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Movement structure in fencing lunge in elite fencers and beginners

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Abstract

Background & Study Aim: The criterion for successful hitting the opponent during the lunge in fencing is the right timing of the attack and suitable timing in muscle coordination. From the elite fencers we expected application of movement patterns, which had been reinforced during the training. The aim of this study is knowledge about kinematic characteristic of fencing lunge in different performance-related groups of fencers (elite and beginers).

Material & Methods: The first group (n = 7) consists of elite fencers of the Czech Republic, who are active in fencing an average of 12 years (±3.4). In the second group (n = 7), there are fencers who are active in fencing up to two years. Athletes performed lunge on a visual stimulus of LEDs, which is part of the Fitrosword device. Video recording (high-speed camera) and Dartfish Team Pro 6 Data software were used to evaluation of movement structure of the lunge.

Results: The elite fencers had lower value of reaction time. Significant differences between beginners and elite fencers was found in time required for front elbow extension and in activation of front upper limb before front lower limb. In elite fencers were armed arms activated before the lower front leg significantly earlier than in beginners who initiated their lunge preferentially with activity of the lower limb on the side closer to the target.

Conclusions: The results of our study can be used in the training proces for improving the efficiency on the implementation of the lunge with regard to the optimal structure of this motion act applied by an elite group of fencers.

Key words: combat sports, kinematic analysis, movement time, reaction time, visual stimulus

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Reaction time – is the time from occurence of stimulus to first initiation of movement of the relevant segment of the body

Movement time (MT) – was characterized as the time from the moment of displacement of epee goblet over the horizontal obstacle to the moment of hitting of the target

INTRODUCTION

The presented study is focused on qualitation analysis of movement structure of the lunge of elite fencers and novices. As in many other sports disciplines, there was a progress and change of claims on sports performance in the last few decades. The current waveform of the fight in fencing can be characterized as sequence of actions, which are proceeding very quickly and unexpectedly due to the spatial conditions, time contrains and opponent´s movement. These activities are substancially quicker than the ones which were applied right before development of signalizing equipment (epee 1937, foil 1957, saber 1988) which perfectly identify the hit of the opponent. It has led to raising of claims on speed and elimination of redundant and complicated actions, which were applied in fencing in the beginning of 30´s of the last century. Performance in fencing is determined by many factors, which has to be in mutual interaction [1]. The main part is endoubtely also the level of simple and complex of reaction time and speed ability. The other factor (technique, tactics, psychological factors, somatic factors, conditioning factors) are just complementing these variables. Roi and Biachedi [2] are saying, that for successful performance in fencing seem to be important also morphological factors. Their influence is relatively small if the physiological, technical and tactical factors are not out of the appropriate level. In other sports is also very important the level of reaction time for example in boxing, in activities of goalkeepers in ball games etc. In some cases cant his reaction be almost automatical for top athletes. This relates, as Schmidt and Wrisberg [3] say, with experience and long-time training.

In training process in different sports dominate various stimuli on which has the sportsman react [4]. For the performance in fencing is according to Borysiuk [5] optimal to use reactions on visual and tactile stimuli without increased bioelectric muscle tension. In case of fancing is it in training proces largely about reactions on specific activities of the trainer with the weapon, who previously designated, how should the fencer reacts to a given stimules. During the training it can lead to their combination and the fencer is ecposed to a large number of stimuli, from which are leading to realization of appropriate physical action, it occures to ceating a specific purpose motion program according to Véle [6]. Movement pattern saved in memory is then realized by muscle apparatus as a simple movement. The frequent repetition of the motion program or the pattern lead to mantaining and improving the quality of them. The conception of our study was built on this base. It was monitoring differences in the structure of the lung after the visual stimulation. During the fight, however, there are situation requiring extension of motion acts, which may affect movement patterns during the implementation of the lunge.

As is known, more experienced athletes have better analysis of surrounding environmental information. Movements of these experienced athletes are more effective than at beginners. Important information is from the surrounding environmental we are perceiving by our sensory systems, thanks to them we can better perceive and act on the base of this information with the increasing experience [3].

Reaction time (RT) is the time from acceptance of sense stimuli to the beginning of volitional reaction (first muscle contraction) it means time of transfer of stimuli of the receptor to the effector. For some motion tasks, the reaction time is longer than the time which is needed to implement them. Very often we encounter with this reality in fencing. Recorded time of the reaction then contains the sum of reacting time and movement time [7]. Very often is this sum defined as overall response time of the organism. In previous studies many authors had tried to characterize kinematic profile of the lunge or to analyze time activations of selected muscles through surface electromyography at different performance groups of fencers. From the conclusions of these studies is clear, that time activations of individual segments of the body and the structure of the motion itself are very important at this motion act. The priority action of the arm with a weapon before the leg making a lunge is signicifant factor for the future result of the performed action according to representative trainers.

After determining the level of reaction time and movement time there was not detected difference at 10 elite fencers and 4 beginners according to study of Harmenberg et al. [8]. The authors also state, that in the test where the stimulus was determined by extension of trainers arm for simple reaction, there were detected differences in reaction time between elite fencers and beginners. Elite fencers had above 35% faster movement time and after also the whole time of the response. With right and succesful performance of the lunge i salso related the strenght of muscles (dominant and non-dominant) of the lower limb [9, 10].

Through surface EMG for observation of muscle coordination during the lunge, Williams and

Walmsley [11] figured out, that at the group of elite and subelite fencers there exist differences in the time activation of observed muscles. Elite fencers had significantly faster starting-up of action at five form six observed muscles. EMG analysys revealed high compliance of muscle coordination of observed muscles in both of the groups. This result was probably formed by high performance level of both of the groups. Reaction time and the total response time were faster at elite fencers than at fencers of lower performance level.

In another investigation Williams and Walmsley [12] discovered, that the order of involved muscles during the lunge had the same sequence as in the previous study. At first the *m. rectus femoris* was activated, then m. *deltoideus anterior*, m. *biceps femoris* (lower limb), m. *triceps*, the same muscles of the front lower limb started their action later. These results are also confirming the claim of Harmenberg et al. [8] who is stating, that more experienced fencers are launching the lunge with the action of muscles of front upper limb rather than with front lower limb.

The aim of this study is knowledge about kinematic characteristic of fencing lunge in different performance-related groups of fencers (elite and beginers).

MATERIAL AND METHODS

Participants

The researched group consists of elite fencers (n = 7), who have position to 15th place in actual series of Czech Republic cup. These fencers have done this discipline for 12 years in average (±3.4). The other group consists of fencers (n = 7), who can we include among beginners (devoted to this sport activity up to 2 years). Local bioethics committee has given consent to the study.

Design of the study

For the measuration of reaction time and the movement time was used the Fitrosword equipment, which was developed by representative trainers for observation of the speed of response to visual stimuli. For this equipment was used SWORD software, which evaluates separately reaction time and movement time. By the sum of these two times we get the total time required to perform the lunge (the whole response time).

The part of the system is also a target (28 x 35 cm) with steel rings (2.5 cm) and with one middle ring (5 cm), which identifies the hit (lowest value 0, highest value 5). In the middle of the upper edge of the target there are three LED diods of different colours. In our case we need only the red one. Another component of the Fitrosword system is very sensitive horizontal barrier, on which have the tested fencer lay the cord FIE BF Uhlmann (underneath part of the safeguard).

The reaction time was determined from the moment of illumination of the red LED diod, which is an incentive to start a lunge to the movement of the underneath part of the safeguard over the horizontal barrier. From this moment the movement time is measured and it´s terminated after the hit to the target or to the space around the target. We used the same method to determinate the movement diststance as Williams and Walmsley [11, 12].

The height of tested fencer we multiplied by a coefficient 1.5. The nearest part of the foot of back lower limb had the fencer of the relevant mark just before starting the lunge.

The video was recorded by multi-format high-speed AVCHD camera Panasonic AG-HMC 41 which takes 50 frames per one second. In our case, we used the recording of 720/50p. Camera was placed 3.5 metres away from the plane where the lunge was tested. For analysis of video was used Dartfish 6 TeamPro Data software.

Statistical analyses

We analyzed 10 trials of lunge each fencer. The aritmetic mean and standard deviation we counted at each variable in Microsoft Excel 2010 program. For aberrant frequency distribution of monitored values was for statistical processing used Mann Whitney test for detecting differences between two groups of fencers. Individual attemps of all subject were interindividually compared. Subjects were also instrued to make every trial in maximum possible speed. The side where the fencer had his weapon was designated as „front“ (lunge) side. The side without weapon was designated as „back“ (bounce) side.

RESULTS

The total response time at elite fencers in visual stimulus was 753 ms. The reaction time was participating on 36.5 % of the total response time. The remaining was formed from movement time. At the moment of leaving the pad by the „front“ foot had elite fencers in elbow joint increased by 41° in phase from

guard position to leaving the pad by „front“ foot. During hitting the targets, the angle of the knee joint of front lower limb was about 142°. Time of flight phase, when both of the feet were out of touch with the pad lasted about 69 ms. In this respect the flight phase was used by five from seven elite fencers. All subjects were hitting the target at maximum extension in elbow joint on the weapon side (180°). The „back“ foot was shifted away on average of 23 cm straight to the target from the original mark during the lunge. It undoubtedly related with using the flight phase. On average the elite fencers had the angle in „front“ knee joint about 83° in the moment of maximal range of the lunge. In all cases it occured to foot twisting on it´s interior side during implementation of the lunge. It undoubtely relates with the shifting of the „back“ foot. In most cases the hitting of the target happened before the treading of the „front“ foot. In time of extension in „front“ elbow joint was 417 ms. All elite fencer´s lunge was launched by action of „front“ upper limb and by front lower limb after, according to the video tape. The difference between this periods was about 142 ms (Table 1).

The total average of response time needed to perform the lunge was 763 ms in this group of fencers. In the total response time the reaction time was involved from 46%. No fencer from a group of beginners did use the flight phase for implement the lunge, when both feet were on the pad. In the last moment of leaving the „front“ foot from the pad was the average angle in „front“ elbow joint about 115°, which was about 29° less than at the group of elite fencers. The angle in the elbow joint has not changed from the previous guard position. The elite fencers had raised the elbow angle up to 41° in this case. At the time of hitting the targed the beginners group had the anggle in „front“ knee joint about 117°, which was 25° less than at the group of elite fencers. The „back“ foot had shifted from the original mark just about

Table 1. Experimental variables elite fencers (n = 7)

Observed variables	S1	S2	S3	S4	S5	S6	S7	X	SD
MD [cm]	279	289	270	259	271	282	292	**277**	11.6
FF x BF – before **L** [cm]	83	36	36	39	46	50	52	**49**	16.4
FE – before **L** [degrees]	111	90	91	109	90	110	115	**102**	11.3
FK – before **L** [degrees]	127	126	133	144	126	129	136	**132**	6.7
RT [ms]	267	276	332	265	247	290	245	**275**	29.8
TRT [ms]	618	890	859	746	742	676	738	**753**	95.4
FE at the moment of leaving the pad **FF** [degrees]	158	118	151	135	141	126	177	**144**	20.1
FK x hit (degrees)	137	144	134	147	173	155	105	**142**	20.9
FF over the pad [ms]	240	580	420	480	380	400	280	**397**	115.1
FP (both feet) [ms]	0	100	60	140	120	0	60	**69**	55.2
BF – before **L** after **MLR** [cm]	6	48	29	33	21	0	24	**23**	16.2
FK in **MLR** (degrees)	100	71	66	89	73	106	79	**83**	15.3
Extension **BK** in **MLR**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**7/7**	
Hitting the target at the same time with tread **FF**	No	Yes	Yes	No	No	No	Yes	**3/7**	
HT	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**7/7**	
Extension **FE** [ms]	380	340	440	420	460	442	440	**417**	42.5
Action of **FUL** vs. **FLL** [ms]	120	80	200	120	140	34	300	**142**	86.4

S1-7: subject 1-7; MD: movement distance; FF: front foot; BF: back foot; L: lunge; FE: front elbow; FF: front foot; FK: front knee; BK: back knee; SD: standard deviation; FLL: front lower limb; FUL: front upper limb; MLR: maximum lunge range; HT: heel tread; RT: reaction time; TRT: total response time; FP: flight phase; X: arithmetic mean / or ratio

6.6 cm at elite fencers was distance about 16.4 cm longer (Table 2).

All subjects of this group had always one foot in contact with the pad and so there was no flight phase. In maximal range of the lunge was in this group the knee joint angle of lower limb (105°) which was 22° less than at elite fencers. Only two subjects in this group twisted the „back" foot on it´s interior side. In remaining two cases, the back foot was in contact with the pad just by resting the foon ot it´s front part. Compared with elite fencers, all subjects of this group treated by their „front" foot at first and then they hitted the target. Most of beginners did not make the maximal enstension in „front" elbow joint during hitting the target (Table 3).

The elite fencers had lower value of reaction time. This difference showed as significant (p = 0.009, *d* = 0.989). In total response time (sum of reaction time and movement time) was not found difference in both groups (p = 0.949, d = 0.024). In time required for front foot movement over the pad there was not found significant difference between monitored groups of fencers (p = 0.277, *d* = 0.105). Significant differences between beginners and elite fencers was found in time required for front elbow extension (p = 0.002, *d* = 1.159) and in activation of front upper limb before front lower limb (p = 0002, *d* = 1.183). In elite fencers were armed arms activated before the lower front leg significantly earlier than in beginners who initiated their lunge preferentially with activity of the lower limb on the side closer to the target (Figures 1 to 5).

DISCUSSION

We reasoned the efficiency in the lunge performance used by elite fencers. In this case we have used the Schmidt and Wrisberg [3] and Véle [6] publications. In the context with our investigation we discovered that Stewart and Kopetka [13] for example, that speed of the lunge depends on maximal speed of movement

Table 2. Experimental variables beginners fensers (n = 7)

Observed variables	S1	S2	S3	S4	S5	S6	S7	X	SD
MD [cm]	276	262	251	267	254	270	255	**262**	9.3
FF x BF – before **L** [cm]	42	39	57	51	49	40	31	**44**	8.7
FE – before **L** (degrees)	107	141	107	125	101	112	115	**115**	13,6
FK – before **L** (degrees)	145	121	137	125	130	128	123	**130**	8.5
RT [ms]	283	356	325	322	349	400	350	**341**	36.1
TRT [ms]	834	780	705	727	851	705	741	**763**	60
FE at the moment of leaving the pad **FF** [degrees]	100	141	114	125	97	115	114	**115**	14.9
FK x hit [degrees]	85	121	114	136	129	124	110	**117**	16.6
FF over the pad [ms]	420	400	180	340	300	240	400	**326**	90.7
FP (both feet) [ms]	0	0	0	0	0	0	0	**0**	0
BF – before **L** after **MLR** [cm]	0	11	0	21	0	14	0	**6,6**	8.7
FK in MLR (degrees)	78	112	103	101	115	134	90	**105**	18.1
Extension **BK** in **MLR**	Yes	No	No	Yes	No	No	Yes	**3/7**	
Hitting the target at the same time with tread **FF**	No	No	No	No	No	No	No	**0/7**	
HT	Yes	No	Yes	Yes	Yes	Yes	Yes	**6/7**	
Extension **FE** [ms]	480	460	680	500	500	620	700	**563**	101
Action of **FUL** vs. **FLL** [ms]	–120	–220	–100	–140	– 80	–220	–240	**–160**	65.3

S1-7: subject 1-7; MD: movement distance; FF: front foot; BF: back foot; L: lunge; FE: front elbow; FF: front foot; FK: front knee; BK: back knee; SD: standard deviation; FLL: front lower limb; FUL: front upper limb; MLR: maximum lunge range; HT: heel tread; RT: reaction time; TRT: total response time; FP: flight phase; X: arithmetic mean / or ratio

Table 3. The basic data of differences processing between elite (n = 7) and beginners (n = 7) fencers

Variables	Beginners [median in ms]	Elite [median in ms]	Z	p-level	ES
RT	349	267	2.619	0.009	0.989
TRT	741	742	−0.063	0.949	0.024
FF	340	400	−1.086	0.277	0.105
FE	500	440	3.066	0.002	1,159
FUL vs. **FLL**	−140	120	−3.130	0.002	1.183

RT: reaction time; TRT: total response time (reaction time + movement time); FF: time required for front foot movement over the pad; FE: time required for front elbow extension; FUL vs. FLL = FLL: activation of front upper limb before front lower limb; ES: effect size

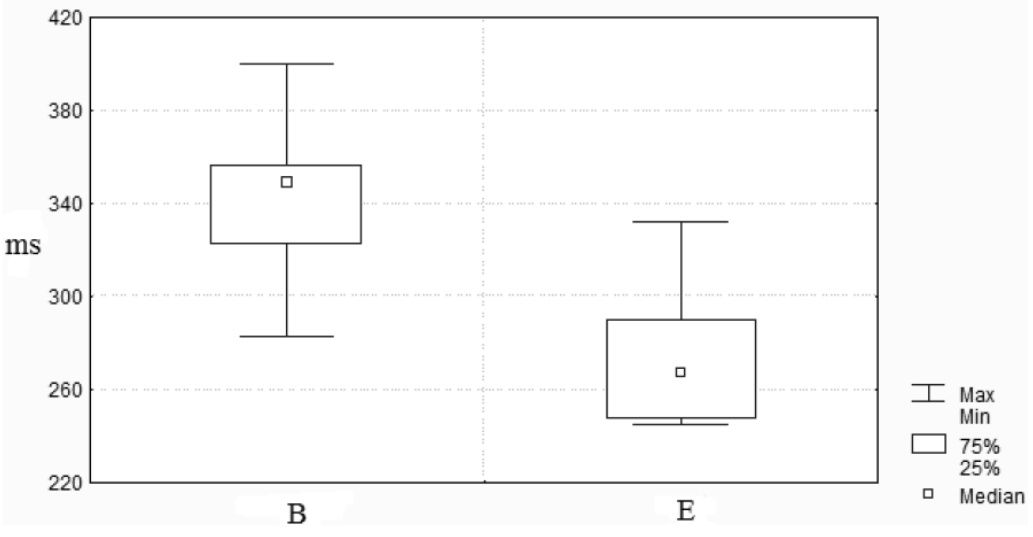

Figure 1. Reaction time in two groups of fencers B: beginners (n = 7); E: elite fencers (n = 7)

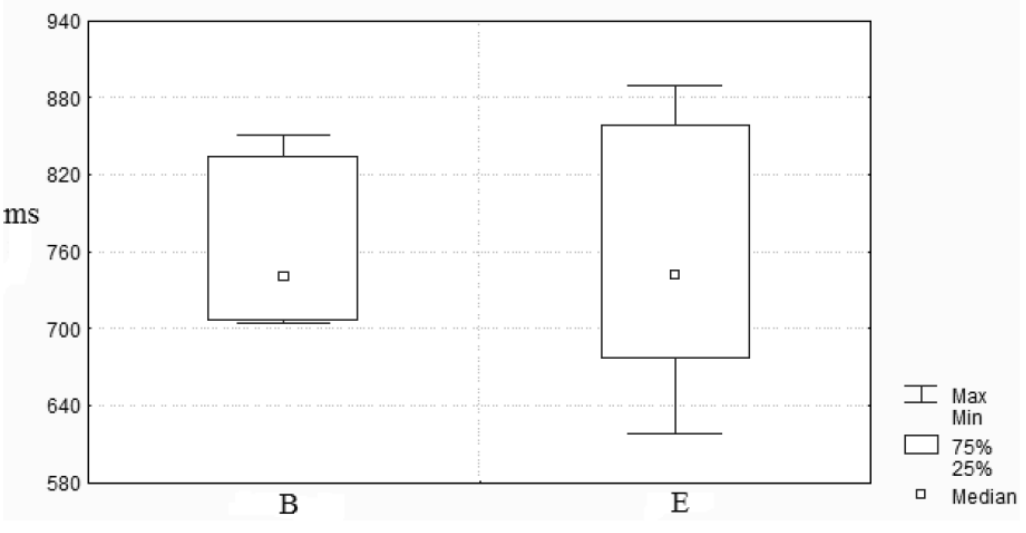

Figure 2. Total response time in two groups of fencers B: beginners (n = 7); E: elite fencers (n = 7)

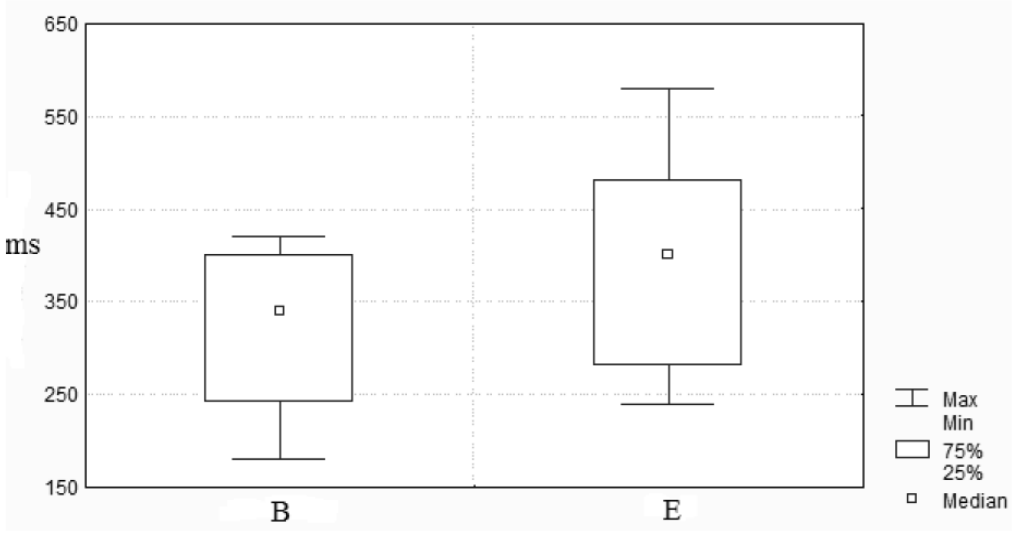

Figure 3. Time required for front foot movement over the pad B: beginners (n = 7); E: elite fencers (n = 7)

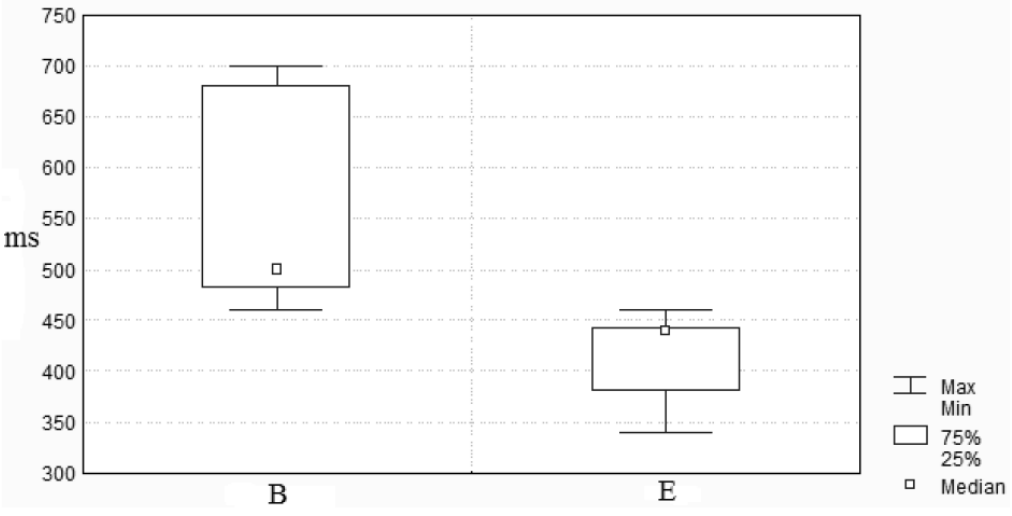

Figure 4. Time required for front elbow extension B: beginners (n = 7); E: elite fencers (n = 7)

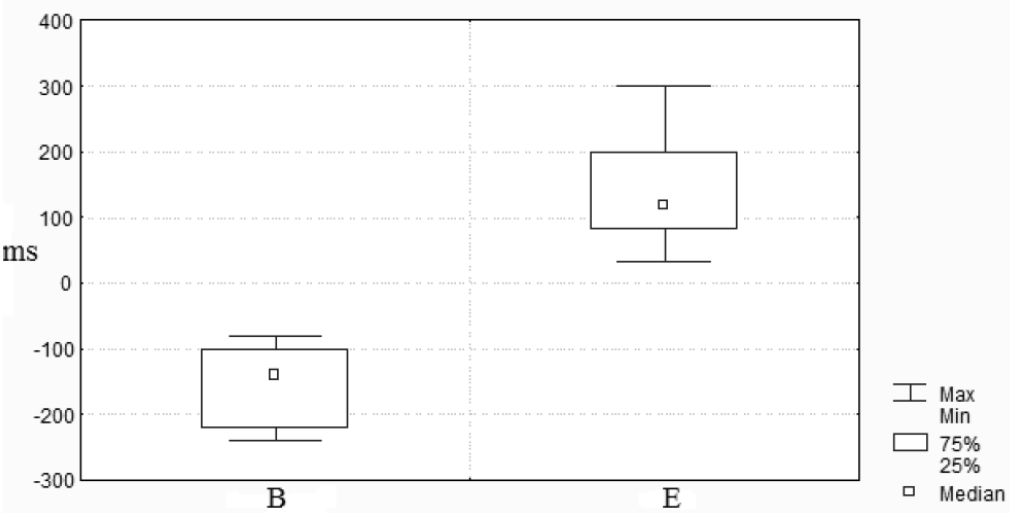

Figure 5. Activation of front upper limb before front lower limb B: beginners (n = 7); E: elite fencers (n = 7)

of the elbow and arm with a weapon and on the movement of both knees. Through kinematic analysis of the lunge at two performance-related groups of fecers did Gholipour et al. [14] found out, that lunge realized by elite fencers was on average 15 cm longer than at beginners. Influence of different types of shoes on the implementation of the lunge did study Geil [15]. The author found out that in comparison of fencing and indoor shoes, those indoor shoes can influence the technique used during the match, it also depend on which hand is the weapon holded and on the overal movement of the arm. In his study there were differences in the movement speed of the front arm and the lower limb when both types of shoes were used.

Sillero et a. [16] found out by kinematic analysis, that during the internal and external knee rotation the lower back limb does not act differently in case of speed of making a lunge. The results of study are clearly pointing to the fact, that more experienced fencers are launching the lunge by arm (by arm where the weapon is holded). Similar results were presented in Harmenberg et. al. [8] or Williams and Wamsley [11,12] for example.

By our investigation we found out, that less experienced fencers are launching the lunge with „front" lower limb and after with „front" upper limb by an average of 160 ms. Due to the identified results of elite fencers is this difference beside the beginners on average 302 ms. The elite fencers therefore initiated the extension in elbow joint of „front" upper limb significantly earlier. Speed of the lunge measured from the stimuli to the hit was almost identical at both of the groups. Bigger differences were observed at the level of reaction time. The elite fencers achieved lower values on average of 66 ms. The group of beginners (mostly) does not hit the target on maximal (180°) extension of the elbow joint.

Results reveal that the elite fencers had lower value of reaction time (Figure 1). This difference showed as significant ($p = 0.009$, $d = 0.989$). In total response time (sum of reaction time and movement time) was not found difference (Figure 2) between both groups ($p = 0.949$, $d = 0.024$). This result shows that the time saved during a reaction time due to the overall response time is used for the optimal coordination of the movement during lunge. Significant differences between beginners and elite fencers was found in time required for front elbow extension ($p = 0.002$, $d = 1.159$) and in activation of front upper limb before front lower limb ($p = 0.002$, $d = 1.183$) showed in Figures 4 and 5.

In elite fencers were armed arms activated before the lower front leg significantly earlier than in beginners who initiated their lunge preferentially with activity of the lower limb on the side closer to the target. This fact probably related to the speed of maximal extension of armed arm. Elite fencers were significantly faster in extension of the elbow of armed arm. Any delay in the speed of this segment could have negative impact on the resulting action.

CONCLUSIONS

The criterion for sucessful hitting the opponent during the fencing lunge is the right timing of the attack, optimal timing of used muscles and right operation of individual body parts. From the elite fencers we expected application of movement patterns, which had been reinforced during the training. From the results of our study we can conclude that through long years of training there was created the most efficient movement pattern at elite feners, which was than applied in each attempts of monitored subjects.

We belive, that a similar structure of the lunge we could watch during the matches with some degree of modification which certainly relates with the distance from the opponent or his movement. We believe, that the results of our study can be used in the training proces for improving the efficiency on the implementation of the lunge with regard to the optimal structure of this motion act applied by an elite group of fencers.

COMPETING INTERESTS

Authors declare no conflicts of interest.

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