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On the Biomechanics of the Foil "Flick" - Kinematical Comparison of the Execution in Non-elite and Elite Fencers

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Abstract Fencing is the only discipline, which was part of all modern Olympic games. Elite fencing is a sport demanding high-end physical performance, top motor control and coordination. In the present study, we investigated the kinematics of execution of a special technique in foil fencing – the flick. This is a rather complex motoric system including the movement of the upper body, the shoulder, the elbow, the wrist and proper bending of the blade. The physics of the flick was described in detail in previous experiments based on the use of a rather bendable "model" foil. In the present study, we investigate the kinematical patterns in six fencers (two elite male fencers, two female fencers and two under-15 male fencers) when using competition foils. We used high speed videography by 1000 fps and calculated a total of 43 variables for every run. The main goal of the investigation was to study the motorics of the anatomical structures of the fencer and the blade in a situation simulating a real encounter. On the base of our calculations, we were able to understand which elements of the execution of the flick are crucial for its successful implementation. In addition, we developed an operational test algorithm for the evaluation of the quality of every single trial. It may be used by trainers to quantify the skills of their students in performing foil flick.

Keywords Biomechanics, Training, Performance, Metrics, Movement Coordination, Kinematical Analysis

1. Introduction

Modern Olympic fencing [1,2] is a sport discipline, which demands high-end neuro-motoric coordination and performance [3,4]. Previous studies demonstrated that fencers may outcompete even high-fit non-fencers in numerous sports aspects [5]. The specifics of the perceptual and decision-making processes were studied in the different fencing disciplines and in different skill-level groups [6-17]. Studies on the fencer's strength, condition and other physiological aspects have provided coaches and sports scientists with data to form and modulate training programs [18-24]. In comparison to other sports, biomechanical studies in fencing are relatively scarce [25]. Most of the studies were focused on the execution of different locomotion elements like the fencing steps, fleche, lounge and change of direction [16-18,21,22,26-32].

The kinematical analyses and the comparison between the performances of novices and elite fencers provided important data, which can be used for optimizing the execution of different elements of the three fencing disciplines and the physical training of the sportsman.

Unfortunately, some components of modern fencing remained understudied and one of these was the so-called "flick". The flick evolved as a touché technique in the 1970s [33] and represented a type of hit, based on the use of the blade's flexibility. It is characteristic of epee and foil fencing.

One of the most important consequences of taking a flick into the arsenal is the fact that it can affect the choice of blade type. Naturally, flicking is performed with a softer foil, but choosing a softer alloy can negatively affect aiming and thrusting performance. The physics of the foil flick and some aspects of its successful execution were explained by Michaelsen and Cleland [34]. These authors used a rather bendable "model foil" and provided a detailed description of the kinematics of the fencer's upper body, arm, wrist and the movements of the blade during the execution in the laboratory. They compare the flick to whip or fly-fishing cast. Recently the flick has been a very important element of foil and epee fencing, but because of the demand for special skills and enough muscle power, it is used mostly by more advanced fencers [34]. The flick allows for scoring on areas which are well hidden from direct linear thrust or are defended by the opponent's blade. The execution of the flick in epee and foil differs drastically (Nikolov, N., Natchev, N., pers. observations) - in the present study, we concentrated on the analysis of the foil flick. We investigated the kinematical patterns of the upper body, arm, wrist and different blade sections in flicking with standard foil blades, which were used in competition by the fencers included in our experiments. In this way, we contribute to a better understanding of the problematic aspects in the execution of a successful flick in a real bout. We compared the kinematical profiles of the flicks in two females, two under-15 male and two elite male fencers.

As the foil flick is a rather complex exercise, demanding both muscle strength, as well as precise coordination, we expect strong variations among the three groups of participants concerning performance and success rate. We hypothesize, that there are defined kinematical pattern clusters, which characterize the execution of the foil flick in elite fencers compared to that in less-skilled fencers. In addition, we provided a scoring system for testing the quality of the flick execution, which does not demand expensive gear and can be used by the trainers to improve the skills of the fencers.

2. Materials and Methods

2.1. Participants

Our experiments were performed in the summer of 2019 under laboratory conditions at the Shumen University (Shumen, Bulgaria). We used three groups of fencers, members of the foil-fencing club "Volov" (Shumen, Bulgaria). In the investigation two female fencers - A (17 years, 60 kg, 168 cm) and S (16 years, 58 kg, 163 cm), two under 16 boys – V (15 years, 66 kg, 178 cm) and T (14 years, 60 kg, 176 cm) and two members of the Bulgarian national junior team – Vi (20 years, 95 kg, 190 cm) and I (19 years, 75 kg, 170 cm) were included. Both junior national fencers participated in three World Cup series. The female fencers never trained the flick and never used this technique in competition. The two boys trained the flick but used it rarely and predominantly unsuccessfully during bouts. Both elite fencers use the flick regularly and predominantly with success in bouts. All of the participants executed 10 successive attempts to fulfil the fencing task. Each fencer was free to select the distance of the initial en garde position relative to the target for each run. The participants were asked to take as many breaks as they needed to reduce fatigue during the repetitions. All fencers confirmed by signature their willingness to participate in the experiment and to provide their biometrics for further analysis. The parents of all participants were informed of the experiment and provided their permission.

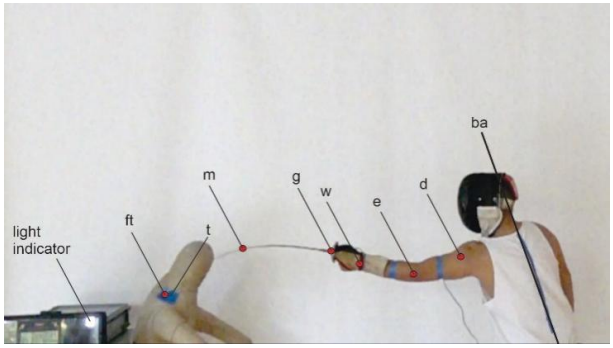

Figure 1. Selected frame of the successful execution of the exercise in one of the elite fencers. The red dots indicate points on the fencer's body and the foil which were selected for tracking: e, elbow; d, deltaideus muscle; ft, foil tip; g. guard of the foil; m, middle point of the blade; w, wrist; Other elements; ba, dorsal axis; t, target

2.2. Task

We constructed our experiment as a fencing situation, where the flick was used as an action after contact with the opponent's blade or as a parry-repost (see Appendix 1). This concept was rather logical, as the flick is rarely used as an initial action in foil fencing. To simulate an attacking opponent, we used an upper body dummy and a target (6x6 cm) was positioned at its shoulder (Figure 1). Each repetition started from the en garde position. The electrical system was set in a regular regime, so if the foil tip contacted the torso with the standard pressure (4.9 N for 15 ms) the white light signal would indicate the touché. The light indicator was triggered in case the foil tip contacted the surface of the dummy, no matter whether the contact was on- or off-target. The precise hits were counted after analysis of the video records. We grouped the results as follows: "miss" (no light signal and tip off-target), "flat, on target" (no light signal and tip on-target), "touché, off-target" (light signal on, tip off-target), "touché, on-target"

(light signal on, tip on-target). We loaded every result with a number of points, which indicate the quality of each attempt (see Discussion).

2.3. Blades

All of the used foils carried blades, which were used in competitions. These were not the only blades that were used by the fencers in tournaments but were these with medium stiffness. All blades were manufactured by "Vniti", series "FIE FOIL VNITI MARAGING".

2.4. High-Speed Videography

We filmed the participants in a dorsal view. High-speed video sequences were performed by using a "Sony RX10III" system (Sony Electronics Corporation). We filmed with 1000 fps in post-trigger mode. For illumination two "Quadralite MiLED Bi-Colour 180" panels (Quadralite Systems Inc, Krakow, Poland) and one "LEDLENSER T-16" (Ledlenser GmbH) were used. Markers were positioned along the vertebral column, the deltoid muscle, the elbow joint, the wrist, the guard of the foil, the midpoint of the blade, and the tip of the foil. The marker displacement was digitized by using "SIMI-MatchiX" (SIMI RMS). In our study, we adopted the five sections of the flick execution as proposed by Michaelsen and Cleland (2019): En garde, Backward rotation, Peak backward rotation, Forward rotation and Deceleration.

2.5. Measured Parameters

For our analysis we calculated the following elements of the kinematical profiles: 1. angle of the elbow at the start of backward stroke (degrees), calculated as the angle between the lines formed between markers d, e and w; 2. distance of the shoulder to the target centre at en garde (cm), calculated as the distance between markers d and t; 3. distance between the foil tip and centre of target at en garde (cm), calculated as the distance between markers ft and t; 4. angle of the wrist at en garde (degrees), calculated as the angle between the lines formed by markers e, w and g; 5. angle between the body axe and the upper arm at en garde (degrees), calculated as the angle formed between the lines along the markers ba d and e; 6. max. speed of the foil tip during backward rotation (cm/s); 7. duration of the backward rotation (ms); 8. duration between the end of backward duration and the start of forward rotation (ms); 9. distance passed by the foil tip during the backward rotation (cm); 10. average speed of the foil tip during the backward rotation (cm/s); 11. angle of the elbow at the end of the backward rotation (degree), calculated as the angle between the lines formed between markers d, e and w; 12. angle of the wrist at the end of the backward rotation (degrees), calculated as the angle between the lines formed by markers e, w and g; 13. angle between the body axe and the upper arm at the end of the backward rotation (degrees), calculated as the angle formed between the lines along the markers ba, d and e; 14. angle of the blade at the start of forward rotation (degrees), calculated as the angle between the lines formed between markers g, m, ft; 15. distance of the guard and the target at the end of backward rotation (cm), measured as the distance between markers g and t; 16. distance of the foil tip and the target at the end of backward rotation (cm), measured as the distance between markers ft and t; 17. distance of the shoulder to the target center at the end of backward rotation (cm), measured as the distance between markers d and t; 18. duration between the end of backward duration and the start of forward rotation (ms); 19. speed of the tip by bending start speed by the foil tip by the start of deceleration (cm/s); 20. distance passed by the shoulder from en garde to the start of deceleration (cm), measured as the displacement of marker d; 21. the angle of the elbow at the start of deceleration (degree), calculated as the angle between the lines formed between markers d, e and w; 22. angle of the wrist at the start of deceleration (degrees), calculated as the angle between the lines formed by markers e, w and g; 23. angle between the body axe and the upper arm at the start of deceleration (degrees), calculated as the angle formed between the lines along the markers ba, d and e; 24. duration of the cycle before the start of deceleration (ms); 25. interval between forward rotation start and the start of deceleration (ms); 26. distance between the foil tip and the center target at the start of deceleration (cm), measured as the distance between markers ft and t; 27. angle of the blade during the start of deceleration (degrees), measured as the angle formed by the lines of markers g, m and ft; 28. distance passed by the foil tip at the start of deceleration (cm); 29. max. speed of the foil tip during forward rotation (cm/s); 30. duration of the deceleration phase until touché (ms); 31. angle of the blade by touché (degrees), measured as the angle formed by the lines of markers g, m and ft; 32. duration of the forward rotation (ms); 33. average speed of the foil tip during forward rotation (cm/s); 34. the angle of the elbow by touché (degree), calculated as the angle between the lines formed between markers d, e and w; 35. angle of the wrist by touché (degrees), calculated as the angle between the lines formed by markers e, w and g; 36. distance of the shoulder displacement by touché (s), measured as the distance passed by the marker e; 37. total distance passed by the foil tip (cm); 38. distance of the guard to center target by touché (cm), measured as the distance between markers g and t; 39. angle between the body axe and the upper arm by touché (degrees), calculated as the angle formed between the lines along the markers ba, d and e; 40. duration of the whole cycle (ms); 41. The angle between the lining of the body axis at en garde and by touché (degree), measured as the angle formed by the position of the marker ba in the first and the last frame of each sequence; 42. hip displacement (cm) compared to en garde and by touché, measured by the displacement of marker p; 43. average speed of the tip of the foil during the whole cycle (cm/s).

2.6. Statistics

Descriptive statistic procedures were used for the analysis of the data. To determine the correlation between groups, the standardized Pearson correlation coefficient was used. If Pearson's contingency coefficient (r) is in interval 0-0.3 correlation is weak, in the interval 0.3-0.5 correlation is moderate, in the interval 0.7-0.9 correlation is strong and if "r" is over 0.9 there is a strong correlation. ANOVA was used to test significant differences between all experimental groups (p-value of < 0.05). With the use of principal component analysis (PCA) and cluster analysis (CA) we performed a multivariate analysis of the results. PCA is the best multivariate method for expressing the similarities and differences of data patterns, and we used it to elucidate the relationships between participants and different kinematical elements. To confirm the PSA results and to make groups of variables with similar characteristics, a CA was done. CA results were presented in dendrograms where the lower the axis value, the more significant the relationship. All calculations were performed using SPSS Version 22 (IBM Corp.) and Microsoft Excel Version 19 (Microsoft Corporation).

3. Results

When plotting the data on all calculated elements, we see a clustering of the elite fencers against the novices (the female) and less-skilled (under 16 male) fencers (Figure 2). Our kinematical analysis indicated that some elements in the execution of the foil flick differ drastically between fencers (Appendixes 2 and 3). The success rate of the elite fencers was almost optimal for both accuracy and proper tip contact. Only the elite fencers lacked "miss" hits (Table 1, Appendix 2).

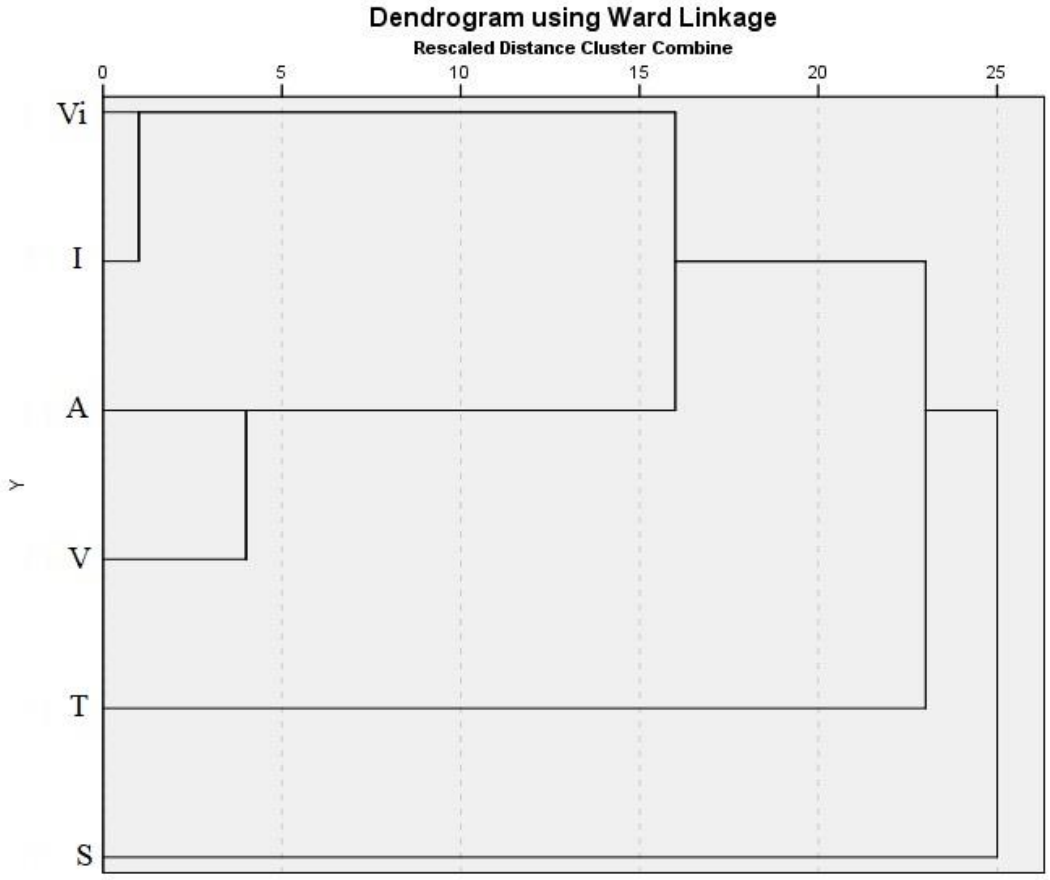

Figure 2. Dendrogram demonstrating the clustering of all measured parameters between all investigated fencers: fencer "A"; fencer "V"; fencer "T"; fencer "Vi"; fencer "S"; fencer "I"

Table 1. Descriptive statistics of the success rate in the investigated fencers and the credits that they had received: “miss” (no light signal and tip off-target), “flat, on target” (no light signal and tip on-target), “touché, off-target” (light signal on, off-target), “touché, on-target” (light signal on, tip on-target). We loaded every result with a number of points, which indicate the quality of each attempt

target/ touch é	all	% of all	A (n=10)	pints	V (n=10)	points	T (n=10)	points	Vi (n=10)	points	S (n=10)	points	I (n=10)	points
on/yes	23	38.33	2	30	3	45	4	60	6	90	0	0	8	120
on/flat	11	18.33	4	20	0	0	2	20	2	20	3	30	0	0
off/yes	20	33.33	3	15	6	30	3	15	2	10	4	20	2	10
miss	6	10.00	1	0	1	0	1	0	0	0	3	0	0	0
Credits total				65		75		95		120		50		130

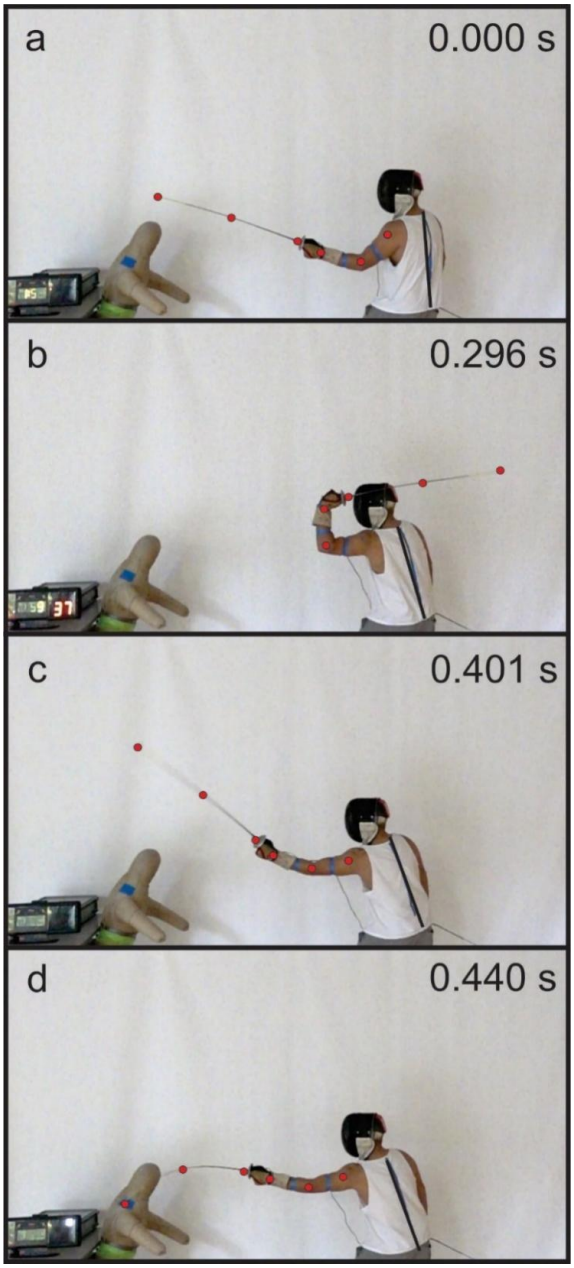

Figure 3. Selected frames from a video sequence in an elite fencer: a, start of the backward rotation; b, end of backward rotation = start of the forward rotation; c, start of deceleration; d, touch é, on-target, indicated by the position of the foil tip and the white light signal

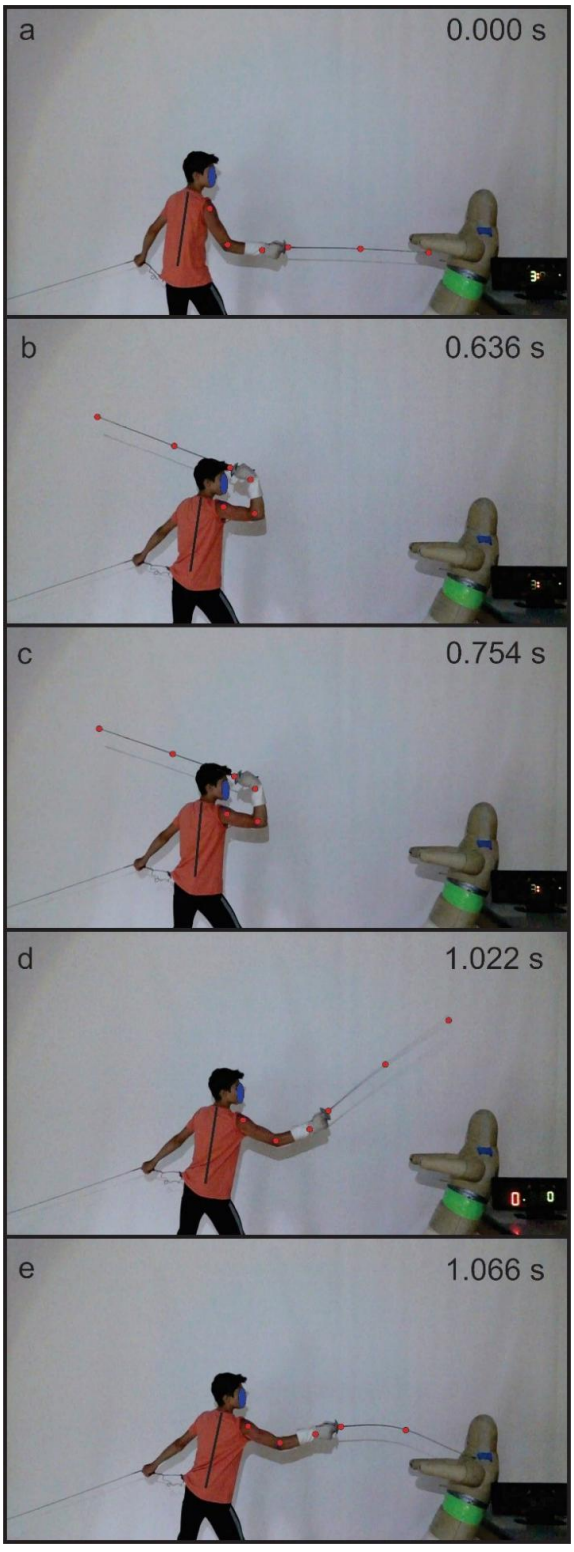

Figure 4. Selected frames from a video sequence in U16 fencer: a, start of the backward rotation; b, end of backward rotation; c, start of the forward rotation; d, start of deceleration; e, flat, on-target, indicated by the position of the foil tip and the lack of white light signal. Note the static phase, where the tip of the foil remained motionless between frames 4b and 4c

The elements grouped firmly in both elite fencers were as follows: max. speed of the foil tip during backward rotation, duration of the backward rotation, duration between the end of backward duration and the start of forward rotation, average speed of the foil tip during the backward rotation, angle of the blade at the start of forward rotation, duration of the cycle before the start of deceleration, interval between forward rotation start and the start of deceleration, distance passed by the foil tip at the start of deceleration, max. speed of the foil tip during forward rotation, duration of the forward rotation, average speed of the foil tip during forward rotation, total distance passed by the foil tip, distance of the guard to centre target by touché, average speed of the tip of the foil during the whole cycle. In all other elements, the fencers are grouped in different variations with each other (Appendixes 2 and 3).

In both elite fencers, the execution of the flick consisted of two main phases: 1. backward rotation and 2. forward rotation including deceleration (Figure 3, Appendixes 2 and 3). In the other four fencers, the execution of the exercise was split into three main phases: 1. backward rotation, 2. a static phase with different duration (up to 148 ms) between the end of backward rotation and the start of forward rotation and 3. a forward rotation that included the deceleration phase (Figure 4, Appendixes 2 and 3).

4. Discussion and Implications

Our results indicate, that the style of execution of the foil flick may differ even between elite fencers. The differences between the measured angles and distances (Appendixes 2 and 3) may be explained by specifics in the anatomy of both elite fencers – “Vi” is almost 20 cm higher than “I”. However, some elements showed great kinematical similarity. The speed of the foil tip during the flick has to be high in both backward rotations, as well as in forward rotation. The blade has to bend significantly during the deceleration. A key element, which indicated the actions of the elite fencers was that they executed the flick in one contentious movement without splitting the hit by a static phase. In all 20 hits of both elite fencers, there was no stop after the backward rotation and the blade was immediately moved in a forward rotation (Figure 3). In all other sequences, there was a static time period between the end of backward duration and the start of forward rotation. We tentatively termed this phase “Parasitic stop”. In the sequences of the elite fencers, a backward deformation of the foil blade was clearly detectable (Appendix 1). This elastic force was redirected during the forward rotation of the forearm and apparently contributed to the speed of the flick execution. Such bending was absent in the other four fencers and during the redirection phase the tip of the foil remained static in “Parasitic stop” (Figure 4 b,c). This crucial difference in the kinematical patterns between the two groups indicated, that the non-elite fencers control their movements in feedback modus and in the elite athletes, the

hit was performed in a more automatized manner. According to Gutierrez-Cruz et al. [31], the feed-back control of the motorics is crucial during a foil bout, however in the execution of the fastest elements in foil fencing (like the lounge and the flick), the routine will benefit the performance of the fencer as timing and distance estimation are of crucial importance.

Intensive fencing training impacts the anthropometry [24,26,35,36,37]. Having in mind that the foil flick demands a big amount of muscle power of the arm, the use of this element is characteristic for male fencers over 15 years. In females, only elite foil fencers use the flick successfully. In this context, the beginning of the flick training has to start when the fencers are physically prepared for the process. The specifics of the execution of the flick are related to abrupt changes in the directions of the arm and the wrist and also to the heavy load on the muscles, tendons and ligaments. Detailed investigations are lacking to date, however, we propose, that the flick training may be rather stressful for the elbow joint (radial collateral ligament) and for the wrist ligament complex (ulnar collateral ligament, dorsal radio-carpal ligaments). The stress on the anatomical structures may be especially high during deceleration and contact. Special attention from the trainers had to be paid when working with young fencers, because the training of the flick at an early age may impact the stability of some structures in the athlete's arm.

The proper execution of the flick is crucial for its effectiveness. Our data indicate that the flick in elite foil fencer is performed under feed-forward control. That means that the proper learning of the movements in the training process is crucial for the use of this element in competition. In case of incorrect execution, it is easy to get a backlash due to the large amplitude of the movements required in a flick. The large amplitude of the movement also implies the expenditure of time, and it is difficult to remis é without receiving a touch é. A special aspect of the application of the flick is the fact, that the preparation of the action prevents a transition into another technique. In other words, once the movement was started, it had to be completed successfully, otherwise, there is a high risk of losing a point.

In recent years, proposed holistic fencing training programs [38, 39] and the training effects may be directly tested by using different methods developed especially for fencing (see [40.41]). Having in mind all specific aspects of the foil flick we proposed a testing system, developed to measure the level to which this technique was mastered. We regarded the following scenarios:

"miss" (no light signal and tip off-target) – the fencer was awarded with 0 credits;

"touché, off-target" (light signal on, off-target) – the fencer was awarded with 5 credits

"flat, on target" (no light signal and tip on-target) – the fencer was awarded with 10 credits;

"touché, on-target" (light signal on, tip on-target) – the fencer was awarded with 15 credits;

The fencer has to develop the skill to land the foil tip more perpendicular to the target surface. In foil fencing, the targets of a flick are predominantly small areas which are temporarily undefended by the opponent's weapon. Hence, priority was given to the accuracy, as the proper landing of the tip may require simply more muscle power, which may be developed with time. The increased muscle performance could compensate for the lack of proper bending of the distal section of the foil after deceleration in young fencers (see Figure 4e). Scores over 100 points from 10 attempts have to be considered highly successful (see Table 1). Using this simple method, the trainers can monitor the progress of their students in mastering the flick. For implementation of the proposed method, no complicated gear has to be used. A normal camera capable of shooting video with 120, or 240 fps can be applied for the "on-target"/ "off-target" analyses. After the development of the point-algorithm represented here (in 2019), we used it in the training process of both "under 16" participants "V" and "T". The proposed method allowed for increasing the results of both fencers and they always scored 100 or more points on every test provided in the years 2020 to 2023. The results of the implementation of the test indicated, that we had developed a reliable tool for the foil trainers. Based on the monitoring of the foil flick execution, both "Volov" fencers improved their technique significantly. Currently, "T" is competing as a cadet (U 17) and is already using successfully the flick in competitions. "V" is a foil fencer in Junior (U 20) category and is a member of the national team of Bulgaria - he is using the flick in competition on a regular basis with a high rate of success. Future research will provide data on the exact sensibility of the test, however, the study provided a valid and reliable algorithm for evaluation of the execution of the foil flick in the training process. The sensitivity of the test can be fine-tuned by testing the success within a group of foil fencers with different sexual, age and skill characteristics.

5. Conclusions

In conclusion, we have to mention, that a detailed analysis of the kinematics of the execution of different elements in fencing can contribute to the correction of "Parasitic" phases and movements and for faster improvement of the skills and technique. With the development of modern AI and the involvement of robots in the training process in fencing [40,41], mathematical algorithms based on kinematical investigation will become very valuable.

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Conflict of Interest

The authors declare no conflict of interest.

Appendix

Appendix 1: High speed film sequence (1000 fps), demonstrating the use of the flick by an elite fencer (right) in parry-repost situation after trainer's (left) attack; https://youtu.be/xERAxOX2fCM.

Appendix 2:

Appendix 2. Kinematical variable and descriptive statistics from all elements and all fencers

All	Mean	Standard Error	Median	Standard Deviation	Sample Variance	Range	Minimum	Maximum	Count
1	117.88	1.72	118.00	13.30	176.99	60	77	137	60
2	167.45	1.14	167.59	8.83	77.88	45.94	138.34	184.28	60
3	38.24	2.13	34.26	16.53	273.34	86.04	14.56	100.6	60
4	168.12	1.10	168.50	8.51	72.48	44	143	187	60
5	45.85	2.23	41.50	17.28	298.54	60	14	74	60
6	11.65	0.58	10.64	4.49	20.15	18.86	2.58	21.44	60
7	366.37	18.84	331.00	145.95	21301.32	748	164	912	60
8	26.40	4.33	19.00	33.54	1125.13	148	0	148	60
9	252.08	10.75	275.89	83.24	6929.40	329.7	58.71	388.41	60
10	7.45	0.37	6.89	2.85	8.11	13.82	1.30	15.12	60
11	89.35	1.99	92.00	15.45	238.60	55	61	116	60
12	124.63	1.29	125.00	9.99	99.90	43	102	145	60
13	70.68	2.10	74.50	16.24	263.75	62	34	96	60
14	173.25	0.98	177.00	7.58	57.51	26	158	184	60
15	137.80	2.23	133.45	17.27	298.14	67.94	109.88	177.82	60
16	215.14	4.69	227.50	36.34	1320.36	125.37	140.57	265.94	60
17	159.07	1.00	159.38	7.73	59.75	36.96	139.52	176.48	60
18	26.43	4.33	19.00	33.53	1124.08	148	0	148	60
19	23.55	0.67	23.63	5.17	26.70	22.42	12.96	35.38	60
20	17.43	0.72	16.94	5.61	31.53	27.86	0	27.86	60
21	147.25	1.41	148.00	10.91	118.97	40	124	164	60
22	158.33	0.81	159.00	6.30	39.75	25	147	172	60
23	84.75	1.48	87.00	11.48	131.85	51	53	104	60
24	539.22	25.52	460.00	197.65	39065.56	898	338	1236	60
25	149.98	7.05	135.00	54.62	2983.07	192	82	274	60
26	59.57	1.47	61.64	11.42	130.40	57.56	34.32	91.88	60
27	173.27	0.35	173.00	2.71	7.32	12	168	180	60
28	474.50	17.84	527.77	138.18	19093.71	503.23	194.36	697.59	60

Appendix 2 continued

29	31.20	1.50	29.15	11.63	135.26	42.22	13.85	56.07	60
30	38.00	1.02	36.00	7.93	62.92	32	22	54	60
31	153.82	0.87	157.00	6.77	45.88	26	137	163	60
32	187.45	7.18	174.00	55.63	3094.62	194	116	310	60
33	16.48	0.80	13.54	6.17	38.03	21.02	5.99	27.00	60
34	154.38	1.37	154.00	10.65	113.36	44	131	175	60
35	170.72	0.82	169.00	6.36	40.48	28	159	187	60
36	19.43	0.68	19.25	5.25	27.57	26.15	4.14	30.29	60
37	537.47	18.65	603.18	144.49	20878.46	515.91	237.72	753.63	60
38	84.99	0.80	86.66	6.22	38.70	24.09	72.18	96.27	60
39	89.25	1.13	91.50	8.73	76.16	33	69	102	60
40	571.19	25.99	484.00	201.30	40521.13	988.78	279.22	1268	60
41	10.25	0.79	9.00	6.10	37.21	25	0	25	60
42	4.80	0.44	4.97	3.45	11.87	12.27	0	12.27	60
43	10.17	0.47	9.17	3.60	12.98	16.89	2.26	19.15	60
A	**Mean**	**Standard Error**	**Median**	**Standard Deviation**	**Sample Variance**	**Range**	**Minimum**	**Maximum**	**Count**
1	110.90	2.75	110.50	8.70	75.66	30	101	131	10
2	167.19	3.32	164.65	10.49	109.97	28.89	153.71	182.6	10
3	39.24	2.99	36.87	9.45	89.34	30.64	30.28	60.92	10
4	164.20	1.33	164.00	4.21	17.73	13	156	169	10
5	20.00	1.12	19.50	3.53	12.44	11	14	25	10
6	9.70	0.26	9.56	0.83	0.69	2.71	8.58	11.29	10
7	329.00	35.69	273.00	112.86	12737.11	282	242	524	10
8	17.80	3.50	14.00	11.05	122.18	36	6	42	10
9	214.75	22.86	183.51	72.29	5225.80	189.51	160.2	349.71	10
10	6.57	0.18	6.68	0.58	0.33	1.96	5.69	7.64	10
11	89.30	3.44	88.00	10.86	118.01	32	74	106	10
12	121.40	1.37	121.50	4.33	18.71	15	114	129	10
13	47.20	3.33	42.50	10.53	110.84	32	34	66	10
14	176.10	1.23	175.50	3.90	15.21	12	169	181	10
15	131.88	5.36	126.28	16.95	287.17	49.17	113.06	162.23	10
16	186.41	12.87	170.43	40.71	1657.40	109.92	140.57	250.49	10
17	163.04	2.97	163.80	9.39	88.12	26.4	150.08	176.48	10
18	18.00	3.45	14.00	10.91	119.11	36	6	42	10
19	18.97	0.67	18.79	2.13	4.53	5.9	16.37	22.27	10
20	13.19	1.25	12.74	3.94	15.50	11.45	8.4	19.85	10
21	135.60	2.08	134.50	6.59	43.38	19	126	145	10
22	150.30	0.78	151.00	2.45	6.01	7	147	154	10
23	67.60	3.23	68.00	10.22	104.49	27	53	80	10
24	481.60	49.81	412.00	157.51	24808.71	408	354	762	10

Appendix 2 continued

25	132.70	11.83	118.00	37.40	1399.12	102	92	194	10
26	62.68	2.12	64.65	6.70	44.90	21.68	47.85	69.53	10
27	173.40	0.90	173.50	2.84	8.04	8	170	178	10
28	382.03	41.49	320.23	131.19	17210.33	329.32	265.98	595.3	10
29	20.36	1.70	18.25	5.37	28.82	16.87	16.37	33.24	10
30	48.20	1.47	49.00	4.66	21.73	14	40	54	10
31	159.00	0.58	158.50	1.83	3.33	6	157	163	10
32	181.00	12.05	166.00	38.09	1450.89	94	142	236	10
33	12.29	0.50	12.04	1.59	2.52	4.74	10.55	15.29	10
34	144.60	2.57	146.50	8.14	66.27	22	131	153	10
35	167.20	1.71	167.00	5.41	29.29	14	162	176	10
36	15.05	1.28	14.25	4.06	16.47	12.18	9.57	21.75	10
37	440.55	43.60	373.87	137.88	19011.27	337.52	326.69	664.21	10
38	88.97	0.94	87.79	2.96	8.76	9.69	86.58	96.27	10
39	77.40	1.96	76.50	6.20	38.49	16	69	85	10
40	530.50	49.49	459.00	156.49	24488.72	395	408	803	10
41	12.80	0.87	13.00	2.74	7.51	8	9	17	10
42	4.88	0.65	5.39	2.05	4.22	7.48	0	7.48	10
43	8.28	0.16	8.22	0.50	0.25	1.72	7.45	9.17	10
V	**Mean**	**Standard Error**	**Median**	**Standard Deviation**	**Sample Variance**	**Range**	**Minimum**	**Maximum**	**Count**
1	106.10	5.21	110.00	16.49	271.88	49	77	126	10
2	167.74	0.98	167.59	3.08	9.52	11.04	163.69	174.73	10
3	49.29	6.83	44.89	21.59	466.08	70.82	29.78	100.6	10
4	163.90	1.94	166.00	6.14	37.66	17	153	170	10
5	36.70	1.17	38.00	3.71	13.79	11	29	40	10
6	9.63	0.69	9.75	2.19	4.82	7.64	4.49	12.13	10
7	326.70	37.44	305.00	118.38	14014.68	330	164	494	10
8	29.00	4.84	32.00	15.30	234.00	46	2	48	10
9	209.64	27.67	204.56	87.49	7655.20	255.98	58.71	314.69	10
10	6.27	0.35	6.57	1.11	1.23	4.16	3.58	7.74	10
11	72.00	2.77	73.00	8.77	76.89	21	61	82	10
12	134.20	2.23	133.00	7.04	49.51	20	125	145	10
13	66.70	5.90	65.00	18.67	348.46	55	38	93	10
14	177.10	0.57	177.00	1.79	3.21	7	173	180	10
15	146.79	5.28	143.40	16.69	278.54	37.04	129.47	166.51	10
16	216.77	12.24	216.03	38.71	1498.58	107.83	153.69	261.52	10
17	159.95	0.96	160.45	3.05	9.27	10.3	155.86	166.16	10
18	29.00	4.84	32.00	15.30	234.00	46	2	48	10
19	23.56	1.28	24.31	4.03	16.26	11.66	16.96	28.62	10

Appendix 2 continued

20	14.17	0.63	14.62	1.98	3.91	6.38	10.02	16.4	10
21	157.10	1.14	156.00	3.60	12.99	11	153	164	10
22	159.00	1.30	160.00	4.11	16.89	13	151	164	10
23	85.00	1.09	86.00	3.43	11.78	10	80	90	10
24	538.80	51.63	499.00	163.28	26660.62	416	356	772	10
25	183.20	14.35	173.00	45.39	2060.62	112	136	248	10
26	49.16	2.48	48.22	7.86	61.73	25.12	36.39	61.51	10
27	173.30	1.17	172.00	3.71	13.79	11	169	180	10
28	435.32	47.77	421.15	151.06	22817.99	426.9	194.36	621.26	10
29	25.25	1.06	26.71	3.35	11.23	9.39	18.96	28.35	10
30	32.20	1.92	30.00	6.07	36.84	22	22	44	10
31	151.10	0.71	151.50	2.23	4.99	8	147	155	10
32	213.60	13.51	203.00	42.72	1824.71	104	172	276	10
33	13.09	0.49	13.09	1.54	2.39	5.02	10.41	15.42	10
34	164.40	1.57	165.00	4.97	24.71	16	155	171	10
35	166.30	1.35	165.50	4.27	18.23	14	159	173	10
36	16.26	0.40	16.74	1.26	1.58	4.04	13.36	17.4	10
37	489.53	47.81	478.41	151.18	22856.00	433.52	237.72	671.24	10
38	87.54	1.18	87.11	3.72	13.84	10.3	83.02	93.32	10
39	89.00	1.29	89.00	4.08	16.67	13	83	96	10
40	570.40	50.09	528.00	158.40	25089.60	414	388	802	10
41	3.60	0.58	3.50	1.84	3.38	6	0	6	10
42	3.01	0.91	3.78	2.87	8.23	7.8	0	7.8	10
43	8.53	0.33	8.68	1.06	1.12	3.83	6.13	9.96	10
T	**Mean**	**Standard Error**	**Median**	**Standard Deviation**	**Sample Variance**	**Range**	**Minimum**	**Maximum**	**Count**
1	116.10	3.41	116.00	10.77	116.10	34	99	133	10
2	172.24	1.99	172.09	6.29	39.54	24.11	160.17	184.28	10
3	36.31	2.99	38.67	9.44	89.15	25.91	24.07	49.98	10
4	172.50	2.16	170.00	6.82	46.50	24	163	187	10
5	42.20	1.50	41.00	4.76	22.62	12	37	49	10
6	12.85	1.30	11.55	4.12	17.00	10.24	8.21	18.45	10
7	480.60	56.09	418.00	177.36	31457.82	610	302	912	10
8	66.00	13.63	49.00	43.09	1856.89	130	18	148	10
9	306.52	19.16	305.39	60.59	3671.43	178.74	209.67	388.41	10
10	7.02	0.80	6.69	2.53	6.40	7.18	3.22	10.40	10
11	72.30	2.67	68.50	8.43	71.12	25	62	87	10
12	130.40	2.49	132.00	7.88	62.04	24	118	142	10
13	78.20	2.09	77.50	6.61	43.73	21	68	89	10
14	180.40	0.45	180.00	1.43	2.04	4	179	183	10

Appendix 2 continued

15	162.25	3.05	164.37	9.66	93.23	36.73	141.09	177.82	10
16	251.00	4.63	256.61	14.63	214.05	47.84	218.1	265.94	10
17	166.84	1.19	167.76	3.76	14.12	13.34	159.47	172.81	10
18	66.00	13.63	49.00	43.09	1856.89	130	18	148	10
19	25.34	0.95	25.18	2.99	8.95	8.36	21.51	29.87	10
20	19.16	1.06	20.01	3.36	11.26	11.22	11.95	23.17	10
21	138.40	1.74	137.50	5.50	30.27	16	130	146	10
22	154.20	1.76	154.50	5.55	30.84	13	148	161	10
23	76.80	0.88	76.50	2.78	7.73	9	72	81	10
24	745.60	52.43	682.00	165.79	27486.04	468	554	1022	10
25	226.60	8.78	223.00	27.76	770.71	84	190	274	10
26	72.85	3.87	74.44	12.24	149.90	38.75	53.13	91.88	10
27	174.40	1.06	175.00	3.34	11.16	11	168	179	10
28	556.85	28.90	556.37	91.38	8350.29	291.38	406.21	697.59	10
29	32.28	0.99	31.19	3.12	9.75	8.89	27.99	36.88	10
30	41.20	1.87	41.00	5.90	34.84	18	34	52	10
31	159.10	0.35	159.00	1.10	1.21	4	157	161	10
32	266.80	9.33	264.00	29.52	871.29	82	228	310	10
33	12.45	0.66	12.44	2.08	4.31	6.47	9.55	16.02	10
34	145.80	2.14	145.00	6.78	45.96	21	136	157	10
35	169.60	1.06	168.00	3.34	11.16	9	166	175	10
36	21.46	0.86	22.36	2.71	7.36	8.25	16.02	24.27	10
37	634.10	27.83	636.18	88.02	7747.39	274.49	479.14	753.63	10
38	89.49	1.11	88.68	3.52	12.37	10	86.09	96.09	10
39	81.30	0.94	82.00	2.98	8.90	9	76	85	10
40	786.60	52.99	725.00	167.58	28081.82	476	590	1066	10
41	9.00	0.93	9.00	2.94	8.67	10	5	15	10
42	7.25	0.85	7.36	2.70	7.30	8.46	2.5	10.96	10
43	8.43	0.72	8.36	2.29	5.23	5.72	5.60	11.32	10
Vi	**Mean**	**Standard Error**	**Median**	**Standard Deviation**	**Sample Variance**	**Range**	**Minimum**	**Maximum**	**Count**
1	123.60	1.16	123.50	3.66	13.38	11	117	128	10
2	176.21	1.27	176.66	4.01	16.07	15.09	167.18	182.27	10
3	39.55	2.36	38.43	7.46	55.71	24.16	26.15	50.31	10
4	167.50	1.11	167.00	3.50	12.28	11	162	173	10
5	58.10	1.68	58.00	5.32	28.32	17	51	68	10
6	15.14	0.44	15.47	1.38	1.92	4.64	12.35	16.99	10
7	307.80	13.04	310.00	41.24	1700.84	130	246	376	10
8	0.00	0.00	0.00	0.00	0.00	0	0	0	10
9	285.54	3.96	284.31	12.54	157.17	44.31	271.85	316.16	10

Appendix 2 continued

10	9.43	0.43	9.12	1.36	1.85	3.52	7.71	11.23	10
11	103.70	1.62	102.00	5.12	26.23	15	98	113	10
12	124.00	0.91	124.50	2.87	8.22	9	119	128	10
13	83.80	0.20	84.00	0.63	0.40	2	83	85	10
14	164.40	0.70	163.50	2.22	4.93	6	162	168	10
15	129.83	2.12	130.83	6.72	45.11	25.12	115.5	140.62	10
16	231.09	3.32	232.61	10.51	110.56	35.53	209.69	245.22	10
17	157.90	1.18	158.81	3.74	13.96	11.56	150.48	162.04	10
18	0.00	0.00	0.00	0.00	0.00	0	0	0	10
19	26.72	1.18	26.25	3.75	14.03	13.54	21.84	35.38	10
20	22.97	0.94	23.37	2.96	8.75	10.81	17.05	27.86	10
21	158.80	0.63	159.00	1.99	3.96	8	155	163	10
22	157.50	0.95	158.00	2.99	8.94	10	152	162	10
23	97.60	1.35	96.50	4.27	18.27	11	93	104	10
24	409.20	14.17	412.00	44.80	2007.29	132	338	470	10
25	100.40	2.38	100.00	7.53	56.71	24	92	116	10
26	59.76	1.58	61.48	5.01	25.12	16.62	51.29	67.91	10
27	172.90	0.66	173.50	2.08	4.32	6	170	176	10
28	551.12	9.05	547.94	28.63	819.89	106.04	499.72	605.76	10
29	48.42	1.50	47.35	4.75	22.56	15.37	40.7	56.07	10
30	34.20	1.13	33.00	3.58	12.84	10	30	40	10
31	142.40	1.25	143.50	3.95	15.60	12	137	149	10
32	133.60	2.38	134.00	7.53	56.71	22	122	144	10
33	24.66	0.36	24.95	1.15	1.31	3.57	22.31	25.88	10
34	168.20	1.01	167.50	3.19	10.18	10	165	175	10
35	165.40	0.56	166.00	1.78	3.16	5	162	167	10
36	24.54	0.85	24.48	2.68	7.17	9.96	20.33	30.29	10
37	614.76	8.23	612.83	26.02	677.12	91.65	570.64	662.29	10
38	78.63	1.37	79.33	4.34	18.79	14.12	72.18	86.3	10
39	97.40	0.98	96.50	3.10	9.60	8	94	102	10
40	441.50	13.82	447.00	43.71	1910.94	122	378	500	10
41	7.00	0.37	7.00	1.15	1.33	4	5	9	10
42	8.96	0.52	8.69	1.65	2.74	6.19	6.08	12.27	10
43	14.02	0.38	13.67	1.22	1.48	3.38	12.32	15.69	10
S	**Mean**	**Standard Error**	**Median**	**Standard Deviation**	**Sample Variance**	**Range**	**Minimum**	**Maximum**	**Count**
1	115.90	3.35	115.00	10.60	112.32	35	96	131	10
2	159.47	3.18	161.55	10.06	101.17	33.61	138.34	171.95	10
3	40.00	8.38	30.18	26.51	702.71	69.43	20.79	90.22	10
4	161.20	3.24	161.00	10.25	105.07	32	143	175	10

Appendix 2 continued

5	46.70	3.66	42.00	11.57	133.79	36	31	67	10
6	5.91	0.74	5.96	2.35	5.53	8.06	2.58	10.64	10
7	442.80	67.25	360.00	212.67	45226.84	614	208	822	10
8	45.60	11.71	35.00	37.04	1372.27	124	16	140	10
9	157.68	13.09	156.30	41.39	1713.01	138.39	90.01	228.4	10
10	4.19	0.59	4.23	1.87	3.48	6.38	1.30	7.68	10
11	106.40	2.06	108.50	6.50	42.27	22	94	116	10
12	129.90	0.82	130.50	2.60	6.77	9	125	134	10
13	63.90	2.28	64.00	7.22	52.10	21	53	74	10
14	178.80	1.06	178.50	3.36	11.29	12	172	184	10
15	121.41	2.25	121.01	7.12	50.74	23.24	109.88	133.12	10
16	174.60	6.16	167.55	19.49	379.73	61.98	150.45	212.43	10
17	156.70	2.48	158.24	7.84	61.40	27.39	139.52	166.91	10
18	45.60	11.71	35.00	37.04	1372.27	124	16	140	10
19	17.50	0.88	17.99	2.78	7.74	8.23	12.96	21.19	10
20	12.34	1.57	13.70	4.97	24.71	16.82	0	16.82	10
21	154.10	1.15	155.00	3.63	13.21	12	147	159	10
22	165.20	1.20	165.50	3.79	14.40	13	159	172	10
23	89.90	2.04	89.00	6.45	41.66	21	76	97	10
24	643.40	85.95	569.00	271.79	73872.04	866	370	1236	10
25	153.60	13.84	142.00	43.78	1916.27	156	112	268	10
26	48.56	2.73	48.64	8.64	74.57	28.17	34.32	62.49	10
27	173.30	0.63	174.00	2.00	4.01	7	169	176	10
28	319.89	20.53	314.69	64.92	4213.98	208.55	228.69	437.24	10
29	18.90	1.06	19.38	3.34	11.15	10.6	13.85	24.45	10
30	41.00	2.22	43.00	7.01	49.11	18	30	48	10
31	159.50	0.70	160.00	2.22	4.94	7	156	163	10
32	194.40	13.58	188.00	42.94	1844.27	156	144	300	10
33	11.62	0.92	11.93	2.92	8.51	9.33	5.99	15.31	10
34	152.00	1.58	153.00	5.01	25.11	19	140	159	10
35	178.30	1.33	178.00	4.19	17.57	15	172	187	10
36	14.68	1.45	16.97	4.59	21.08	14.03	4.14	18.17	10
37	373.86	22.50	370.56	71.16	5064.39	223.01	279.22	502.23	10
38	88.21	1.28	88.98	4.05	16.37	14.57	79.28	93.85	10
39	93.80	1.81	95.00	5.73	32.84	19	82	101	10
40	647.72	94.44	546.00	298.64	89183.32	988.78	279.22	1268	10
41	8.00	0.99	9.00	3.13	9.78	11	0	11	10
42	1.27	0.53	0.00	1.68	2.81	3.66	0	3.66	10
43	6.65	0.72	6.35	2.29	5.24	7.74	2.26	10.00	10

Appendix 2 continued

I	Mean	Standard Error	Median	Standard Deviation	Sample Variance	Range	Minimum	Maximum	Count
1	134.70	0.63	135.00	2.00	4.01	6	131	137	10
2	161.87	1.34	161.45	4.24	17.94	13.29	156.82	170.11	10
3	25.06	2.23	24.67	7.04	49.61	22.39	14.56	36.95	10
4	179.40	0.52	179.50	1.65	2.71	5	177	182	10
5	71.40	0.54	71.00	1.71	2.93	5	69	74	10
6	16.65	1.18	17.59	3.74	13.97	11.2	10.24	21.44	10
7	311.30	17.42	311.00	55.08	3034.23	165	236	401	10
8	0.00	0.00	0.00	0.00	0.00	0	0	0	10
9	338.35	8.63	339.08	27.30	745.30	84.38	296.73	381.11	10
10	11.21	0.73	11.58	2.31	5.33	7.72	7.40	15.12	10
11	92.40	1.00	92.00	3.17	10.04	11	88	99	10
12	107.90	1.30	109.00	4.12	16.99	12	102	114	10
13	84.30	1.79	84.50	5.66	32.01	19	77	96	10
14	162.70	1.15	162.50	3.62	13.12	10	158	168	10
15	134.62	1.63	134.30	5.16	26.65	16.49	127.89	144.38	10
16	230.97	2.44	230.94	7.72	59.67	20.92	221.73	242.65	10
17	149.96	1.39	149.64	4.40	19.38	14.17	142.53	156.7	10
18	0.00	0.00	0.00	0.00	0.00	0	0	0	10
19	29.22	0.96	29.92	3.03	9.17	9.54	23.54	33.08	10
20	22.77	1.13	21.41	3.59	12.87	9.03	18.23	27.26	10
21	139.50	2.52	141.00	7.96	63.39	24	124	148	10
22	163.80	0.77	163.00	2.44	5.96	9	161	170	10
23	91.60	1.35	90.00	4.27	18.27	12	87	99	10
24	416.70	16.51	418.50	52.20	2725.34	158	340	498	10
25	103.40	3.39	102.00	10.71	114.71	42	82	124	10
26	64.40	1.05	63.68	3.32	11.01	10.65	58.88	69.53	10
27	172.30	0.63	172.00	2.00	4.01	7	169	176	10
28	601.79	13.89	603.14	43.93	1930.25	123.94	545.18	669.12	10
29	41.99	0.72	42.12	2.27	5.18	7.18	37.87	45.05	10
30	31.20	1.24	31.00	3.91	15.29	12	24	36	10
31	151.80	1.28	151.00	4.05	16.40	13	145	158	10
32	135.30	3.74	136.50	11.81	139.57	44	116	160	10
33	24.78	0.54	24.74	1.71	2.91	5.71	21.29	27.00	10
34	151.30	2.06	153.50	6.50	42.23	22	137	159	10
35	177.50	0.52	178.00	1.65	2.72	4	175	179	10
36	24.57	0.82	25.18	2.60	6.75	6.5	20.72	27.22	10
37	672.04	12.84	670.30	40.60	1648.07	128.95	613.98	742.93	10
38	77.11	1.03	76.44	3.27	10.69	10.77	72.66	83.43	10

Appendix 2 continued

39	96.60	0.98	96.50	3.10	9.60	10	91	101	10
40	450.40	14.42	453.00	45.60	2078.93	138	388	526	10
41	21.10	0.84	21.50	2.64	6.99	9	16	25	10
42	3.45	0.85	3.10	2.69	7.24	7.41	0	7.41	10
43	15.09	0.65	15.42	2.07	4.28	7.48	11.67	19.15	10

Appendix 3

Appendix 3. Significant differences between all experimental groups

N	**Elements of the kinematical profiles**	**Results of Vi & I to results of:**	
		A & S	**V & T**
1	angle of the elbow at start of backward stroke	+	+
2	distance of the shoulder to the target centre at en garde		
3	distance between the foil tip to centre of target at en garde		+
4	angle of the wrist at en garde	+	+
5	angle between the body axe and the upper arm at en garde	+	+
6	max. speed of the foil tip during backward rotation	+	+
7	duration of the backward rotation		+
8	duration between the end of backward duration and the start of forward rotation	+	+
9	distance passed by the foil tip during the backward rotation	+	+
10	average speed of the foil tip during the backward rotation	+	+
11	angle of the elbow at the end of the backward rotation		+
12	angle of the wrist at the end of the backward rotation	+	+
13	angle between the body axe and the upper arm at the end of the backward rotation	+	+
14	angle of the blade at the start of forward rotation	+	+
15	distance of the guard and the target at the end of backward rotation		+
16	distance of the foil tip and the target at the end of backward rotation	+	
17	distance of the shoulder to the target center at the end of backward rotation	+	+
18	duration between the end of backward duration and the start of forward rotation	+	+
19	speed of the tip by bending start speed by the foil tip by the start of deceleration	+	+
20	distance passed by the shoulder from en garde to the start of deceleration	+	+
21	angle of the elbow at the start of deceleration		
22	angle of the wrist at the start of deceleration		+
23	angle between the body axe and the upper arm at the start of deceleration	+	+
24	duration of the cycle before the start of deceleration	+	+
25	interval between forward rotation start and the start of deceleration	+	+
26	distance between the foil tip and the center target at the start of deceleration	+	
27	angle of the blade during the start of deceleration		
28	distance passed by the foil tip at the start of deceleration	+	+
29	max. speed of the foil tip during forward rotation	+	+
30	duration of the deceleration phase until touché	+	+
31	angle of the blade by touché	+	+

Appendix 3 continued

32	duration of the forward rotation	+	+
33	average speed of the foil tip during forward rotation	+	+
34	angle of the elbow by touch é	+	
35	angle of the wrist by touch é	+	+
36	distance of the shoulder displacement by touch é	+	+
37	total distance passed by the foil tip	+	+
38	distance of the guard to center target by touch é	+	+
39	angle between the body axe and the upper arm by touch é	+	+
40	duration of the whole cycle	+	+
41	angle between the lining of the body axis at en garde and by touch é	+	+
42	hip displacement	+	
43	average speed of the tip of the foil during the whole cycle	+	+
+ There is a significant difference between groups, P≤ 0.05;			

N	**Elements of the kinematical profiles**	**Correlation between results of:**		
		A & S	**V &T**	**Vi & I**
1	angle of the elbow at start of backward stroke			+
2	distance of the shoulder to the target centre at en garde			+
3	distance between the foil tip to centre of target at en garde		+	+
4	angle of the wrist at en garde	+	+	+
5	angle between the body axe and the upper arm at en garde	+	+	+
6	max. speed of the foil tip during backward rotation	+	+	
7	duration of the backward rotation		+	
8	duration between the end of backward duration and the start of forward rotation	+	+	
9	distance passed by the foil tip during the backward rotation	+	+	+
10	average speed of the foil tip during the backward rotation	+		
11	angle of the elbow at the end of the backward rotation	+		+
12	angle of the wrist at the end of the backward rotation	+		+
13	angle between the body axe and the upper arm at the end of the backward rotation	+		
14	angle of the blade at the start of forward rotation		+	
15	distance of the guard and the target at the end of backward rotation		+	
16	distance of the foil tip and the target at the end of backward rotation		+	
17	distance of the shoulder to the target center at the end of backward rotation		+	+
18	duration between the end of backward duration and the start of forward rotation	+	+	
19	speed of the tip by bending start speed by the foil tip by the start of deceleration			
20	distance passed by the shoulder from en garde to the start of deceleration		+	
21	angle of the elbow at the start of deceleration	+	+	+
22	angle of the wrist at the start of deceleration	+	+	+
23	angle between the body axe and the upper arm at the start of deceleration	+	+	+

Appendix 3 continued

24	duration of the cycle before the start of deceleration		+	
25	interval between forward rotation start and the start of deceleration		+	
26	distance between the foil tip and the center target at the start of deceleration	+	+	+
27	angle of the blade during the start of deceleration			
28	distance passed by the foil tip at the start of deceleration		+	+
29	max. speed of the foil tip during forward rotation		+	+
30	duration of the deceleration phase until touch é	+	+	
31	angle of the blade by touch é		+	+
32	duration of the forward rotation		+	
33	average speed of the foil tip during forward rotation			
34	angle of the elbow by touch é	+	+	+
35	angle of the wrist by touch é	+		+
36	distance of the shoulder displacement by touch é		+	
37	total distance passed by the foil tip		+	+
38	distance of the guard to center target by touch é			+
39	angle between the body axe and the upper arm by touch é	+	+	
40	duration of the whole cycle		+	
41	angle between the lining of the body axis at en garde and by touch é	+	+	+
42	hip displacement	+	+	+
43	average speed of the tip of the foil during the whole cycle	+		
+ There is a significant difference between groups, P≤ 0.05;				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Fencers	358871.171	5	71774.23	30.934	1.45E-30	2.218
Elements of the kinematical profiles	55651776.92	42	1325042	571.086	0	1.389
Interaction	3723612.993	210	17731.49	7.642	2.7E-151	1.175
Within	5387539.944	2322	2320.215			
Total	65121801.03	2579				

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