Tips for safety: Assessing the protection of after-market sword tip material and size in Historical European Martial Arts

Daniel J.E Cousins, Mackenzie Whitten

1. Introduction

A sword does not need to be sharp to cause serious damage. Historical European Martial Arts (HEMA) is a full contact sport that involves wielding a variety of sword types. The common sword types are: longsword, saber, rapier, arming sword, and dagger. No matter the style of sword, they all have dulled edges and a blunted tip in one of three common methods: rolled, spatulated, or rounded. A rolled tip involves bending the tip of blade back over on itself; a spatulated tip involves flattening the tip out making it wider than normal; a rounded tip is a normal width but does not actually come to a point. In addition to the manufacturing of the sword making it safer to wield, an aftermarket safety tip will be applied to help reduce the force of impact and prevent puncturing (MacIver et al., 2025). The material and shape of the safety tip will vary based on the club, the competition rules, and personal preference. Common options of tips include: leather, rubber, silicone, a bullet casing or thermoplastic; all are shaped to be either rounded or flat (MacIver et al., 2025). The swords are one part of the safety equipment; the other is the clothing. Typical HEMA gear consists of a jacket and pants rated to 350N or 800N of puncture resistance, a hard plastic plastron, a plastic or metal gorget, a mesh mask at 1600N, elbow, forearm, and shin guards. Despite the protection, injuries happen. During the rapier and dagger competition at the Black Horns Cup Tournament in June 2025, a rapier punctured the jacket of one fencer and continued deep into their biceps. The tournament organizers determined the jacket, the sword and tip met the tournament safety guidelines. This event has led to an increased scrutiny on tip material and size.

HEMA and Olympic fencing (OF) share many aspects, unfortunately the safety protocols in place for OF are not transferable. The main reasons for this are the intent behind the sport and rules of the two sports. People have been training with swords as long as they have existed and there has always been a distinction between "play" and "true" fighting. Safety measures were developed to mimic the reason behind the training. Soldiers could train with practice swords and wear full gear but any further changes would take away from the chaos of an actual fight. Play fighting does not have the same chaos and does not need the same level of equipment; to accommodate this, a practitioner would limit the types of blows and where they would deliver those blows to protect their partner and to keep the fight respectable.

Having rules in place on how/where you can hit, will change the equipment to be better suited to deliver allowed hits and be able to ignore actions that do not need to be defending from.

The swords used in Olympic fencing are very light and flexible while HEMA blades are heavier and stiffer. This is a result of the martial vs sport difference; the historical weight of the sword and force associated with it are not required in order to perform the sport but would be required for martial training. An Olympic fencing blade will bend more than a HEMA blade, this would increase the force absorption of the blade greatly reducing the risk of a puncture. The flexibility testing of Olympic fencing blades has a standard procedure of placing a set weight along the length of the blade a measuring the amount of bend. Under a 200g weight, a foil requires a bend of 5.5-9.5cm, the epee requires 4.5-7cm and saber requires 4-7cm (FIE, 2021). The protective gear worn in Olympic fencing is rated at 350N for lower levels, while high level competition run by Federation Internationale D'Escrime (FIE) requires 800N puncture resistance. HEMA does not have an international regulatory body and every tournament will have unique rules regarding equipment regulation. Commonly, there are dimension requirements on the weapon and a flexibility test performed in a variety of unstandardized ways. The Black Horns' requirements for rapier were a maximum blade length of 111cm, weight 1000-1250g, flexibility of 5.5-12kg, the jacket requirements were 350N. The flexibility test was performed by thrusting into the ground until additional force would result in the blade bending and observing the degree to which it bent.

There is a large range of designs for HEMA swords all with customizable length, geometry, weight, and flexibility forcing the blade safety requirements to be quite broad. This leaves two main options for increasing safety of the practitioners: wearing 800N or greater equipment and putting additional safety tips on the blade to reduce the potential for puncture. A study was performed on the changes to safety ratings on a rapier and longsword using untipped, rubber blunt, 0.303 brass cartridge, and thermoplastic (MacIver et al., 2025). They found that thermoplastic performed better than any of the other tips and did not increase the risk of head rotational injuries from thrusts to the masks. They did not test leather tips, or evaluate a variety in size of the tip. The purpose of this study is to compare force reduction between leather tipping affixed with hockey tape, bare tip, and thermoplastic. Additionally, how the tip size will affect the puncture depth. There are two hypotheses 1) the leather tip will have greater force reduction than the no tip and thermoplastic and 2) there will be a strong negative correlation betweentip size and puncture depth.

2. Methods

2.1 Swords and Tips

Three swords were with three tips conditions were used for the force assessment and one sword was used with 4 tip conditions for the puncture assessment. The three swords were a rapier, a longsword and a federschwert (feder) (characteristics can be found in Table 1), and the tips used were no tip, thermoplastic and leather (Table 2). The feder was the only to offer an option of flex customization and was the medium flex option. For the puncture test, only the feder was used and the tips assessed were the no tip, leather, a leather size matched thermoplastic tip, and a larger thermoplastic tip (an area of 506.25 mm^2).

Table 1: Sword characteristics used in the drop test.

Sword	Manufacturer	Length (cm)	Weight (Kg)	Tip
Economy Rapier	Darkwood Armoury	106	1.1	Cut
TodescaLongsword	Malleus	101	1.6	Spatulated
Feder	Regenyei	100	1.3	Rolled

Table 2: Tip surface area for each sword and material tested in the drop test.

Sword	No tip (mm^2)	Leather (mm^2)	Thermoplastic (mm^2)
Rapier	16.32	196.00	346.88
Longsword	72.88	260.80	135.85
Feder	132.25	306.0	162.56

2.2 Experimental conditions

A custom drop stand was built using 8020 aluminum tracks. The swords were fixed into a drop track, lifted to a height of 30cm and released (Figure 1). Each tip condition for each sword was dropped 15 times. The leather tip for the rapier was dropped 12 times before the metal tip began to puncture through the leather. For the puncture testing, the sword was lifted to 30cm and released into custom ballistic gel (Jussila, 2004) and multiple sizes of tips and different materials were used. The leather tip was unable to be manipulated to change its size but the thermoplastic had three different sizes, one closely match to the leather tip area, one moderate size and one large size

Table 3: Thermoplastic tip sizes during the puncture test

Rapier	Feder	Longsword
206 mm^2	315 mm^2	240 mm^2

270 mm^2	401 mm^2	410 mm^2
529 mm^2	638 mm^2	702 mm^2

2.3 Instrumentation

Data was collected using a BTS P-6000 force plate (BTS Bioengineering, MI, Italy) at 1000 Hz and recorded using Vicon Nexus through a Lock+ A/D convertor (Vicon, Oxford, England). The geometrical constants for the force plate are: width, 400mm; length, 400mm; a, 164mm; b, 164mm; aZo 26.5mm.

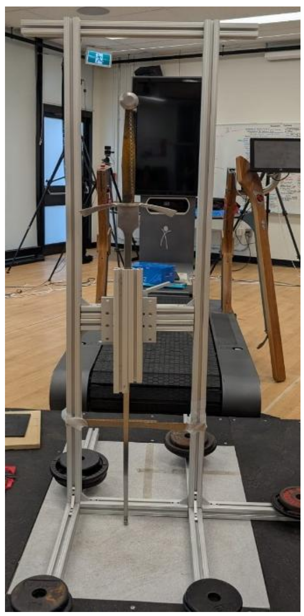
A.  B. 

Figure 1: The feder fixed to the drop rig against the force plate (A). The blade inside the track of the 8020 to control to drop direction (B).

2.3 Data Processing

2.3.1 Impact Characteristics

All processing was performed in custom MatLab (MATLAB 2023A, MathWorks, Natick MA, USA) script. The bias was removed and second order dual pass Butterworth filter with a 50Hz cut off was applied to the data. The point of impact and stabilization were visually inspected and the data was windowed to analyze the impact characteristics.

2.4 Statistical Analysis

Individual repeated measures ANOVAs were performed for each sword with the three tip types as the independent variable. The dependent variables for the impact test were the peak force and the pressure. A linear regression was performed for each sword type with the independent variable being the tip size and the puncture depth as the dependent variable.

3. Results

3.1 Impact

A summary of the impact testing for all of the swords can be seen in Table 4. The rapier had a significant effect of tip type on peak force (F=7.71, *p*=0.002, η_p^2=0.29). The post hoc analysis revealed a significant increase (*p*<0.001) of 11.29% from the naked tip (60.57 ± 9.68N) to the thermoplastic tip (74.19 ± 10.82N). There was also a significant effect for pressure (F=416.44, *p*<0.001, η_p^2=0.96). The post hoc analysis revealed a significant decrease of 90.84% (*p*<0.001) from the naked tip to the leather tip and a decrease of 94.34% (*p*<0.00l) from the naked to the thermoplastic tip.

The feder had a significant effect of tip type on peak force (F=6.79, *p*=0.003, η_p^2=0.25). The post hoc analysis revealed the thermoplastic tip (96.86 ± 12.48N) was greater than the naked tip (84.86 ± 4.47N) by 14.14% (*p*<0.001) and greater than the leather tip (98.98 ± 15.6N) by 19.77% (*p*<0.001). There was also a significant effect for pressure (F=203.15, *p*<0.001, η_p^2=0.91). The post hoc analysis revealed the leather (0.26 ± 0.05) and thermoplastic (0.60 ± 0.08) were less than naked tip (0.64 ± 0.03) by 59.38% (*p*<0.001) and by 6.25% (*p*=0.035) respectively. Additionally, the leather was less than thermoplastic by 56.67% (*p*<0.001).

The longsword had a significant effect of tip type on peak force (F=8.05, *p*=0.001, η_p^2=0.28). The post hoc analysis revealed the naked tip (89.23 ± 7.22N) was less than the thermoplastic tip (101.75 ± 9.10N) by 14.03% (*p*=0.011) and the leather tip (98.98 ± 10.71N) by 10.93% (*p*=0.004). There was also a significant effect for pressure (F=520.63, *p*<0.001, η_p^2=0.96). The post hoc analysis revealed the leather (0.38 ± 0.04) and thermoplastic (0.75 ± 0.36) were less than naked tip (1.12 ± 0.10) by 66.07% (*p*<0.001) and by 33.04% (*p*<0.001) respectively. Additionally, the leather was less than thermoplastic by 49.33% (*p*<0.001).

Table 4: Results from impact testing across the three sword and tip materials.

Sword	DV	Naked	Leather	Thermoplastic	F	p	Effect Size η_p^2
Rapier	Peak Force (N)	60.57 (9.68)	66.60 (6.65)	74.19 (10.82)	7.71	0.002	0.29
	Pressure (N/mm^2)	3.71 (0.59)	0.34 (0.03)	0.21 (0.03)	416.44	<0.001	0.96
Feder	Peak Force (N)	84.86 (4.47)	80.87 (15.66)	96.86 (12.48)	6.79	0.003	0.25
	Pressure (N/mm^2)	0.64 (0.03)	0.26 (0.05)	0.60 (0.08)	203.15	<0.001	0.91
Longsword	Peak Force (N)	89.23 (7.22)	98.98 (10.71)	101.57 (9.10)	8.05	0.001	0.28
	Pressure (N/mm^2)	1.12 (0.10)	0.38 (0.04)	0.75 (0.36)	520.63	<0.001	0.96

3.2 Puncture Possibility

Using the size of the tip, the amount of force required to meet the pressure that will result in a puncture can be calculated as pressure multiplied by the surface area. The amount of required force for each sword and each tip type to puncture different levels of clothing can be seen in Table 5-6. If the calculated force value is greater than the clothing rating, the tip size is protective. All of the swords and tips require greater force than the clothing rating except for the naked tip on the rapier. Additionally, the amount of pressure the sword and tip would apply if the force used was the maximum newton rating for that article of clothing can be calculated as force/ surface area (e.g naked rapier tip: 350N/16.32 = 21.45N/mm^2). If the calculated pressure is less than the clothing rating, the tip is protective. All of the tips on all of the swords are less than the clothing rating except for the naked rapier.

Table 5: The requirements to puncture different levels of clothing using a rapier with different types of tips

Clothing rating		Force required to puncture (N)			Concentration under target load (N/mm^2)		
Newton	Pressure	Naked	Leather	Thermoplastic	Naked	Leather	Thermoplastic
350N	12.56	204.98	2461.76	4356.75	21.45	1.79	1.01
800N	28.71	468.55	5627.16	9958.78	49.02	4.08	2.31

1600N	57.42	937.09	11254.32	19917.56	98.04	8.16	4.61

Table 6: The requirements to puncture different levels of clothing using a feder with different types of tips

Clothing rating		Force required to puncture (N)			Concentration under target load (N/mm^2)		
Newton	Pressure	Naked	Leather	Thermoplastic	Naked	Leather	Thermoplastic
350N	12.56	1661.06	3843.36	2041.79	2.65	1.14	2.15
800N	28.71	3796.90	8785.26	4667.17	6.05	2.61	4.92
1600N	57.42	7593.80	17570.52	9334.34	12.10	5.23	9.84

Table 7: The requirements to puncture different levels of clothing using a longsword with different types of tips

Clothing rating		Force required to puncture (N)			Concentration under target load (N/mm^2)		
Newton	Pressure	Naked	Leather	Thermoplastic	Naked	Leather	Thermoplastic
350N	12.56	915.31	3275.65	1706.28	4.80	1.34	2.58
800N	28.71	2092.24	7487.57	3900.25	10.98	3.07	5.89
1600N	57.42	4184.48	14975.14	7800.51	21.96	6.13	11.78

3.2 Puncture Depth

Each sword had a strong negative relationship between tip surface area and puncture depth. The rapier had an r^2 value of 0.945, the feder was 0.968 and the longsword was 0.913. The leather tips fit well along the regression with the thermoplastic tips. The naked tip rapier tip is not plotted as it punctured the full depth of gel.

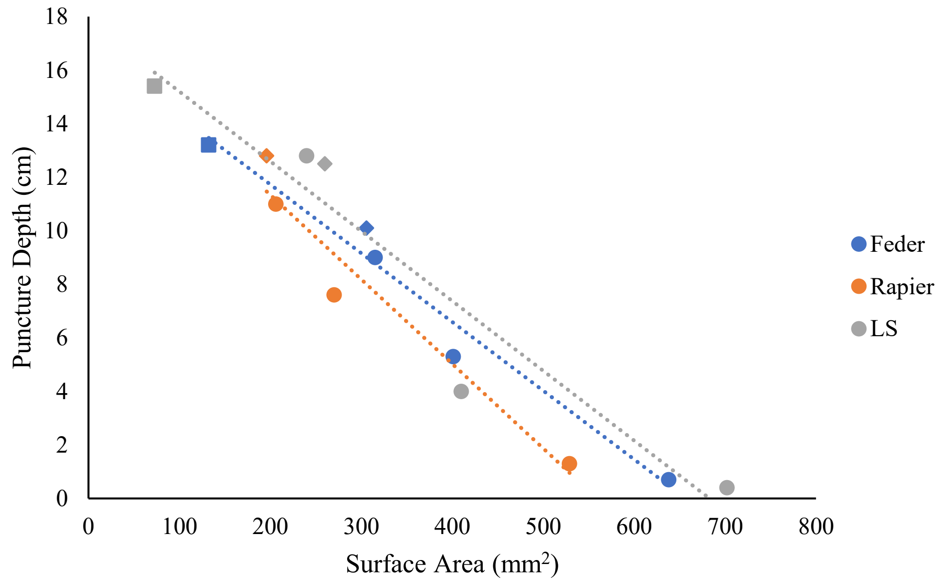


Figure 2: The depth of puncture into ballistic gel for each sword across different tip sizes. The naked tip is represented as a square, the leather tip is a diamond and the thermoplastic tips are circles.

4. Discussion

There are many opportunities for serious injury in armed martial arts, despite precautions taken to reduce them.. With a thrust, the main risks are contusions, fractures, concussions and punctures. Contusions and fractures are more related to the direction, magnitude, rate, and duration of force being applied to the body part (Passalacqua & Fenton, 2012). Puncture injuries share the rate, duration and direction factors but its main contributors would be the size and shape of the object applying force. The injury mechanics of concussions are more complicated and are more related to the strain on brain tissues from combinations of linear and rotational acceleration (Giordano & Kleiven, 2014; Kleiven, 2007; Patton et al., 2015). The link to a thrust would be the force of impact and the location of impact.

In order to effectively evaluate the performance of different tips, the main purpose behind the tip should be clear. A safety tip will change the geometry of the point, for this reason its most important function is to reduce the possibility of a puncture This project views the main purpose behind a safety is to reduce the probability of a puncture and does so by altering the geometry of blade. The previous research on the safety tips expanded the purpose to evaluate both the puncture prevention and the risk of a concussion (MacIver et al., 2025). The rational on the concussion evaluation was the tip will change friction between the mask and the tip so the blade should glance off the mask instead of catching and create a high amount acceleration to the head. The main take-away from this assessment was that rubber resulted in higher accelerations and a greater potential for concussion. In their study the puncture was assessed by changing the impact force to evaluate the depth of puncture and did not use the same puncture medium and did not evaluate the thermoplastic tips. In their results, the rubber performed much better than the bullet casing and the untipped but much of this may be due to the size difference than the material type. The rubber had a surface area of 2.3cm^2 while the bullet was 1.48cm^2 and the untipped was 0.32cm^2. Given the much higher acceleration from the rubber tip, it was recommended to no longer be used and switch to thermoplastic.

A consideration to any changes in equipment involved in an impact is how will it change affect the impact. Our hypothesis that there would be minimal changes in the impact force across the tip types was incorrect;adding a thermoplastic tip to any of the swords increased the amount of force at impact and adding a leather tip to the longsword increased force. While this was unexpected, it can be explained by increasing the stiffness at the tip by adding layers of material. The thermoplastic is a hard material and would not deform under impact and therefore not absorb any force. The leather will compress and is not as rigid as the plastic therefore does not always increase impact force. Fortunately, protective gear being worn by practitioners will more than compensate for the amount of force being applied.

A precursor to the second hypothesis is determining if a tip is capable of puncturing the clothing. The rating given by the manufacturers based on EN 13567, the amount force under a constant velocity using a circular probe at a diameter of 4mm and then slowly increasing the force until a puncture occurs. The first step in determining the protective capability of a tip would be to see the amount of pressure that would be applied under the critical load of the material; a lowering of the pressure would be protective. Both leather and thermoplastic greatly reduce the amount of pressure and would be protective. From this, the amount of force that would be required to puncture the material can be estimated by taking the surface area of the tip and the target pressure to get force. Adding a tip will greatly increase the amount of force that would be required in order to puncture the material. Using thrust speeds, the amount of force seen in actual training can be evaluated to see if the required force might actual be met and lead to a puncture. The highest acceleration seen in a thrust to mask was 80g or 784m/s^2 (MacIver et al., 2025), from this the maximum force of a rapier would be 863.28N, a longsword would be 1255.68N and a feder would be 1020.24N. For all three swords, this value is higher than the amount of force to puncture without a tip meaning that using any sword without a tip will leave the possibility of a puncture. The minimum tip size can then be determined using the target puncture pressure: the rapier it would be 68.73 mm^2, the longsword would be 99.97 mm^2 and the feder would be 81.23 mm^2. Heavier swords would require a larger tip to account for the greater force. Much of this prediction requires an assumption that the second hypothesis of the tip size having a very strong negative relationship with puncture is correct. The data in this study supports the second hypothesis. The tip size had an r^2 over 0.91 for all three sword and the different tip materials were still part of the same linear relationship.

5. Conclusion

Puncture injuries are a low risk in HEMA but still do occur and for this reason a serious evaluation of the safety tip requirements needs to be evaluated. The different tip types will increase the amount of force at an impact but the gains in surface area greatly outweigh this. After repeated exposures, a leather tip may fail, which occurred during this study after 13 strikes while a thermoplastic tip does not. Additionally, the ability to easily modify the size of a thermoplastic tip makes them superior to leather. The rapier (17.2mm^2) and the spatulated longsword tip (72.88mm^2) have a smaller area than the predicted minimum size of stopping all punctures of 68.73mm^2 for the rapier and 99.97mm^2. The rapier needs of tip with a diameter of ~9.5cm and the spatulated longsword would need to change it width and thickness dimensions in any combination to meet the target area. The minimum tip size will be scaled to the sword but can be fairly easily calculated as the maximum acceleration of 784.8 x mass of the sword and then divide by the pressure rating of the clothing.

References

FIE. (2021). *Material Rules*. Federation Internationale D'Escrime.

Giordano, C., & Kleiven, S. (2014). *Evaluation of Axonal Strain as a Predictor for Mild Traumatic Brain Injuries Using Finite Element Modeling* (SAE Technical Paper Nos. 2014-22–0002). SAE International. https://doi.org/10.4271/2014-22-0002

Jussila, J. (2004). Preparing ballistic gelatine—Review and proposal for a standard method. *Forensic Science International*, *141*(2), 91–98. https://doi.org/10.1016/j.forsciint.2003.11.036

Kleiven, S. (2007). *Predictors for Traumatic Brain Injuries Evaluated through Accident Reconstructions* (SAE Technical Paper Nos. 2007-22–0003). SAE International. https://doi.org/10.4271/2007-22-0003

MacIver, J., Dame, K., Palmer, A., & Ratnavale, M. (2025). *Safety Tips Phase 1 Report* (Safety Tips Project, p. 32). Historical Fencing Research Ltd.

Passalacqua, N. V., & Fenton, T. W. (2012). Developments in Skeletal Trauma: Blunt-Force Trauma. In *A Companion to Forensic Anthropology* (pp. 400–411). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118255377.ch19

Patton, D. A., McIntosh, A. S., & Kleiven, S. (2015). The Biomechanical Determinants of Concussion: Finite Element Simulations to Investigate Tissue-Level Predictors of Injury During Sporting Impacts to the Unprotected Head. *Journal of Applied Biomechanics*, *31*(4), 264–268. https://doi.org/10.1123/jab.2014-0223