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Possible influences on bullet trajectory deflection in ballistic gelatine

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ABSTRACT

The influence of the distance to the top and bottom of a gelatine block and to bullet tracks from previously fired shots on a bullet's trajectory, when passing through ballistic gelatine, was studied. No significant difference in deflection was found when trajectories of 9 mm Luger bullets, fired at a 3.5 cm distance to the top and bottom of a gelatine block and to bullet tracks from previously fired shots, were compared to trajectories of bullets fired 7 cm or more away from any of the aforementioned aspects. A surprisingly consistent 6.5° absolute deflection angle was found when these bullets passed through 22.5 to 23.5 cm of ballistic gelatine. The projection angle, determined by the direction of the deflection, appeared to be random. The consistent absolute angle, in combination with the random projection angle, resulted in a cone-like deflection pattern.

1. Introduction

In shooting incident reconstructions, assumptions must often be made about a bullet's deflection from its original trajectory after perforation of a victim. An incorrect estimation of such a deflection will result in an inaccurate trajectory representation. Unfortunately, there are no published data from controlled experiments available to help guide these assumptions. One possible way to test the made assumptions would be to conduct deflection experiments with ballistic gelatine. Ballistic gelatine is a well-established medium for studying bullet behaviour in soft human tissue [1–12]. The most common way to use gelatine in ballistic research is to shoot at rectangular (cuboid) blocks placed on a firm subsurface, like a table. Other shapes can be used in function of the needs. Depending on the experimental set-up, the ammunition type or the used test-protocol, one or more bullets can be fired at one block. Despite the fact that rectangular gelatine blocks do not resemble human bodies in all aspects, the ability to adequately simulate a bullet's penetration depth, deformation and other behaviour in human soft tissues is generally unquestioned. When blocks of gelatine are to be used to study bullet deflection, the following (threefold) question will have to be answered first before the data from these experiments can safely be interpreted: 'is a bullet's deflection, when shooting through a block of gelatine, influenced by the distance to:

- the top or side of the block;
- the tracks from previous shots in the block;
- the surface that supports the block.'

Human beings have no flat tops like rectangular blocks do. In general, most human beings have no bullet tracks in their bodies either and often rest on solid surfaces with only a small part of their body (e.g. their feet when standing or their buttocks when seated). Because of these differences between the object of many shooting scene reconstructions (the human body) and the medium used for experimentation (gelatine blocks) the possible influence of the three aforementioned aspects on bullet deflection will have to be taken into account. When bullet deflection in gelatine is influenced by the proximity of the top, side or bottom of a block or by tracks from previously fired shots, this deflection must be considered, at least in part, a consequence of the experimental set-up. In other words, the results from such an experiment must be regarded as artefacts. Ruling out the possibility of artefacts is necessary in order to correctly interpret the deflection results of experiments with gelatine blocks.

The influences of the three aspects mentioned above have not been studied before. Jussila [7], referring to Fackler [13] and Yoganandan et al. [14], noted that gelatine cannot expand evenly in all radial directions because of the supporting subsurface. Both Fackler [13] and Yoganandan et al. [14] mention this issue briefly without mentioning a possible influence on bullet deflection.

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McPherson [15] found a small influence on penetration depth caused by bullet tracks from previously fired shots. When he fired two 0.45 ACP calibre expanding bullets 2 cm apart in gelatine, the second bullet penetrated a little more than the first, presumably due to partially overlapping bullet tracks. More information on these influences was not found in the literature. The possible influence of the three aforementioned aspects on bullet deflection is the focus of the current study. The results of this study should be considered as information which can be used to optimise the set-up of future research using ballistic gelatine.

2. Methods and materials

2.1. Experimental design considerations

2.1.1. Sides and top treated as equal

The possible influence from either the side or the top of a gelatine block is regarded as being equal for these experiments. In both instances, the gelatine can expand more easily towards the outer side of the block, for lack of gelatine mass in that direction. Whether this side constitutes the actual side or the top of a block is a matter of definition determined by the blocks orientation. For the current study, the two situations are regarded as interchangeable and shots were only fired near the top of the blocks.

2.1.2. Chosen distance

A choice had to be made for a quantification of the distance to the top and supporting surface of the gelatine block and to bullet tracks from previous shots. From evaluating high-speed footage of bullets passing through gelatine (see also Section 4) it is known that the formation of the maximum temporary cavity, caused by the acceleration of the gelatine perpendicular to the direction of the bullet, takes place sometime after a bullet's passage. Taking this observation into account, a relative close proximity to the top, bottom and previous bullet tracks was chosen to increase the probability of finding a measurable effect on a bullet's deflection.

A current test protocol for evaluating handgun ammunition prescribes blocks with nominal frontal dimensions of 15 × 15 cm [16]. In this protocol, one shot is fired in the centre of the block. Taking into account an approximate 0.5 cm uncertainty for shot placement in all directions, bullets fired through these block will have a minimum distance of 7 cm to the top, sides and bottom of the block. A choice was made to take half of this distance, equalling 3.5 cm, to test a possible influence of the three aforementioned aspects at. In correspondence to the current test protocols, the 7 cm measure was taken as a minimum distance to the top and bottom of the block and also to bullet tracks from previously fired shots for the '0' or 'null' shots that were fired as a reference for the other shots.

2.1.3. Muzzle-to-target distance

In order to limit the introduction of an additional factor during the experiments, an approximate 5 m muzzle-to-target distance was taken. Gas turbulence in proximity of the muzzle causes bullet yaw and consequential non-orthogonal angles of attack on targets shortly after the muzzle (e.g. Kneubuehl [17]). The used 9 mm Luger full metal jacket bullets, fired with a 1 in 25 cm (1:10 in.) twist from an undamaged barrel, are dynamically stabile and the 5 m muzzle-to-target flight will allow for damping of most of the yaw angle (bullet angle of attack during flight).

2.2. Materials

2.2.1. Ammunition

The selected Magtech 9 mm Luger cartridges were loaded with 8 g full metal jacket bullets with a brass jacket covering a lead core. The cartridges were from the two different lot numbers BR1029 L1931 and BR0314 L1878. The average bullet velocity at 2.5 m was calculated to be 10 m/s higher for lot BR1029 L1931 than for lot BR0314 L1878 (365.3 ± 3.7 m/s and 355.1 ± 3.7 m/s respectively). Bullet mass, shape and size were identical for the two lots. Consequently, kinetic energies at 2.5 m averaged about 534 J and 504 J respectively. Impact energies at 5 m can be expected to be a little lower.

2.2.2. Gelatine

Nine blocks of 10% gelatine were prepared following the guidelines provided by Jussila [12] and stored at 4 °C until used. The nominal frontal (seen from the barrel) dimensions of the blocks where 40 × 25 cm. The thickness of the blocks, in the direction of the shots, lay between 22.5 to 23.5 cm depending on the block. This variation in thickness was caused by a slight difference in height when the molten gelatine was poured in each of the moulds. All nine blocks were prepared with gelatine from the same calibrated batch. Prepared with a mixture of 10.86% gelatine and 89.14% water, the penetration depths of the reference projectiles (4.5 mm steel spheres weighing 0.34 g) in a 3.8 °C temperature block fell within the prescribed boundaries for their respective velocities, as proposed by Jussila [12].

2.3. Methods

A witness panel was placed at the shooting range. Two axes, crossing each other under a 90° angle, were applied to the centre of the panel. In accordance with the ballistics coordinate system (where "z" is considered as the lateral displacement from the centre) the horizontal axis on the panel was named the z-axis and the vertical axis was named the y-axis. The x-axis crosses the z-y plane orthogonally at the z- and y-axis origin. For the orientation of the three axes in the experimental set-up, see the bottom left in Fig. 1. A test barrel was fixed in a gun mount and placed at a distance of 7 m (muzzle-to-panel) in front of the witness panel (Fig. 1). The height of the muzzle, measured from the shooting range floor was identical to the z- and y-axis origin on the panel. The barrel was adjusted, until bullets consistently hit the z- and y-axis origin. A table with a height-adjustable top was placed in front of the witness panel (Fig. 1). The gelatine blocks were placed on the table, leaving a 2.05 m distance between the back of the block and the witness panel.

A sliding mechanism on the table top allowed the blocks to be moved sideways, the motion being along the z-axis. The shot placement on Fig. 2 was achieved by adjusting the height of the table-top and sliding the blocks in between shots. The three 'null' shots (01, 02 and 03 on Fig. 2) on each of the nine blocks were fired in such a way that they fell at least 7 cm from either the bottom, sides or the top of each block, and from bullet tracks from previously fired shots. The three 'near' shots (noted N1, N2 and N3) were each fired 3.5 cm next to one of the three previously fired 'null' shots and more than 7 cm away from either the bottom, sides and top of each block. The four 'top' (noted T1–T4) and the four 'bottom' (noted B1–B4) shots were fired in such a way that they fell 3.5 cm from the top or bottom of each block respectively, and more than 7 cm away from the sides and bullet tracks from previously fired shots.

After each shot, the bullet hole in the witness panel was marked, indicating the type of shot (null, near, top or bottom) and sequence number. To prevent excessive warming-up of the blocks, a maximum of six shots were fired per block in one session after which the blocks were restored in a refrigerator set at approximately 4 °C. After each session, the z- and y-coordinates on the witness panel were measured by two individuals independently. Bullet velocity at 2.5 m from the muzzle was calculated for all