Fencing flèche performed by elite and novice épéeists depending on type of perception

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Abstract

Background and Aim of Study: The effectiveness of a fencing competition is relative to the neuro-muscular coordination coupled with various types of perception. The objective of this study was the multi-faceted movement pattern of a fencing flèche depending on visual and tactile stimulation in a group of elite female épéeists, and Physical Education students (the control group).

Materials and Methods: The testing procedure applied 11 female épéeists, average age 24.6 ±6.2, all members of the Polish national team. The control group comprised 10 female students of Physical Education course, average age 23.3 ±2.8. By application of EMG, the activity of the following 8 muscles of the lower and upper limbs was examined: biceps brachii (BB), triceps lateralis (TL), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), biceps femoris (BF), rectus femoris (RF), gastrocnemius lateralis (GL), gastrocnemius medialis (GM). The assessment of the ground reaction force of the forward and back legs applied a system comprising two combined Kistler force plates. The motion model was developed as a result of the application of 3D motion capture using 36 markers.

Results: The results of the study demonstrated a significant level of variety in the movement patterns followed by the subjects depending on the type of stimulation and level of performance among the female épée fencers and students in the control group. The analysis of the EMG signal demonstrates that the professional épéeists produce lower levels of bioelectrical signal in comparison to the students in the control group. With regard to the movement time (MT) and CRT (complex reaction time), the épéeists demonstrated considerably shorter response times ($p = 0.00012$).

Conclusions: In the light of the results, the sources of anticipation of tactile information include arm flexor and extensor muscles tension that is sensed as a result of the contact with the opponent's blade. For the case of the visual information, anticipation is based on the activation level of gastrocnemius muscle in the back leg.

Keywords: EMG • movement pattern • reaction time • tactile stimulus • visual stimulus

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The study was approved by the Bioethics Committee of the Chamber of Physicians

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Épée – is the heaviest of the three modern fencing weapons (foil, épée, and sabre), each a separate event, épée is the only one in which the entire body is the valid target area. Épée is the heaviest of the three modern fencing weapons.

Reaction time (RT) – is the time from occurence of stimulus to first initiation of movement of the relevant segment of the bod.y

Movement time (MT) –is interval from first EMG activity to the end of movemen.t

Complex reaction time (CRT) - – formed the sum of reaction time and the movement tim.e

Flèche – it is more dynamic form of attack in fencin.g

EMG – electromyogram *noun* a chart showing the electric currents in active muscles [18].

MVC – maximum voluntary contraction is maximum force which a human subject can produce in a specific isometric exercise [19].

INTRODUCTION

Beside the correctly delivered pattern of forearm attack, the fundamental aspect of fencing technique is based on adequately executed footwork. Among the variety of footwork performed as part of fencing, two offensive techniques are of key importance: lunge and flèche [1]. They are described in terms of the biomechanical aspects mainly through the analysis of the kinematics of movement and description of the ground reaction forces [2]. From the perspective of motor control and steering, it is important to investigate movement patterns, which is possible as a result of the analysis of bioelectric signal of the muscle activity. We can note here that both lower and upper limbs offer a potential in this respect due to the fact that fencing technique is based on the coordinated footwork and blade maneuvers when holding the fencing weapon [3].

An important aspect that this often disregarded in the reports in this area is associated with the differentiation of the conditions to which the examined fencers are subjected. In the practice of the fencing competition, the principal role is given to types of activities: one group comprises the movements induced by the fencer during an attack and the other movements to counter the moves by the opponent. Another issue is related to the response timing to the visual stimuli (parrying or pushing aside the opponent's blade) and the issues relating to the reactions to visual stimuli [4]. The present study applied a method of inducing the responses of the fencers to the blade work executed by the coach who imitates the conditions similar to the real elements of a fencing duel. The coach arranged two types of responses: to visual and tactile stimuli. Since the study involved *épée*ists, the present authors considered that with regard to footwork, flèche forms the representative technical tactic that is mounted with a high rate of effectiveness beside lunge.

The principal motivation of the study was to determine the multiple aspects of the fencing flèche in the conditions of the visual stimulation and in response to sensory stimuli. The participants of the study included the female national épée team members and students of Physical Education who had completed of a single term of fencing course at a university forming the control group.

The subject of the study involved the analysis of the time aspects of the fencing flèche, starting from the stage of preparation of the fencing attack and including the measurements of RT, MT and CRT in successfully delivered attacks [5]. At the same time, the ground reaction forces were analyzed (on the basis of two combined Kistler force plates) in relation to the forward and back legs. On the basis of the previous studies involving épéeists, four muscles of the arm and two in the forward and back legs were identified as the ones offering the best level of predictability for the analysis of EMG. In addition, MVC procedure was applied for the selected muscles with the purpose of gaining completely reliable results of EMG. The synchronization of the time and neuro-muscular indictors was achieved as a result of applying movement models using 3D motion capture with 36 markers.

The new approach applied in this study included the involvement of the a coach in the experiments. The coach's outfit had visible markers representing the target areas designed so as to make the fencers execute precise attacks. We can emphasize that the proposed method is a derivative of the fencing drill, i.e. an individual training program, which forms the central element of the fencer training technique and tactical skills development [6]. An individual training program involves the design and simulation of real elements of a fencing duel, and constitutes a type of feedback in the work performed by the coach and the trainee. The scope of the research was to determine the differences in the dependence of the time indictors, EMG signal and ground reaction forces against the background of a model of human movement patterns, and taking into consideration the performance level of the examined épéeists [7].

The objective of this study was the multi-faceted movement pattern of a fencing flèche depending on visual and tactile stimulation in a group of elite female épéeists, and Physical Education students (the control group).

The adopted hypothesis states that the perception of the visual and tactile stimuli leads to different sensory responses and movement patterns on the level of the neuro-muscular processes [8]. In addition, an initial claim was made by these authors that the performance level determines the level of bioelectric signal and variability of the time structure of the fencing flèche executed by the elite fencers and students of Physical

Education.

MATERIAL AND METHODS

Participants

The study involved 11 elite female épéeists (average age 24.6 ±6.2), members of the Polish national team in épée fencing in the junior and senior categories. Some of the participants had medal winning achievements in the World Championships and European Championships.

The control, group comprise 10 female students of Physical Education course (average age 23.3 ±2.8) who completed a single term of fencing classes (30 hours). The students were physically able and fit and had profession experience in combat sports in an academic environment. In accordance with the syllabus of the subject, throughout the classes, the students practiced element of the offensive and defensive techniques at an elementary level, including correct execution of simple attacks on the trunk with variable footwork fencing lunge and flèche.

The scope and goal experiment was approved by the Bioethics Committee of the Chamber of Physicians (Decision no. 208 of June 5, 2014).

Research tools

The study applied a motion capture system (OptiTrack, Natural Point, Inc., Corvallis, USA) comprising 8 motion cameras (with a resolution of 832x832 px, 100 FPS). The professional fencers and students' outfits had 32 markers located on them. The markers were also attached to the parts in the subjects' blade and handle and on the coach's outfit. The coach also had the target area on their trunk marked with 4 square markers with the side of 10 cm each. The measurement of the bioelectric signal applied 8-channel *EMG* system by Noraxon (DTS, Noraxon, Scottsdale, USA) with an accuracy of 16 bits for a sampling frequency of 1500 Hz. The assessment of the muscle function applied Ag/AgCl electrodes attached to the 8 muscles to in accordance with the SENIAM procedures. The assessment of the ground reaction forces applied two combined Kistler force plates (Kistler type 9286AA, Winterthur, Switzerland) with the sampling frequency of 1500 Hz). The equipment: cameras, EMG system and force plates were synchronized using TTL. For setting the baseline (Onset/Offset) of muscle activation the Noraxon MR-XP 1.07 Master Edition was used. The Onset and Offset values were determined on the basis of local peak value 5% [9].

Methods

As a result of using EMG, the activity of the following 8 muscles in the lower and upper limbs was examined: biceps brachii (BB), triceps lateralis (TL), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR), biceps femoris (BF), rectus femoris (RF), gastrocnemius lateralis (GL), gastrocnemius

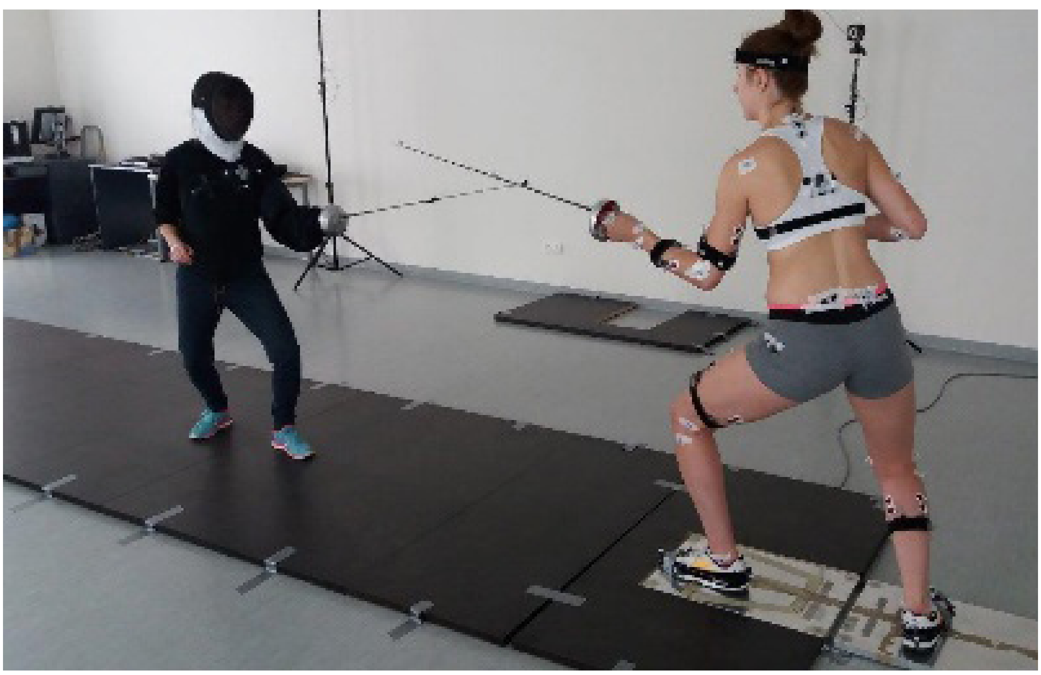

Figure 1. Illustrated research system shows markers and electrode placement on the coach and fencer body.

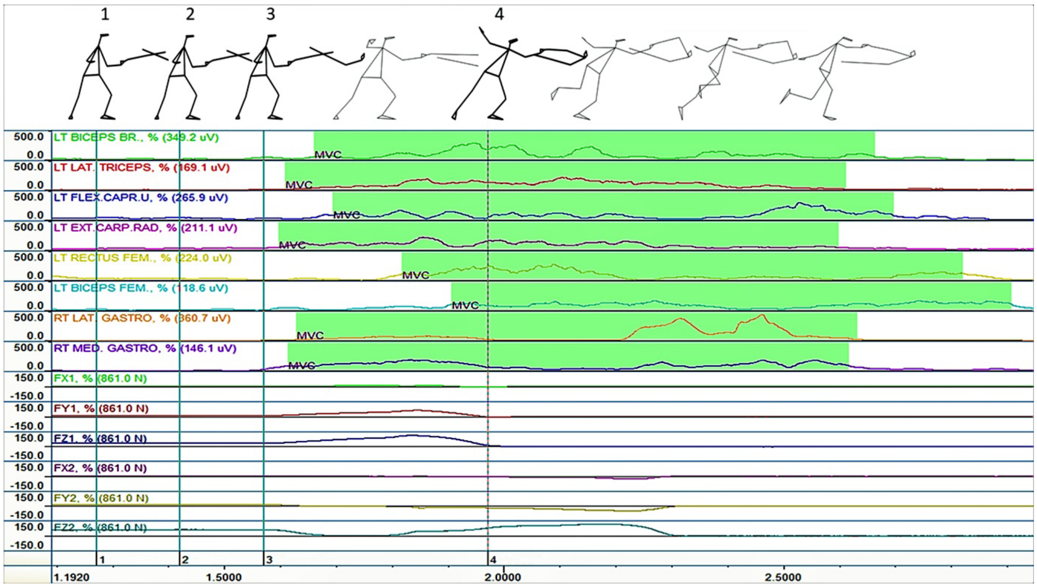

Figure 2. Shows EMG structure on visual stimulus performed by V-ce champion of the world.

medialis (GM). The electrodes were attached to the subjects' bodies before a warm-up exercise lasting for 20 minutes. This warm-up exercise included stretching exercise and fencing training.

In response to the signal provided by the coach, the fencers and students in the control group executed three flèche attacks in response to a visual stimulus, which was provided by the coach's forward step and then performed three flèche moves in response to a tactile stimulus (separation of the coach's blade from the one held by the épéeist). Among three trials, the result selected for the further analyses and calculations was based on the best score that was recorded in the trials.

During the trials, the subjects stood on two force plates, forward leg standing on the plate closer to the coach and the back leg on the plate more distant from the coach (Figure 1). We need to note that the subjects wore light sport clothes so as to provide more reliable final results (i.e. to facilitate the analysis of telemetric signal EMG and markers). This was done with the purpose of not interfering in the reception of biosignals, which would be possible for the case of using full fencing outfit.

Statistical analysis

The study involved the calculation of the basic descriptive statistics: media, standard deviation, and the results were summarized in a chart as to be able to provide a compilation of the data gained from measurements. The statements regarding the inter-group differences applied the Mann-Whitney non-parametric U test for independent variable with the significance level of 0.05 (Statistica 13.1 package was used for this purpose).

RESULTS

The ideal sequence of the bioelectric activity of the particular muscles during the fencing flèche executed by the épée world vice-champion in response to a tactile stimulus: the anticipatory initial activation of the arm (triceps lateralis) and forearm muscles (extensor carpi radialis); in the next phase, the activation of the calf muscles in the forward leg (lateralis gastrocnemius and medialis gastrocnemius); the third phase of activation involves biceps brachii and flexor carpi ulnaris muscles; the sequence of movements is completed after the activation of the high muscles (leg rectus femoris and biceps femoris) in the forward leg (Figure 2).

A different order of muscle activation is recorded in response to the visual stimulus (Figure 3). The bioelectric activity that is free of the anticipation effect is initiated by the calf muscles in the back leg (gastrocnemius lateralis and gastrocnemius medialis). Next in order, triceps lateralis and extensor carpi radialis occurs are activated, followed by biceps brachii and flexor carpi ulnaris. The muscles in the forward leg are final to be activated, i.e. rectus femoris and biceps femoris.

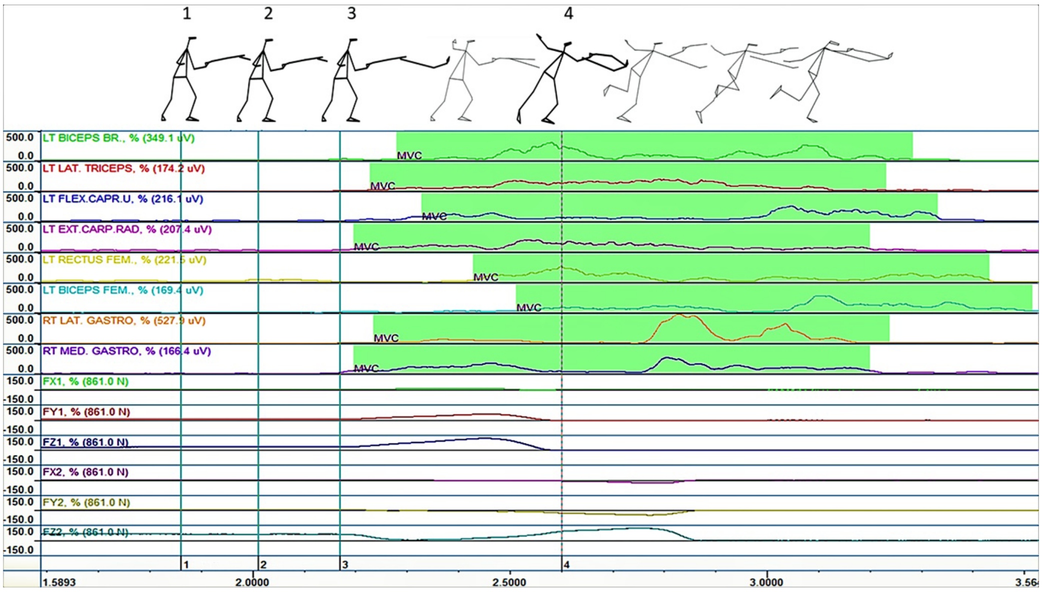

Figure 3. Shows EMG structure on tactile stimulus performed by V-ce champion of the world.

The key differences between the two types of perception concern the initial phase of the response, where the key muscles in the arm and forearm are first activated in response to tactile stimuli whereas calf muscles in the back leg for the case are the first to be activated in response to visual stimuli. The sequence of the activation of the remaining muscles is almost identical.

On the basis of analysis of the curves representing the ground reaction forces (100-150 N), we note the synchronization between the activity of the back leg and muscle EMG (for lateralis and medialis gastrocnemius muscles). For the case of forward leg, the ground reaction forces are even smaller from the values recorded at rest and this reaction increases throughout the phase when the back leg is raised from ground before launching an attack.

The postures held by the professional épéeists represented in the stick shapes in the figures corresponding to the EMG sequence (at the top of Figures 2 and 3) that were recorded in the motion images demonstrate the correct technique of attack performed with a flèche. The fencer›s back foot hits the ground only after the hit is delivered with a flèche.

The statistical differences in the latency stage of the sensory-response phase for the 6 analyzed muscles, there are statistically significant differences involving the higher levels of EMG generated by students in comparison to the elite épéeists. The activity of triceps lateralis is distinct in response to a tactile stimulus ($p = 0.0006$), as the values equal to 8.62 and 25.68 were recorded in the épéeists' and students' groups, respectively (Table 1).

There are differences only in two groups of muscles: biceps femoris 56.88 for students and 31.12 for épéeists in reaction to the visual stimulus ($p = 0.0003$) and to the tactile stimulus: students 59.61 and épéeists 32.32 ($p = 0.0001$) was well as in rectus femoris ($p = 0.0377$) to the tactile stimulus 52.70 for épéeists and 68.55 for students. The results demonstrate a significant tendency to have lower values of EMG in elite épéeists in comparison to the control group. This regularity is more apparent in the latency stage of the sensory-response phase and demonstrates the rational programming of timing by the elite epeeists (Table 2).

The students recorded the mean values of EMG in response to visual 58.81 and tactile stimulation 63.45, whereas the respective results for the épéeists were 51.17 and 55.27. In each case, the sensory stimuli generate higher levels of EMG regardless of the subjects' competence level.

In response to the visual stimuli, there are no statistically significant differences between the épéeists 0.187 and the control group 0.181 with regard to reaction time RT ($p = 0.916$). With regard to MT 0.511, the results were statistically significant differences ($p = 0.00012$): 0.697 for épéeists and 0.831 for students (Figure 4).

Table 1. Mean, standard deviation (SD) and p-values for épéeists and students muscle activations in the latency stage (statistically significant differences, the value of "p" is in bold).

Muscle	Épéeists		Students		p
	mean	SD	mean	SD	
Visual					
biceps brachii	22.36	14.60	20.72	7.35	0.9719
triceps lateralis	7.26	3.68	13.84	6.40	**0.0151**
flexor carpi ulnaris	20.31	9.99	17.59	4.55	0.5974
extensor carpi radialis	22.43	11.46	26.46	7.80	0.2749
biceps femoris	11.63	6.93	7.26	3.54	**0.0980**
gastrocnemius lateralis	6.93	4.18	15.95	8.68	**0.0083**
gastrocnemius medialis	5.94	4.54	16.63	12.13	**0.0620**
rectus femoris	22.50	5.78	11.17	7.77	**0.0028**
Tactile					
biceps brachii	24.31	15.69	36.67	18.99	0.1131
triceps lateralis	8.62	3.45	25.68	19.08	**0.0006**
flexor carpi ulnaris	33.81	15.85	31.50	17.18	0.8603
extensor carpi radialis	29.46	12.16	38.47	12.30	0.2178
biceps femoris	12.44	5.72	17.33	20.80	0.6985
gastrocnemius lateralis	7.21	4.33	16.37	11.84	**0.0265**
gastrocnemius medialis	5.86	4.88	21.38	23.31	**0.0124**
rectus femoris	24.51	6.35	22.50	22.54	0.1697

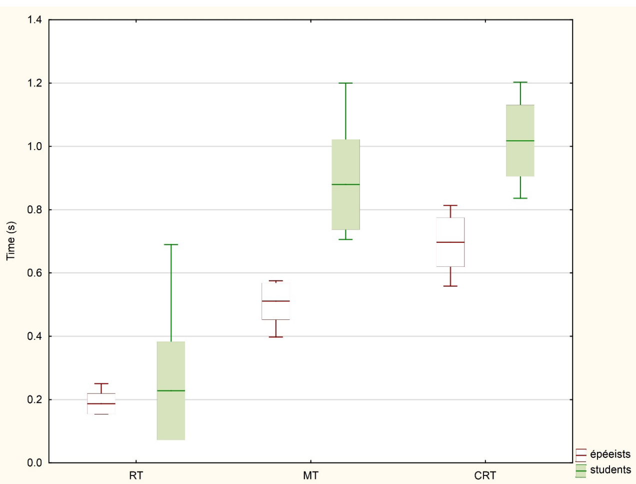

Figure 4. Presents statistical indicators (means, standard deviation and range) in RT, MT, CRT in refer visual stimulus.

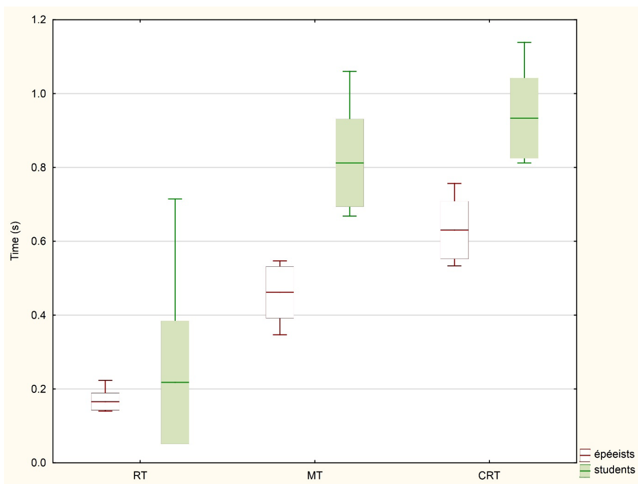

Figure 5. Presents statistical indicators (means, standard deviation and range) in RT, MT, CRT in refer tactile stimulus.

There are no significant differences with regard to the simple reaction times 0.166 for épéeists and 0.168 for students (p = 0.725). The significant differences were noted with regard to the values of movement time (MT): 0.462 for épéeists and 0.772 for students (p = 0.00012), as well as complex reaction time (CRT): 0.630 for épéeists and 0.940 for students (p = 0.00012). However, the two times lower values of the indicators were gained by the elite épéeists in the movement phase of the CRT, which had a considerable impact on the overall duration of the

Table 2. Mean, standard deviation (SD) and p-values for épéeists and students muscle activations in the response stage (statistically significant differences, the value of "p" is in bold).

Muscle	Épéeists		Students		p
	mean	SD	mean	SD	
Visual					
biceps brachii	46.64	15.56	52.30	11.09	0.4181
triceps lateralis	53.30	12.00	52.09	9.52	0.8603
flexor carpi ulnaris	52.35	8.17	60.07	10.17	**0.0725**
extensor carpi radialis	59.16	14.52	63.41	7.35	0.3418
biceps femoris	31.12	9.18	56.88	9.57	**0.0003**
gastrocnemius lateralis	55.06	21.35	60.72	9.01	0.9719
gastrocnemius medialis	56.22	21.74	64.07	10.93	0.4595
rectus femoris	55.67	12.40	60.94	14.15	0.2178
Tactile					
biceps brachii	49.69	15.61	61.34	13.95	**0.0845**
triceps lateralis	56.85	11.71	57.90	11.33	0.5035
flexor carpi ulnaris	65.06	12.23	65.87	11.39	0.7513
extensor carpi radialis	66.65	15.31	67.66	8.23	0.8603
biceps femoris	32.32	7.31	59.61	9.33	**0.0001**
gastrocnemius lateralis	58.60	19.93	62.73	8.21	0.8603
gastrocnemius medialis	60.15	23.14	67.05	9.96	0.9719
rectus femoris	52.70	9.24	68.55	20.87	**0.0377**

response (Figure 5). The study confirmed the significantly faster reaction times in response to the tactile stimuli in both groups, with a note that this tendency was more clearly visible in the group of épéeists and resulted from the long-term training program followed by them.

DISSCUSSION

The central focus of the research reported in this paper fits in the stream of studies applying recognized technologies based on 3D motion capture, EMG, and force platforms combined in an integrated system of analysis of the indicators in a synchronized timing. This is particularly noteworthy since OptiTrack cameras utilized to play the role of the motion capture tool excluding EMG and combined with Kistler force plates does not provide information regarding the bioelectric signal throughout the phase of the leg movement when they are not in contact with the ground. The use of surface electromyography techniques provides insight both into the neuro-muscular indicators during phase of motor activity without the contact with the surface and throughout the latency stage associated with the phase of the response involving movement. The selection of the muscles selected for the current analysis resulted from applicatory considerations based on feedback from coaches and various authors who have dealt with the analysis of fencing technique from the perspectives of motor control and biomechanics [10].

In accordance with the initial hypothesis, the results demonstrated a significant differentiation between the movement patterns of the flèche relative to the type of stimulation and performance level of épéeists and students in the control group. Tactile stimulation generated a motor response additionally boosted by the factors associated with the movement anticipation. The touch of the coach's weapon and its anticipated release formed a sensory stimulus, which led to the activation of the TL and ECR muscles already at the latency stage at the neuro-muscular level. This resulted in a high efficiency of the motor response expressed in terms of CRT 0.630

in the group of épéeists when we compare the result 0.697 in the same group in response to the visual stimulus. On the basis of various reports in the area we learn that in combat sports the reaction is the fastest in response to tactile stimuli, followed by the acoustic and visual stimuli. The current study confirms this observation; yet, the results cannot be directly transferred to the fencing training program. In this context, visual perception continuously plays an important role in the fencing duel forming a measure capable of integrating various types of stimulation.

The crucial conclusion from the present study is associated with the considerable shorter complex reaction time (CRT) in elite épéeists in comparison to the control group formed by the students. The component of the simple reaction time (CR) did not differentiate the two groups. The justification is quite simple, as this indicator is determined by the genetic factors and only marginally undergoes training. At the same time, the component of the movement time (MT) gives a clear advantage (low values) to the elite épéeists. We are aware that a large number of studies report that RT correlates well with MT [11]. The present study did not confirm such a dependence. We can state a hypothesis that in the conditions of an experiment, where a technical task takes on a complex character (response involving a alternative), the advantage of the épéeists expressed in terms of RT would be even greater, thus affecting significantly the reduction of the complex reaction time (CRT) [12].

The analysis of EMG signal demonstrates that the épéeists generate lower values of bioelectric signal in comparison to the control students' group. This tendency is more clearly noted in the latency stage, which is associated with the process of identification of stimuli and response programing. The priming process conveys the neuro-muscular processes on the movement phase in which the épéeists are capable of completing complex technical tasks due to the ability to perform ideal and rational movement patterns free of any redundant muscle activity [13]. For the case of tactile information, the generated values of EMG are greater both in regard to épéeists and in the group of students. Hence, we are justified to conclude that tactile stimulation generates a distinct type of neuro-muscular coordination, which is reflected in the increase of the level of bioelectric signal produced by the two examined groups [14].

The research applying the motion capture system and force platforms offers a valuable contribution to the current knowledge regarding the technique of fencing flèche. The study found, just as noted by the coaches, that the elite épéeists tend to transfer the center of the body weight to the back leg, which is reflected in the anticipatory activation of the calf muscles accompanied by ground force reaction at a level of 150 N. This process is accompanied by the weight transfer and even detaching the forward leg from the ground, which was represented by the zero ground reaction force recorded on the force plate. In addition, as demonstrated by the results, an effective flèche should take around 600-700 ms, despite the complex structure of this movement pattern. This time includes the period from the occurrence of the stimulus to the contact of the blade with the coach's trunk. In contrast, the novice subjects performed the pattern within 1 second (1000 ms). The instant when the attack hit the target corresponded to the maximum forward movement of the épéeist's trunk with the forward leg resting on the surface and the back leg detached from the force plate [15].

CONCLUSIONS

On the basis of the procedure that was followed, we can establish the following two practical conclusions:

Fencing technique, including flèche maneuver investigated in terms of the footwork constantly evolves and the data regarding the sequence of muscle activity, coordination and ground reaction forces can have an application in the training program concerned with technique improvement and accounting for individual elements of the training program.

The greater role attributed to anticipatory information and perception strategies applied for observing opponent's actions results in the need to identify the initial signals produced in a competition. Such identification needs to be coupled with the development of adequate responses at the stage when they are being launched [16]. In the light of the presented analysis, the sources of anticipation for tactile information include the signals produced by the arm flexor and extensor muscles perceived through the contact with the opponent's blade and for visual information the source is in the activation of the gastrocnemius muscle in the back leg [17].

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