Reviewed and accepted for publication on July 11th 2018 in The Journal of the Arms and Armour Society ISSN 0004-2439 Vol. XXII No 6 pp 356-384. Publication date 10/09/2018.

The *Colichemarde*: Historical Curiosity or Efficient Weapon?

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Abstract

The so-called *Colichemarde,* a minority small-sword blade design which was used approximately between 1680 and1780, was examined in order to assess its fitness as a weapon of self-defence and for duelling. Following a summary of the historical background, which shows that the name itself dates to later than its period of use, this paper compares *colichemardes* with swords of different blade designs in dynamical and mechanical tests to show that its design was indeed a very efficient one both for the purpose of attack and defence. It out-performed the other relevant blade designs examined in this regard.

Introduction and Historical background.

In the seventeenth and the eighteenth centuries gentlemen in Western Europe, particularly in countries which were influenced by French culture such as England, were expected to duel when "called out". Their gentle status had the privilege (and indeed, duty) to "walk forth in their coat and sword".[i] This sword duelling culture, which in England mainly morphed into duelling with pistols by the 1770's, was a very serious matter; cowardice meant not just loss of face but loss of patronage from the nobility in an era when gentle status implied not actually having to work for a living. In addition, most gentlemen who lacked great personal wealth lived on credit, which they would inevitably lose if they were socially ostracised. If they ended up in debtor's jail they and their dependants might be entirely ruined.[ii] As well as this social class factor life in a great city such as London was dangerous, and a sword would come in handy if a man were faced with a footpad eager to rob him.

The fashionable item of weaponry and the badge of status for a gentleman was the small-sword.[iii] This was short thrusting weapon of approximately 80cm blade length, of which the so-called *Colichemarde* is a curious and interesting instance of a particular blade design. This hybrid blade existed for longer than some authorities have claimed (see *infra* Sir Richard Burton) so it must have had some merit as a weapon. What was it, who invented it and why? These are the questions addressed in this paper.

When one looks at original sources of the period in order to find information about the *Colichemarde* (see, Fig1*)* one discovers practically nothing, apart from Sir William Hope's mention in 1707 of the *Koningsberg blade*, which from the context of his paragraph had the same unusual blade design as the C*olichemarde*, a blade wide at the hilt end which suddenly becomes thin a quarter to a third toward the tip.

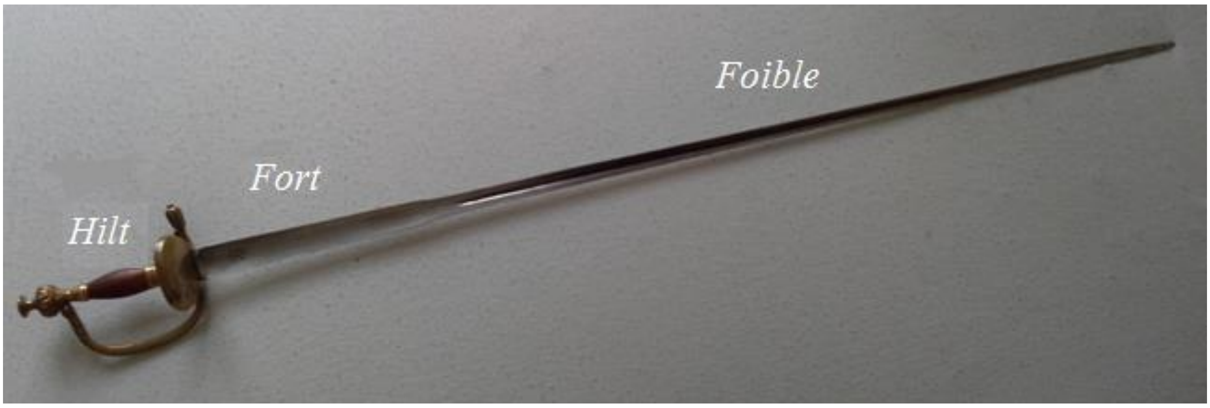

Fig 1. A typical Colichemarde, showing the characteristic blade profile, a wide fort rapidly narrowing to a thin foible. Private collection.

Sir William comments[iv] on the blade in passing while extolling his own superior fencing techniques, '.....the Breadth of certain kind of *German Blades,* called *Koningsbergs,* [*sic*] and which breadth is no Advantage under Heaven in *Parieing* [*sic*] as some People fancy; because, if I make a true *Cross* in *Parieing,* I will defend myself as well with a *blade* no bigger than a *Lark-Spit,* provided it be stiff enough, as I can possibly do with a *Koningsberg Blade,* yea or with one three inches broad in the *Blade,* which is double the breadth of any *Koningsberg* I ever did see........'

This lack of information is hardly surprising; the present author has discovered that the word is a nineteenth century neologism first mentioned in French as late as 1801 in S. Mercier, *Néologie,*[v] many years after small-swords ceased to be serious weapons carried by gentlemen and had become merely decorative items of uniform.

In secondary historical sources its name purported to come from its inventor, a certain Count von Königsmarck, but that is a disputed matter, because, as the following family tree, table 1, shows, there were several Counts, none of whom can be definitively linked to the weapon.

Hans-Christoph von Königsmarck. [1600-1663]

Otto-Wilhelm von K. [1639-1688] — *Maréchal-de-camp under Louis XIV.*

Conrad (Kurt)-Christoph von K. (1634-1673) — *Soldier, served under William of Orange.*

Karl-Johann von K. [1659-1686]

Philipp-Christoph von K. [1665-1694]

Murderer of Thomas Thynne. *Lover of the wife of the future George I - Murdered.*

Table 1. von Königsmarck family tree (males only)

Sir Richard Burton[vi] , writing in 1884 mentions a "Count Königsmark" [*sic*] as its inventor, but he does not mention which particular Count Königsmarck.

Burton states, 'The Colichemarde blade, so called from its inventor, Count Königsmark [*sic*]...was invented about 1680, and became a favourite duelling blade....it remained in fashion during the reign of Louis XIV (*who reigned from 1643 to 1715 - author's note*) and then suddenly disappeared.' In a footnote Burton writes, 'Mr Wareing Faulder (Exhibition of Industrial Art, Manchester, June and July 1881, Catalogue p.24) suggests that the *colichemarde,* "fell into disuse probably in consequence of its costliness, combined with its inelegant appearance when sheathed".'

Burton was wrong, at least in one part of the quoted passage. The *colichemarde* as a blade-type did not suddenly disappear, it certainly survived the reign of Louis XIV. The author has seen several later *colichemardes*, one silver-hilted, dated by hallmarks, with a contemporary scabbard also with silver fittings and hallmarked 1768-9, and George Washington's sword (see below) is dated 1776-1777.

Egerton Castle[vii] in 1885 mistakenly confuses one Count with his *maréchal-de-camp* uncle, but he must have been referring to Karl Johann, 1659-1686, since he gives the date of the count's death as 1686. Most probably, if at all, it was Karl-Johann's name which was intended by Mr Castle, because he was the only documented duellist of the family and his dates fit, but there is no evidence definitely linking him to the sword.

Even into the 1960's the word *colichemarde* was not universally used throughout Europe. Eduard Wagner[viii], writing in Czech, uses the description translated as "rapier with a squeezed blade" to describe the weapon and its function, see *Fig 2*.

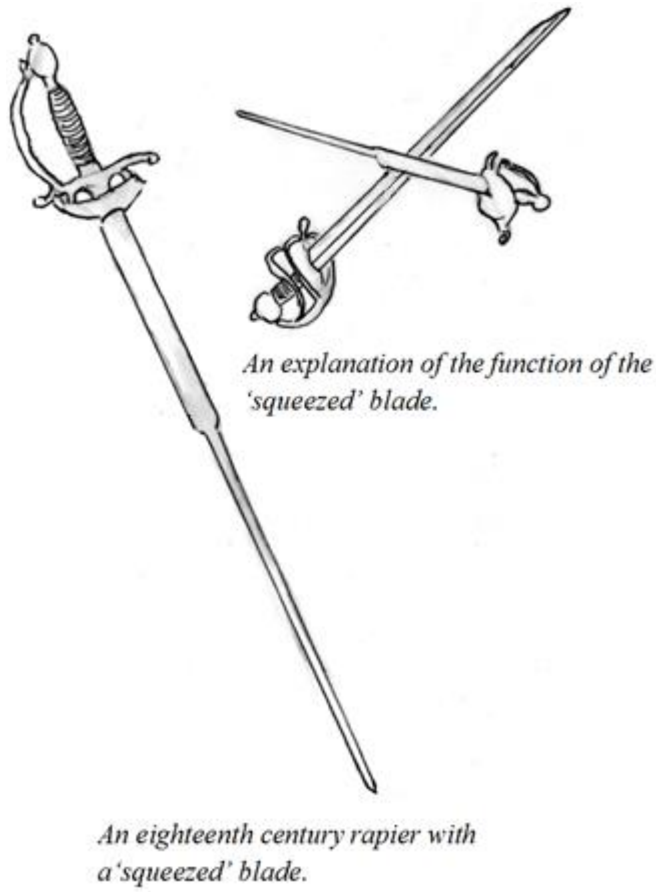

Fig.2 The Colichemarde described as a squeezed blade (after Wagner).

What can be said with some certainty is that it first appears in the 1680's on the continent as a type of small-sword and its design originated for its intended function. The practical problem, when many different sword designs existed simultaneously, was what should a small-swordsman do when faced with a man armed with, for example, the heavier rapier, which continued to be carried by nations such as the Spanish, or by a soldier armed with a sabre? The solution the bladesmiths hit upon, in order for the smaller, more delicate, but faster weapon to have a blade strong enough to withstand a heavier weapon in a parry was to make the *fort*[ix] of the small-sword strong and thick, hence the curious design of the *colichemarde* with its broad *fort* but thin *foible* to keep it light and hence swift in the hand. This then is clearly a hybrid weapon, designed to be useful in both speed and strength. As many hybrid weapons, for example, the 1796 infantry sword, it may have been an uneasy compromise. The latter was at the time most heavily criticised as, "A perfect encumbrance," useless in both cut and thrust.[x] I contend, however, that unless there were faults in the manufacture of the blade, particularly in the junction between the *fort* and *foible*, the *colichemarde* blade was very well suited to its task, as the following historical evidence of its use demonstrates, as does the analysis and experiments described.

In1796, the British army introduced pattern swords for infantry, heavy and light cavalry, and in 1805 the Royal Navy introduced pattern swords for officers of commander's rank and above .[xi] But, before these dates, officers, being gentlemen, and therefore accustomed to wearing a small-sword in civilian dress, often carried a *colichemarde* blade[xii] in uniform; and they did so even late into the eighteenth century. The reason that it was the preferred weapon of officers was that it could, at least in theory, be used in battle, though in truth despite its thick and effective *fort* any small-sword made a poor battlefield weapon. The hilt offers little protection to the hand and the tang is fairly flimsy compared with that of a rapier or sabre. In addition a light thrusting blade is only immediately truly effective if it pierces a vital organ. The wounds which would render an enemy instantly *hors de combat* are much more easily made by the much heavier military sword, sabre or cutlass but they are difficult to make with a small-sword. Also, small-sword training takes a long time but a relatively un-skilled soldier or sailor armed with a heavy-bladed weapon makes for a formidable opponent. However, an officer, *de facto* a gentleman, would have been expected to have had the time and money to learn how to use a small-sword properly.[xiii]

Evidence exists that the *colichemarde* went as far afield as America; it was carried by George Washington and other officers of the time. Washington owned four small-swords: the 1753 sword, the 1767 sword, the 1770 boat-guard, all silver-hilted, and the post-inauguration steel-hilted sword, and the last three all had *colichemarde* blades. The American weapons historian Merrill Lindsay [xiv] states that Washington favoured this blade design. Another authority[xv] writes that, certainly by the time he was president and he required the most fashionable cut-steel hilt, the blade itself would have had no practical use and the *colichemarde* was, "a reflection of his conservative nature". According to Lindsay his most notable *colichemarde* sword, the Inauguration Sword, was made in London. It has a silver hilt hallmarked James Perry dated1776-1777 and furbished by William Loxham, with a blade made in Solingen.

Even Benjamin Franklin, that most rational of enlightenment men, who could give good reasons for everything he did, owned two *colichemardes* [xvi]. Although not chiefly remembered nowadays for his military prowess Franklin had had some experience leading troops in the French and Indian War in 1756[xvii].

The National Maritime Museum, Greenwich, has in its collection the following several *colichemarde* swords with provenance relevant to Royal Navy officers:

WPN1056 Admiral Cuthbert Collingwood;

WPN1312 Richard, Earl Howe (see also 1246);

WPN1183 Captain James Cranston;

WPN1246 Admiral Richard Howe, 1st Earl Howe (*see also WPN 1312*).

Contemporary paintings also show that these swords were worn by officers, see that of Captain Edward Vernon shown in Figures 3a and 3b.

Fig 3. Capt. Edward Vernon (1723-1794) by Francis Hayman, Painted c.1755[xviii]. The enlargement, Fig 3b(R) shows the characteristic bulge in the scabbard, indicating that he is wearing a colichemarde small-sword.

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The first blades were usually diamond or lentoid (lens-shaped) cross-section in the *foible* and flat or hollow-ground in the *fort* (*Ref.7*), but with the passage of time the cross-section became uniformly triangular, often with a deep fuller in the *foible,* to produce a surprisingly light blade. It should be noted, however, that the *colichemarde,* with its thicker *fort*, weighed more than small-swords with a simply tapering blade; the author has weighed thirteen small-swords dating from the 1680's to the 1820's, and their mean mass is 352g (correct to three significant figures), including the mass of the hilt. The mean mass of thirteen *colichemardes*, as detailed below in table 2, weighed courtesy of the Royal Armouries, Leeds, was 466g, and this also includes the mass of the hilt.

RA Catalogue Ref.	Mass (g)
IX 2609	640
IX 689	538
IX 1392	453
IX 2554	553
IX 2644	450
IX 2242	453
IX 2804	453
IX 2082	425
IX 1438	320
IX 2140	482
IX 2083	383
IX2804	453
IX 1020	453
Mean	466
Standard Dev.	78.7

Table 2. The mean mass of thirteen *colichemardes* in the Royal Armouries.

As can be seen from table 2 above the sword IX 2609 is an outlier in the sample, without it the mean mass of the remaining swords is 451g and the standard deviation is 61 g.

The following plate, Figure 4, from Diderot shows the cross-section of different small-swords available in France in the 1760's, which also illustrates that the *colichemarde* was a minority design among blades.

Pl. V.

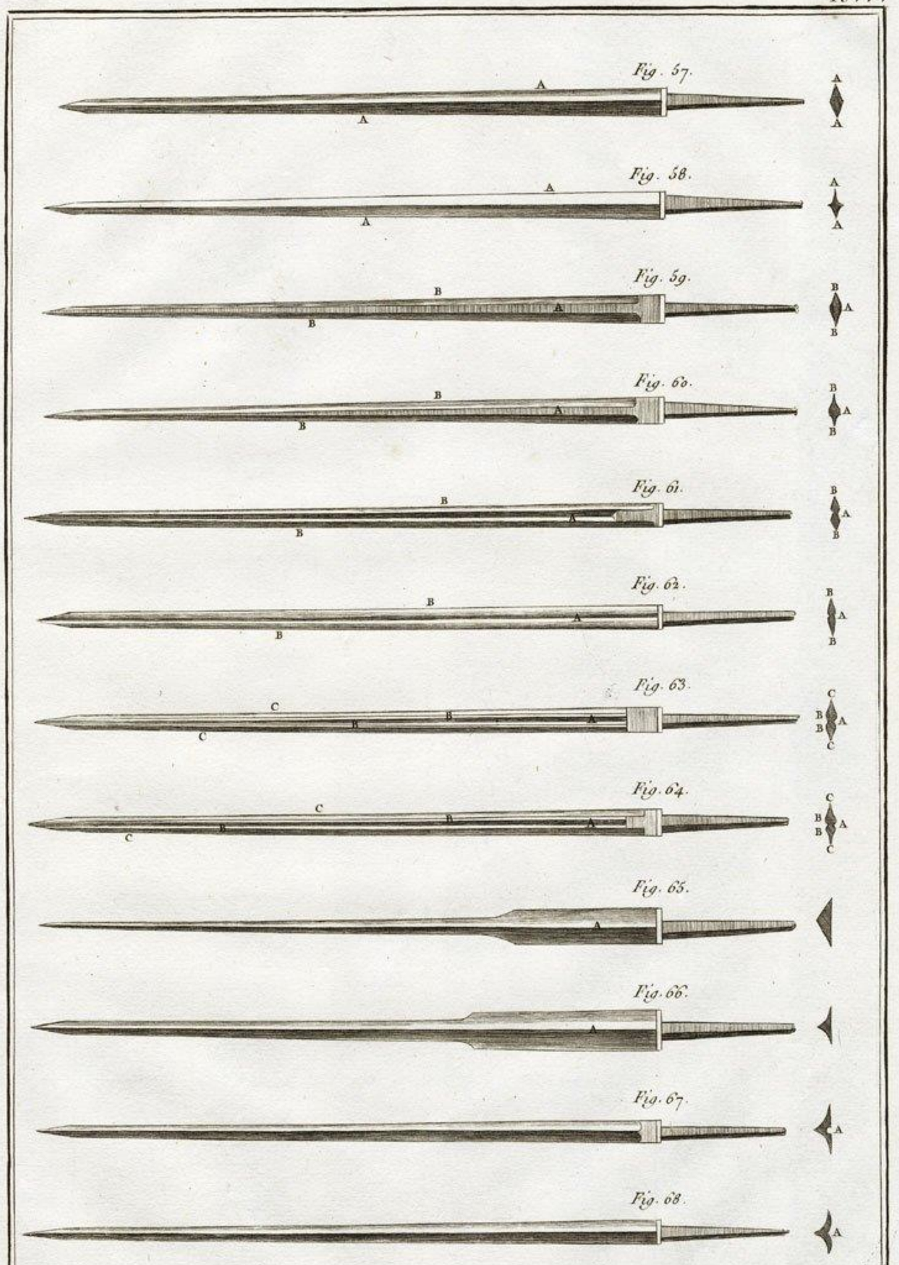

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Fig 4. Colichemardes third and fourth from the bottom.Plate from Diderot & D'Alembert, "*ENCYCLOPÉDIE OU DICTIONNAIRE RAISONNÉ DES SCIENCES, DES ARTS ET DES MÉTIERS*." 1765. The description of the plate does not use the word "*Colichemarde*", just using "*le renfort*" to describe the reinforcement of the blade at the *fort* [xix].

Nowadays *colichemardes* remain in the minority in collections. For example, the Metropolitan Museum New York has 160 small-swords in its catalogue, but only 4 *colichemardes*, the Royal Armouries Leeds has about 300 small-swords but only 14 *colichemardes,* the Royal Collection has 325 small-swords but only 2 labelled *Konigsbergs* (an early synonym as described above), and the National Maritime Museum Greenwich has over 120 small-swords but only 6 *colichemardes.*

The last mention of the blade in duelling use comes from America in the nineteenth century, when duelling with swords had lingered as more or less a socially acceptable practice. One source writing in 1885[xx] states the *colichemarde* was a popular duelling sword in New Orleans, especially among the Creoles who were originally native-born Louisianans of French or Spanish descent.

> "....... In the very heart of the town and only a few steps from the public ballroom on the rue d'Orleans, a duel could be carried on comfortably and without the least danger of interruption. If *colchemards* [*sic*], or Creole rapiers, which were generally used, and are to this day, in Creole duels, could be obtained, they were brought into use; but, if this was impossible, the young men had to content themselves with sword-canes."*(ibid).*

This paper only begins to explore the lost history of the *colichemarde* blade. Did it perhaps originate in Konigsberg? Did it, as Burton so confidently states in his high Victorian style, "fall into disuse probably in consequence of its costliness, combined with its inelegant appearance when sheathed"? These remain questions the author will continue to investigate. However, we will now turn to examining what an investigation of the dynamics and physical properties of *colichemarde* blades tell about their comparative utility in action.

Dynamical and mechanical property tests and comparison with other blade designs.

Introduction to the techniques of small-sword combat

From the time of the early French writers on the techniques of the small-sword, for example, Liancour, [xxi] to the last great classical author on the subject, Angelo,[xxii] the basic principles of technique remained the same, despite the increasing numbers of parries, slight variations in posture and the question of whether the un-armed hand should be used in defence. A proponent of this latter technique was Sir William Hope, writing in 1687, [xxiii] who advocated the use of the non-sword arm to parry, but most later masters generally disapproved of this, arguing that it would expose more of the body as a target.

From the point of any person involved in an antagonistic encounter with blades throughout history the primary objective has been the preservation of his or her life (*fencing* = *defence*) and the secondary objective is hitting the opponent. The small-sword is a short, light, piercing weapon designed for duelling and self defence rather than for use on the battlefield and its use was not confined to men, though women duellists were very uncommon. One notable example was the actress and opera singer Julie de Maupin, who was notorious for publicly challenging (and even killing) men at social occasions.[xxiv]

Throughout the period of the small-sword the constraints imposed by the design of the weapon, for example the rather awkward hilt (as described by the author in a 2016 paper[xxv]) influenced its technique. As far as the blade itself is concerned, its length (approximately 32 inches or 81cm), mass distribution and stiffness made it fit for purpose in attack with just a thrust or with a lunge. Should a gentleman meet another gentleman armed with a small sword, they would of course be equally matched with respect to weapon. However, should one man use a heavier weapon, in particular a cutting sword such as a sabre, different techniques needed to be employed by the small-swordsman and the next section of this paper considers whether the design of the small-sword, in particular the *colichemarde,* was fit for purpose in defence in such an encounter.

In defence against a heavier cutting blade such as a military sabre the shell-guard and knuckle-guard of any small-sword were fairly flimsy and easily damaged. In addition, in any encounter between a small-swordsman and an opponent wielding a sabre the hand and forearm of the small-swordsman would become the primary target of the *sabreur*, who would take great care not to expose his body to the potentially deadly thrust of the small-sword when cutting with his blade. In such encounters the small-swordsman would rely on the speed of his lighter weapon and on control of distance between him and his opponent; once *within* the sabre's length cuts with the sabre would prove impossible to deliver but thrusts with the small-sword could still kill. Should the *sabreur* decide to thrust with his point he would be putting himself in the position of a small-swordsman armed with a much heavier (and slower) weapon, whereupon the faster speed of the small-swordsman would put the *sabreur* at a disadvantage.

The approach

Consequently the following section deals with blade properties, specifically with comparative dynamics - the least energy required to deliver an effective hit by a *colichemarde* in comparison with a cutting weapon such as the sabre - and with the energy required by both weapons to execute a successful parry.

In addition, the *colichemarde* is investigated in comparison with other small-sword blade designs to see if its *Centre of Percussion* lies in the fort of the blade for successful beats (which are attacks directly on the opponent's blade in order to deflect it or knock it out of his hand) and parries (techniques of blocking or deflecting the opponent's attack).[xxvi]

Finally initial investigations are made to investigate if the *colichemarde* is stiff enough not to buckle when making a hit.

The results are summarised and the details of the data and calculations, including simplifying assumptions, are included in appendices.

Comparing the kinetic energies of a cutting weapon (the sabre) and the *colichemarde* in attack and defence.

To compare the two weapons in action one can envisage an encounter as illustrated below, figure 5 between a small-swordsman armed with a Colichemarde blade and a *sabreur.* Representative phases and individual "cuts" in the encounter are shown in figures 5 to 7 for attack, with the energies shown in figure 8, and 9 to 11 for defence, with the energies shown in figure 10. Appendix 1 describes the methods of estimating the kinetic energy of attack and defence in detail.

It is important to recognise that the comparison should take account of the tactics necessary for each antagonist, consequently for the sabre the motion of the blade in this investigation was measured just for a single 90 degree rotation of the *sabreur's* wrist, which is a *manchette* cut to the small-swordsman's wrist, figure 6. Any larger angle of movement would expose the *sabreur* to a potentially lethal stop-thrust from the small-swordsman. The *manchette*, as described by Sir Richard Burton[xxvii] is a cut to the wrist or forearm. In contrast, the *molinello* is a larger circular movement of a sabre from the elbow in making a cut. In the later style of the 19th century Italian school, it was recommended that movements should be made from the elbow but in a duel between a *sabreur* and a small-swordsman this move would be most dangerous for the *sabreur*. If the *sabreur* should attempt a *molinello*, he would have to bend his elbow and raise his arm, exposing him to a counter-attack (a *coupe d'arrête* or stop-thrust) from the small-swordsman. The danger was pointed out as early as the seventeenth century, when the Italian master Marcelli wrote, " In order to have the necessary speed..., one must remember the universal rule regarding cuts: they are to be delivered with the wrist only, without moving the whole arm, or they become wide and slow movements".[xxviii]

Fig 5. The small-swordsman on the left is using his coat as an added protection against cuts from the sabreur[xxix].

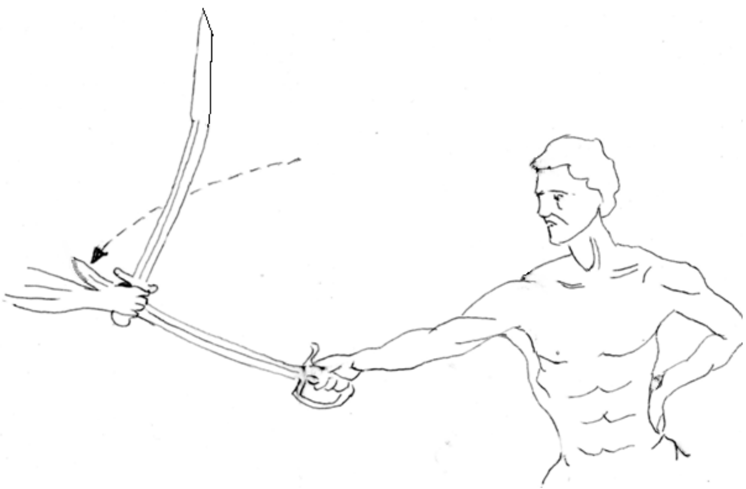

Fig. 6. A sabre cut to the wrist (“manchette”). After Starzewski [xxx] and Zablocki [xxxii]

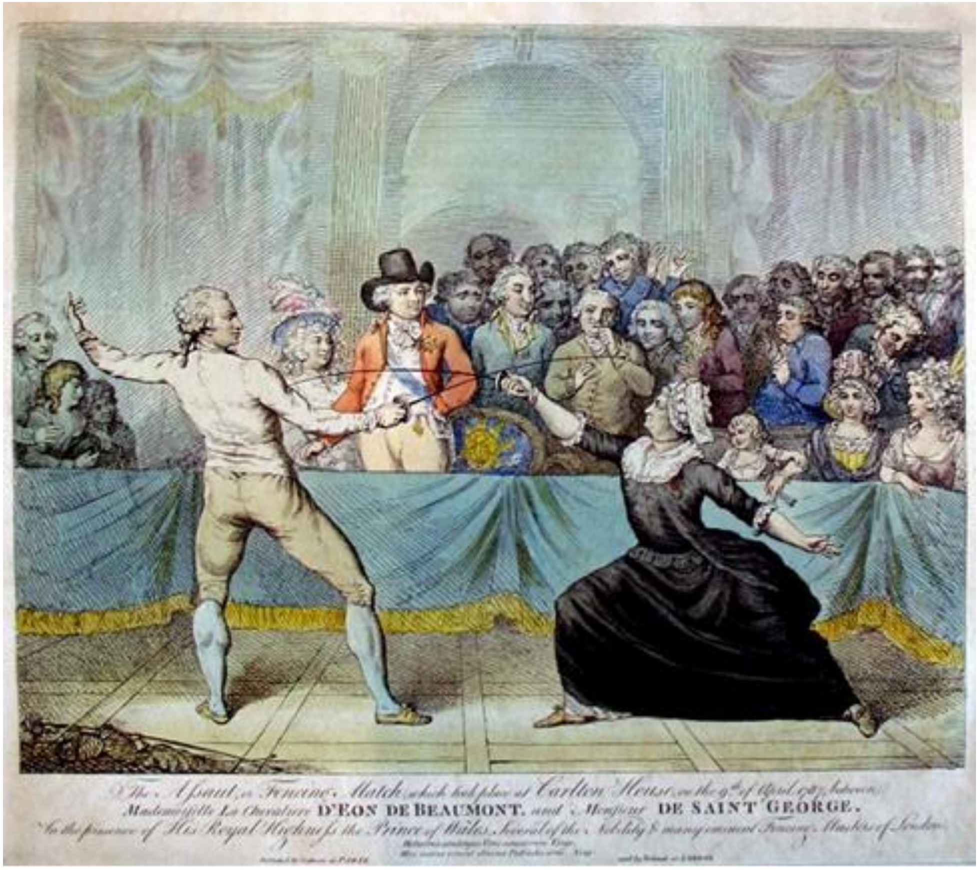

Fig 7. The lunge. The Chevalier D’Éon on the right lunges into the Chevalier de Saint-George at Carlton House on April 9^{th}, 1787, with the Prince Regent looking on[xxxi].

The energy of attack

The energy of the Colichemarde thrust is 2.39≤ KE ≤3.16 and the lunge 13.0J≤ KE ≤14.7J, while the Sabre cut energy is 3.53J≤ KE ≤4.37J and the lunge 14.9J≤ KE ≤16.8J. These are plotted in figure 8.

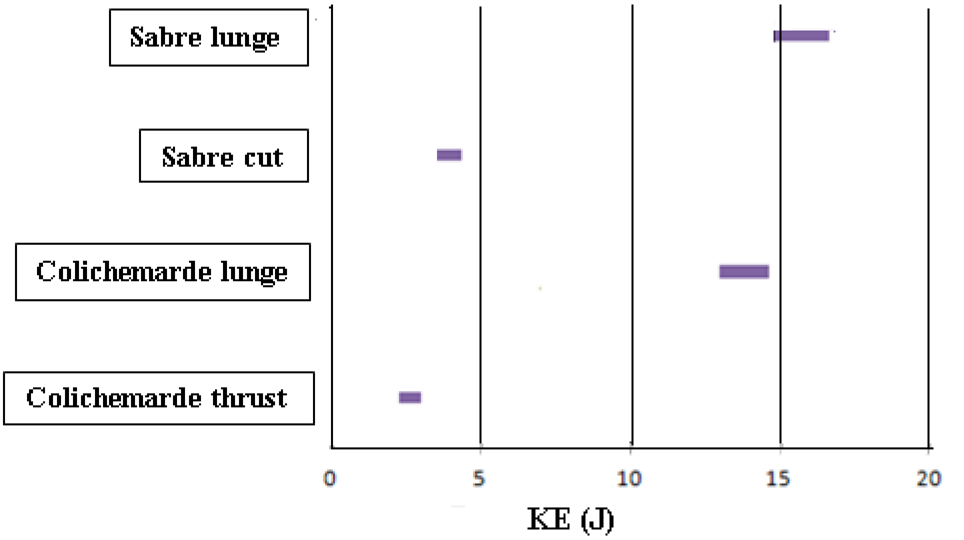

Fig 8. The attack Kinetic Energy of the colichemarde and sabre in cut and thrust, showing not only that the sabre cut has generally more kinetic energy than the colichemarde thrust but also that the lunge increases the amount of kinetic energy considerably.

Fig 9. A small-swordsman parrying an attack to the head by a rapierist, using the parry of high tierce. He would use the same technique against a sabre. From Domenico Angelo, "The School of Fencing" London 1787, first published in French 1763, English edition by his son Henry Angelo.

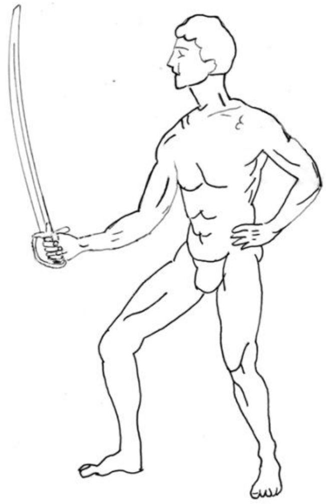

Fig 10. Sabre. The on-guard position after Zablocki[xxxii]

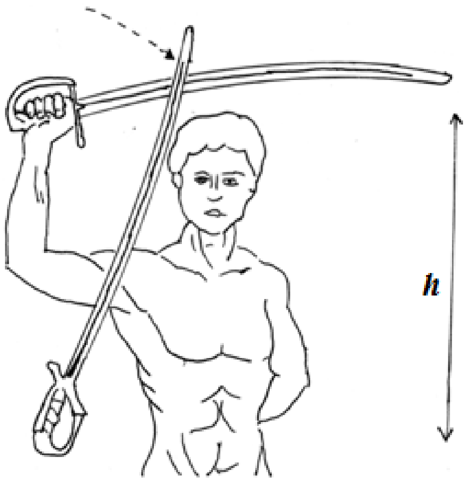

Fig 11. The Fifth sabre parry ("Quinte"). ***h*** *refers to the distance moved from on-guard. The sabreur would also use this parry to protect his neck and face from a small-swordsman's thrust or lunge.*

The Energy required in Defence.

For the sabre parry of *quinte* the energy needed to parry is 22.3J≤ Total Energy ≤24.5 J

The same calculation may be performed for the *Colichemarde* performing the parry of *High Tierce*, giving 21.6J≤ Total Energy ≤22.6 J

These are plotted on figure 12 and compared to the energies required in attack.

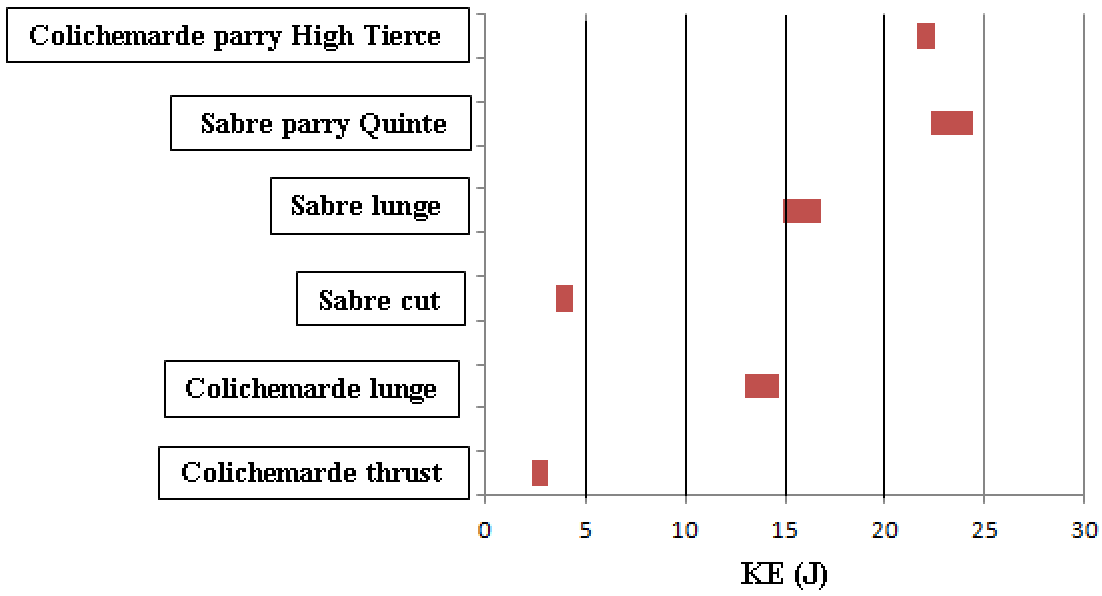

Fig.12. Summary results for the total energy required for the two attacks and the two defensive parries. The sabreur requires more energy to parry because he has a heavier weapon.

Discussion

These results take into account the range of mass of the fencers (see Appendix 1) which plays a major role in the energy needed and transferred. As can be seen from the results shown in figure 8 the cutting sabre has more kinetic energy than the thrusting *colichemarde*, due to the heavier weight of the blade and the fact that its motion has both rotational and translational linear components of kinetic energy, which have to be provided by the fencer. The sword is being rapidly angularly accelerated (as well as linearly) and something with a large moment of inertia will resist this. In the lunge the effect of the fencer's mass increases the kinetic energy dramatically, and one can clearly see why the lunge was adopted as the most efficient method for delivering an attack. Figure 12 shows a greater kinetic energy when wielding a heavier sword, the sabre, and that motion will be more difficult to stop with a parry, that is, it will be potentially capable of doing more damage. Similarly, when the sword is used for defence, the strength of the defending swordsman and the mass of the sword will help in warding off a potentially damaging blow, as well as the point along the blade the swordsman receives the blow, and the perfect point to do this from the defender's side is at the Centre of Percussion as is discussed below. The Centre of Percussion closer to the hand and a blade heavier towards the hilt are helpful to do this, and the *colichemarde*'s design, of all the small-swords examined, is optimal. In addition, a very light blade will have substantial advantage to the swordsman/woman in terms of rapid motions in attack and defence, especially for physically weaker fighters.

It must not be though, however, that the effectiveness of these weapons depends solely on their kinetic energies, clearly the target, and hence the technique required to deliver the attack with accuracy, is crucial. A thrust into the heart will prove instantly fatal whereas a thrust into a less vital organ or a muscle will leave the victim still able to fight. Conversely, a cut or even a heavy blunt blow into a leg, wrist, shoulder or arm may render the victim *hors de combat* yet still alive. It has been reported by R. Bruce Martin *et al.* [xxxiii] that the energy needed to fracture an adult tibia or femur is only 15J so that the kinetic energy of a sabre in a lunge as shown in figure 12 would be more than enough.

Angelo lays great emphasis on the small-swordsman controlling distance between himself and the sabreur; if he steps back on the sabreur's attack he will be safe, and if he steps in after parrying he will be within the sabre's distance and able to deliver a successful riposte.[xxxiv] In addition, Angelo advocates the very practical suggestion that the small-swordsman uses his coat with his other arm to catch any sabre cuts to his face, figure 5.

This illustrates the most important difference in purpose between the military and the civilian weapon, the former is effective if it injures the enemy sufficiently to incapacitate him on the battlefield whereas the latter is designed to defend and to kill stylishly in a duel, thus demonstrating the bravery of a gentleman willing to risk his life for the sake of his honour. In the case of the parries the results show that most energy is used to lift the arm, and once again more energy is required for the sabre, which is the heavier weapon, but also the fencer also has to supply the energy to lift his arm, which proportionally is at least three times as heavy as the sword. In battlefield use, clearly strength and stamina training for the use of heavy weapons was essential, continuous fighting required great fitness and muscle strength.

Donald McBane, that eminently practical man, soldier, fencing-master, prize-fighter and somewhat of a "ruffin," wrote *...But still the small-sword hath great odds of the broad, for the small-Sword Kills, and you may Receive Forty Cuts and not be Disabled"*[xxxv]. The author would agree with this statement with one proviso; only if the small-sword is used with skill, which can come only with practice.

We will examine now two details of the design of the *colichmarde*, the position of its Centre of Percussion and its critical force to buckling. Examination of these will help us understand how the small-swordsman armed with the *colichmarde* experiences the energy of the parry in defence and the relative risk of his sword buckling in the attack. The examination will show the particular advantages to the small-swordsman who has chosen a weapon with a *colichemarde* blade.

The Centre of Percussion of the Small-sword.

In his 2017 paper (JAAS, Vol. XXII No 3, 2017, 149-158) the present author concluded that the Centre of Percussion of cutting swords is towards the tip of the blade but it lies towards the handle in the small-sword because the cutting sword is more intended for offence in battle whilst the small-sword is more intended to defend the fencers in a one-on-one duel. This Centre of Percussion for any design of small-sword is the point at which no reaction will be felt in the hand when the opponent's blade is successfully deflected, that is parried, at that point. The tapering design of the small-sword's blade ensures its fitness of purpose for defence by the technique of the parry. The Centre of Percussion also comes into play in attack when it is used to strike or beat the opponent's blade out of the way to make an opening for a thrust or lunge. By measuring its position using the method described in this paper for 22 small-swords in private collections, ranging from the late 17th century to the first quarter of the 19th the mean can be calculated and an inference made of its distribution.

Assumptions

The greatest assumption is that the data are a representative sample of small-swords. Of course not all small-swords made have survived, and many in private hands are there only because of their artistic value, usually that of the hilt, although some have beautifully engraved or blued and gilded blades. Nevertheless, a) the sample below covers the age-range of the small-sword, b) there is enough data to make it statistically significant and c) they are all small-swords, and all small-swords were made to be used (if ever needed) in a defined set of particular techniques , that is, in the fast parry-riposte techniques exemplified by the French School. Small-swords would occasionally break (the author has seen blades which have broken due to metallurgical flaws, and this will be discussed in a future paper), and more work needs to be done to compare the strength of the *colichemarde fort* in comparison with that of an evenly tapering blade.

Figure 11 shows in red the distribution of the Centre of Percussion/Total Blade Length for 22 small-swords,a distribution skewed to the left. This result is not unexpected because the Centre of Percussion for thrusting civilian weapons lies in the *fort* region of the blade, as previously shown by the author. The mean indicates that the Centre of Percussion for this data was in general less than 0.4 of the way along the blade from the hilt. Anything greater than this would make the sword feel "blade-heavy" in movement, a great disadvantage to a fencing weapon whose technique relied on speed rather than on the *force majeure* of a cutting weapon such as the sabre, broad-sword or cutlass. The Spanish rapier of the eighteenth century also had its edges sharpened towards its tip and was used to make cuts at the head, as shown in figure 9, and the small-swordsman would use the parry of *high tierce* to parry its attack, just as he would against a sabre. Adding the data from eleven *colichemarde* small-swords held by the Royal Armouries, Leeds, shown in green, the following graph is obtained:

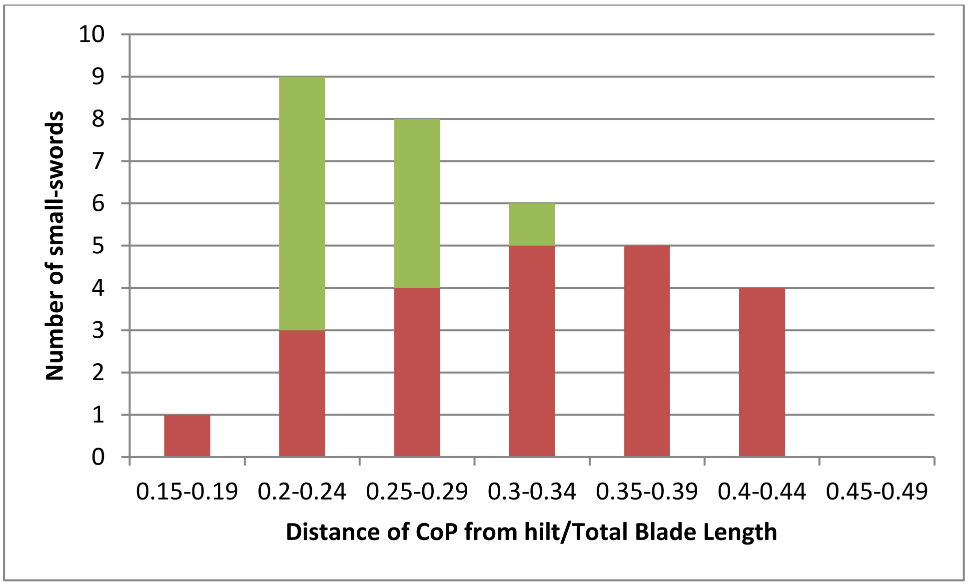

Fig 13. The distribution of the Centre of Percussion/Total Blade Length for 33 small-swords, including 11 Royal Armouries colichemarde blades.

The distribution is now altered by the fact that in all the Royal Armouries Colichemarde swords the Centre of Percussion lies between 0.21 and 0.32 of the distance along the blade (mean 0.24) indicating that its design is best of all the various swords examined for correctly parrying with the *fort.* All of the Centre of Percussion data is presented in Appendix 2.

The critical force to buckling of the *Colichemarde*.

If a thin thrusting blade encounters an obstacle such as bone it may bend plastically (i.e. without returning to its former shape) or buckle elastically, both phenomena rendering it useless in attack. These are noted as having occurred in duels, as in the case of the Rev. Mr Bate vs. Captain Stoney in 1777, when Mr Bate's sword bent on encountering Captain Stoney's breastbone.[xxxvi] The critical buckling force is defined as the limiting force where the blade starts to buckle and continues to buckle with no increase in force and then is able to recover elastically.[xxxvii] Considered as a beam, the *colichemarde* has a very wide and barely-tapering hollow triangular *fort* (for example, in the 1787 swordstick in a private collection, from a width of 2.1 cm to 1.9cm in a distance of 20 cm, and a thin tapering *foible*). It is reasonable to assume that the buckling would occur in the *foible*, that is, towards the tip end of the blade, where it is thinnest, if it were to meet an obstruction such as bone. It has been shown that the hollow triangular blade is theoretically the stiffest per unit mass of all the most common types of blade cross-section in use during the small-sword period (*see note 26*).

In essence, then, the *colichemarde* may be considered as just a shorter small-sword, fixed at the junction between *fort* and *foible.* In order to examine whether the *fort* on its own will buckle it is reasonable to model it as a steel beam, fixed at one end, subject to a compressive longitudinal axial force. For a steel beam, if its *slenderness ratio* $\lambda<50$ it is commonly assumed that the beam will not buckle but will fail by fracture, which would occur at a much greater force than that needed to cause buckling in the *foible.* The cross-section of the *fort* is an isosceles triangle (in the case of the 1787 swordstick a right-angled triangle) with hollowed-out sides, hence the name of this type of blade, a *hollow blade.* The results of the theory and experiments show that the *colichemarde* has the strongest force to buckling of all the different blade designs examined. Appendix 3 for shows the detailed analysis.

The critical buckling force can also be straightforwardly tested using the same experimental method as in *note 26*, where the blades were fixed in at the hand and then forced vertically downwards onto a digital balance until they underwent elastic buckling. Table 3 summarises experiments that show that the *colichemarde* result exceed the results for the critical buckling forces for other small-sword blade designs (with a modern fencing foil as comparison) quoted from note 47, which were, $\pm$1N.

Colichemarde blade	150 N
Russet-handled small-sword (hollow triangular)	103 N
Hollow diamond section	82.3 N
Rhomboidal section blade	72.5 N
Silver-handled sword (Hollow triangular)	69.6 N
Mourning sword (lentoid cross section)	59.8 N
French Military (hollow triangular)	68.6 N
Modern fencing foil (rectangular cross section)	50.0 N

Table 3. Comparison of Critical Buckling Force

Conclusion

These results show that the *colichemarde,* of all the small-swords of different blade cross-sections tested best satisfies the criteria of appropriate Centre of Percussion as is shown in figure 13 and stiffness, from the concept of force to buckling as is shown in table 3 above. The Centre of Percussion results are most persuasive in showing that the *colichemarde* can parry and beat without causing any reaction to the hand and therefore can be manipulated most efficiently. Of course, blades also broke due to metallurgical faults such as slag inclusions and cracks but these are factors distinct from the force to buckling, which for the purpose of this paper assumes uniform elastic beams in axial compression. In an encounter with a heavier sword, such as a sabre, the kinetic energy transferred is less due to its smaller mass as is shown in figures 8 and 12. With a lunge, where the mass of the fencer comes into play, differences in kinetic energy between the two weapons are less marked. For a parry, the greater mass of the sabre requires generally more energy, implying greater effort from the fencer. If used correctly, the small-sword will kill more efficiently than the cutting sabre which may only wound or disable. It remains to be investigated whether the construction of the weapon is robust enough to withstand any sustained use, for example, on the battlefield, but the fact that contemporary treatises such as Angelo's describe techniques to use a small-sword against heavier swords suggest that it was considered possible in a one-on-one encounter. Modern demonstrations (Note 34) show that this is indeed the case; the speed of manipulation of the point of the lighter sword is a great advantage in delivering a hit against an opponent with heavier blade, particularly if the swordsman is within the distance of the heavier blade, that is, close to his opponent. The fact that the *colichemarde* is the weapon of an officer who may only occasionally have to use it in battle indicate that its primary use was in duelling, self-defence and as a badge of status rather than as a battlefield weapon. It remains to be the subject of further investigations whether other hybrid weapons used by officers, such as the cut-and-thrust *spadroon,* were any better on the battlefield. We may, however, conclude from this study that in its time the *colichemarde* had exceptional fitness for purpose as a duelling and civilian weapon of defence.

It is a matter for further investigation why such an effective weapon was not universally used and then faded from history; at present the author's tentative opinion is that it was to do with the vagaries of fashion as well as the passing of the sword-duel as a means of preserving honour among gentlemen, but this is as yet an unanswered question.

APPENDIX 1. Method of comparing Cut and Thrust.

In this section details are provided of the calculations of Kinetic Energy. The calculation of the Centre of Percussion has been dealt with in a previous paper by the author (JAAS, Vol. XXII No 3, London 2017, 149-158).

For the non-technical reader the following definitions may be helpful. The Moment of Inertia is a concept analogous to Mass when a body (for example, a sword) is rotating about an axis, in the case of a sabre, about the wrist. The Radius of Gyration is the distance from the axis of rotation to the point where the entire mass of the sword appears to be concentrated, analogous to Centre of Mass (or Centre of Gravity) for a non-rotating body. The angular velocity is the rate at which a body rotates about the chosen axis, analogous to linear velocity (distance/time in a specified direction). The Kinetic Energy is the energy of movement of a body, whether linear, rotating or a combination of both, and the work needed to provide this energy has to come from the fencer's muscles.

Modelling the cut

The cut can be simply modelled as a circular motion of sabre pivoted at the handle. The Kinetic Energy of a rotating body is $½I\omega^2$ where I = Moment of Inertia of the sword and ω = angular velocity of the sword[xxxviii]. In order to calculate the Moment of Inertia the concepts of Centre of Percussion and Radius of Gyration can be used.

The detailed method of finding the centre of Centre of Percussion (also known as the Centre of Oscillation) of a body rotating around a given point is explained in detail in the author's previously published paper[xxxix].

Defining the variables,

Let L = distance from the pivot point to the Centre of Percussion of the sabre[xl].

M = Mass of Sabre.

T = Period of one oscillation of the sabre.

R = Radius of Gyration, $R = \sqrt{(Ld)}$ where d = distance from the pivot to the Centre of Mass of the sword,[xli] d can be determined by balancing the sword on a knife edge.

I = Moment of Inertia of the sword, $I = R^2M$. Hence $I = LdM$

ω = Angular velocity of the sword.

m_a = Mass of the fencer's arm.

Komlos[xlii], by studying the heights of several thousand recruits to the Austrian army in the eighteenth century, produced data which show that their heights 5% either side of the mean lay in the range 159 cm≤ h ≤176cm. By using the Body Mass Index of 22 for a typically fit young man we obtain their mass as 56.8kg≤ M ≤69.6kg. Assuming that, as de Leva (Note 45) calculates, the arm is approximately 5% of the body mass we obtain 2.84kg≤ m_a ≤3.48kg as the range of mass of the arm.

Since $KE = ½I\omega^2$ for rotation, we obtain $KE = ½LdM\omega^2$

In addition, because the centre of mass of the sabre moves vertically downwards the change in Gravitational Potential Energy of the weapon (*Mgh*) adds to the KE. Also the arm is extended forward from the on-guard stance so the linear kinetic energy of the arm plus the sabre, $½(m_a + M)V^2$, is added.

Total Energy $= ½LdM\omega^2 + Mgh + ½(m_a + M)V^2$ where g=9.8m/s^2 and h = vertical difference in height of the centre of mass of the sabre, in this instance = d, hence

Total Energy $= Md(½L\omega^2 + g) + ½(m_a + M)V^2$.

The mass of the arm m_a is 4.8kg (*see note 45*).

The motion of the blade in this investigation was measured just for a single π/2 radian rotation, a strike to the wrist (*manchette*) because a larger angle would expose the *sabreur* to a potentially lethal stop-thrust from the small-swordsman. The *manchette*, as described by Sir Richard Burton[xliii] is a cut to the wrist or forearm. In contrast, the *molinello* is a larger circular movement of a sabre from the elbow in making a cut. In the later style of the 19th century Italian school, it was recommended that movements should be made from the elbow but in a duel between a *sabreur* and a small-swordsman a *molinello*, which is a blade movement bigger than that made from the wrist, that is, by raising the arm, would expose the *sabreur* to a potentially fatal counter-attack (a *coupe d'arrête* or stop-thrust) from the small-swordsman. This was pointed out as early as the seventeenth century, when the Italian master Marcelli wrote, " In order to have the necessary speed..., one must remember the universal rule regarding cuts: they are to be delivered with the wrist only, without moving the whole arm, or they become wide and slow movements".[xliv]

Modelling the Thrust

The thrust can be modelled as a linear motion of arm and small-sword, so simply,

$$KE = ½mV^2$$

where m is the total mass in motion (which may include the whole body in a lunge, see Figure 7). Because the motion of this sword is horizontal there is no change in Gravitational Potential Energy.

Typically, the mass of an arm is approximately 5% of body weight.[xlv] The mass of the *colichemarde* small-sword used was 0.49kg.

Experimental Method for Determining Masses, Distances and Linear (*V*) and Angular Velocity (ω)

Mass was measured using an appropriate electronic balance, accurate to 0.001kg.

Distances were measured with a tape-measure, accurate to 0.01 m.

Measurement of *V* and ω were made using a Samsung Galaxy Tab 3 and *Coach's Eye* app, precise to 0.027s, as calibrated by videoing an electronic stopwatch.

The method can be summarised as follows:

1. Three videos of a thrust and a lunge using a *colichemarde* small-sword were made and examined frame by frame in order to measure the mean time of each action.
2. The average speed (=total distance moved/time taken) was calculated.
3. The kinetic energies were calculated using the formulae $KE = ½mV^2$ for the colichemarde thrust and $KE = ½(m_o + M)V^2$ for the lunge. For the cut, Total Energy $= Md(½L\omega^2 + g) + ½(m_a + M)V^2$ for the sabre. In the case of the sabre lunge, the term $½(m_a + M)V^2$ was replaced by $½(m_o + M)V^2$ where m_o is the total mass of the sabreur.
4. In the case of the sabre, ω was fixed at π/2 radians and the cuts timed by frame-by-frame analysis as in 1. In addition, the change in Gravitational Potential Energy of the centre of mass of the sabre was evaluated and added to the Kinetic Energy.
5. *L* was determined using the pendulum method described above and *d* by balancing the sword on a knife-edge and using a ruler accurate to 0.001m.
6. The experiments with the sabre were repeated including a lunge.

Mass of Colichemarde M		0.49 kg
Mass of sabre M		0.87kg
Mass of arm		2.84kg≤ m_a ≤3.48kg
Mass of fencer m_o		56.8kg≤ M ≤69.6kg
Sabre	d=	0.21m
Sabre	L=	0.529m
Mean time of cut (sabre)		0.399s (+/- 0.027s)
Mean time of thrust (Colichemarde)		0.456s (+/- 0.027s)
Mean time of lunge (both weapons)		0.855s (+/- 0.027s)
Horizontal distance moved by Colichemarde in thrust		0.3m
Horizontal Distance moved by fencer's centre of mass in lunge		0.5m
Colichemarde	d =	0.19m
	L=	0.31m

Table Appendix 1.1. Collected Data

Results for the Kinetic Energy of the Cut, Thrust and Lunge

The data collected are shown in table Appendix 1.1 Calculating using the measurements above and also accounting for the systematic errors in timing the results, using Komlos's data for the 18th century, the mass of the fencer's arm is 2.84kg≤ m_a ≤3.48kg and for his body it is 56.8kg≤ M ≤69.6kg. so, assuming the timing of the movements is the same, we obtain the following results for the kinetic energy, table Appendix 1.2:

Colichemarde thrust	2.39J≤ KE ≤3.16J
Colichemarde lunge	13.0J≤ KE ≤14.7J
Sabre cut	3.53J≤ KE ≤4.37J
Sabre lunge	14.9J≤ KE ≤16.8J

Table Appendix 1.2. Kinetic Energy of the Cut, Thrust and Lunge

The Energy required for Defence.

The same simple model can be used to compare the energy needed by each weapon to parry an attack.

In the case of the cutting blade trying to protect the head, figure 11, the model needs to take into account two rotations of the wrist as the arm is lifted to from the on-guard position, figure 10, to cover the head with the sabre. There is, in addition to a small upward rotation in the plane of the cutting edge of $\pi/4$ radians, a sideways rotation at right angles, in which a different moment of inertia must be calculated because of the asymmetry of the blade in an orthogonal plane. Fortunately the same apparatus as shown in note 39 can be used to measure L_o, the distance from the pivot point to the Centre of Oscillation of the blade, by suspending and oscillating the sabre at right angles to that shown in figure 2. The formula then becomes Total Energy $= \frac{1}{2}Md(L\omega^2 + L_o\omega_o^2) + (M + m_a)gh$, where d remains the same as that used to evaluate the Kinetic Energy of a cut, and h is the vertical height moved by the sabre's centre of mass.

By repeating the oscillation experiment with the sabre in the new orientation, $L_o = 0.529m$, which is the same as L.

The results are as follows, using the range of mass of the 18th century arm:

Total Energy $= MdL(\omega^2 + \omega_o{}^2) + (M + m_a)gh$

Now $(\pi/4)/(0.285+0.027) \leq \omega \leq (\pi/4)/(0.285-0.027)$

And $(\pi/2)/(0.285+0.027) \leq \omega_o \leq (\pi/2)/(0.285-0.027)$ and h=0.55m.

Hence by substitution into the formula above the Total Energy for the sabre performing the parry of Quinte is

22.3J≤ Total Energy ≤24.5 J

The same calculation may be performed for the *Colichemarde* performing the parry of High Tierce, giving

21.6J≤ Total Energy ≤22.6 J

APPENDIX 2. The Centre of Percussion Data.

The data plotted the body of the paper for Centre of Percussion is summarised in tables Appendix 2.1 and Appendix 2.2 below. Centre of percussion data for 22 small swords in private collections is presented in table Appendix 2.1 and Centre of percussion data for 11 *Colichemardes* in the Royal Armouries, Leeds in table Appendix 2.2.

Small-sword	Distance of CoP from handle/ Length of Blade
1830's English cut-steel court sword	0.17
1780 silver handle hollow blade	0.31
French Naval sword c 1820	0.34
Boy's small-sword c.1680	0.35
1720 (?) QUADRANGULAR section	0.36
Mourning sword 1790	0.38
Early 19c.French Navy 2-edged sword (1)	0.38
French military 1820	0.33
1780-90 russet handle hollow blade	0.41
18/19th.century Court sword	0.41
1787 Colichemarde sword-stick	0.44
1780's cut steel hilt mourning sword	0.40
silver-handled french colichemarde	0.34
silver boat-hilted colichemarde	0.22
English silver-handled colichemarde	0.38
Italian 1690 colichemarde	0.20
Modern colichemarde with 19th.c. handle	0.24
1690-1700 English fullered rhomboid section *foible*	0.38

1730 steel hilt hollow blade	0.30
1740 French russet & gilt	0.30
1800 Adam-styled silver handled Naval sword	0.28
1825-1832 Naval Purser's sword	0.29
Mean	0.34
Standard deviation	0.06

Table Appendix 2.1. Centre of percussion data for 22 small swords in private collections

	Colichemarde	Distance of CoP from handle/ Length of Blade
IX.2609	1840-1860 hilt. Early type blade, not hollow ground, sun, moon & star decoration.	0.25
IX.689	1730-1750. Early blade type sword, not hollow, decorated blade.	0.24
IX.1392	1690-1710. Hollow blade, gilded iron hilt.	0.25
IX.2554	1730-1770 Hollow blade.	0.21
IX.2644	1760-1780. Hollow blade. Hollow pierced pommel.	0.22
IX.2242	1748-1749 silver hilt. Hallmarked London. Hollow blade.	0.21
IX.2804	1751 silver hilt. Hallmarked London. Hollow blade.	0.26
IX.1438	1771 very ornate pierced silver handle & pommel. IR signature hallmarks. Hollow blade	0.24
IX.2140	1650- 1710. Blade marked "Antonio Pichinio". Early steel hilt. Fullered forte.	0.32
IX.2083	1680-1720. Composite. Norman type 112. A little rusty.	0.25
IX.3689	1701 Silver hilt. Hallmarked Richard Fuller. Very broad fort (3.5cm)	0.21
	Mean	0.24
	Standard Deviation	0.03

Table Appendix 2.2. Centre of percussion data for 11 *Colichemardes* in the Royal Armouries, Leeds.

APPENDIX 3. The Force to Buckling.

For the purpose of this paper we assume the simplest model for buckling, that is, the sword is a uniform elastic beam in axial compression. In addition, we assume the boundary conditions that the sword is fixed in at the attacker's hand and pinned at its point, when it hits a bone. These are of course approximations to what happens in a real sword fight but they give us a meaningful insight into comparisons between different blade designs.

Calculating the Slenderness Ratio

The *slenderness ratio* λ is defined as λ = D/k where k = the least Radius of Gyration about the centroidal axis of the cross-section and D is the length of the beam, in this instance, the *fort* of the *colichemarde*.

The Centre of Oscillation, and hence the Radius of Gyration of the cross-section of the blade may be determined by constructing a model of the cross-section of the blade because it is purely a property of the mass distribution of the shape of the cross-section. Using the same pendulum method as described to find the Centre of Percussion of a sword but in this instance a thin lamina polycarbonate scale model of the cross-section of the 1787 blade, swinging freely about a pivot point enables the determination of L the distance to its Centre of Oscillation (which is the same as the Centre of Percussion) from the pivot point as shown in figure 14.

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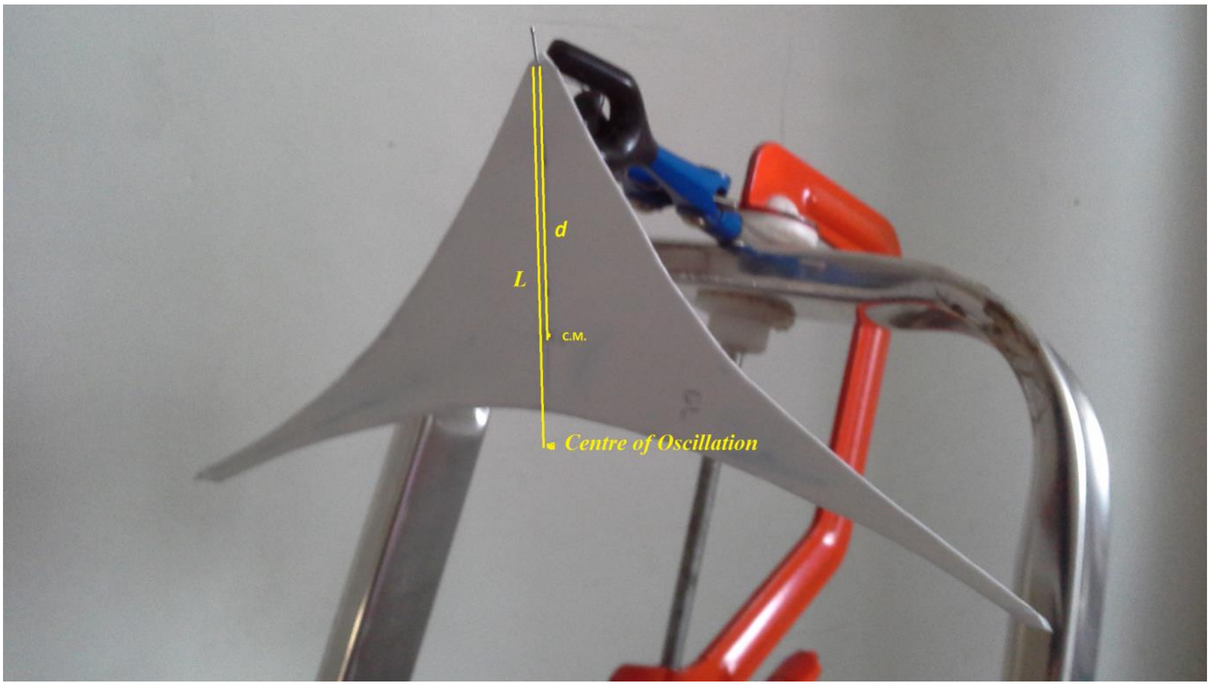

Fig 14. The lamina model of the Colichemarde blade cross-section suspended, with L and d marked.

A similar, but static, method was used to find the Centre of Mass and hence d, the distance from the pivot to the Centre of Mass, may be measured by suspending the cross-section model successively about several pivot points, letting it hang freely each time, and using a plumb line in each case to mark a vertical line, the centroid (that is, the position of the Centre of Mass) appears at the intersection of these marked lines.

Using these two experimental methods the Radius of Gyration, defined as $\mathrm{k} = \sqrt{Ld}$, may be evaluated. Hence $\lambda = \mathrm{D}/\sqrt{(Ld)}$, Where L and d are measured as shown above. Using the Parallel Axes Theorem to move the axes from those at the pivot point to the centroid, around which buckling will occur, the following relationship is obtained,

$$\lambda = \frac{\mathrm{D}}{\sqrt{(Ld - d^2)}}$$

For the 1787 *colichemarde* swordstick, the model being on a scale of 1: 12.7, and measuring the original to +/- 1mm,

240≤ D ≤243 cm and 7.50≤ d ≤7.70cm.

L was determined by video analysis and using the same formula as in Appendix 1 $L = 0.248T^2$ where T was the period of oscillation of the model of the cross-section as in *Fig 13*, to be 11.5≤ L≤12.5cm.

Hence λ was obtained as 39.5≤ λ ≤44.4, a ratio less than 50 required for buckling a steel beam. This strongly suggests that the *fort* of this *colichemarde* blade will not buckle but if it were to fail at all it would fail by fracture.

The *foible* of the blade, being a slender tapering column will buckle if the axial force exceeds its critical buckling force. Theoretically, as a first-order approximation this critical force is given by the Euler formula which may be written[xlvi]

$$F = \frac{\pi^2 EI}{(KL)^2}$$

Where E is the Modulus of Elasticity of steel (typically 200 GPa)

I is the Second Moment of Area of the cross-section.

K is the length factor, for the small-sword one end fixed and the other end effectively pinned it is approximately 0.7071.

L is the length of the blade.

Removing constants and considering other factors as equal,

$$F \alpha \frac{I}{L^2}$$

For a similar cross-section to the *fort* but of smaller dimensions I will be smaller. Therefore the foible of this blade, being some 30% shorter than a small-sword without the thick *fort*, should have F correspondingly nearly twice as large as a hollow non-*colichemarde* blade.

One may see from these results that the theory suggests that the design of the *colichemarde* gives it the greatest critical force to buckling of all the blade designs investigated. The experimental results are shown in table 3.

Thanks and Acknowledgments.

The author would like to express his particular thanks especially to the following; Dr Paul Bills and The Reverend Dr Paul Wilcock BEM of the University of Huddersfield for their encouragement and guidance in this research, and also to the following for their invaluable help:

Professor David Williams OBE, FREng, FSA, Loughborough University & Honorary Historical Consultant to the Royal Armouries, Leeds.

Professor Michael Questier, Hon. Professor, Department of History, Durham University & British Fencing Association Coach, Crawley Sword Club.

Dr John McGrath.

Mr Peter Smithurst, Mr Simon McKenna, Mr Christopher Dawson, Dr Bob Cattley, (all of the University of Huddersfield). Mr Henry Yallop, Mr Stuart Ivinson, Mr Keith Dowen (Royal Armouries, Leeds).

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[xxiv] Morton, E.D, "*Martini A-Z of Fencing",* Queen Anne Press, Macdonald, London. See also Robert Baldick, "*The Duel"* Spring Books, London, 1965. p.171.
[xxv] Maciej Pulaczewski*, "To Kill or to Score a Hit: Two Aspects of Form and Function of the Small-sword".* Journal of the Arms and Armour Society, Vol. XXII No 2, London 2016, p 50-71.

[xxvi] Maciej Pulaczewski, "*The Dynamics of Duelling and the Kinetics of Killing: Notes on the Centre of Percussion of Different Sword Designs."* JAAS, Vol. XXII No 3, London 2017, 149-158.
[xxvii] Sir Richard Burton, "*A New System of Sword Exercises for Infantry"*, London, 1876. The *molinello* is described in *"Instruction for the use of Sword and Sabre of Professor Giuseppe Radaelli*" by Capt. Del Frate, Milan 1876.
[xxviii] Francesco Antonio Marcelli, "*Regole Della Scherma.*" Rome, 1686, libro quarto, trans. Carlo Parisi.
[xxix] Domenico Angelo, article in Denis Diderot "*ENCYCLOPÉDIE OU DICTIONNAIRE RAISONNÉ DES SCIENCES, DES ARTS ET DES MÉTIERS*." Paris 1772.
[xxx] From Michal Starzewski, *" Traktat O Szermierstwie"*,written 1830, first pub. Kraków 1932. This illustration is from a treatise on the Polish military sabre tradition, as quoted by Zablocki (*vide infra*)..
[xxxi] Stipple engraving with aquatint by Victor Marie Picot (1744-1805) after a painting by Charles Jean Robineau.
[xxxii] Wojciech Zablocki, "*Ciecia prawdiwa szabla",* Warsaw 1989.
[xxxiii] R.Bruce Gordon *et al."Skeletal Tissue Mechanics"*, Springer, New York 1998 p 140.
[xxxiv] This was shown to be effective in a demonstration at The Arms and Armour Society meeting in the Tower of London in February 2017 by the present author and Professor Michael Questier, then of Queen Mary College, University of London. Professor Questier's body mass is smaller than that of the author and yet his exemplary technique enabled him to parry the sabre and riposte successfully.
[xxxv] Donald McBane, *"The Expert Swordsman's Companion"* Glasgow 1728.
[xxxvi] William Douglas, *"Duelling Days in the Army"*, London 1887.
[xxxvii] Maciej Pulaczewski, *"To Kill or to Score a Hit: Two Aspects of Form and Function of the Small-sword".* Journal of the Arms and Armour Society, Vol. XXII No 2, London 2016, p 50-71, Endnote 43.
[xxxviii] D.H.Fender*, "General Physics and Sound"*, English Universities Press Ltd. London 1957.
[xxxix] Maciej Pulaczewski, "*The Dynamics of Duelling and the Kinetics of Killing: Notes on the Centre of Percussion of Different Sword Designs."* JAAS, Vol. XXII No 3, London 2017, 149-158.
[xl] Maciej Pulaczewski, *"To Kill or to Score a Hit: Two Aspects of Form and Function of the Small-sword".* Journal of the Arms and Armour Society, Vol. XXII No 2, London 2016, p 50-71.
[xli] H.Goldstein, CP Poole, JL Safko, "*Classical Mechanics (3rd edition),"* Addison Wesley 2001.
[xlii] J. Komlos*, "Nutrition and Economic Development in 18th Century Hapsburg Monarchy",* Princeton University Press 2014.
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[xliv] Francesco Antonio Marcelli, "*Regole Della Scherma.*" Rome, 1686, libro quarto, trans. Carlo Parisi.
[xlv] Paolo de Leva "Adjustments to Zatsuorsky-Seluyanov's Segment Inertia Parameters", Journal of Biomechanics 29(9), pp 1223-1230 1996.
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