The ballistics of seventeenth century musket balls

David P. Miller\textsuperscript{a}, Derek Allsop\textsuperscript{b} and Debra J. Carr\textsuperscript{*}

\textsuperscript{a}Centre for Defence Engineering, Cranfield University, Defence Academy of the United Kingdom, Shrivenham, UK; \textsuperscript{b}Cranfield Forensic Institute, Cranfield University, Defence Academy of the United Kingdom, Shrivenham, UK; \textsuperscript{c}Impact and Armour Group, Centre for Defence Engineering, Cranfield University, Defence Academy of the United Kingdom, Shrivenham, UK

\textbf{ABSTRACT}

This paper investigates the firing of seventeenth Century musket balls. Prior to this research, the main concerns with making range predictions were associated with the deformed shape of the musket balls affecting their drag coefficient and therefore their distance to ground impact. However, the distance due to bounce and roll after initial impact has been unknown. In this work, the distance travelled after the first ground impact greatly exceeded expectations, with the musket balls approximately doubling the distance to their final resting positions. From these findings the initial factors thought to have had high relevance to the final resting position of the musket ball (velocity variation and drag co-efficient) become less significant and factors such as ground hardness become more prominent. The knowledge gained during this investigation will allow more accurate information to be obtained on the firing positions of opposing forces during conflicts in the English Civil War.

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\section*{Introduction}

\textit{Seventeenth century muskets}

Inspection of the 52 weapons in the Littlecote Collection (The Royal Armouries, Leeds, UK) suggested that the main weapon used in the English Civil War was typically a 10 bore matchlock musket with a 48” (1.22 m) long barrel; the internal diameters of the barrels actually varied from 18.87 mm to 22.35 mm (mean diameter = 19.87 mm; Eyers 2006). The true calibre of 10 bore equates to 19.70 mm (i.e. the diameter from a sphere of lead weighing \(\frac{1}{10}\)th of a pound; Eyers 2006).

There are many references to the calibre of seventeenth century muskets in the literature e.g. 'The bore of the barrel was standardised at 10, and this was designed to provide an easy-fit for a 12-bore bullet' (Rogers 1968). With regards to the barrel length, again there are many references to be found e.g. ‘c.1640 commonest of all infantry arms in the seventeenth Century was the matchlock musket. The regulation 48 inches long’ (Bull 1991). As well as variations in individual musket calibre it is likely that most barrels would not have been perfectly straight. According to Greener (1910):
Previous to 1795 there was no reliable method of ascertaining when a barrel was or was not perfectly straight. The barrels of the finest ancient guns were usually far from straight.

The seventeenth century musket would not have been capable of withstanding the pressures that a modern weapon could, as modern steels and manufacturing processes were not available. Greener states:

The method of making barrels prior to the introduction of Damascus iron (1820) from the east was to forge them from plates or strips of iron – this iron manufactured from old horseshoe nails (Greener 1910)

This could be one of the limiting factors affecting the maximum velocity of the seventeenth century musket.

**Seventeenth century musket balls**

In the seventeenth century, musket balls were cast using a split mould of two halves; the sprue was usually removed after casting, although it is frequently found on pistol balls (Foard 2008). There are several articles that provide information on seventeenth century musket balls recovered from archaeological sites (e.g. Harkins 2006; Foard, 2009). A musket ball recovered from the site of the Battle of Marston Moor in 1664 had a Vickers hardness of 6.32 and was 99.7% lead (Harkins 2006). Musket balls recovered from the Battle of Edgehill (1642) were 12 bore with a mean diameter of 18.51 mm and had a typical mass of 37.9 g (Harkins 2006). Foard (2008) also studied musket balls recovered from Edgehill and reported that 12 bore was the most common calibre represented.

Musket balls recovered from archaeological sites are frequently banded; this is a distinctive firing mark where the bullet is flattened in a band around the circumference of the bullet (Foard 2008). Other features visible on fired musket balls include pitting and evidence of melting; usually affecting the hemisphere of the musket ball adjacent to the powder (Foard 2008). However, it is important to be aware that diagnostic marks do not always appear on fired musket balls.

A seventeenth century musket with a barrel of 10 bore (19.68 mm) internal diameter which fired a 12 bore (18.51 mm) musket ball had a large amount of windage i.e. the space between the musket ball and the inside of the barrel. Windage ensured that the musket ball would easily slide to the bottom of the musket barrel even when the barrel had become fouled from black powder residue after several firings. The disadvantage of such a large amount of windage is that it results in a reduction in muzzle velocity due to gases escaping past the musket ball and quite possibly a reduced accuracy.

**Seventeenth century powder and wadding**

The propellant used in seventeenth century firearms was black powder (often called gunpowder) which consisted of a mixture of saltpetre (potassium nitrate), sulphur and charcoal (Brown 2005). A modern black powder consists of 75% potassium nitrate, 15% wood charcoal (carbon) and 10% sulphur; earlier mixtures contained much smaller
amounts of saltpetre (Brown 2005). The three components must be well mixed and finely powdered for efficient burning.

When black powder is ignited, the oxygen from the nitrate allows the sulphur and the carbon to burn rapidly producing a mixture of hot gases including sulphur dioxide and carbon dioxide, this in turn causes a rapid increase in volume (Brown 2005). If the black powder is lit in a confined space such as inside a barrel, this rapid increase in gas volume will lead to an increase in pressure propelling the musket ball along the barrel.

Little archaeological evidence is available regarding gunpowder manufactured during the Civil War. It is known that powder mills were made from local converted water mills (Cocroft 2000). With the limited amount of historical data available and small amounts of research previously conducted, it is difficult to accurately establish how the seventeenth century powders would compare to those of today.

Nathaniel Nye (1647) a master gunner from Worcester gave a detailed description of black powder production during the Civil War . . . ‘four parts petre, one part Brimstone and one part Cole.’ (Nye 1647). It is hard to establish the exact purity of the saltpetre or the grain size of powder used and it is not until much later in history that grain sizes are mentioned; it required technology to developed to be able to measure grain sizes reliably (Hime 1904). Modern military black powders are classified according to British INT DEF STAN 13–166/1 and INT DEF STAN 13–167/1. An example is G12, dark glazed, uniform granulation and free from foreign matter, granulation 1–2 mm. Other classifications can carry a U.N. number and a designation, for example type 3A (Fine) U.N. number 0027 grain size 0.25–0.50 mm. Otherwise, black powder is simply classed as fine or coarse grain.

Reported muzzle velocities include: i) between 1425 fps (434 m/s) – 1700 fps (518 m/s) with a ¾” (19.05 mm) diameter ball and 45” (1.143 m) long barrel (Benjamin Robins in 1742); and ii) an average muzzle velocity of 1561 fps (476 m/s) for an English musket (Captain Alfred Mordecai in 1840; Roberts et al. 2008). Other data in the literature state that sixteenth, seventeenth, and eighteenth century muskets (17 mm calibre, 15 g of powder) produced muzzle velocities of between 450 m/s and 500 m/s (Harding 1997).

Deposits left inside the barrel of the musket after firing (fouling) will alter the amount of windage, especially if there is a cumulative effect. Over 50% of constituents produced by black powders are non-gaseous. This material either takes the state of a liquid during the combustion cycle, or as a powder found either escaping as smoke at the end of the barrel or as particles left inside the barrel (Greener 1910).

It was suggested by Roger Boyle (the first Earl of Orrery from Grose) in 1801 that wadding was sometimes used during the Civil War; he stated that

… such softe haire as they stuff saddles with … this soldier must use when time permits (Eyers 2006).

Wadding reduces the amount of windage in the barrel, which can increase velocity and range (Eyers 2006, 38–41; Allsopp & Foard 2008). Other researchers have suggested wadding was not used to shorten the time to load and fire the weapon (e.g. Foard 2008; Rogers 1968), but this would have been a question of balancing reduced performance against the need to reload and fire as quickly as possible.

The aim of the research summarised in this paper was to investigate the ballistics of seventeenth century musket balls through a combination of experimental firings
conducted in: i) an indoor range which considered the effect of the type of black powder used, windage and elevation; and ii) outdoor firings which investigated range, accuracy and bounce and roll of musket balls.

Methods

Manufacture of reproduction musket balls

Reproduction 12 bore lead musket balls (18.51 mm diameter) were cast using a split mould. After cooling, the mould was opened and the sprue removed. Flash was visible where the two halves of the mould joined; this is consistent with the observations of seventeenth century musket balls recovered in the field (Figure 1).

Firings in the indoor ballistic range

Firing system

A firing system was developed for the indoor range work (Figure 2). A muzzle loading barrel was used: 48” 10 bore (19.69 mm internal diameter), which had a screw thread on one end to attach it to a breech block, with a counter-sunk touch hole to allow priming gunpowder to used. A tapping for a pressure transducer was located in the end of the breech which was inserted into a Number 3 proof housing and secured with a back nut. The pressure transducer was connected to a charge amplifier and the signal was then transferred to a pc via a data capture card. The proof housing was bolted to a stand which allowed movement of the gun horizontally and vertically. A laser pointer was

Figure 1. Reproduction musket ball.
attached to the rear of the proof housing for accurate aiming. A Weibel Doppler radar type W700 was used to record the velocities of the musket balls.

For each firing, a small wooden dowel was inserted into the touch hole to ensure that the powder did not leak out when it was being poured into the barrel. For wadding, nine sheets of rolled tissue paper were lightly rammed in with a ram rod. The musket ball was then inserted into the barrel and very gently rammed in. Two sheets of tissue paper were inserted into the barrel and gently rammed in on top of the musket ball. The barrel and the proof housing were then lifted onto the stand and secured. The dowel was removed and a small amount of priming powder (Swiss no.1) poured into the touch hole and allowed to spread around the counter-sink. An electrical igniter consisting of two wires joined by a match head was taped over the priming powder. The match was initiated with a 20 V electrical supply completing the circuit to the match head.

A soft capture system was set up, consisting of multiple sheets of Plastozote foam located 10 m from the end of the barrel. This was used to determine the depth of penetration (DoP) of the musket balls, and to examine the musket balls post-firing. The intention was to capture the musket balls in a way that did not add post-firing damage that might affect the analysis of the musket balls.

**Effect of type of black powder**

Three black powders were compared: i) Swiss No.1 a fine grained and fast burning black powder (grain size = 0.23–0.51 mm); ii) 3A which is a fine grained powder (grain size = 0.25–0.50 mm); and iii) G12 which is a coarse grained powder (grain size = 1–2 mm). As it is possible that wadding may have been used (though frequently
not) during the English Civil War (Foard 2008), tests were conducted with and without a wad. The criteria for establishing the most appropriate powder was determined by the quantity required to obtain correct velocities without overpressure but also to be able to generate enough pressure to produce the banding effects seen on musket balls retrieved from the battle field. A charge mass of 12.5 g was used.

**Effect of bore diameter**

Two additional barrels, each 48” long, were manufactured; one barrel had a bore diameter of 18.7 mm to recreate a very tight-fitting musket ball, while the other barrel had a bore diameter of 20.4 mm for a loose-fitting musket ball. Trials were carried out firing a 12 bore lead musket ball (diameter = 18.51 mm) to investigate the effect of barrel bore diameter on musket ball ballistics and damage.

**Effect of elevation**

The effect of elevation needs to be considered, i.e. the vertical angle of the barrel. A Figure 11 target (a type of military target used on firing ranges) was placed 5 m from the end of the barrel. This allowed the effect of altering the elevation of the barrel from 0° to 10° to be determined.

**Long range trials**

**Location and apparatus**

Long range outdoor trials were conducted along the main grass ride at Ashdown Wood (Ashdown House, Ashbury, Oxfordshire, UK) (Figure 3). The ride is 18 m wide and 1500 m long; the first 300 m is almost flat and largely free of metallic debris, a requirement for finding the musket balls post-firing using a metal detector. Ground hardness was measured with a cone penetrometer.

The apparatus used in the indoor trials was transported to the outdoor venue. The barrel was 1.39 m above the ground; this distance was the mean shoulder height for volunteers from The Battlefields Trust (Pollard 2008). Witness screens were placed down

![Figure 3. Outdoor firing location.](image-url)
the ride. The horizontal position was sighted to the first witness screen by looking along the barrel. An optical level was used to mark the witness screens with a 0, 0 coordinate at 1.39 m high and centred to enable drop and sideways movement to be measured. A Weibel Doppler radar model W700 (powered by a portable generator) was used to record the velocities. A metal detector was used to find the musket balls after firing.

Test day 1
The grass length was approximately 30 mm and the soil damp; wind conditions were calm. To measure impact positions, cartridge paper witness screens (1.2 m wide x 2.0 m high), mounted in custom-made steel tubing frames, were used at 20 m intervals from the gun to a total distance of 200 m. Four musket balls were fired using a 48 " 12 bore barrel with 0° elevation; the barrel was loaded with 18 g of G12 black powder.

Test day 2
The grass was approximately 30 mm long, the ground dry; wind conditions were calm. Due to difficulties encountered with impacting the witness screens during Day 1 trials, a slightly different witness screen arrangement was used on Day 2. The first witness screen was placed 50 m from the muzzle; seven further witness screens were then placed at intervals of 30 m to a total distance of 260 m and a further two sets of screens were placed at 20 m intervals to a total distance of 300 m.

A total of nine musket balls were fired on Day 2 with 0° elevation; each used 18 g of G12 black powder. Shots 1 to 5 used a 48” 10 bore barrel (internal diameter = 19.49 mm), shots 6 and 7 used a 48” barrel with an internal diameter of 18.7 mm and shots 8 and 9 used a 48” barrel with an internal diameter 20.4 mm. The musket balls were painted with a thin coat of white paint to aid location post-firing.

Test day 3
The ground was damp and the grass approximately 30 mm long; there was a light wind. A total of ten musket balls were fired used a 48” 12 bore barrel with 0° elevation; the barrel was loaded with 18 g of G12 black powder with no wads used. The musket balls were painted with a thin coat of bright orange paint to aid location post-firing. A single witness sheet of paper was positioned 100 m from the barrel and a cross marked on it as a point of aim by bore sighting. A telescopic sight was then positioned on the barrel and adjusted to the cross so each shot would have the same aiming mark. Due to limited time, the Doppler radar was not used, and the muzzle velocity was predicted from previous data.

Results and discussion

Indoor firings

Effect of black powder
The effect on the peak pressure measured by the pressure transducer of the type of black powder and whether or not a wad was used is summarised in Table 1. Swiss no. 1 black powder resulted in an unacceptable peak pressure and was excluded from the trials after the first shot. The 3A and G12 black powders resulted in velocities in the order
of those for seventeenth Century muskets. However, the pressure vs. time curve for G12 identified it as a slower burning black powder compared to 3A; seventeenth Century propellant was likely to be slower burning as it would have been less refined than a modern powder. Until the nineteenth century Napoleonic Wars, English gunpowder had been considered the worst powder in Europe (Cocroft 2000, 65).

The musket balls were retrieved from the soft-capture system post-firing, examined and compared to the reported appearance of seventeenth century musket balls recovered from archaeological sites. All musket balls fired with wadding showed visible banding irrespective of black powder type. The musket ball fired using Swiss No.1 showed signs of melting around the banding circumference. The musket balls fired without a wad showed similar characteristics to those found on the Edgehill battlefield musket ball (Foard, 2008). Non-wadded balls showed evidence of pit marks produced from the burning propellant on the base of the projectile whereas the wadded musket balls showed no sign of powder pitting (e.g. Figure 4). These results suggested that the Edgehill musket ball was fired without a wad.

The remainder of the experiments were conducted using G12 black powder.

**Effect of bore diameter**

The effect of bore diameter on the peak pressure measured by the transducer mounted on the breech block is summarised in Table 2. Velocity and peak pressure increased with

| Powder     | wad used? | Muzzle velocity (µs) | Peak pressure (bar) | Time after trigger |
|------------|-----------|-----------------------|---------------------|--------------------|
| 3A         | yes       | 417                   | 228                 | 2.65 ms            |
| G12        | yes       | 341                   | 176                 | 2.32 ms            |
| Swiss no. 1| yes       | 453                   | 779                 | 7.62 ms            |
| 3A         | no        | 388                   | 268                 | 1.86 ms            |
| G12        | no        | 334                   | 174                 | 1.70 ms            |

![Figure 4. Examples of fired musket balls.](image)
decreasing bore diameter and with the use of wads; the bore diameter had the greatest
effect on both velocity and peak pressure.

More visible banding was evident on musket balls fired from the smallest bore
diameter barrel compared to musket balls fired from the largest bore diameter barrel. Musket balls fired from larger bore diameter barrels deformed less than those fired from smaller bore diameter barrels. Musket ball mass lost was recorded for all conditions; the
greatest loss of mass (1.729 g) was recorded for one of the musket balls shot without
wadding using the largest bore diameter barrel.

**Effect of elevation**
Impact sites increased vertically with elevation angle; this vertical increase was 0.88 m
when the elevation angle was increased from 0° to 10°.

**Long range tests**

**Day 1**
Mean ground hardness for musket ball rest locations was 110 CI. Ground impact
distance varied from 115 m to 213 m (Table 3). Comparing shots 1 and 4 which had
similar muzzle velocities (410 m/s and 438 m/s respectively), a large difference in ground
impact distance was observed (213 m and 146 m respectively); this was due to the
variation in trajectory identified by impact location on the witness screens. The final
resting position distance varied less (288 m to 323 m) compared to the ground impact
position (Table 3).

### Table 2. Effect of bore diameter on peak pressure.

| Internal diameter (mm) | wad used? | Muzzle velocity (m/s) | Peak pressure (bar) |
|------------------------|-----------|-----------------------|---------------------|
| 18.70                  | yes       | 472                   | 419                 |
| 18.70                  | yes       | 459                   | 393                 |
| 18.70                  | no        | 452                   | 319                 |
| 18.70                  | no        | 465                   | 403                 |
| 19.49                  | yes       | 427                   | 308                 |
| 19.49                  | yes       | 431                   | 331                 |
| 19.49                  | no        | 410                   | 270                 |
| 19.49                  | no        | 420                   | 314                 |
| 20.40                  | yes       | 410                   | 284                 |
| 20.40                  | yes       | 403                   | 283                 |
| 20.40                  | no        | 346                   | 182                 |
| 20.40                  | no        | 351                   | 203                 |

### Table 3. Data from Day 1 firings.

| Shot 1 muzzle velocity = 410 m/s | Shot 2 muzzle velocity = 361 m/s | Shot 3 muzzle velocity = 298 m/s | Shot 4 muzzle velocity = 438 m/s |
|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| ground impact position          | 213 m                            | 115 m                            | 146 m                            |
| final position                  | 288 m                            | not found                         | 323 m                            |
|                                  | 2.3 m right                       | 5.7 m left                        | 310 m                            |
|                                  |                                  |                                  | 2.5 m right                       |
**Day 2**

Mean ground hardness for musket ball rest locations was 195 CI. Ground impact distance varied from 140 m to 234 m (Table 4). Only three musket balls were recovered; the final resting position varied from 296 m to 402 m (Table 4). There appeared to be no relationship between bore size and muzzle velocity and between muzzle velocity and ground impact distance.

**Day 3**

Mean ground hardness for musket ball rest locations was 85 CI. Muzzle velocity was assumed to be 413 m/s from previous firings. The results from the testing are summarised in Table 5. Six musket balls (out of ten firings) were recovered. Impact distance could not be determined as the Doppler radar was not used. Final resting position varied from 230 m to 313 m (Table 5).

**Conclusions**

This research achieved a number of goals: i) it developed a method for firing seventeenth century muskets; ii) it reproduced the firing marks found on musket balls recovered from battlefields of the seventeenth century; and iii) it investigated a number of important variables affecting ballistics of weapons from that period. The distance to the musket balls’ final resting positions (after bounce and roll) was approximately 315 m, almost double the distance from the initial landing point. In reality, this value is likely to be greater because of the limitation of the width of the range which almost certainly resulted in the musket balls travelling the furthest being lost in the undergrowth so not being included in the results.

**Table 4. Data from Day 2 firings.**

| Shot number | Distance from muzzle (m) | Ground impact | Final position |
|-------------|--------------------------|---------------|----------------|
| (muzzle velocity in m/s) | | | |
| 1 (429) | 170 | - | |
| 2 (423) | 166 | 402 | |
| 3 (423) | 203 | 330 | |
| 4 (412) | 153 | 296 | |
| 5 (412) | 170 | - | |
| 6 (467) | 140 | - | |
| 7 (484) | 182 | - | |
| 8 (339) | - | - | |
| 9 (351) | 234 | - | |

**Table 5. Data from Day 3 firings (missing data due to musket balls missing witness screens or deviating beyond the 18 m wide of the ride; muzzle velocity assumed 413 m/s).**

| Recovered musket ball | Final position (m) | Distance deviated from centre line | Direction deviated |
|-----------------------|--------------------|-----------------------------------|--------------------|
| 1                     | 229.99             | 1.35                              | Left               |
| 2                     | 312.49             | 4.60                              | Left               |
| 3                     | 270.29             | 0.60                              | Left               |
| 4                     | 266.39             | 3.40                              | Left               |
| 5                     | 265.39             | 2.20                              | Right              |
| 6                     | 227.89             | 1.29                              | Left               |
Wadding was used by seventeenth century musketeers, but clearly not always (Foard 2008). Indeed, it was shown in the test firing that the appearance of the musket balls fired without wadding showed a closer resemblance to some of the original seventeenth century musket balls than those which were fired with wadding. Wadding increases the muzzle velocity of the musket by preventing gas leakage past the musket ball in the barrel (Eyers 2006; Allsop and Foard 2008). This was found to be the case, but the effect was found to be surprisingly low, especially considering that Foard reported in an increase of nearly 30% in muzzle velocity in the Allsop and Foard research (Foard 2012, 105), and Eyers managed an increase in one case of 20% (Eyers 2006). One possible explanation is that wadding varied quite widely in its nature, and some forms of wadding clearly do not work as well as others (Blackmore 1976). While the wadding seemed to have little effect, the variations in bore diameter showed a significant variation in velocity, especially when fired without a wad because of the change in gas leakage past the ball. However, this produced little change on the outcome of the final resting position of the musket balls; there was a limited difference in how far the musket balls carried through bounce and roll.

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No potential conflict of interest was reported by the authors.

Notes on contributors

David P. Miller (Msc) is a Senior Technical Officer at Cranfield University, 20 years experience of working in small arms ballistic testing and research.

Derek Allsop (PhD) is a formally Senior Lecturer at Cranfield University.

Debra J. Carr is a formerly Reader in Impact and Armour at Cranfield University.

References

Allsop, D., and G. Foard. 2008. “Case Shot: An Interim Report on Experimental Firing and Analysis to Interpret Early Modern Battlefield Assemblages.” Journal of Conflict Archaeology 3: 111–146. doi:10.1163/157407807X257403.

Blackmore, H. L. 1976. The Armouries of the Tower of London: The Ordnance. London: HMSO.

Brown, G. I. 2005. The Big Bang: A History of Explosives. Stroud: Sutton Publishing.

Bull, S. 1991. A Historical Guide to Arms and Armor. New York: Checkmark Books.

Cocroft, W. D. 2000. Dangerous Energy: The Archaeology of Gunpowder and Military Explosives Manufacture. London: HMSO, England Heritage.

Eyers, V. 2006. “Ballistics of Matchlocks.” Forensic Engineering and Science MSc Thesis, Cranfield University.
Foard, G. 2008. “Investigating Documentary and Archaeological Evidence in the Investigation of Battles. A Case Study from the seventeenth Century, England.” PhD thesis, University of East Anglia.

Foard, G. 2012. “Battlefield Archaeology of the English Civil War.” *British Archaeological Reports British Series 570*. Oxford: Archaeopress.

Greener, W. W. 1910. *The Gun and Its Development*. 9th ed. London: Arms and Armour Press.

Harding, D. F. 1997. *Small Arms of the East India Company, 1600–1856*. London: Foresight Books.

Harkins, S. 2006. “The Application of Modern Forensic Techniques to Battlefield Archaeology.” Forensic Engineering and Science MSc Thesis, Cranfield University.

Hime, Lt. -Col. H. W. L. 1904. *Gunpowder and Ammunition: Their Origin and Progress*. Waltham Abbey: Royal Gunpowder Mills.

Miller, D. P. 2009. “Ballistics of 17th Century Muskets.” Forensic Engineering and Science MSc Thesis, Cranfield University.

Nye, N. 1647. *The Art of Gunnery*. EEBO ed.

Pollard, T, and I Banks, 2008. Scorched Earth: Studies in the archaeology of Conflict. Brill Academic Publishers, Leiden, Netherlands. ISBN. 9789004164482

Roberts, N. A., J. W. Brown, B. Hamnett, and P. D. F. Kingston. 2008. “A Detailed Study of the Effectiveness and Capabilities of 18th Century Musketry on the Battlefield.” *Journal of Conflict Archaeology* 4: 1–22. doi:10.1163/157407808X382737.

Rogers, H. C. B. 1968. *Weapons of the British Soldier*. London: Seely Service.