

A Comparison of Late 16th to Early 17th Century Rapiers with Modern Reproductions

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Abstract

This paper presents a comparison of original period rapiers from 1590-1620 with modern reproductions for historical fencing use. After the definition of relevant parameters follows a description each weapon with detailed measurements including blade cross section profiles for seven original period rapiers and five modern rapiers. These measurements clearly show, that on average, historical originals are longer, heavier and exhibit a stronger ricasso and forte which strongly influences handling and therefore the possible style of fencing.

I. INTRODUCTION

FOR THE STUDENT who aims to recreate the fencing style of a chosen master or school as accurately as possible, not only source material study and assiduous training do matter - the correct tool for the job is imperative.

Although there are many reproduction rapiers across a wide price range available, most of them do not have the handling characteristics of period originals. The aim of this article is a comparison of detailed measurements, especially of the blade geometry of original swords with modern reproductions.

Of course, the application and therefore the requirements differ. Back then, a rapier had to be quite stiff, hold a sharp edge and point and still be flexible enough not to break. Today we want rapiers that are very flexible and durable, so they are suitable for full contact sparring, while retaining the handling characteristics of an original as much as possible. This is a difficult compromise, especially if the budget is limited.

The range of weapons we will be considering in this article are applicable to italian style rapier fencing as described in the treatises of the late 16th to early 17th century. These include, among other authors: Salvator Fabris [Fabris, 1601], [Fabris, 1606], Ridolfo Capoferro [Capoferro, 1610], Nicoletto Giganti [Giganti, 1606].

This article is divided into following sections:

- Definition and explanation of the parameters and properties which define the handling characteristics of a rapier.
- Description and measurements of seven original rapiers from the Hofjagd- and Rüstkammer in Vienna, spanning a wide range of types from a limited time period (appr. 1590-1620).
- Description and measurements of five modern reproduction rapiers all suitable for full contact sparring, spanning a wide range of quality and price.

- Discussion of the results and comments on weapon handling.

II. RAPIER HANDLING PARAMETERS

Before we can compare different weapons, we must define all parameters that affect the handling of a rapier. Most of these parameters are common to all swords and quite clear, although some need a more detailed explanation, which follows. We begin with directly measurable properties.

- *Overall Length* – This is one of the most important properties of any sword. For rapier fencing it is crucial to use a weapon of suitable length to be able to perform techniques correctly. Some masters explicitly mention their preferred length, for example Ridolfo Capoferro states that the sword should reach to your armpit while standing [Capoferro, 1610]. The actual overall length of period as well as modern rapiers varies considerably as we will see in the measurements.
- *Overall Weight* – This is an equally important property of any sword and for a thrusting weapon like the rapier to a degree related to its length. We do not know of a source or a master who states any weight preferences, so here we have to rely on measurements of period weapons.
- *Handle Length* – Often overlooked, the handle length as well as handle shape of a rapier strongly influence its handling. Only few sources explicitly describe how to hold the rapier and the plates show two methods. One is a standard hammer grip, the other a grip with the index finger wrapped around the ricasso. Joachim Köppen, for example, dedicates a plate on how to hold the rapier and apparently prefers the former [Köppen, 1619]. Handle length is measured from the pommel to the crossguard.
- *Blade Length* – This is a property directly related to overall length. It can be calculated as overall length minus pommel, handle and ricasso length. See fig. 17.
- *Point of Balance (POB)* – The point of balance is usually considered the main parameter of handling and it can also be easily located by balancing the sword on a finger. However, it only determines a small part of the handling characteristics. For further information, see [Le Chevalier, 2011]. It is measured from the center of the crossguard.
- *Centers of Oscillation or Pivot Points* – In addition to the POB, pivot points are important parameters of the handling properties of a rapier. For an explanation of pivot points, see [Le Chevalier, 2011] and [Johnsson]. In this article we have chosen the pair of pivot points where one is located in the center of the crossguard and the corresponding one along the blade. This accurately represents the handling of a rapier, because the center of movement is usually near the ricasso block.
- *Ricasso Length, Width and Thickness* – Like the handle, the ricasso also doesn't get the attention it deserves. Especially if the sword is held with one finger over the ricasso, the width, thickness and shape have a major impact on the handling of the weapon. Ricasso length is measured from the crossguard to the beginning of the blade.
- *Blade Cross Section along the Blade* – We have included this set of measurements, because it is the only way to completely define a blade, especially if one wants to reproduce it.

From the above measurements, one can derive calculated, or "virtual" parameters, which help describe blade handling and dynamic properties of the rapier.

- *Virtual Blade Weight* – This is the weight measured at the pivot point on the blade. It is a virtual indicator of perceived blade weight, not to be confused with actual blade weight.
- *Virtual Crossguard Weight* – This can be calculated as: overall weight minus blade weight.

- *Dynamic Length* – This is the distance from the center of the crossguard to the blade pivot point.
- *Blade Presence* – This is a calculated parameter, representing the ratio of blade weight to overall weight.

III. BLADE CROSS SECTION CALCULATION

Blade cross sections can be calculated along each blade according to its shape. To keep matters simple, we have omitted fullers in this paper, as their influence on handling is in most cases insignificant and would unnecessarily complicate the calculation of cross sections. Of course they need to be regarded when reconstructing blades, yet this will be covered in another paper. Modern training blades have a striking edge and are not ground sharp. For those blades we can calculate:

Hexagonal Cross Section

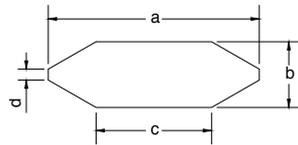


Figure 1: Hexagonal cross section.

$$A = (b - d)c + ad + \frac{(b - d)(a - c)}{2} \quad (1)$$

Diamond Cross Section

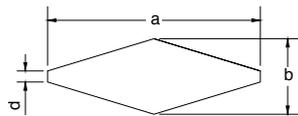


Figure 2: Diamond Cross Section.

$$A = ad + \frac{(b - d)a}{2} \quad (2)$$

For sharp blades we can disregard the striking edge and therefore simplify as follows:

Hexagonal Cross Section

$$A = bc \frac{(b(a - c))}{2} \quad (3)$$

Diamond Cross Section

$$A = \frac{ba}{2} \quad (4)$$

Square and triangular cross sections are trivial and therefore omitted here.

IV. DESCRIPTION AND MEASUREMENT OF SEVEN PERIOD RAPIERS FROM 1590 TO 1630

In this section we present descriptions and detailed measurements of seven original period rapiers from the Hofjagd- and Rüstkammer in Vienna. All weapons can be dated to the time period between 1590 and 1630, which corresponds well with the publication dates of relevant treatises.

IV.1. OBJECT A1032

This rapier is an outstandingly well preserved specimen from the early 17th century. It features a long, strong blade made by Juan Martin in Toledo, well suitable for cuts while still retaining very swift handling.

The ricasso is rectangular, with two fullers, the blade is of hexagonal shape with one fuller, ending in a diamond shape shortly before the point.

The hilt consists of solid, blackened, hexagonal bars, with a short rectangular wire-wrapped handle intended to be gripped with the index finger around the ricasso. The pommel is of tapered cylindrical shape with 10 bevels.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 60
- *Inner Guard*: Type 31
- *Pommel*: Type 32 (Decagon)



Figure 3: Object A1032 - Hilt and forte.



Figure 4: Object A1032 - Point.

IV.2. OBJECT A1248

Object A1248 is a classic two-ring rapier, with a doubly-fullered hexagonal blade. The ricasso is rectangular with two wide fullers on both sides.

The hilt is made of round, undecorated bars with a straight crossguard. The handle is made of wood with almost rectangular cross section. It probably had been wire-wrapped in the past, due to the rough finish of the handle surface. The pommel is a tapered cylindrical shape with six bevels.

Due to the uncommon form of the point and the hammer marks near the point, we assume that the blade was originally longer and either broke or had been reworked at some point.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 58
- *Inner Guard*: Type 30
- *Pommel*: Type 32 (Hexagon)



Figure 5: Object A1248 - Hilt and forte.



Figure 6: Object A1248 - Point.

IV.3. OBJECT A1600

This rapier from the early 17th century features a very stiff thrusting blade and a rather rare hilt form.

The ricasso is of narrow, hollow-ground rectangular shape. The blade starts with almost rectangular cross-section with three fullers, at 10cm changing to hexagonal shape with one fuller ending in a diamond shaped debole.

The hilt is made of rectangular bars, with a perforated protection plate for added hand protection. In- and outside of the guard are symmetrical. The handle is wire-wrapped, spirally fluted, tapered on both ends with an oval cross section. The pommel is a simple type with smooth spherical shape.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: No exact match.
- *Inner Guard*: Symmetrical to outside.
- *Pommel*: Type 29



Figure 7: Object A1600 - Hilt and forte.



Figure 8: Object A1600 - Point.

IV.4. OBJECT A1027

Object A1027 has been dated to 1613. The blade is exceptionally long at 118.5cm. It starts with a narrow, hollow-ground ricasso, followed by an almost square shaped forte, changing to hexagonal cross section along the blade and ending diamond shaped in the last quarter. This is a pure thrusting weapon, not suitable for heavy cuts. Interestingly, the blade is quite flexible.

The hilt is a three-ring design, lavishly decorated with chisel work and partly gilded. The wire-wrapped handle has an oval cross section along its length and is tapered on both ends, a perfect design to be held in a hammer grip. The pommel is heavy, ovoid-shaped and as nicely decorated as the rest of the hilt.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 61
- *Inner Guard*: Type 35
- *Pommel*: Type 29



Figure 9: Object A1027 - Outer guard and forte.



Figure 10: Object A1027 - Point.

IV.5. OBJECT A1340

This rapier, dated to appr. 1590, has a narrow diamond shaped blade of average length.

Interestingly, the transition from ricasso to blade is inside the hilt, which is usually not the case. See fig. 11.

The hilt is a symmetrical ring hilt with additional decoratively pierced protection plate. It has been repaired in some spots, presumably with brass solder. The wire-wrapped handle has a rectangular cross section, tapered towards the pommel. The pommel is pear-shaped and bevelled.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 73
- *Inner Guard*: Symmetrical to outer guard
- *Pommel*: Type 58



Figure 11: Object A1340 - Hilt and forte.



Figure 12: Object A1340 - Point.

IV.6. OBJECT A572

This beautiful specimen has a solid rectangular ricasso, a hexagonal blade with two fullers, decorated with perforations. The fuller inscription and bladesmith's mark identifies its maker as Juan Martin of Toledo.

The german-style hilt, as well as the pommel, is finely engraved and partly gilded. The fluted wire-wrapped handle has roughly octagonal cross section and is tapered towards the pommel.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 52
- *Inner Guard*: Type 30
- *Pommel*: Type 29



Figure 13: Object A572 - Hilt and forte.



Figure 14: Object A572 - Point.

IV.7. OBJECT A1318

Object A1318 is a rapier with a very rare triangular blade. It has a narrow but thick ricasso that transitions to a quite wide triangular blade. The back side of the blade is hollow-ground similar to some saber blades, yet from 10cm from the point the back side is also sharpened to an edge. The blade is extraordinarily rigid and balances nicely.

The hilt is a simple, plain three-ring hilt with a rare inner guard not found in Norman's classification. The pommel shape is a tapered, fluted cylinder. The rectangular handle is wire-wrapped and tapered towards the pommel.

It can be classified according to [Norman, 1980]:

- *Outer Guard*: Type 61
- *Inner Guard*: No match
- *Pommel*: Type 31



Figure 15: Object A1318 - Hilt and forte.



Figure 16: Object A1318 - Point.

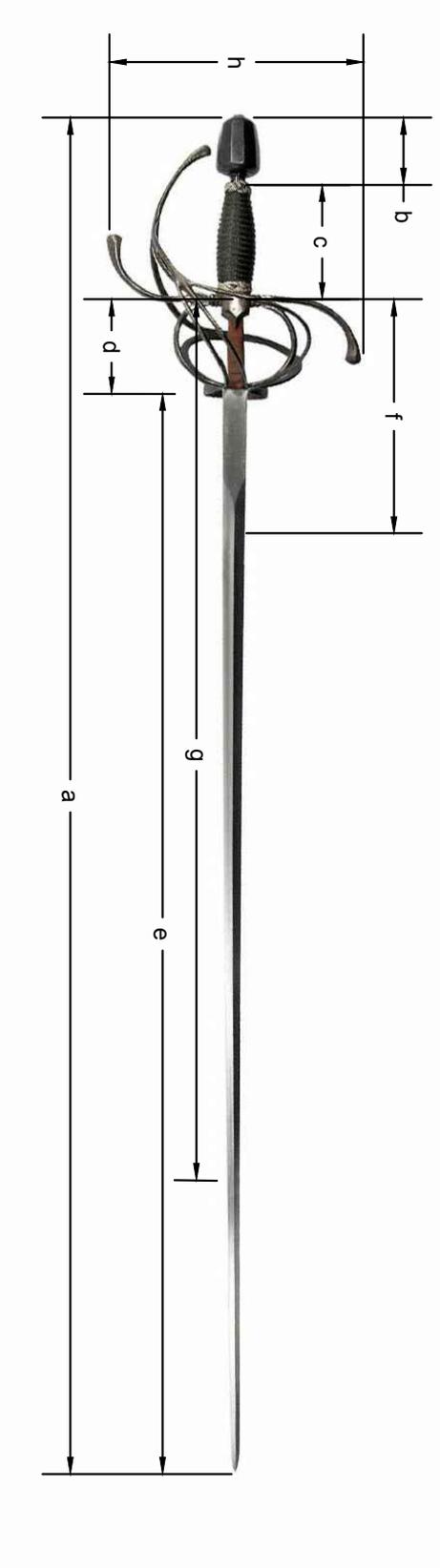


Figure 17: Sketch of rapier dimensions of table 1.

	A1032	A1248	A1600	A1027	A1340	A572	A1318
Overall Length [mm]	a 1307	1136	1243	1405	1242	1198	1296
Overall Weight [g]	1630	1140	1340	1340	1260	1220	1360
Pommel Length [mm]	b 70	66	58	64	55	61	62
Handle Length [mm]	c 79	83	84	83	77	80	77
Ricasso Length [mm]	d 66	62	66	73	45+25	71	77
Blade Length [mm]	e 1092	925	1035	1185	1040	985	1080
Point of Balance [mm]	f 120	110	95	115	140	135	155
Dynamic Length [mm]	g 788	692	736	783	710	616	?
Virtual Blade Weight [g]	246	182	184	199	202	280	319
Virtual Crossguard Weight [g]	1384	958	1156	1141	1058	940	1041
Blade Presence [%]	15	16	14	15	16	23	23
Ricasso Width [mm]	24.4	18.3	17.5	14.7	17.5	22	16.8-18.2
Ricasso Thickness [mm]	9	8.3	9.2	10.3	9.2	8.3	9.5
Number of Fullers	1	2	3	-	-	2	1
Fuller Length [mm]	244	210	190/100	-	-	240	990
Fuller Width [mm]	6.2	3.6	5/2.5	-	-	4	Blade thickness
Fuller Depth [mm]	2.7	1.3	2/1	-	-	1.8	1
Crossguard Length [mm]	h 280	225	235	230	275	-	220
Crossguard Thickness [mm]	8.6	7.4	4.8x8.5	5.6	5	6.1x11	6.7
Blade Cross Section	Hexagonal / Diamond	Hexagonal	Hexagonal Diamond	Hexagonal / Diamond	Diamond	Hexagonal / Diamond	Triangular
Crossguard Cross Section	Hexagonal	Round	Rectangular	Square	Square	Rectangular	Round

Table 1: Comparison of measured parameters of seven period rapiers.

Length [mm]	Width [mm]	Thickness [mm]	Hexagon Width [mm]	Cross section [mm ²]	Shape
Ricasso	24.4	9	0	219.6	Rectangle
0	26.5	9.0	11	168.75	Hexagon
100	23.6	7.5	8.9	121.88	Hexagon
200	20.2	7.0	7.65	97.48	Hexagon
300	18	6.5	3.6	70.2	Hexagon
400	17.4	5.7	3.4	59.28	Hexagon
500	16.9	5.4	2.85	53.33	Hexagon
600	16.1	5.2	2.15	47.45	Hexagon
700	15.6	5.0	2.15	44.38	Hexagon
800	15.6	4.6	1.6	39.56	Hexagon
900	15.3	4.0	0	30.6	Diamond
1000	14.5	3.0	0	21.75	Diamond
1100	9.2	1.2	0	5.52	Diamond

Table 2: Blade cross section of object A1032

Length [mm]	Width [mm]	Thickness [mm]	Hexagon Width [mm]	Cross section [mm ²]	Shape
Ricasso	18.3	8.3	0	151.89	Rectangle
0	20.8	7.5	11.7	121.88	Hexagon
100	17.2	6.3	10.7	87.89	Hexagon
200	15.6	6.4	9.5	80.32	Hexagon
300	14.7	6.1	-	-	Hexagon
400	14.5	5.9	-	-	Hexagon
500	14.2	5.9	-	-	Hexagon
600	14.2	5.5	-	-	Hexagon
700	14.2	4.9	-	-	Hexagon
800	13.8	4.0	-	-	Hexagon
900	13.8	2.6	-	-	Hexagon

Table 3: Blade cross section of object A1248

Length [mm]	Width [mm]	Thickness [mm]	Hexagon Width [mm]	Cross section [mm ²]	Shape
Ricasso	17.5	9.2	0	161	Rectangle
0	18.3	8.8	13.5	139.92	Hexagon
100	15.7	6.8	6.5	75.48	Hexagon
200	15.6	6.2	5.1	64.17	Hexagon
300	14.6	5	-	-	Hexagon
400	14.5	4.7	-	-	Hexagon
500	14.4	4.4	-	-	Hexagon
600	15	4.2	0	31.5	Diamond
700	15.2	3.8	0	28.88	Diamond
800	15.5	3.5	0	27.13	Diamond
900	15.7	3.7	0	29.05	Diamond
1000	15.7	1.7	0	13.35	Diamond

Table 4: Blade cross section of object A1600

Length [mm]	Width [mm]	Thickness [mm]	Hexagon Width [mm]	Cross section [mm ²]	Shape
Ricasso	14.7	10.3	0	151.41	Rectangle
0	14.5	9.6	10.23	118.7	Hexagon
100	11.9	8.8	8.4	89.32	Hexagon
200	11.2	8.6	7.4	79.98	Hexagon
300	10.5	7.7	1.9	47.74	Hexagon
400	10	6.9	1	37.95	Hexagon
500	9.8	6.4	1	34.56	Hexagon
600	9.7	5.6	1	29.96	Hexagon
700	9.7	5.2	1	27.82	Hexagon
800	9.6	5	1	26.5	Hexagon
900	9.7	4.7	0	22.8	Diamond
1000	9.9	4.1	0	20.3	Diamond
1100	10.2	3.1	0	15.81	Diamond
1160	10.2	1.7	0	8.67	Diamond

Table 5: Blade cross section of object A1027

Length [mm]	Width [mm]	Thickness [mm]	Cross section [mm ²]	Shape
Ricasso	17.5	9.2	161	Rectangle
0	20.6	8.6	88.58	Diamond
100	19.2	7.6	72.96	Diamond
200	18.9	7.3	68.99	Diamond
300	18.6	6.4	59.52	Diamond
400	16.8	5.9	49.56	Diamond
500	15.8	5.6	44.24	Diamond
600	15.3	5.2	39.78	Diamond
700	14.7	4.5	33.08	Diamond
800	13.7	4.2	28.77	Diamond
900	13.5	3.9	26.33	Diamond
1000	11.8	3	17.7	Diamond

Table 6: Blade cross section of object A1340

Length [mm]	Width [mm]	Thickness [mm]	Hexagon Width [mm]	Cross section [mm ²]	Shape
Ricasso	21.95	8.3	0	182.19	Rectangle
0	26	8.22	15.8	171.8	Hexagon
100	23.2	6.5	12.4	115.7	Hexagon
200	20.3	6.1	10.4	93.64	Hexagon
300	17.8	6	5.1	68.7	Hexagon
400	16.4	5.7	3.3	56.15	Hexagon
500	15.5	5.7	2.65	51.73	Hexagon
600	14.7	5.3	2.65	45.98	Hexagon
700	14.3	4.9	2.65	41.53	Hexagon
800	13.6	4.4	2.1	34.54	Hexagon
900	13.2	3.8	0	25.08	Diamond
950	12.5	3.36	0	21	Diamond

Table 7: Blade cross section of object A572

Length [mm]	Width [mm]	Thickness [mm]	Cross section [mm ²]	Shape
Ricasso	18.2	9.5	172.9	Rectangle
0	27.1	9.9	134.15	Triangle
100	23.6	8.7	102.66	Triangle
200	22.15	8.2	90.82	Triangle
300	20.8	7.7	80.08	Triangle
400	19.3	7.2	69.48	Triangle
500	17.8	6.6	58.74	Triangle
600	17.3	6.6	57.09	Triangle
700	16.7	6.35	53.02	Triangle
800	15.5	5.85	45.34	Triangle
900	13.7	5	34.25	Triangle
1000	9.3	3.85	17.9	Triangle

Table 8: Blade cross section of object A1318

V. DESCRIPTION AND MEASUREMENT OF FIVE MODERN RAPIERS

In this section we list a range of modern training and sparring rapiers. All of them are made with cost effectiveness in mind and are designed for modern training and sparring use.

V.1. ARMS & ARMOR LOMBARDY RAPIER

This is a high quality, modified reproduction of a weapon from the Museo Poldi Pezzoli in Milan. The blade has a diamond cross section along the entire length and a fuller in the first quarter of the blade. The hilt is made from round bars, intersected with small discs. The wire-wrapped handle starts with a rectangular cross section and merges towards a round cross section near the pommel. The pommel has a cone-section shape and is finely fluted.

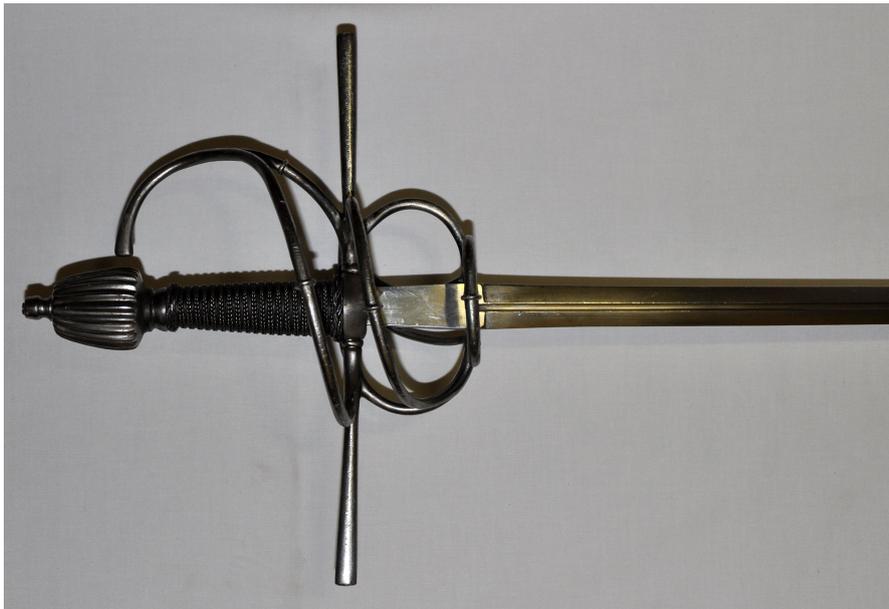


Figure 18: Arms & Armor Lombardy Rapier - Hilt and forte.

V.2. DARKWOOD ARMORY 45" THREE RING SWEPT HILT RAPIER

This practical rapier has a diamond shaped blade that merges straight into a thin ricasso. The hilt is a simple three ring design without decoration, a wooden handle and an ovoid pommel.

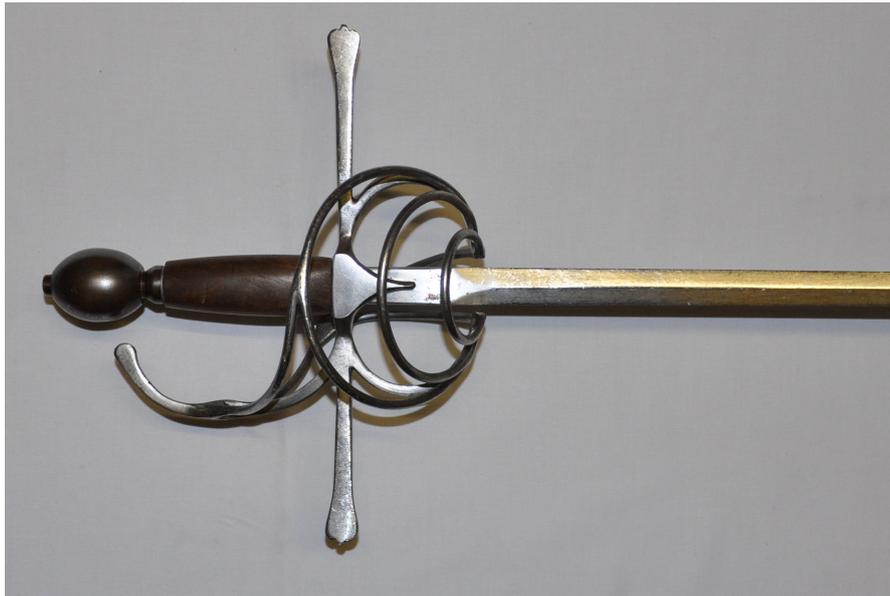


Figure 19: Darkwood armory 45" three ring swept hilt rapier - Hilt and forte.

V.3. MARCO DANELLI BASIC CUP HILT RAPIER

This is an entry level cup hilt rapier with a diamond shaped blade with a nail-head. The sword features a leather covered handle and a simple spherical pommel.

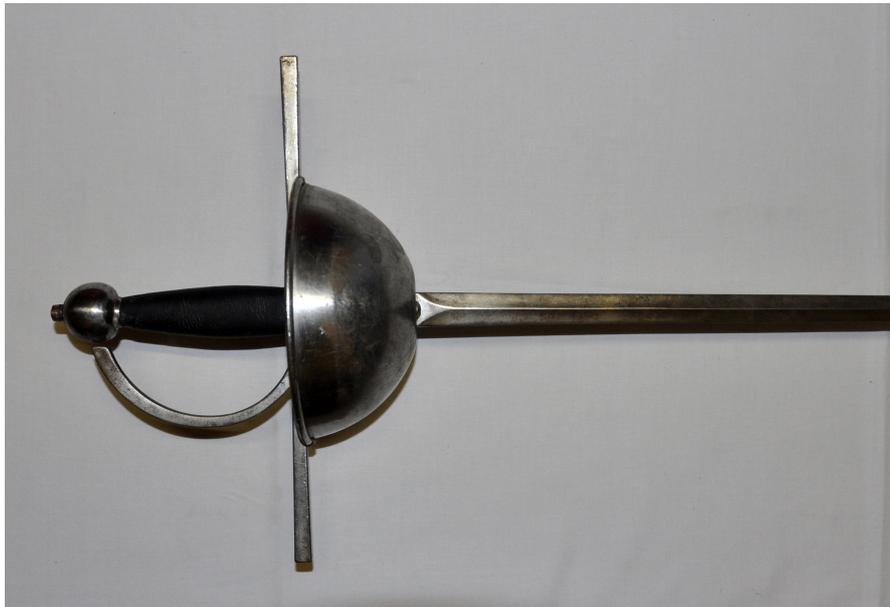


Figure 20: Danelli basic cup hilt rapier- Hilt and forte.

V.4. HANWEI TORINO RAPIER

The Hanwei Torino rapier is a chinese entry-level sword with a light, diamond shaped blade, a simple two ring hilt with wire-wrapped handle and a cylindrical pommel.

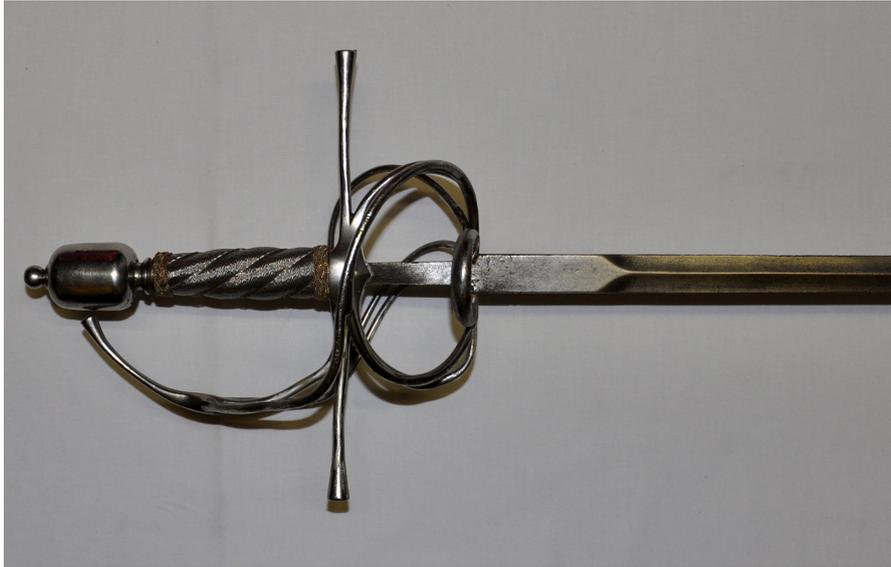


Figure 21: Hanwei Torino rapier - Hilt and forte.

V.5. FABRI ARMORUM PAPPENHEIMER RAPIER

This is a massive, rather short rapier with a wide diamond shaped blade, a simple Pappenheimer hilt with a wooden, leather covered handle and a pommel of truncated cone shape.



Figure 22: Fabri Armorum pappenheimer rapier - Hilt and forte.

	Arms & Armor	Darkwood	Danelli	Hanwei	Fabri Armorum
Overall Length [mm]	a	1295	1194	1145	1095
Overall Weight [g]	1035	1180	990	932	1330
Pommel Length [mm]	b	60	40	64	62
Handle Length [mm]	c	90	92	85	93
Ricasso Length [mm]	d	65	60	56	60
Blade Length [mm]	e	1070	1002	935	865
Point of Balance [mm]	f	113	113	75	73
Dynamic Length [mm]	g	705	755	680	560
Virtual Blade Weight [g]	153	201	202	98	184
Virtual Crossguard Weight [g]	882	1094	788	834	1146
Blade Presence [%]	15	16	20	11	14
Ricasso Width [mm]	18	21	20	10	20
Ricasso Thickness [mm]	6.2	6.2	6	5.4	5
Number of Fullers	1	-	-	-	-
Fuller Length [mm]	230	-	-	-	-
Fuller Width [mm]	3.9	-	-	-	-
Fuller Depth [mm]	1.5	-	-	-	-
Crossguard Length [mm]	h	250	280	218	225
Crossguard Thickness [mm]	5.4x6.2	6.2x7	5.8x6.2	5.4	5
Blade Cross Section	Diamond	Diamond	Diamond	Diamond	Diamond
Crossguard Cross Section	Oval	Rectangular	Rectangular	Round	Round

Table 9: Comparison of measured parameters of five modern rapiers.

Length [mm]	Width [mm]	Thickness [mm]	Striking Edge [mm]	Cross section [mm ²]	Shape
Ricasso	21.3	6.45		137.39	Rectangle
0	21.3	6.45	1	79.34	Diamond
100	18.5	5.2	1	57.35	Diamond
200	17.7	4.7	0.9	49.56	Diamond
300	16.9	4.35	0.8	43.52	Diamond
400	16.3	4.1	0.8	39.94	Diamond
500	15.1	3.85	0.7	34.35	Diamond
600	14.2	3.45	0.7	29.47	Diamond
700	13.2	3.35	0.7	26.73	Diamond
800	11.6	2.95	0.7	21.17	Diamond
900	10.5	3.1	0.7	19.95	Diamond
1000	8.9	2.6	0.7	14.69	Diamond
1050	6.4	2.3	0.5	8.96	Diamond

Table 10: Blade cross section of Arms & Armor Lombardy rapier

Length [mm]	Width [mm]	Thickness [mm]	Striking Edge [mm]	Cross section [mm ²]	Shape
Ricasso	18.05	5.95		107.4	Rectangle
0	18.05	5.95	3.5	85.29	Diamond
100	17.3	5.5	2.2	66.61	Diamond
200	16.35	5.25	2.1	60.09	Diamond
300	15.5	5.2	2.1	56.58	Diamond
400	14.6	5.15	2.1	52.93	Diamond
500	13.5	4.75	2	45.56	Diamond
600	12.6	4.5	2	40.95	Diamond
700	11.6	4	1.8	33.64	Diamond
800	10.6	3.65	1.6	27.83	Diamond
900	9.6	3.2	1.5	22.56	Diamond
1000	8.6	2.9	1.3	18.06	Diamond

Table 11: Blade cross section of Darkwood Armory 45" three ring swept hilt rapier

Length [mm]	Width [mm]	Thickness [mm]	Striking Edge [mm]	Cross section [mm ²]	Shape
Ricasso	20	6		120	Rectangle
0	19.1	5.7	1	63.99	Diamond
100	16.6	5.3	1	52.29	Diamond
200	15.8	5	1	47.4	Diamond
300	14.7	4.8	1	42.63	Diamond
400	13.7	4.8	1	39.73	Diamond
500	12.7	4.8	1	36.83	Diamond
600	11.4	4.6	1.5	34.77	Diamond
700	10	4.4	1.5	29.5	Diamond
800	8.8	4.3	1.5	25.52	Diamond
900	7.4	3.4	1.5	18.13	Diamond
1000	6.2	3.3	1.5	14.88	Diamond

Table 12: Blade cross section of Danelli Armouries basic rapier

Length [mm]	Width [mm]	Thickness [mm]	Striking Edge [mm]	Cross section [mm ²]	Shape
Ricasso	10	5.4		54	Rectangle
0	19.8	5.4	0.8	61.38	Diamond
100	18.4	5.2	0.8	55.2	Diamond
200	17.3	5.2	0.8	51.9	Diamond
300	16.1	4.8	0.8	45.08	Diamond
400	15.3	4.6	0.8	41.31	Diamond
500	13.9	4.4	0.8	36.14	Diamond
600	12.4	4	0.7	29.14	Diamond
700	11	3.5	0.7	23.1	Diamond
800	9.8	3.5	0.7	20.58	Diamond
900	8.4	2.7	0.7	14.28	Diamond

Table 13: Blade cross section of Hanwei Torino rapier

Length [mm]	Width [mm]	Thickness [mm]	Striking Edge [mm]	Cross section [mm ²]	Shape
Ricasso	20	5		100	Rectangle
0	26.5	5	1	79.5	Diamond
100	22.5	4.2	1	58.5	Diamond
200	20.6	4.1	1	52.53	Diamond
300	18.8	3.9	1	46.06	Diamond
400	17.4	3.8	1	41.76	Diamond
500	15.9	3.7	1	34.37	Diamond
600	14.2	3.3	1	30.53	Diamond
700	12.3	3.3	1	26.45	Diamond
800	10.2	3.1	1	20.91	Diamond

Table 14: Blade cross section of Fabri Armorum Pappenheimer rapier

VI. DISCUSSION

VI.1. COMPARISON OF MEASUREMENTS

The measured parameters of historical rapiers from the "Hofjagd- und Rüstammer" are shown in Table 1 and the parameters of modern training replicas are shown in Table 9 .

The period originals have overall weights from 1130 g to 1630 g. Modern replicas are much lighter with 990 g to 1330 g.

Another difference is the length of the handle. The lengths of the measured period handles are from 77 mm to 84 mm, which is a rather small range possibly only due to variation of hand size. In direct comparison the handle length and variation of replicas can be much larger, with a length of up to 93 mm.

The comparison of the sword length only shows that the original rapiers can be much longer, with an overall length of up to 1400 mm. Most replicas are not longer than 1300 mm.

The POB of the measured original rapiers is between 95 mm and 140 mm from the cross-guard. The POB of A1318 is at 155 mm, but the shape of its blade is very different to the other historical rapiers. The replicas of Arms & Armor, Darkwood and Danelli show a very similar POB to the original rapiers. Only the POB of the replicas of Hanwei and Fabri Armourum are much closer to the hilt with around 75 mm.

Another big difference between the original and the modern rapiers can be seen in the thickness of the ricasso. All measured historical rapiers have a ricasso thickness of at least 8.3 mm and the thickest modern rapier is only 6.2 mm. This results in a very different way of handling of the sword, especially when pressure is present.

The cross sectional areas vs. relative blade lengths are depicted in fig. 23 and 24. We have split up the graphs in two figures, so the differences are still visible further down the blade. We chose relative blade length for these graphs, so the values of different blade lengths can be compared directly.

The figures show, that all period rapiers have a greater cross sectional area in the first 20% of the blade as compared to the modern replicas. After the first 20%, the cross sectional area of the sword A1027 decreases significantly to values similar to the replicas. Rapier A1027 has a very low weight compared to its length and the blade is very narrow with a width at the beginning of the sword of 14.5 mm. The other measured historical rapiers have a width between 18.3 mm to 26.5 mm.

The graphs of the original swords are very similar. The cross sectional area in the beginning of the sword decreases drastically in the first 10% of the blade. After this, the negative slope is flatter and the area doesn't decrease as much. Rapier A1027 has another drastic decrease after around 18% of the blade length. A1340 has a nearly linear decrease in the value of the cross sectional area. This very peculiar graph may be explained by the very unique shape of the blade, which is triangular.

The graphs of the Darkwood, Arms & Armour and the Fabri Armourum rapier have lower starting values and a less steep decrease in cross sectional area compared to the historical rapiers. The graphs of the Danelli and the Hanwei rapier show a linear decrease of the cross sectional area throughout, starting with a small area from the hilt.

Fig. 24 shows cross sectional areas vs. relative blade lengths from 25% to 100%. In this figure, it can be observed, that most of the original rapiers, except A1027, have a larger cross sectional area up to 90% of blade length. After this, the area decreases drastically because the points had to be thin and sharp.

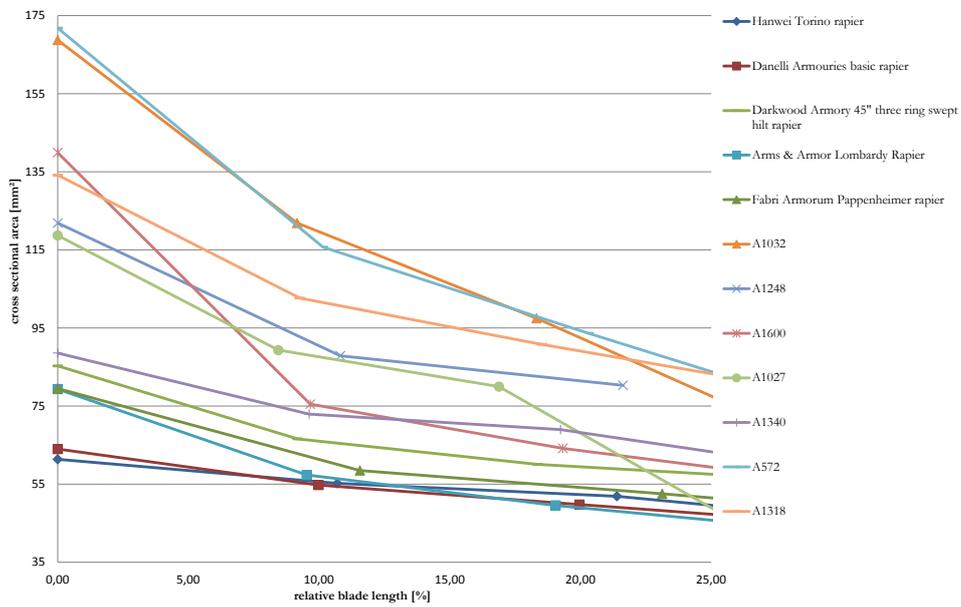


Figure 23: Cross section vs. relative blade length from hilt to 25%.

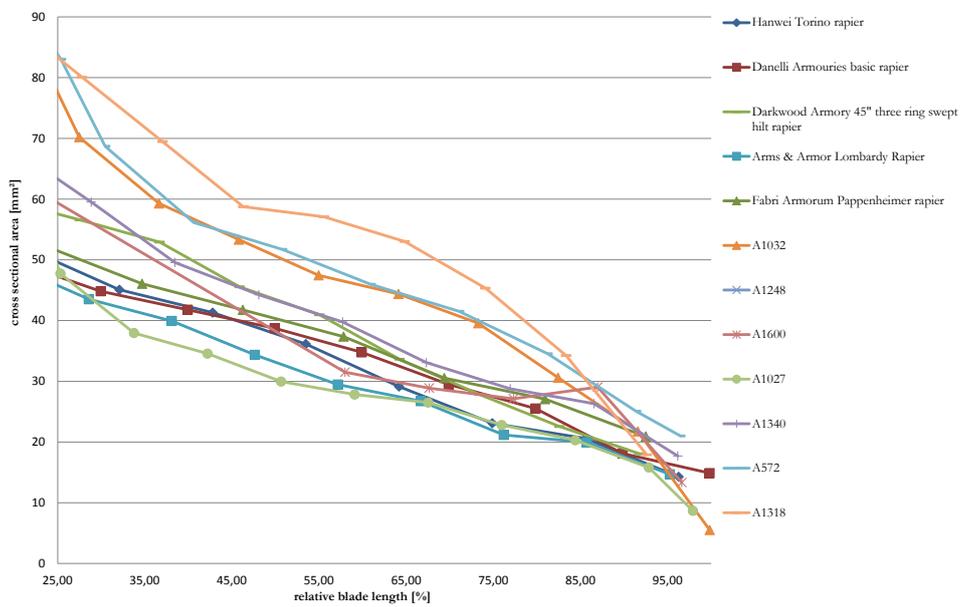


Figure 24: Cross section vs. relative blade length from 25% to point.

VI.2. HANDLING

It is difficult to get an idea of the handling of a weapon from tables and numbers, as handling is subjective and experiential. So we try to describe the handling differences related to measured parameters as well as possible.

Most modern reproductions have a low weight but still feel comparatively heavy in the hand. The graphs of cross sectional area vs. blade length have shown that modern rapiers have an almost linear decrease in cross section area over length, which results in less relative weight in the forte of the sword and more in the debole. This arises due to economical production by stock-removal. Usually a 1/4" stock bar is used as raw material for the blade, which results in a thin ricasso. Diamond cross sections are preferred, because they are easier and faster to manufacture.

On the other hand, period rapiers show a steep decrease from a very large cross sectional area along the forte of the sword and then merge into a more linear decrease. This results in much more weight in the ricasso and forte of the sword, which in turn makes the rapier more agile, especially in movements of the point, even though it has more overall weight. Another advantage of a stronger forte is more stability in parrying and actions that involve pressure on the blade. Most modern reproductions bend in the forte when parrying cuts or when the opponent applies pressure in the bind.

A thicker ricasso also allows to hold the sword more comfortably and safely. The handle is related to this as well, because the length of the handle is determined by the style of grip and the size of the hand. When holding the rapier with an extended arm in Terza, the pommel should rest against the ulnar side of the hand which adds stability to the grip.

These differences strongly influence the applicable style of fencing. The period manuals place a strong focus on body movements, footwork and movement of the sword point. Wide movements with the entire weapon are rare and Salvator Fabris [Fabris, 1606] even warns repeatedly not to fling the sword, as this is slow and dangerous with longer and heavier weapons. Modern rapiers seem more like a compromise, being suitable for a hybrid of historical fencing and modern sports fencing.

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