 bullets were fired from eight different firearms in the course of this study. Spent cartridge casing locations are illustrated through the use of scatter diagrams and pie charts. During the presentation of this information reference is made to quadrants one, two, three, and four. The quadrants are orientated such that quadrant one and two are in front of the zero point and would indicate spent cartridge casings being ejected in front of the study participant, while quadrants three and four would represent the spent cartridge casings being ejected behind the zero point and to the rear of the study participant. A spent cartridge casing found in quadrant one or four would indicate ejection to the right of the zero point, while spent cartridge casings found in quadrant two or three would indicate ejection to the left of the zero point. When a spent cartridge casing position is specified through angular reference a negative degree value indicates a cartridge casing behind the zero point, while a positive degree value indicates a cartridge casing in front of the zero point. Zero to 180 degrees begins to the right of the participant and follows an arch to the left. In both cases the zero reference is located at the zero stake in the center of the grid. See Figure 1 below for example.

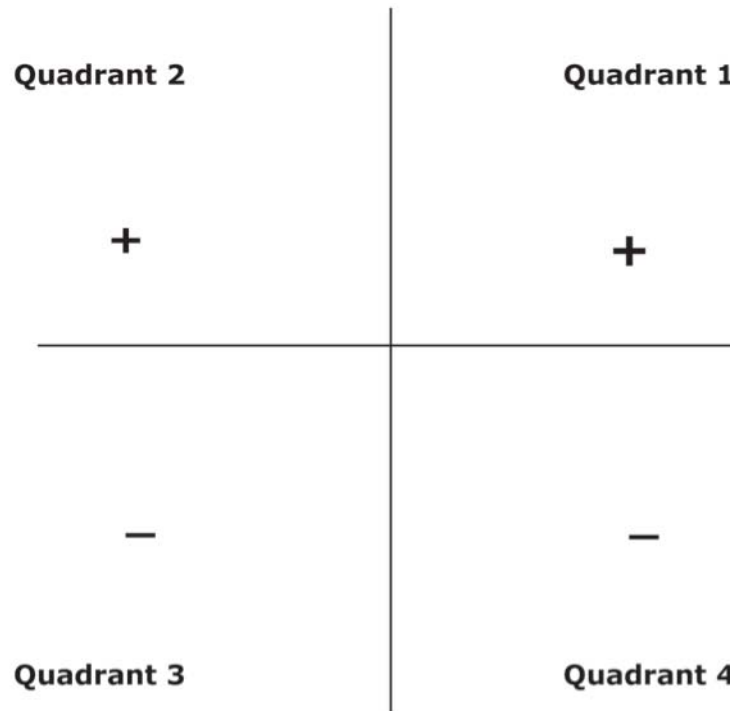


Figure 1: Example of Quadrants

Since all the data obtained from this study is too large to fit in this article the authors have chosen to present specific results in a broad to precise fashion. Significant variables such as firearm position, motion, grip, weapon type, and ammunition will be taken into consideration one-by-one. This one-by-one approach is to illustrate the impact of each individual variable on the spent cartridge casing patterns. First, all 7,670 spent cartridge casing locations will be presented without any other variables being considered. Next, in section two, the impact of firearm position and grip alone will be illustrated while firearm type, ammunition, and weapon motion will be left as an unknown. Then in section three weapon type results will be illustrated, followed by section four, which is firearm motion and finally section five, ammunition type. This is to help demonstrate how unpredictable spent cartridge casing locations are when several variables are not accounted for and are still unpredictable even when these variables are accounted for. The authors' goal in this way of presenting the results is to illustrate how imprecise determining shooter's location is even when several important variables are known and accounted for and not just when variables are unknown.

Further statistical analysis of the tests presented below is contained in a table located after each of the scatter plots. This information is presented in two sections within a single table so that the reader can see both the angles, in degrees, in which the spent cartridge casings flew after being ejected from the weapon and the distance, in inches (and cm), that they traveled from the shooter. First the mean (average), standard deviation, median (the middle number), and mode

(most common number) are given for the angles (degrees) in which the spent cartridge casings flew from the center point where each participant fired his/her firearm. A negative number from 0 to 90 signals the spent cartridge casing flew behind and to the right of the participant; a negative number from 91 to 180 signals the spent cartridge casing flew behind and to the left of the participant. A positive number from 0 to 90 is to the front and right of the participant and 91 to 180 is to the front and left of the participant. Secondly, the mean, standard deviation, median, and mode of the spent cartridge casings for that specific test are given in inches (cm) for each individual quadrant, described above. This tells the reader how far in inches (cm) the spent cartridge casings landed from the center point in any direction. These tables are to help the reader understand more specific areas in which the spent cartridge casings landed for each of the individual tests illustrated below.

All Weapons and Tests

Figure 2 shows the percentage of the spent cartridge casings for all test positions and test firearms inclusive. 73.6% of the spent cartridge casings fell in the 90-degree section to the right and rear of the shooter (Quadrant 4). This confirms what experts cite as the location that spent cartridge casings should land in when ejected from the firearms used in this study. However, this still leaves 26.4% of the spent cartridge casings to be accounted for (Hueske, 2006; Haag, 2006). This means over 2,000 spent cartridge casings landed outside of the area most often cited by experts. It also does not consider that the test quadrant to the right and rear occupies 225 square feet and a specific cartridge casing in that quadrant could be almost anywhere in the 225 square feet.

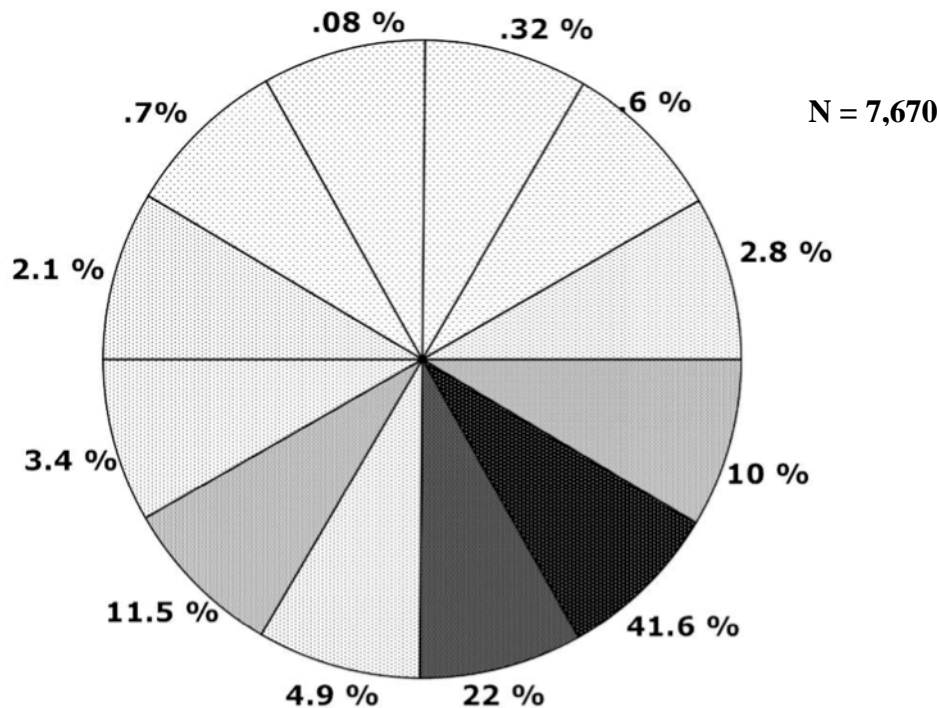


Figure 2: All Weapons/All Tests Pie Chart

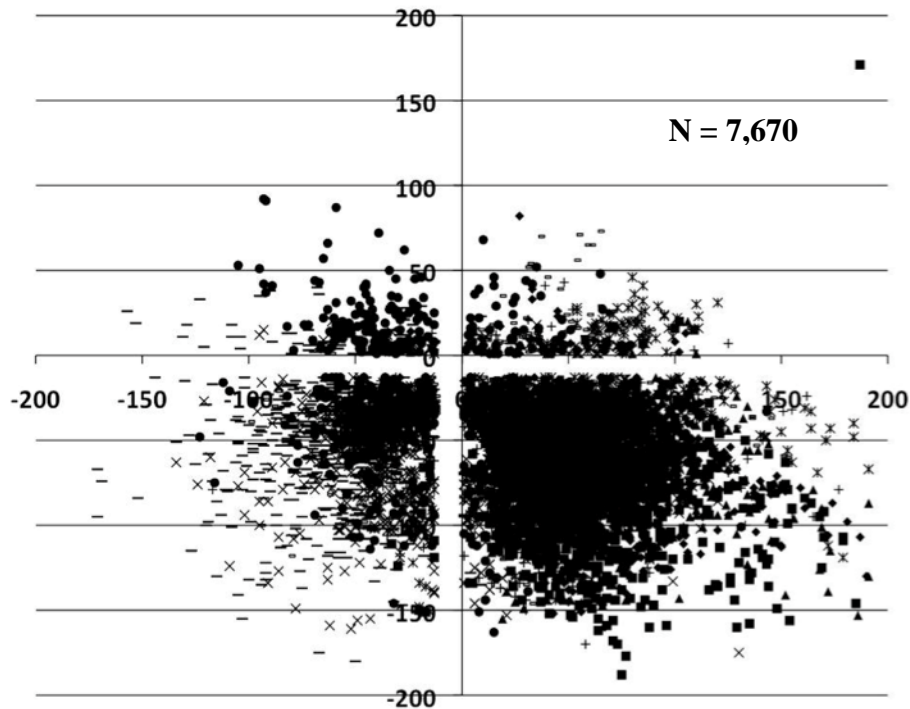


Figure 3: All Weapons/All Tests Scatter Plot

The scatter plot shown in Figure 3 more precisely illustrates the randomness of the landings of spent cartridge casings not only within the entire 360 degrees surrounding the shooter, but also in each individual quadrant. This can be seen in the distance the spent cartridge casings landed from the zero point. The minimum distance the spent cartridge casings traveled from the zero point was 3.61 inches (9.17 cm) while the farthest distance was 253.40 inches (643.64 cm) with an average of 80.93 inches (205.56 cm). The difference from the average distance to the maximum distance is then over 14 feet (4.27 m). Both the fact that over a quarter of all the spent cartridge casings landed outside the area most often cited by experts and the distance the cartridge casings landed from the zero point illustrates how using the placement of a single spent cartridge casing to determine shooter location is not as precise as it may seem.

Table 1: All Weapons/All Tests Statistics

Angles	Degrees	Quadrant	Average (in/cm)	St. Deviation (in/cm)	Minimum (in/cm)	Maximum (in/cm)
Mean	-57.77	1	55.17 / 140.13	30.72 / 78.03	3.61 / 9.17	253.4 / 643.64
St. Dev	54.87	2	53.58 / 136.09	27.47 / 69.77	13.04 / 33.12	159.14 / 404.22
Median	-54.21	3	73.93 / 187.78	32.81 / 83.34	13.45 / 34.16	195.62 / 496.87
Mode	-45	4	85.34 / 216.76	32.31 / 82.07	7.81 / 19.84	240.84 / 611.73

Weapon Position and Grip

Researchers have cited both the position the weapon was held and the grip of the weapon during firing as important variables in using spent cartridge casing ejection patterns in a shooting reconstruction (Hueske, 2006; Haag, 2006). The following tests fixed firearm position and accounted for different grips for all the firearms used in this study, but it still showed significant variability in spent cartridge casing locations. For example, the results shown in Figures 3 and 4 show a normal firearms position and grip for trained police officers, while Figures 5 and 6 involved a one-handed grip and irregular firearm position. The results shown in the previously listed figures and tables are the results obtained for all firearms used in the study.

Figure 4 shows the percentage of spent cartridge casings in each 30 degree section for test 1, a two handed correct grip. This is the standard position in which police officers are trained to shoot. Shown in this figure is that 97 % of the spent cartridge casings landed in the three 30-degree sections to the right and rear of the shooter even when eight different semi-automatic weapons were tested. The reader can see that accounting for firearm position and grip but not firearm motion, type, or ammunition further confirms that most spent cartridge casings land to the right and rear of the shooter. However, this also once again leaves some of the spent cartridges casings unaccounted for in another quadrant and again does not consider dispersal within the quadrant as a significant factor.

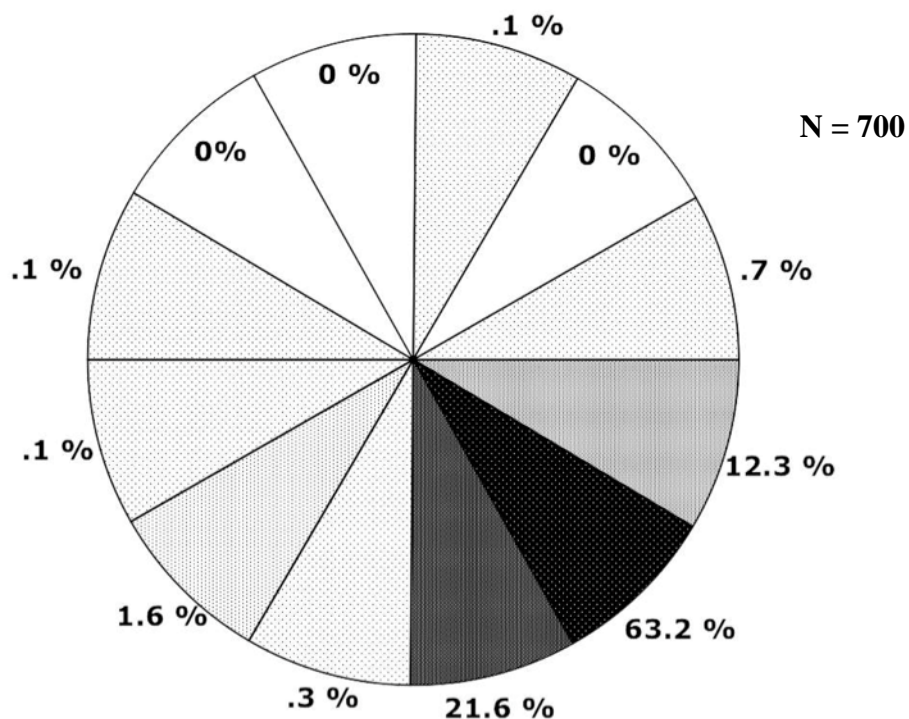


Figure 4: All Weapons Test 1 Pie Chart

The scatter plot (Figure 5) presents a much more compact dispersion of spent cartridge casings than in Figure 2. This confirms that firearm position and grip does contribute to spent cartridge casing ejection patterns for this study. Having both of these variables accounted for gives greater strength to the possibility that a spent cartridge casing ejected from these firearms, held in a tradition fashion, will land to the right and rear of the shooter like other experts say it should. Variability within the individual quadrants, however, still remains large. This can be seen in test one (Table 2) with all firearms present by the minimum, maximum, and average distance the spent cartridge casings traveled from the zero point. The minimum was 22.36 inches (56.79 cm); the maximum distance was 230.22 inches (584.76 cm) with an average of 93.88 inches (238.46 cm).

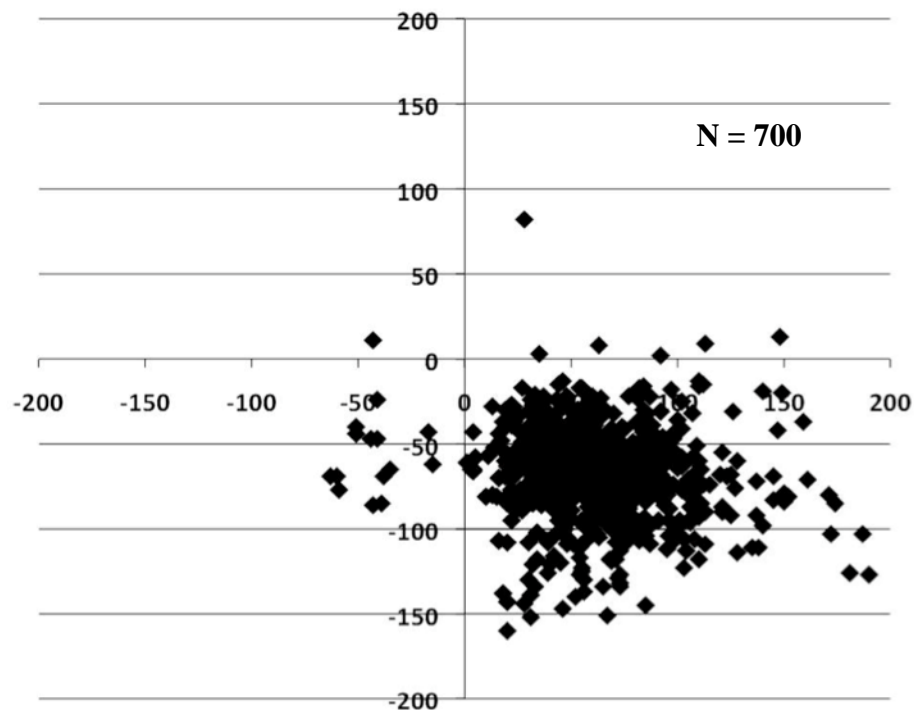


Figure 5: All Weapons Test 1 Scatter Plot

Summary information from test 1 with all firearms can be found in Table 2. Variability is once again illustrated in spent cartridge casing ejection patterns even while controlling for certain variables.

Table 2: All Weapons Test 1 Statistics

Angles	Degrees	Quadrant	Average in. (in/cm)	St. Deviation (in./cm)	Minimum (in./cm)	Maximum (in./cm)
Mean	-48.61	1	80.05 / 203.33	32.04 / 81.38	23.19 / 58.9	105.8 / 268.73
St. Dev	21.92	2	61 / 154.94	0 / 0	61 / 154.94	61 / 154.94
Median	-48.33	3	64.63 / 164.16	19.5 / 49.53	26.63 / 67.64	109.93 / 279.22
Mode	-45	4	94.65 / 240.41	31.56 / 80.16	22.36 / 56.79	230.22 / 584.76

Test six involved holding the firearm with a one handed grip pointed 22 degrees downward and cantilevered 45 degrees inward. Changing the firearm position as in this condition drastically changed the spent cartridge casing pattern from that seen in Figure 4 above. In this case, for all firearms, only 29.2% of the spent cartridge casings landed to the rear and right of the shooter and each of the 30-degree sections had some cartridge casings land in them (Figure 6). This illustrated the impact that firearm position and manipulation of the firearm by the shooter has on spent cartridge casing placements.

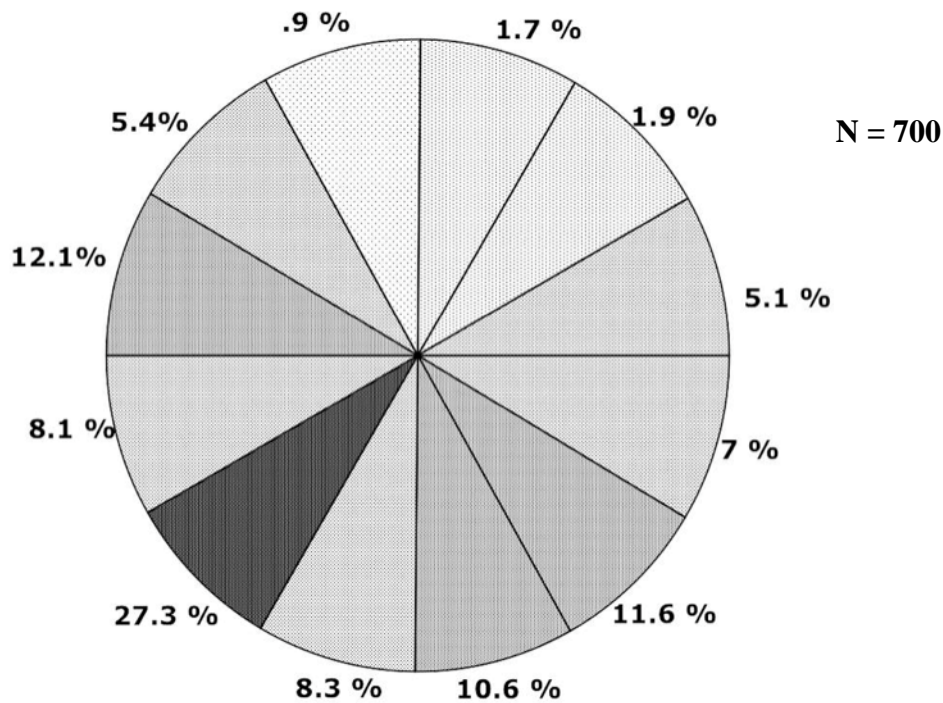


Figure 6: All Weapons Test 6 Pie Chart

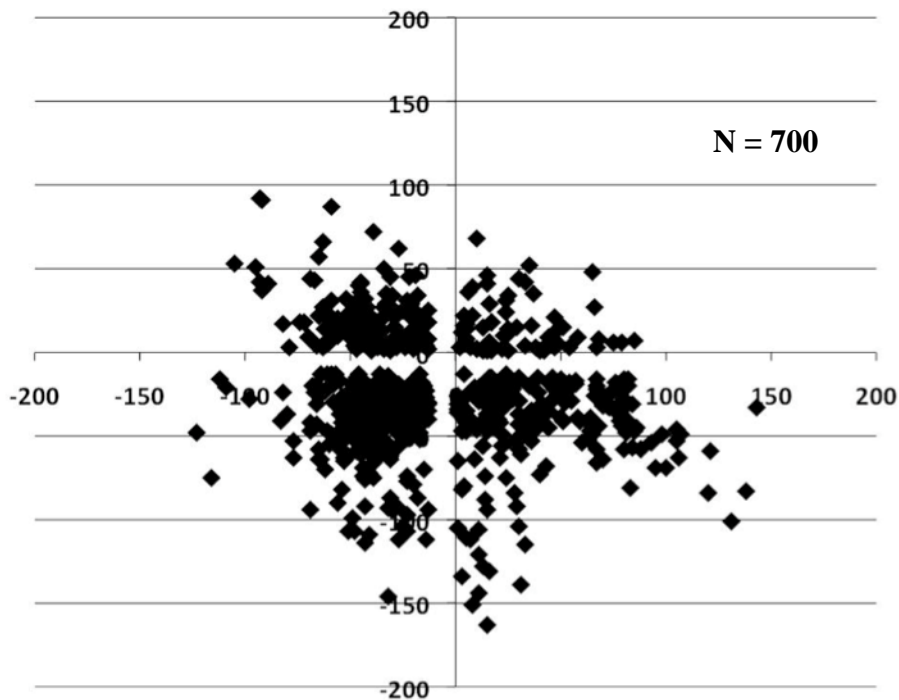


Figure 7: All Weapons Test 6 Scatter Plot

The scatter plot (Figure 7) illustrates the diversity of spent cartridge casing locations in all four quadrants versus a concentration in quadrant four as seen in Figure 4 above. Once again variability in the individual quadrants was found. For this test the spent cartridge casings landed a minimum distance of only 3.61 inches (9.17 cm) and maximum of 165.41 inches (420.14 cm) from the zero point. The rest of the information obtained from test 6 with all firearms is summarized in Table 3 below. As more and more variables are taken into account the reader can see what an impact they can have on the spent cartridge casing patterns. In this section we can observe that just changing the firearm position alone across all the firearm types and ammunition dramatically influenced the spent cartridge casing pattern observed.

Table 3: All Weapons Test 6 Statistics

Angles	Degrees	Quadrant	Average (in/cm)	St. Deviation (in/cm)	Minimum (in/cm)	Maximum (in/cm)
Mean	41.81	1	37.44 / 95.1	20.83 / 52.91	3.61 / 9.17	85.29 / 216.64
St. Dev	108.32	2	50.88 / 129.24	22.73 / 57.73	13.15 / 33.4	130.82 / 332.28
Median	-69.97	3	58.57 / 148.77	22.5 / 57.15	21.4 / 54.36	149.47 / 379.65
Mode	-63.43	4	64.97 / 165.02	33.45 / 84.96	13.6 / 34.54	165.41 / 420.14

Firearm Type

Firearm type is another variable that should to be taken into consideration with shooting reconstruction (Hueske, 2006; Haag, 2006). Eight different semi-automatic firearms were used over the course of this study. When limiting experimental variables to only one type of firearm, the Glock 17, and one firearm position, the standard one, the following results for the ejection patterns were found.

Figure 8 illustrates the spent cartridge casing variation found when using only one firearm, one test position, and no firearm movement. It is then expected that this test with a firm correct grip on the firearm and no motion should result in the most compact distribution of spent cartridge casings the reader has seen so far. Our results indicated that almost 50% of the spent cartridge casings landed in one 30-degree section to the right and to the rear of the shooter while 81% (an additional 31%) landed in two 30-degree sections to right and rear. However, 7.5% of the spent cartridge casings landed outside of the quadrant to the right and rear. This is greater than the 3 % (Figures 4 and 5) of the spent cartridge casings ejections that were found outside of quadrant four when firearm type was not accounted for.

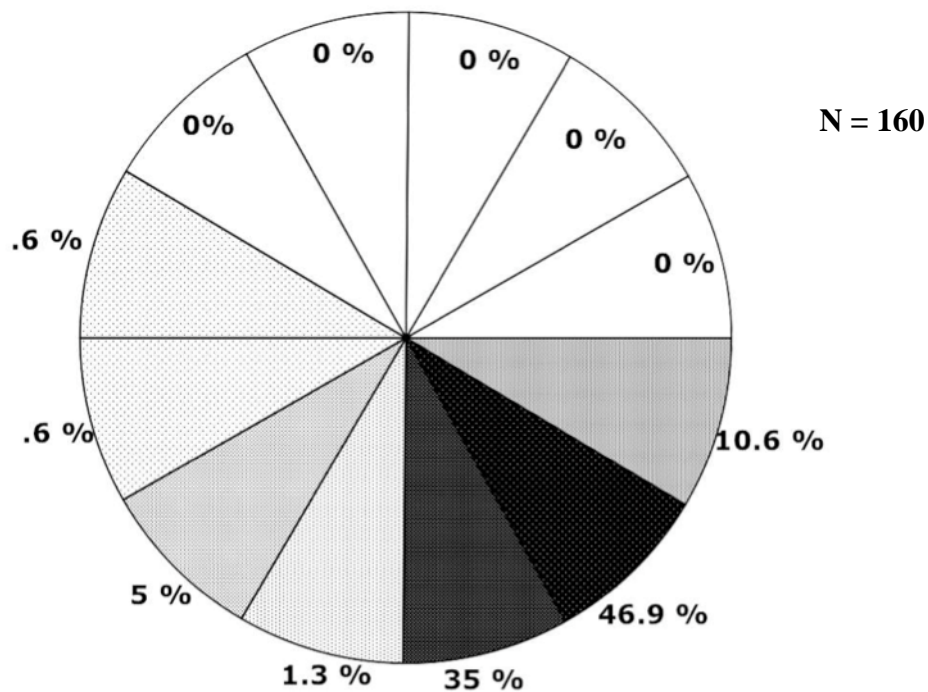


Figure 8: Glock 17 Test 1 Pie Chart

The scatter plot (Figure 9) shows the actual spent cartridge casing locations for the Glock 17. The minimum distance traveled by the spent cartridge casings from the zero point was 22.36 inches (67.64 cm) and the maximum was 157.97 inches (401.24 cm). This is almost two feet (.6 m) from the shooter at a minimum and over thirteen feet (3.96 m) at a maximum. While a rather compact dispersion was found in quadrant four it is important to remember the variability found here in the difference between the minimum and maximum distances when using only one spent cartridge casing to determine shooter location.

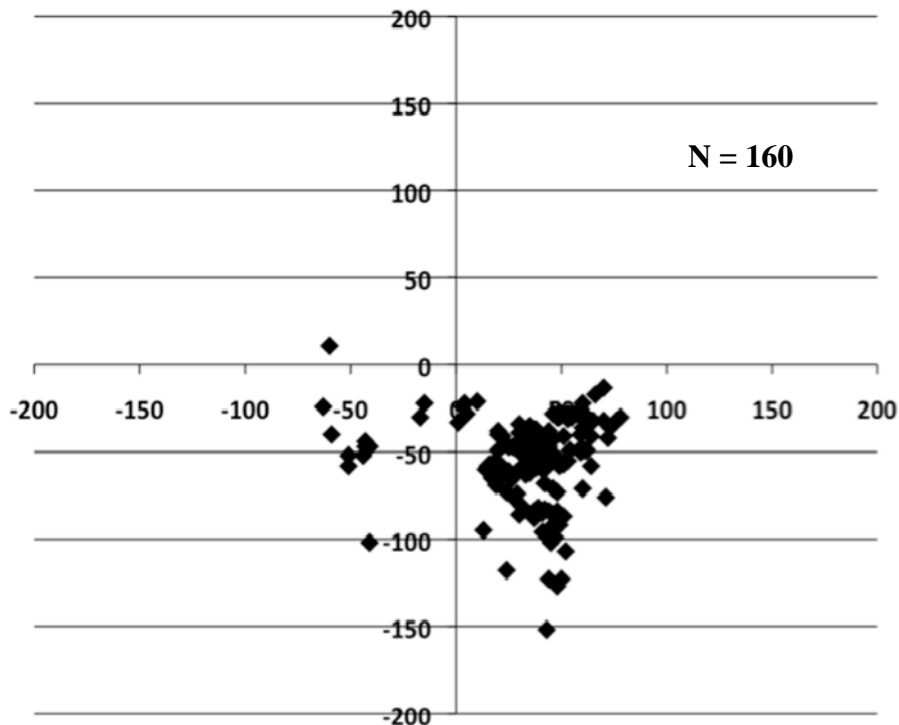


Figure 9: Glock 17 Test 1 Scatter Plot

Table 4: Glock 17 Test 1 Statistics

Angles	Degrees	Quadrant	Average (in/cm)	St. Deviation (in/cm)	Minimum (in/cm)	Maximum (in/cm)
Mean	-57.13	1	0 / 0	0 / 0	0 / 0	0 / 0
St. Dev	31.32	2	61 / 154.94	0 / 0	61 / 154.94	61 / 154.94
Median	-56.38	3	65.05 / 165.23	21.7 / 55.12	26.63 / 67.64	109.93 / 279.22
Mode	-63.43	4	71.46 / 181.51	20.99 / 53.31	22.36 / 56.79	157.97 / 401.24

Movement

Movement of the firearm during firing created a very different pattern of spent cartridge casings. Again restricting the study of the distribution pattern to the cartridges ejected from the Glock 17, we found the distribution as shown in Figure 10. This figure represents test eight and illustrates spent cartridge casings ejected from a firearm held with a two-handed grip, pointed downwards 22 degrees, and the shooter going through a 45 degree body rotation with his/her weapon. Spent cartridge casings landed in all but one 30-degree section. Nearly 30 % landed to the left and rear of the shooter. This was very different from test one with the same semi-automatic weapon. From this test, weapon motion is evident to have contributed to the location of spent cartridge casings as the reader can see from comparing Figure 8 with Figure 10.

The spent cartridge casing locations shown in Figure 10 are found in a 360-degree circle about the shooter illustrating the impact of firearm motion on the exact location of spent cartridge casings. Variability within quadrants is also impacted by firearm motion as the reader can see in the distances traveled by the spent cartridge casings; 7.21 inches (18.31 cm) to 143.13 inches (363.55 cm) away from the zero point. This gave an average distance of 44.43 inches (112.85 cm) from the shooter or a difference of over 8 feet (2.44 m) from the maximum distance. As noted elsewhere the pilot studies where the shooters were able to hold the firearm in the test position and shoot at a target while they were moving rapidly produced a much greater scatter of spent cartridge casing to the left of the shooter than was obtained here.

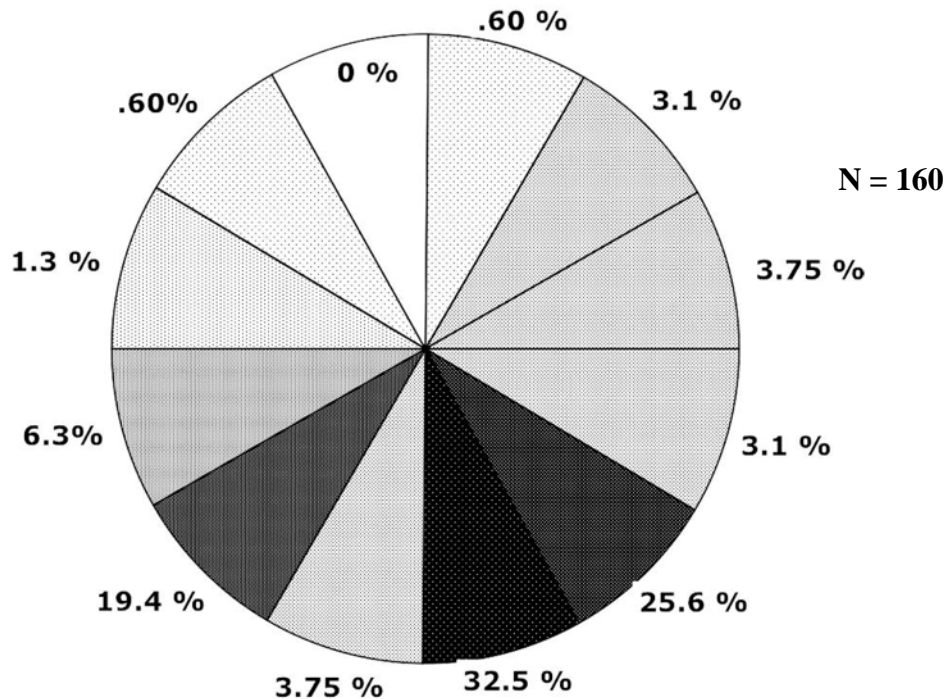


Figure 10: Glock 17 Test 8 Pie Chart

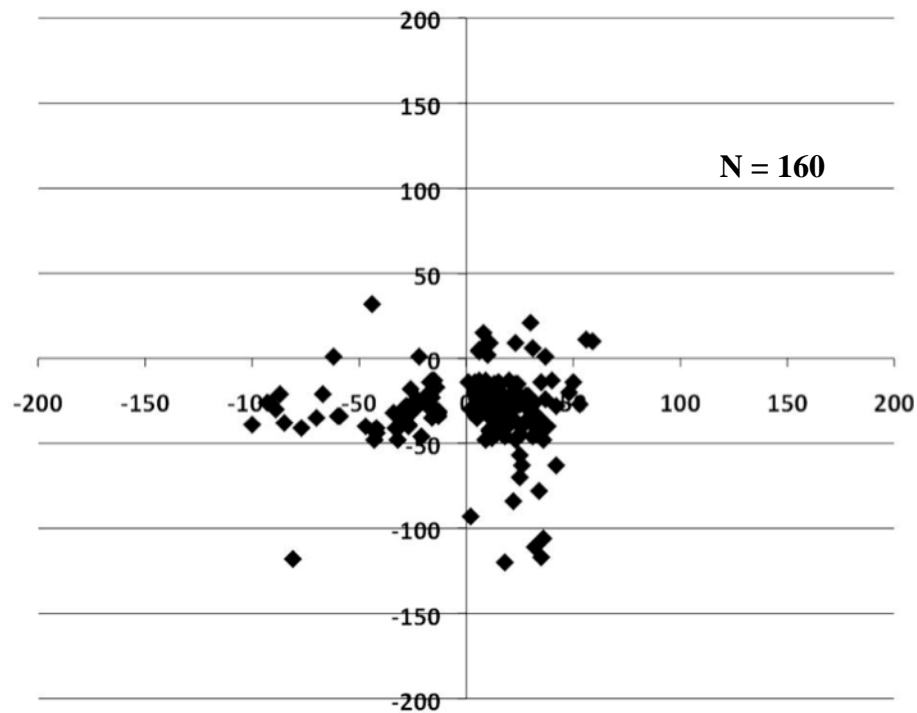


Figure 11: Glock 17 Test 8 Scatter Plot

Table 5: Glock 17 Test 8 Statistics

Angles	Degrees	Quadrant	Average (in/cm)	St. Deviation (in/cm)	Minimum (in/cm)	Maximum (in/cm)
Mean	-70.66	1	26.39 / 67.03	18.31 / 46.51	7.21 / 18.31	59.84 / 151.99
St. Dev	57.85	2	46.15 / 117.22	21.24 / 53.95	22.02 / 55.93	62.01 / 157.51
Median	-69.11	3	52.04 / 132.18	26.03 / 66.12	19.85 / 50.42	143.13 / 363.55
Mode	-63.43	4	42.93 / 109.04	21.56 / 54.76	14.04 / 35.66	122.12 / 310.18

Ammunition Type

Ammunition type is yet another variable said to affect spent cartridge casing patterns (Hueske, 2006; Haag, 2006). In this experiment both the Glock 23 and Sig Sauer 229 used 40-caliber ammunition from the same Federal lot. In these tests when the ammunition is held constant but the firearm is altered and later when the manipulation of the firearm is altered, very significant differences were found among the spent cartridge casings. Therefore, using two different weapons (Glock 23 and Sig Sauer 229) both containing the same ammunition from the same Federal lot, the reader can see variability still exists. Even when firearm type, firearm position, firearm movement, grip, and ammunition type are accounted for, significant variability still existed in where spent cartridge casings landed during the study. This is illustrated in

Figures 12 - 13. These figures show that most often the spent cartridge casings land to the right and rear of the shooter with both firearms but there is still a very significant dispersal within the right rear quadrant. In Figures 14 - 15 where a specific movement pattern was added, we still found significant variability in the placement of the spent cartridge casing. The scatter plots which follow show the difference on the variability in spent cartridge casing locations even within the same quadrant when ammunition is held constant.

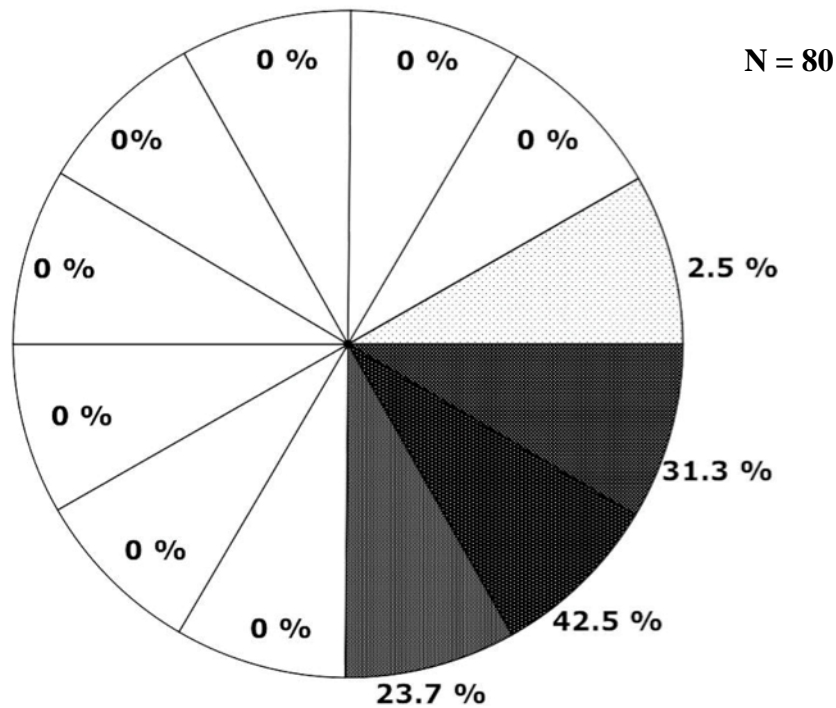


Figure 12: Glock 23 Test 1 Pie Chart

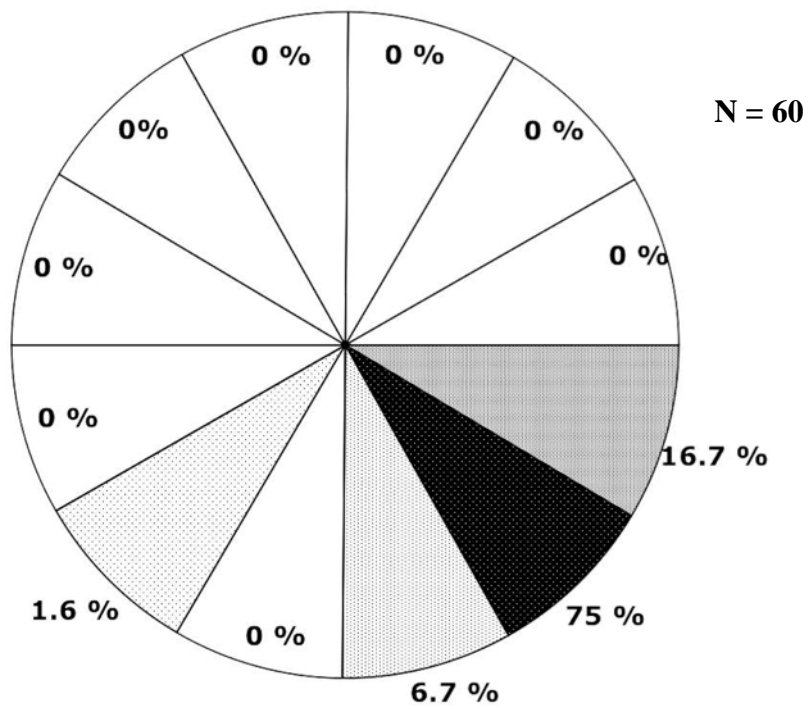


Figure 13: Sig 229 Test 1 Pie Chart

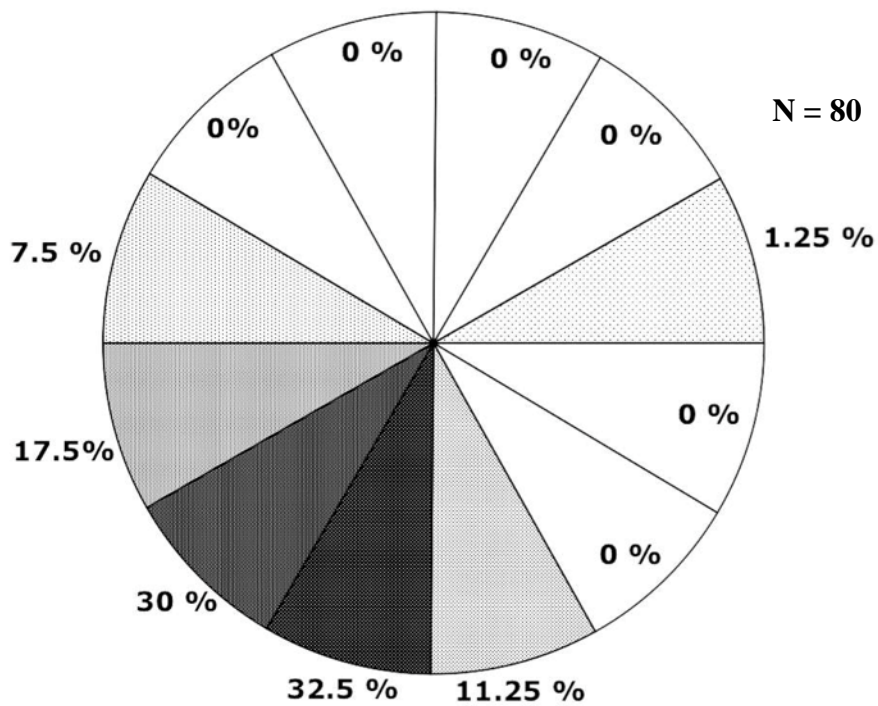


Figure 14: Glock 23 Test 4 Pie Chart

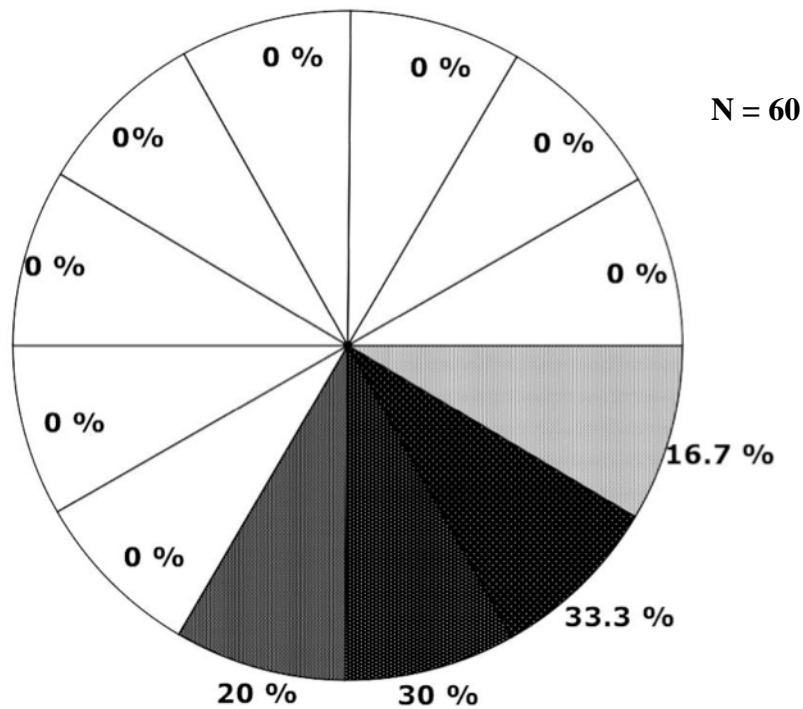


Figure 15: Sig 229 Test 4 Pie Chart

The scatter plots below (Figures 16-19) of the same semi-automatic firearms and test positions as shown in Figures 12 – 15 above, show in detail the dispersion of the spent cartridge casings. The Glock 23 scatter plots show a vertical tendency of spent cartridge casing locations, while the Sig 229 scatter plot indicates a more horizontal trending of spent cartridge casings. In both cases, however, significant variability and uncertainty existed about the location of where a spent cartridge casing would come to rest. This again emphasized the imprecision of identifying shooter location based solely on the location of a spent cartridge casing.

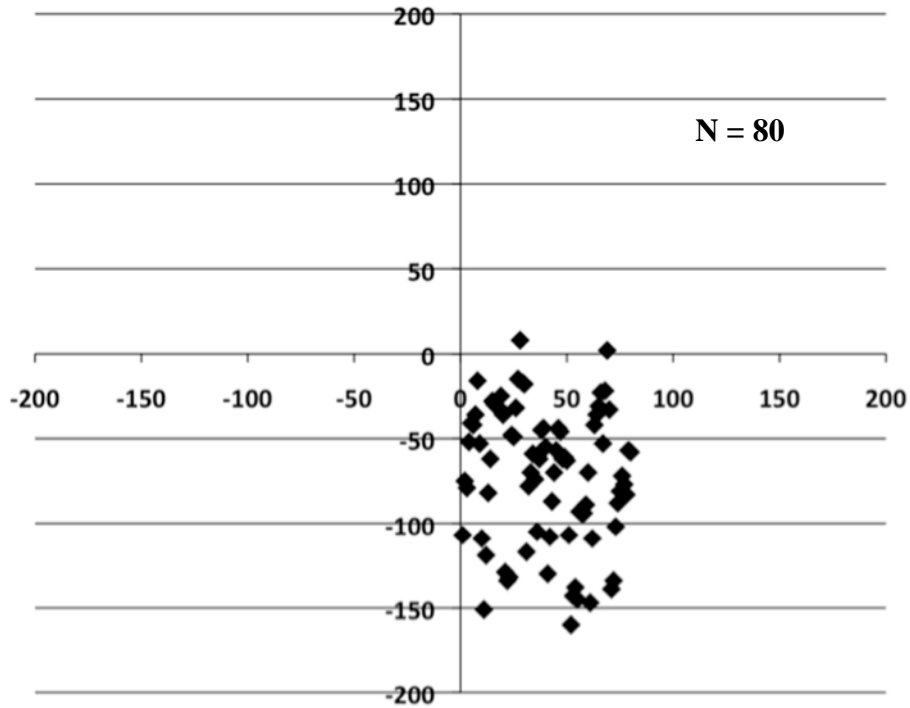


Figure 16: Glock 23 Test 1 Scatter Plot

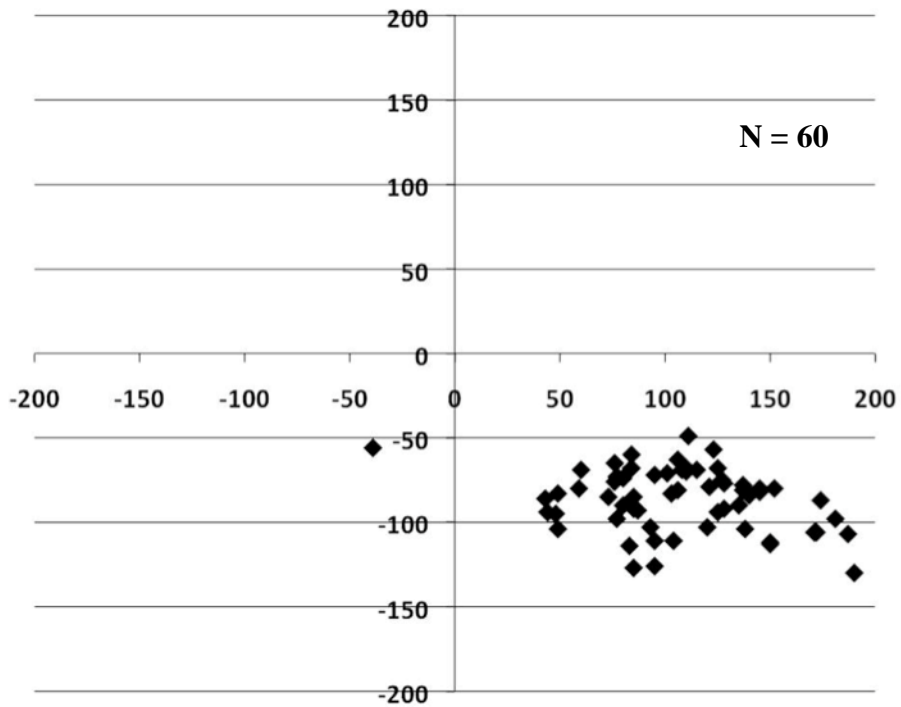


Figure 17: Sig 229 Test 1 Scatter Plot

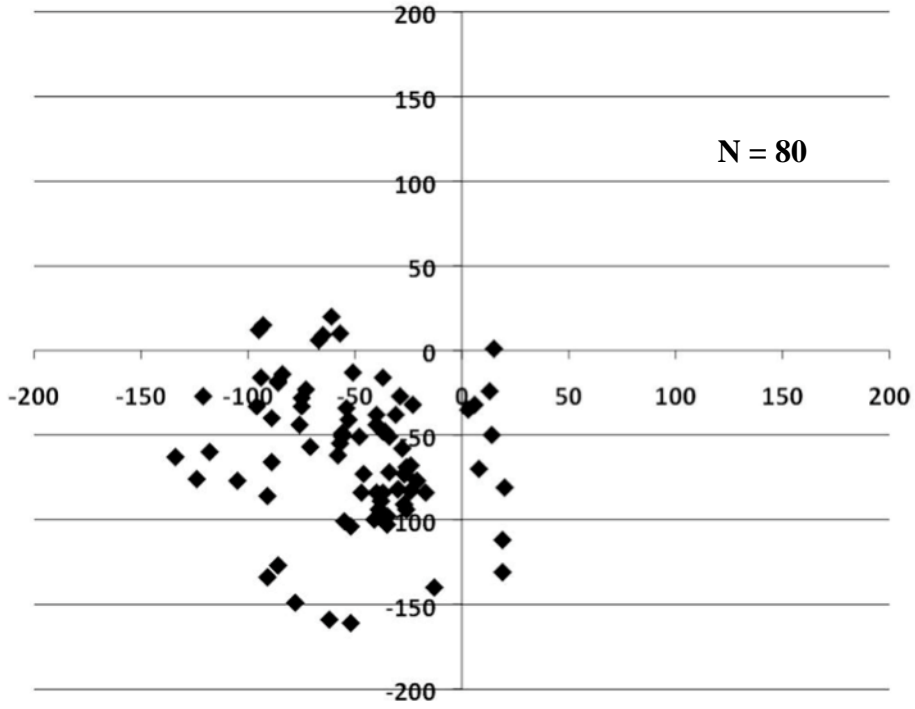


Figure 18: Glock 23 Test 4 Scatter Plot

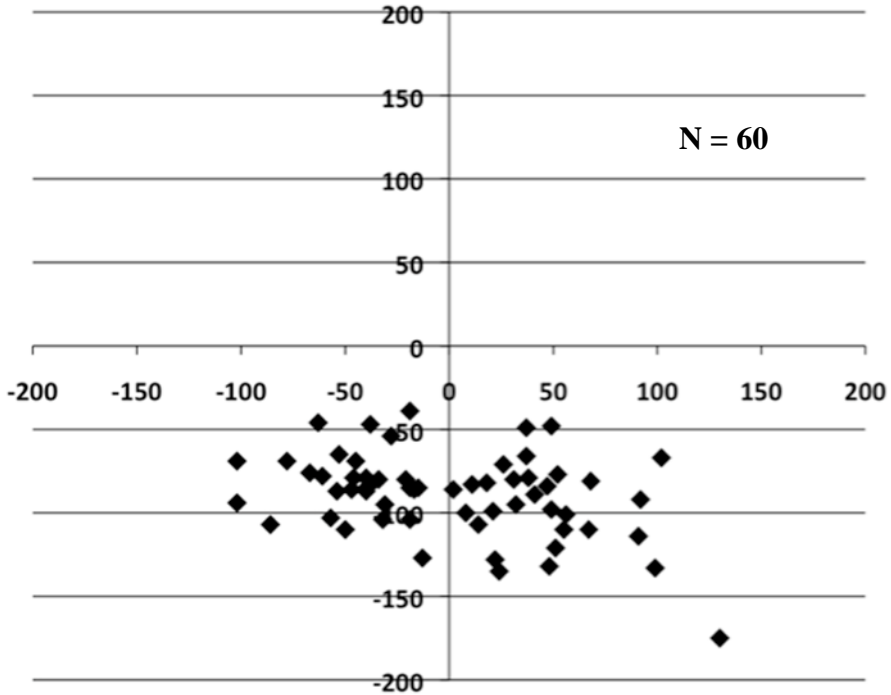


Figure 19: Sig 229 Test 4 Scatter Plot

Not all of the variability in this test can be attributed solely to the ammunition variable. It is thought that even with all of the human factors held constant as conducted in this study, each person will still hold or fire the firearm in his/her own idiosyncratic fashion. Further, there may be variables in the firearm itself, such as the placement and sequence of the bullet in the magazine, that contribute to differences. The only way to really determine the effect of ammunition on spent cartridge casing location is to control for all of the firearm variables and most importantly eliminate all of the human variables by not having humans fire the firearm. As previously noted, ammunition manufacturers inform us there is still a 3% variability when all of these ammunition factors are accounted for. The effects of this variability upon cartridge case ejection is not known but may also contribute to the uncertainty involved in attempting to make determinations from the ejection pattern of a particular handgun and ammunition.

Conclusion

As this study has shown, factors previously listed including firearm design, firearm condition, ammunition type, position firearm is held when fired, movement of the firearm and person during firing, and grip factors such as how, where and how tightly the firearm is held during firing can affect the locations of spent cartridge casings (Hueske, 2006). This study illustrated that even when accounting for the above factors, significant variability occurred in the landing locations of spent cartridge casings. This variability must be considered before efforts are made to establish the location of a shooter based solely on the location of even an undisturbed spent cartridge casing or a group of cartridge casings.

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