Multi-disciplinary approach to a use-of-force investigation: case study

Geoffrey Thor Desmoulin*
and Marc-André Nolette

GTD Scientific Inc.,
2037 MacKay Ave.,
North Vancouver, BC, V7P 2M8, Canada
Email: gtdesmoulin@gtdscientific.com
Email: manolette@gtdscientific.com
*Corresponding author

David M. Blake

Blake Consulting.,
P.O. Box 784,
Brentwood, CA, 94513, USA
Email: Dave@Blake-Consulting.com

Abstract: Investigating a violent encounter can be a complicated endeavour as evidence is often incomplete or misleading. However, with the right combination of expertise, it is frequently possible to establish a verifiable fact pattern. The work presented illustrates this point by reviewing the investigation of a violent police-citizen encounter resulting in a loss of life. The ensuing discussion uses video analysis of body-worn camera footage as the overview for the events under review before quantifying them using both testing and literature. Individually, video forensics, human factors psychology and biomechanics allowed a greater understanding of the timing involved in the discharge of the firearm, relative movement patterns during the altercation and a plausible sequence of shots fired. Using these multi-disciplined approaches together however, provided validation of the same.

Keywords: injury biomechanics; video analysis; human factors psychology; perception-response-time; forensics.

Reference to this paper should be made as follows: Desmoulin, G.T., Nolette, M.A. and Blake, D.M. (2025) 'Multi-disciplinary approach to a use-of-force investigation: case study', *Int. J. Forensic Engineering*, Vol. 5, No. 3, pp.188–205.

Biographical notes: Geoffrey Thor Desmoulin, PhD, RKin, PLEng, is the Principal of GTD Scientific Inc. (www.gtdscientific.com). GTD is an internationally recognised forensic engineering firm with focused practice areas in injury biomechanics, incident reconstruction and the science of violence®. GTD has been retained in significant complex injury litigation cases that involve Police Department use-of-force, homicide investigations, TASER International, and catastrophic vehicle collisions, to name just a few examples. Furthermore, landmark testing and shooting reconstruction methodology developed by Dr. Desmoulin was recently upheld as reliable and admissible by the US Federal District Court for the 9th District of California.

Marc-André Nolette, MSc, is an Injury Biomechanist at GTD Scientific Inc. He received a Master's degree in Biomedical Physiology from Simon Fraser University in 2012 and a Bachelor's degree in Mechanical Engineering from Universté de Sherbrooke in 2009.

David M. Blake, PhD, is a retired California peace officer and a court-certified expert on human factors psychology and police practices with a focus on officer-involved-shootings He is the owner of Blake Consulting and Training.

1 Introduction

Violent encounters that result in death or significant injury often result in large amounts of evidence that require specialised forensic analysis. Complex cases, especially those involving police shootings, will likely benefit from a multi-disciplinary forensic approach (Katz et al., 2015). A multidisciplinary forensic approach can produce sound assessments through a combination of scientific analysis and testing allowing for an empirically founded interpretation of the facts. This case study aims to present a multi-disciplinary approach to a police shooting incident where forensic testing or analysis was conducted in the areas of digital media evidence (video), biomechanics, and human factors. The culmination of which provided a comprehensive understanding of the case under review.

2 Incident brief

This incident began when a suspect fled from a police officer on a bicycle after the officer attempted to conduct a traffic enforcement stop. The officer stated he pursued the suspect in his vehicle for a short distance before the suspect crashed his bike. The suspect fled on foot, and the officer said he ultimately gave chase. The suspect eventually led the chase to a small courtyard located between residential buildings, where he stumbled. The police officer stated he attempted to arrest the suspect, but the suspect continued to resist.

Responding to the suspect's resistance, the officer stated he attempted to use his conducted energy weapon (CEW) multiple times but was ineffective. Hence, the officer then transitioned to using his Streamlight SL20 flashlight (Streamlight SL20) as an impact weapon. Body-worn-camera (BWC) video evidence appears to show the officer delivered blows to the suspect's shoulders, and hips. However, these strikes were also ineffective at overcoming the suspects resistance allowing for the application of restraints. The officer then seems to pause while standing over the suspect when the suspect grabbed the officer's flashlight and was ultimately able to disarm him of it. The officer stated the suspect stood and presented the flashlight aggressively. In response, the officer drew his firearm and fired seven shots striking the suspect in the front, left side and back. The suspect then dropped the flashlight and fell into the nearby bush. The suspect was declared deceased.

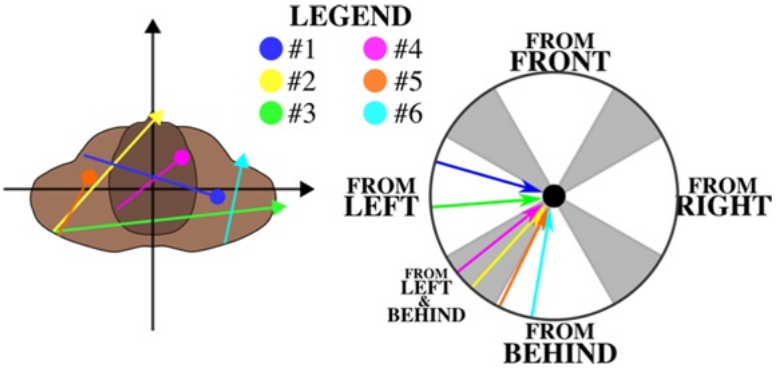
3 Injuries sustained

The suspect received seven gunshot wounds during the incident that resulted in his death. He also sustained multiple bruises and minor lacerations that were important for the overall biomechanical assessment, but for brevity are not discussed here. Focus is placed on the gunshot wounds the suspect received. A summary description of the injuries in question, with each gunshot wound numbered as per the autopsy report is shown in Table 1 and Figure 1. Hence, these numbers do not represent the order in which these injuries were sustained.

Table 1 Summary of the location and directions of gunshot wounds

	Entry	*Final position*	*Direction*
#1	Lower left of abdomen	Recovered in lower right chest cavity	Left to right, front to back, and up
#2	Lateral right mid-back	Exits left chest	Left to right, back to front, and up
#3	Same as #2	Exits the posterolateral upper right chest wall	Left to right, back to front, and up
#4	Superior parietal left scalp	Recovered in right temple above right ear	Left to right and back to front
#5	Lateral lower left shoulder	Recovered near mid-left clavicle	Left to right, back to front, and up
#6	Lateral Mid Right back	Exits on the lower anterior right shoulder	Back to front and up
#7	Posterior mid-left forearm	Exits at posterolateral left elbow	Right to left, back to front, and up

Figure 1 Topographical shot orientation estimates (see online version for colours)



Most bullets penetrated on the left side of the suspect's body as described above. Three shots were recovered inside his body, while the other four entry wounds had matching exit wounds, with wound #2 and #3 sharing the same entry.

4 Video overview

In this case, the officer was wearing an Axon body-worn-camera (BWC) that captured portions of this incident. The BWC video was a key piece of evidence allowing for a forensic analysis of the interaction between the officer and the suspect involved. The BWC activation was delayed by the officer and therefore did not record audio for the first 30 s of the encounter. Due to the lack of audio and limitations within the BWC frame rate and field of view, each gunshot's timing was inconclusive. Additionally, due to low lighting, blur from movement, and the camera's field of view, the suspect's motion was challenging to identify. However, a forensic analysis did provide enough foundational information for subsequent analysis and testing.

The forensic video expert took the following actions:

a verified the file hash

b increased exposure levels and adjusted the colour balance

c identified the frame rate of 29.970 frames per second (fps)

d inserted an overlay frame counter and timer to the video

e provided enhanced video to the defence experts in uncompressed tag image file format (TIFF)

f confirmed the time between frames as constant at ~0.033 s.

This manuscript contains figures that represent frames from the officer's BWC. The frames demonstrate informative points applicable to the analysis. For instance, the time between key points was measured via the number of frames that existed between one moment and the next (i.e., 15 frames × 0.033 s = 0.495 s).

In summary, when taken in context, particular frames of the officer's BWC video were instrumental in linking theory and testing that ultimately allowed for presenting a scientifically sound timeline of events. The following narrative provides an overview of points captured by the officer's BWC. The numerical designator initially assigned to the frame, and the time elapsed from the BWC footage start is referenced.

At the outset, the suspect appears lying on the ground with the officer positioned above. The officer appears to be attempting to 'drive-stun' the suspect with seemingly no visible influence on the suspect's behaviour. The suspect appears to try to stand, and the officer responds by pushing him in what seems to be the sternum area using the butt of his flashlight. The officer makes a second attempt to 'drive-stun' the suspect with similar results.

During the next several seconds, the suspect attempts to 'smack' the conducted energy weapon (CEW) away and again tries to stand. The suspect can be seen in the kneeling position before the video blurs due to circular and repetitive motion indicating the officer is likely striking the suspect with his flashlight. When the video quality returns (approx. 5 s later), the suspect appears to be on the ground to the officer's left. Additional movement is seen from both parties, with the officer likely providing additional flashlight strikes to the suspect.

The BWC field of view pans up and to the left, allowing for a visual of the officer's shadow on the left side of the frame. The outline shown in Figure 2, provides support for the officer's statement regarding holstering his CEW (left hip holster) proximal to this

point in time. This moment spans from frames #3234 to #3278 (21.77 to 23.24 s). Figure 2 also shows the suspect looking in the officer's direction shortly before he lunges to the right-hand side of the frame. Subsequent low noise frames appear to show the suspect and officer struggling for control of the flashlight (Frames #3324-3334).

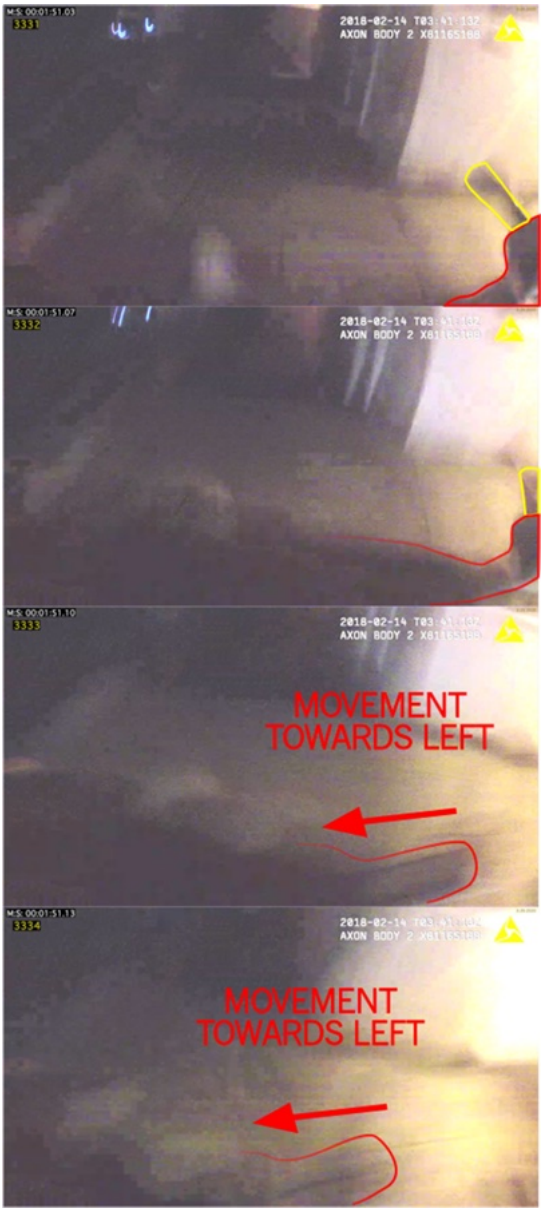
Figure 2 Frame #3255 (22.5 s) is consistent with the officer reaching for his duty belt with his left hand as the suspect looks on (with suspect anonymised) (see online version for colours)

Figure 3 shows the two men struggling for control of the flashlight. On the left side of the frame, the officer's left hand appears to be placed on the suspect's shoulder as the suspect's right arm is extended out of frame and grasping the flashlight at the frame's extreme right.

Figure 3 Frame #3324 showing the physical struggle (see online version for colours)

As shown in Figure 4, the red outline is believed to represent the suspect's arm reaching from left to right and grasping the flashlight, identified as the yellow outline. On the third frame of Figure 4, the arm appears to move back in a leftward direction. While the flashlight cannot be located within this frame subsequent frames suggest that the suspect gained possession of the flashlight no earlier than at frames #3332/3333 (25.04/25.07 s).

Figure 4 Frames #3331 to #3335 (25.00 to 25.14 s) tracking movement of the suspect's arm and the officer's flashlight (see online version for colours)



No more than 0.3 s later, light is seen shining from the left side of the frame, suggesting that the flashlight has been taken away from the officer and is now in possession of the suspect.

At frame #3359 (25.94 s), it is possible to discern the officer's right arm starting to appear in the bottom right corner of the frame as it rises and advances to a shooting position. At frame #3366 (26.17 s), the officer has rotated to his left, facing in the direction occupied by the suspect, and his right arm appears to straighten fully as both

hands can be seen supporting his firearm. It should be noted the officer stated he was in the process of firing as the weapon extended out toward the suspect. However, no muzzle flash or other distinct visual or auditory markers are available to confirm this fact.

It is possible to identify two frames where the suspect's position appears discernible. The first position, at frame #3372 (26.37 s), appears to show the suspect crouched forward with at least one hand on the ground (Figure 5). At frame #3394 (27.10 s), he appears to have stood up with his right foot flat on the ground and his left foot pointing down in plantar flexion.

Figure 5 Frame #3372 (26.37 s) showing the suspect in crouched position (see online version for colours)

Shortly before that, at frame #3390 (26.97 s), it is possible to locate the flashlight. It can be seen pointing in an upward direction at the suspect's thighs. Careful examination of the frame reveals that the butt of the flashlight appears on or near the ground as the suspect's foot can be seen to the right of the flashlight. The position of the flashlight suggests that it had recently been dropped and was just then close to or hitting the ground.

In the frame (frame #3394) shown in Figure 6, it is possible to see that the suspect's left side is facing the officer. The suspect's right foot is also visible next to the flashlight as well as the suspect's left leg partially extended closer to the camera.

Within the next second, the suspect can be seen collapsing into the bush to his right. Following this, at frame #3429 (28.27 s), it is possible to observe the officer's left hand lowering from the grip of his pistol (Figure 7). Meanwhile, the officer's right arm appears to remain mostly extended as he points his firearm in the general direction of the suspect.

The officer appears to reach for his chest-mounted radio before the audio can be heard for the first time. Past this point in the video, the altercation appears to have ended as the suspect seems incapacitated, and the officer informs dispatch of 'shots fired' and asked for Emergency Medical Services.

From the moment the suspect reached for the flashlight to the lowering of the hand from the duty pistol, no more than 5 s elapsed.

The events detailed here are also shown below, in Figure 9, as a visual timeline.

Figure 6 Frame #3394 (27.10 s) showing the suspect in a standing position (see online version for colours)

Figure 7 Frame #3429 (28.27 s) showing the officer lowering his hand from his weapon (see online version for colours)

5 Human factors psychology and biomechanics

5.1 Establishing a shooting timeline.

The law enforcement officer in this case said that after his flashlight was taken, the suspect stood up and moved as if to strike the officer with it. In response, the officer said he immediately drew his weapon and fired his first round from the hip. The officer continued to fire six more rounds while moving into a more traditional two-handed shooting platform and stopped firing only when he perceived the threat from the suspect to have ended. Unfortunately, due to the absence of audio (i.e., audible shots) and visual indicators (i.e., muzzle flash, slide movement), the BWC did not provide conclusive evidence of the first shot, the location of the suspect as shots were fired, or when the shots ceased.

The lack of evidence on these points provided conflicting opinions on whether the suspect was a threat to the officer prior to being shot. Additionally, the number of rounds fired as well as the ballistic impact locations in the suspect's flank and posterior shoulder were also points of contention. Therefore, a forensic evaluation of these issues through the application of human factors psychology and biomechanics were essential.

The BWC video is consistent with the officer's statements of struggling for control of the flashlight using his right hand just prior to drawing his weapon also with his right hand. Hence, several hundred milliseconds after the flashlight appears in the suspects control, the officer is seen drawing from a right-sided holster (determined by evidence photographs) and presenting his firearm. Therefore, the video evidence indicates the officer did not start shooting until after the suspect took the flashlight from his right hand. Based on the evidence and for the purpose of this discussion, the zero point for the shooting timeline begins when the flashlight is taken from the officer's right hand (see Figure 9).

The next step was to establish a timeline for the seven shots that were fired by the officer. Relevant publications were independently reviewed, however, only one experimental result was found describing the speed an officer can draw and fire from the hip. The research (Lewinski et al., 2015) suggests that drawing a pistol and firing a single shot in a close contact (combat tuck) position takes, on average, 1.44 ± 0.31 s. A separate series of laboratory experiments identified the timing between rounds fired in a series. These studies provided mean times of 0.28 ± 0.06 s (Lewisnki et al., 2014); 0.27 ± 0.04 (Haag and Greenberg, 2000) and 0.23 ± 0.04 s (Jason, 2010). An aggregate of these results demonstrate that a more skilled individual might fire within 0.8 s with a firing rate of 0.16 s between rounds while a lesser trained individual might take as long as 2.0 s with a firing rate of 0.40 s between rounds (95th percentile with normal distribution). Using the timing elements extracted from research, it is possible to obtain a probable timeline of the instants surrounding the shooting, as shown in Figure 9.

Due to arguable limitations in combining and generalising the discussed laboratory research results to this case, additional testing was conducted. A test subject with considerable firearms training was asked to fire seven rounds from a comparable retention holster. Unlike the methods used in the research cited, the test subject was asked to begin firing as soon as possible when his weapon cleared the holster (i.e., fired from the hip) and to continue firing while moving toward a two-handed stance. The results of the testing suggest timings to draw and fire (M = 0.92s, SD = 0.04) and the total time to draw and fire seven rounds from a level II holster (M = 2.04s, SD = 0.05s) to be faster than the cited research indicates. We attribute the faster speed to the shooting method, an enhanced state of physiological arousal, the holster used, as well as the additional training of the participant (Blake and Bartel, 2018). It is important to note the shooting officer was a firearms instructor and the method used (i.e., shooting from hip and continuing to fire as a two-handed platform was obtained) are more generalisable to this incident (see Table 2).

Table 2 Timing of seven rounds fired from a firearm carried in a level 2 holster (in seconds)

Shot #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Total*
	0.98	0.18	0.17	0.22	0.17	0.20	0.18	2.1
	0.96	0.18	0.21	0.18	0.18	0.18	0.19	2.08
	0.88	0.17	0.20	0.19	0.17	0.19	0.18	1.98
	0.89	0.19	0.19	0.20	0.18	0.20	0.18	2.03
Mean (*SD*)	0.92 (0.04)			0.18 (0.012)				2.04 (0.05)

Fastest 0.17, Slowest 0.22.

5.2 Application of perception-response-time (PRT) and human factors psychology

The application of laboratory based PRT results should not be considered as a de-facto template for real world events, but rather an important tool for understanding human response time in context (Francis et al., 2020). As stated, the gunshot wounds to the suspects back, side and head were in contention. To some, shots to the back may be viewed as evidence that the shooting victim was not a threat to the shooter. However, the inhibition of a rapidly occurring motor response (i.e., finger press) must be evaluated through the lens of human capabilities and limitations defined within the PRT research (Campbell et al., 2013; Francis et al., 2020).

In this case, the officer perceived the suspect raising up with the flashlight in a threatening manner as the stimulus to fire his weapon. As the officer is drawing and presenting his weapon, the position of both men changes with the suspect turning approximately 90 degrees away from the officer in less than a second from taking the flashlight (see movement validation below). In this short span of time, the research on perception and attention indicates that the officer more-likely-than-not, did not perceive a significant change to his environment as he began firing. One must consider the influence of adverse lighting conditions, ambiguity in the suspects intentions, cognitive load, shifts in attentional focus, and the short stimulus onset asynchrony between the start and plausible stop shooting stimuli (Campbell et al., 2013; Francis et al., 2020; Schmidt and Lee, 2014; Vickers and Lewinski, 2012).

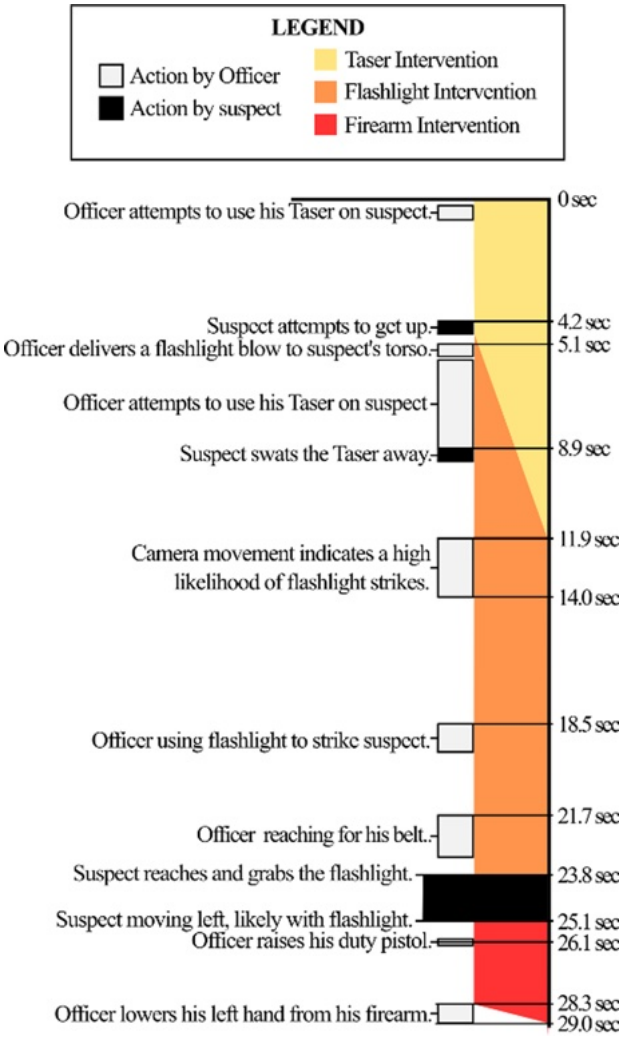
A secondary issue of interest is when the officer ceased firing in consideration of the threat posed by the suspect. We independently agreed the first visual indication of a change in the suspect's threat level appears at approximately 1.9 s when the flashlight can be seen falling from the suspect's hand to the ground. While we cannot state the officer perceived this change at that moment, it is a reasonable point in time for a stop shooting measurement. At the point when the flashlight is dropped, the analysis indicates the officer was in the process of firing his weapon. It was also assumed, due to lack of objective information indicating otherwise, the officer ceased firing when his support hand dropped away from his weapon 3.2 s later. The time between these two points is 1.3 s, as laid out in Figure 8.

Controlled laboratory experiments have shown that officers, engaged in rapid trigger presses, continue to fire zero to four rounds up to 1.5s after an expected and salient stop signal (Jason, 2010; Lewinski et al., 2015; Lewinski and Redmann, 2009; Lewinski et al., 2014). Assuming the officer saw the flashlight drop and perceived the decreased threat, the research suggests the officer's time to stop shooting was within a reasonable limit.

5.3 Movement pattern identification

As with all video analysis investigations, one may only assess the still photographs within the frame rate collected. The clarity and interpretation of each picture are typically argued between experts and counsel as it was here. However, there are often 'low-noise' photographs that allow certain software and investigators alike to identify specific features within the camera frame. The issue then becomes linking these 'low-noise' photographs to a movement pattern that explains and ultimately validates the relative positions during an altercation.

Figure 8 Timeline of the event as seen in body-worn camera footage (see online version for colours)



The suspect sustained seven bullet wounds with different locations and directions as previously outlined. Using the evidence, it is possible to identify with reasonable engineering certainty the relative position of each individual throughout the altercation as well as the timing and sequence associated with each bullet wound. To do so, it is necessary to

a identify the 'low-noise' images of the video

b hypothesise or interpolate the movement patterns between the 'low noise' images

c test the hypothesis by using a re-enactment

d validate the movement patterns by matching the relative positions and timing of both the pistol orientation and wound paths caused by each shot.

As previously shown in Figure 3, in the moments before the suspect taking possession of the flashlight, the two men are in close proximity. From previous frames, it can be inferred that the suspect is at, or recently was, supporting part of his weight with his left hand as he leaned forward towards the officer's flashlight. In frame #3324 (T-0.30 s), the suspect's leg position can be observed as well as the officer's left hand on the suspect's shoulder, as shown in Figure 10. At this instant, the distance between the centre of mass of the two men is measured at approximately 2 to 2.5 feet (via scene documentation measurements and additional methodology outside the scope of this paper).

Figure 9 Timeline of events supported by research data (see online version for colours)

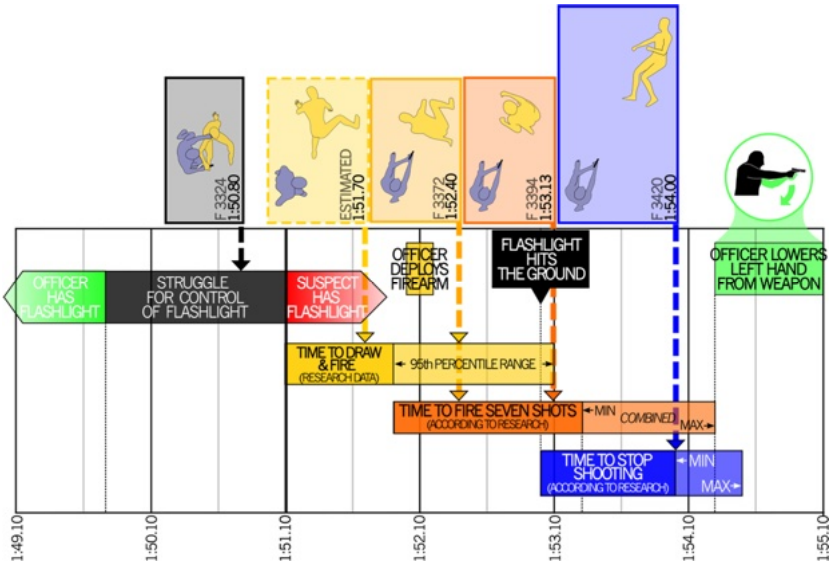
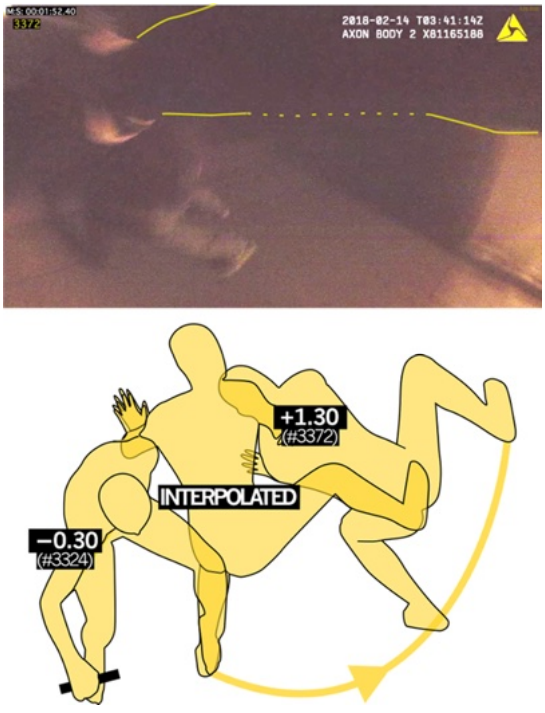


Figure 10 Estimated position of the suspect and the officer at and around (F#3324/–0.30 s) (see online version for colours)

When the suspect takes the flashlight, it is impossible to see him within the frame. However, it is possible to interpolate from available information and obtain a position of high likelihood. Frame #3372 (T+1.30 s) contains the next relatively straightforward image of the suspect as he can be seen in a crouched position supporting his weight on at least his left arm. These two positions (Frames #3324 and #3372) are separated by 1.6 s. Therefore, the likely path linking these positions can be approximated by a scene re-enactment. Doing so allows us to estimate the interim position consisting of a pivot around the suspect's left hand and left foot as he attempts to stand, as illustrated in Figure 11.

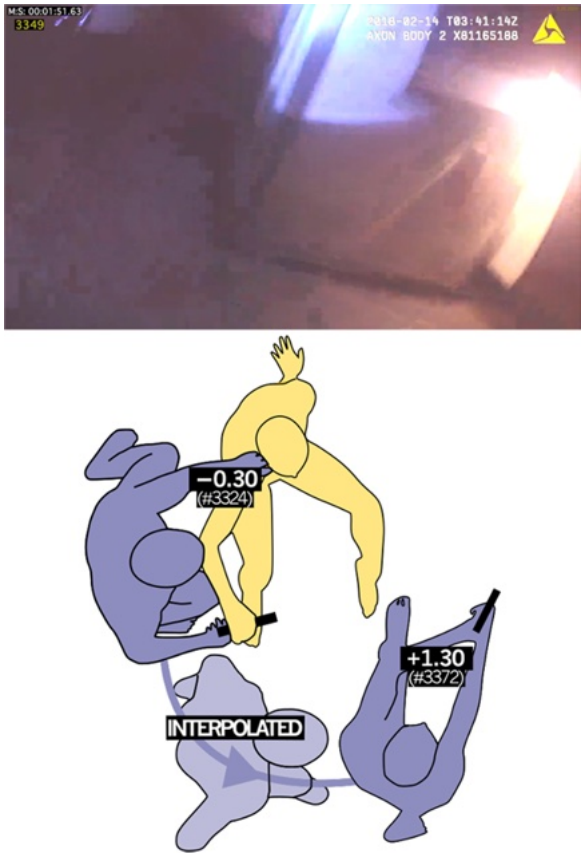
Figure 11 Estimated position of the suspect from F#3324 (T-0.30 s) to F#3372 (T+1.30 s) (see online version for colours)



Meanwhile, in frame #3372 (T+1.30 s), the officer can be seen with his arms outstretched ahead of him, in a shooting position. In the frames leading up to #3372, the officer's camera and, therefore, his torso appear to be pointing approximately towards the nearby building's corner, presumably as he reaches back with his right arm to access his duty firearm and/or side step for a tactical reposition. During this movement, the distance between the two men's centre of mass increases to approximately five feet. Figure 12 shows these positions in relation to the suspect, as well as the supporting evidence of the officer's camera orientation at F#3372 (T+1.30 s).

Until the officer lowers his left hand from his firearm, his feet position remains mostly static. Meanwhile, images indicate the suspect stood up and then fell to his right side, as validated below. When the suspect stands up, he is approximately six feet away from the officer's centre of mass.

Figure 12 Estimated officer position from F#3324 to #3372 (see online version for colours)



5.3.1 Interpolation test

A re-enactment was executed to reduce uncertainty in the characterisation of the suspect and the officer's movements. A chest-mounted camera was used, and a stationary camera was placed behind the position of the individual role-playing the officer.

The suspect's role-player was shown the video evidence and the key 'low noise' positions of frames #3324, 3372, and 3394. The floor was marked with visual landmarks identified both on-site and in the video evidence.

As seen in Figure 13, the subjects were placed in the starting position corresponding to the flashlight struggle identified in the 'low noise' image of Figure 10. Therefore, the re-enactment starts when the flashlight is taken from the officer surrogate (F#3333). From this position, the subject had to roll to his left and step out with his right foot; he could then complete the rotation and start to stand.

The first part of the body-worn camera footage shown in Figure 14 does not show the suspect; therefore, no comparison is available. However, in the second half, it is possible to see a significant correlation between the re-enactment and the evidence. The leg positions and angle of the torso appear approximately equivalent throughout the frames shown. Since no apparent outliers or indicators of different movement patterns exist, it is possible to accept this pattern as most likely to have occurred.

Figure 13 Correlation of key positions during the re-enactment (see online version for colours)

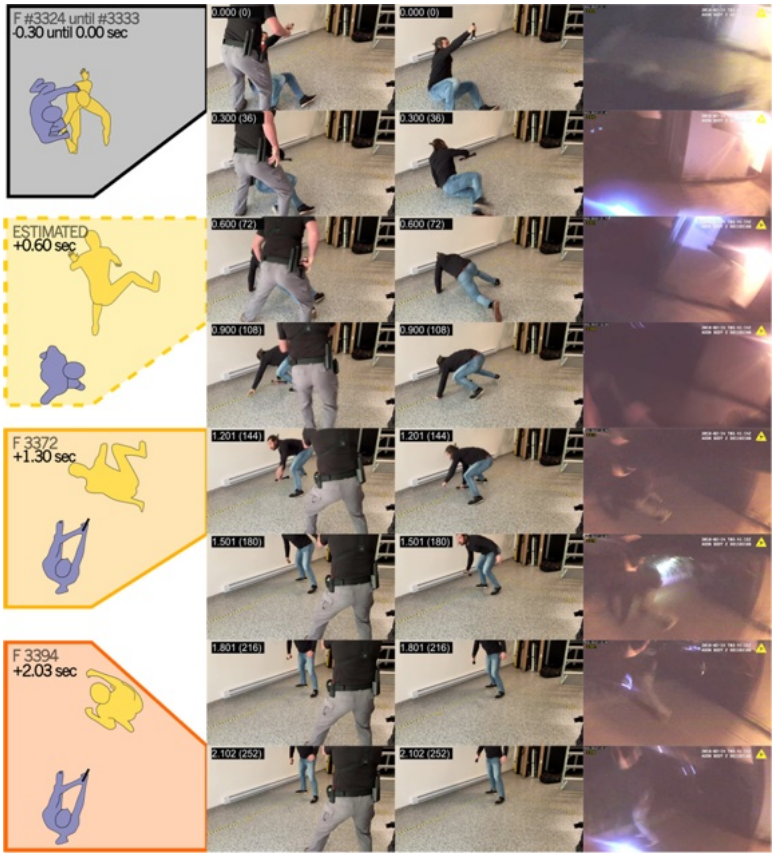


Figure 14 Probable position in which the suspect sustained wound #6. (F#3404/T+2.37 s) (see online version for colours)

Additionally, this re-enactment allowed confirmation of the intermediary position's timing outlined in Figure 11. The position in question can be observed around 0.90 s after

the movement pattern starts, which is approximately equivalent to 26 s into the case video.

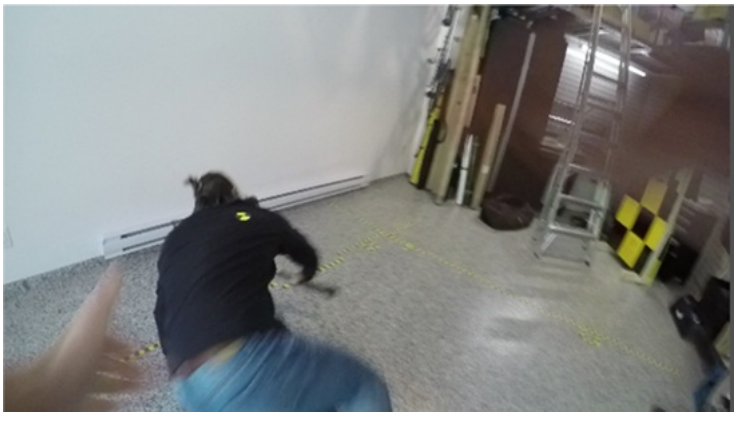
5.4 Movement validation: wound path analysis

Having identified and correlated a series of key positions throughout the intervention, it is now possible to relate the suspect's injuries to each of these positions with a sufficient degree of certainty. In doing so, findings are validated.

The subject was clothed with jeans and a dark sweater similar to the suspect. Circular yellow and black target patches were also affixed to the subject in the approximate anatomical locations of the entry wounds of shots #1, #2/#3, #5 and #7 to help locate them during analysis.

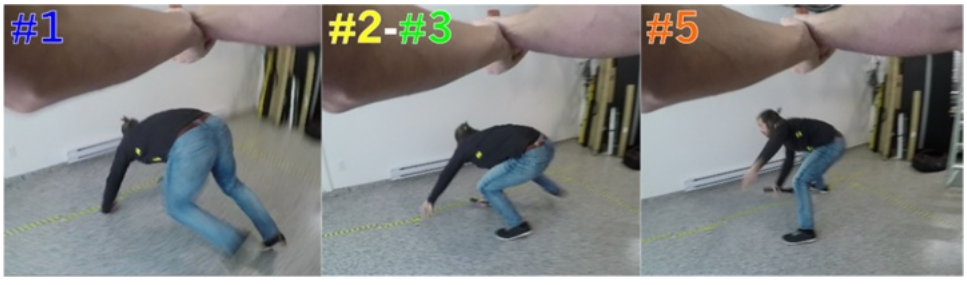
According to the analysis of the video footage and the interpolation test performed, the shot placement revealed themselves one at a time throughout the movement pattern at consistent and regular time frames matching draw and shoot times as well as shot-to-shot intervals. Hence, it was validated that after stripping the officer of the flashlight, the suspect moved to his left and rotated over his left foot, thus exposing his back to the officer for a brief moment, which corresponds with the timing suggested. The position is shown in Figure 15, from the point of view of a chest-mounted camera. This position is consistent with the gunshot wound sustained by the suspect at the upper right back area (wound #6), seen in the figure as a yellow marker. Since the suspect's right mid-back is never exposed in the same manner again in the encounter, it suggests that the officer's first shot occurred around the 26-second mark of the video, approximately 0.8 s after the suspect acquired the flashlight.

Figure 15 Position of the suspect at the time of first shot from the point of view of the chest camera during validation trials (see online version for colours)



As the suspect continued to make his way to a standing position, his body appears to rotate, and his left side becomes exposed. Therefore, as the suspect moves from a back-facing position to a left-facing position, the officer's position is consistent with the angle of the left-sided wound tracts reported. As seen in Figure 16, this portion of the movement suggests agreement with each wound's angle starting with the sharper diagonal angle of wounds #1, #2, and #5 and finishing with the more perpendicular tract of wound #3.

Figure 16 Range of position of the suspect shortly after acquiring the flashlight as shown from the chest camera's point of view during validation trials. Wound paths correspond to Figure 1 (see online version for colours)



Shortly after that, the suspect finishes standing. As seen in Figure 14, while standing, the suspect also angles away from the officer. This position seems consistent with the wound sustained to the suspect's left parietal scalp (wound #4). It is also unlikely that the suspect suffered this fatal injury earlier in the encounter or when the suspect's head was on or near the ground, as suggested by the opposing expert. Had this been the case, it is unlikely that the suspect would have been able to stand and achieve the position seen.

Finally, the timing of gunshot wound #7 cannot be confidently identified with the information at hand due to the arm's highly variable position during the intervention. In other words, the arm could have been in the necessary orientation to align with the wound path multiple times during the intervention.

In summary, the bullet wound to the head was likely one of the last wounds to be sustained, while most left to right wound paths were likely sustained while the suspect was in a crouched position or rising from said position. Hence, the wound paths validate the movement patterns tested.

6 Discussion

There is a significant amount of information to unpack in this analysis; however, the focus is placed on the events proximal to the shooting itself. The forensic examination of the BWC camera footage provided additional important information for the other experts to evaluate. For instance, the video enhancement revealed further details in the frames analysed, which, in turn, allowed investigators to establish several known positions throughout the event. Additionally, the review of individual frames was necessary to adequately examine and 'see' the required details for this analysis.

The use of biomechanics enhanced this analysis by providing the movement patterns associated with each known position. The re-enactment revealed a likely order for which each gunshot wound was sustained hence validating the movement patterns.

The application of PRT and human factors psychology to this case provided support for the biomechanics evaluation in identifying a scientifically validated shot timeline. The timeline was helpful in correlation with determined wound analysis. The application was also beneficial in correlation with the police use of force expert who evaluated the officer's actions.

7 Conclusion

The multi-disciplinary methods used allowed investigators to describe the firearm intervention involved in this use-of-force beyond the balance of probabilities. It was necessary to use video analysis to establish what was known and irrefutable before connecting the dots using injury biomechanics, general biomechanics, and human factors literature and testing.

This combined use of these multi-disciplinary methods limited conjecture and provided investigators with a factual foundation on which to base their opinion regarding the reasonableness of the officer's use of force.

References

Blake, D. and Bartel, L. (2018) 'Holster and handgun: does equipment effect response time', *Law Enforcement Executive Forum*, Vol. 18, No. 2, pp.39–47.

Campbell, A., Roelofs, A., Davey, P. and Straker, L. (2013) 'Response time, pistol fire position variability, and pistol draw success rates for hip and thigh holsters', *Human Factors*, Vol. 55, No. 2, pp.425–434, https://doi.org/10.1177/0018720812453466

Francis, E.L., Tyrrell, R.A. and Owens, A. (2020) 'Perception response time and its misapplication: an historical and forensic perspective', *Theoretical Issues in Ergonomics Science*, Vol. 21, No. 3, pp.327–346. Doi: 10.1080/1463922X.2020.1736204.

Haag, L.C. and Greenberg, I. (2000) 'Rates of fire for some common semi-automatic and full automatic firearms', *AFTE Journal*, Vol. 32, No. 3, Summer, pp.252–258.

Jason, A. (2010) 'Shooting dynamics: elements of time and movement in shooting incidents', *Investigative Sciences Journal*, Vol. 2, No. 1, pp.1–19.

Katz, E., Halámek, J. and Bakshi, S. (2015) 'Forensic science–multidisciplinary approach', *HSOA Journal of Forensic, Legal and Investigative Sciences*, Vol. 1, No. 4, pp.1–4.

Lewinski, W.J. and Redmann, C. (2009) 'New developments in understanding the behavioural science factors in the 'stop shooting' response', in *Law Enforcement Executive Forum*, Vol. 9, No. 4, pp.35–54.

Lewinski, W.J., Dysterheft, J.L., Bushey, J.M. and Dicks, N.D. (2015) 'Ambushes leading cause of officer fatalities–when every second counts: analysis of officer movement from trained ready tactical positions', *Law Enforce. Exe. Forum*, Vol. 15, pp.1–15.

Lewinski, W.J., Hudson, W.B. and Dysterheft, J.L. (2014) 'Police officer reaction time to start and stop shooting: the influence of decision-making and pattern recognition', *Law Enforcement Executive Forum*, Vol. 13, No. 2, pp.1–16.

Schmidt, R.A. and Lee, T.D. (2014) *Motor Learning and Performance: From Principles to Application*, 5th ed., Human Kinetics, Champaign, IL.

Sosnik, R., Chaim, E. and Flash, T. (2015) 'Stopping is not an option: the evolution of unstoppable motion elements (primitives)', *Journal of Neurophysiology*, Vol. 114, No. 2, pp.846–856.

Vickers, J.N. and Lewinski, W. (2012) 'Performing under pressure: gaze control, decision making and shooting performance of elite and rookie police officers', *Human Movement Science*, Vol. 31, No. 1, pp.101–117, https://doi.org/10.1016/j.humov.2011.04.004