A FENCING KINEMATIC ANALYSIS BASED ON COACH'S CRITERIA

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The purpose of this study was to identify, based on coach's criteria, upper body and center of mass kinematic variables that lead to a good performance in epee fencing. We used an Optitrack motion capture system to evaluate one skilled amateur fencing athlete performing a lunge in the presence or not of a static opponent. In the presence of a static opponent (target), the individual developed a lower centre of mass forward velocity, a higher epee's tip forward velocity and improved synchronization between the upper and the lower limbs. The best-performed trials according to coach criteria showed differences in the elbow movement in both the armed and unarmed arm compared to the other trials. Our results highlights the importance of the unarmed arm to lunge performance and corroborate the idea that training with and without the use of a target improve different motor abilities.

KEY WORDS: lunge, teaching, target.

INTRODUCTION In a fencing's review article Roi and Bianchedi (2008) analysed several factors that can influence fencing performance and described that, among others, the biomechanics of fencing gesture is one of them, being able to distinguish novice and advanced fencers. However, there is still few studies on fencing gesture biomechanics. The reduced number of publications concerning fencing (Roi and Bianchedi, 2008) and martial arts in general (Correia and Franchini, 2010), results in a lack of specific knowledge to give support to teaching and coaching. Possibly the limited access of teachers and coaches to the human movement science laboratories is one of the reasons for that. In attempt to approach fencing coaches and researchers in order to explore biomechanical factors that may lead to an improvement on epee fencing technique, as well as teaching and training methods, we performed a study to identify, based on coach's criteria, upper body and center of mass kinematic variables that lead to a good performance during the lunge. Lunge is the basis of most attacking motions and one of the first movements to be learned. During training sessions, it can be performed in the presence or not of a target to be hit. Thus, we also investigate the effect of the target in the athlete's performance.

METHODS: The subject was a skilled epee's amateur fencing athlete (right-handed, eleven years old boy, two years fencing practitioner). After a warm-up time, the subject performed an attack - lunge - from a static en garde sixte position. Two different experimental conditions were asked: a) to attack the best he could, without the presence of any target to be hit (NO-TARGET condition) b) to attack a static opponent (his coach) having the chest as the target (TARGET condition). Three dimensional (3D) coordinates of 37 retro-reflective markers fixed in the lower and upper limbs, pelvis, trunk and head were recorded with an Optitrack motion capture system (Prime 13) using eighteen cameras (sampling rate: 120Hz). The subject performed four trials in each target condition. In order to record epee's tip trajectory it was also placed a retro-reflective stick on it. On another day, the coach (a fencing athlete and children's fencing teacher for eight years) qualitatively evaluated the athlete's recorded performance in each target condition (balance and posture during lunge) and, identified the best-performed trials according to his own criteria. The coach also participated on the choice of the variables to be analysed pointing what would be the most important ones to judge the performance.
The Calibrated Anatomical System Technique (CAST; Cappozzo et al, 1995) was used to calculate the body segments instantaneous position and orientation. The 3D joint rotations

(joint angles) were computed via Euler angles using the Cardan sequence (flexion-extension, abduction-adduction, axial rotation). All the relevant physical quantities calculation, as well as the necessary data processing, were done with the Visual 3d software (5.01 version).

We considered attack period (T_A) to be comprised between the sudden increase of the pelvis centre of mass anterior-posterior (CM_{AP}) velocity and the instant when it drops to zero. For this period of the movement, we obtained the body CM displacement and the body CM_{AP} velocity; the armed arm (AA) and the unarmed arm (UA) upper limb joints angular displacements; the UA elbow extension velocity; the relative position between the UA arm wrist and shoulder and the epee tip velocity. Those time series were filtered using a 4th order, zero leg, low-pass Butterworth filter, with a 6 Hz cut off frequency. In fencing, proper coordination between the AA, the front leg and the UA is essential to stabilize the body and allow a powerful attack. Thus, in each trial we identified the instant when AA extension (IAAE; armed hand CM starts moving away from the trunk), foot elevation (IFE; sudden increase in front foot CM vertical velocity) and UA extension (IUAE; sudden increase in elbow extension velocity) occurred in the attack period.

Based on coach prescription we extracted the following variables from the above time series: the athlete's CM displacement range, peak CM_{AP} velocity and the instant when it occurred, AA and UA joint range of motion (only the more relevant joint rotations were analysed), peak UA elbow extension velocity, peak epee tip AP velocity, relative position between UA wrist and shoulder at the beginning of attack ($H_{S\text{-}W}$). Those variables, as well as IAAE, IUAE and IFE, were compared between target conditions, in order to evaluate the effect of a TARGET in the lunge performance, and between the best-performed trials and the others, in order to detect parameters that could improve the individual performance. We considered relevant the differences (between target or performance conditions) for which Z-score (see supplementary material) were greater than 2.0.

RESULTS: We excluded from the analysis one not well-executed trial in the TARGET condition. Mean attack period was not significantly affected by the presence of the static opponent (table 1). The peak CM_{AP} velocity, however, was lower in the TARGET condition, causing a reduction in the CM_{AP} displacement (see CM_{AP} Range in table1). Despite the lower CM_{AP} velocity, epee tip peak forward velocity achieved higher values when the individual was instructed to hit the opponent. In this condition, we also observed a reduction in the CM_V oscillation (CM_V Range, table 1) during the lunge acceleration phase (the period of ascending CM_{AP} velocity). Lunge deceleration phase in the TARGET condition lasted slightly less (~5% T_A) since peak CM_{AP} velocity was achieved later (table 1).

In the TARGET condition, the individual started the attack with the AA extension, followed by front foot elevation and UA extension. Unlike, in the NO-TARGET condition, the individual started the lunge with the movement of the front foot rather than with the AA and, in some trials, the UA movement preceded the AA. The shoulder, elbow and wrist joints displacements were similar in both target conditions (figure 1) and, excluding elbow pronation-supination, the joint range of motion around the considered anatomical axes did not significantly differ between conditions (table 1). When comparing the best-performed trials (interrupted lines in figure 1) and the other trials, it was noticed differences in the elbow flexion-extension movement in both the armed and unarmed arm: the best trials were performed with greater UA elbow range of motion and extension velocity and lower AA elbow excursion. In the best-performed trials the athlete also started the attack with the UA wrist in a higher position (see $H_{S\text{-}W}$ in table1).

DISCUSSION: The results suggest that the presence of the target induced the athlete to adopt a different motor strategy to perform the lunge. When asked to hit the coach chest, the individual performed the lunge with lower CM_{AP} velocity but with less CM_V oscillation. In addition, he started the AA extension always before the front foot and the UA movement (in this sequence). According to Roi and Bianchedi (2008) the more skilled fencers start the lunge with an AA movement instead of a front foot movement and their CM high decreases monotonically until the end of the attack. Thus, decreased CM_V oscillation and the observed sequence of AA, front leg and UA movements reflect a better fencing technique, that may lead to a more precise and controlled movement, which, in turn, was achieved by the coast of CM forward progression speed. By the other hand, peak epee's tip anterior-posterior velocity was greater in the TARGET condition. We believe that the improved synchronization between the upper and the lower limbs in the TARGET condition may have played a role in the observed higher epee's tip velocity, since a proper coordination between the AA, the front leg and the UA, may result in greater trunk angular momentum and, thus, in greater hand and epee forward velocity.

Unlike, in the NO-TARGET condition the greater CM_{AP} velocity was achieved in a smaller period. This suggests that the horizontal impulse applied on the ground and thus the external forces acting on the body were greater during this condition, indicating that the athlete performed the lunge prioritizing power by the cost of balance and precision. Gutiérrez-Dávila et al. (2014) found a similar result comparing the lunge performed with reduced and increased uncertainty levels. The marked difference between target conditions may also be a result from the young age coupled with the little practice experience of the individual analysed and may be less pronounced in experienced adult fencers (Klauck and Hassan, 1998).

Table 1: Mean and standard error of the mean (SEM) across trials grouped according target and performance condition. Z-score for both comparisons are displayed and the significant differences signalized with a star (*). The instants when relevant event occurred during the attack are given in percentage of attack period (% T_A).

Variable	Group Mean ± SEM		Z	Group Mean ± SEM		Z
	TARGET	NO-TARGET		BEST TRIALS	OTHERS	
IAAE (% T_A)	8±4	20±1	3.0*	19±3	12±5	1.2
IFE (%T_A)	18±2	11±2	1.8	13±3	15±3	0.5
IUAE (%T_A)	41±7	24±5	2.0	23±3	38±7	1.8
CM_{AP} Range (cm)	75.9±0.9	91.5±1.8	7.7*	86.9±5.9	83.2±4.3	0.5
CM_{ML} Range (cm)	5.9±2.4	4.6±0.8	0.5	4.3±0.6	5.8±1.8	0.8
CM_V Range (cm)	3.4±0.7	5.4±0.3	2.6*	4.5±0.6	4.6±0.8	0.1
CM_{AP} velocity (m/s)	1.74±0.01	1.88 ±0.01	19*	1.83 ±0.05	1.81 ±0.05	0.2
Instant of Peak CM_{AP} Velocity Occurrence (%T_A)	60±1	55±1	3.2*	56±1	57±2	0.6
Attack Period (s)	0.98 ±0.02	1.03 ±0.03	1.2	0.99±0.02	1.02 ±0.04	0.7
Armed Arm Shoulder Flex.-Ext. Range (°)	78±2	76±2	0.7	74±2	78±2	1.5
Armed Arm Shoulder Abd.-Add. Range (°)	17±2	14±2	1.2	14±3	16±1	0.5
Armed Arm Elbow Flex.-Ext. Range (°)	68±2	73±5	0.9	65±2	75±3	2.7*
Armed Arm Elbow Pron.-Sup. Range (°)	53±5	81±8	3.1*	65±7	73±12	0.6
Armed Arm Wrist Flex.-Ext. Range (°)	22±1	22±3	0.0	20±3	24±2	1.2
Armed Arm Wrist Uln.-Rad. Dev. Range (°)	25±3	25±2	0.1	24±2	25±2	0.4
Unarmed Arm $H_{S\text{-}W}$ (cm)	-13±5	-10±5	0.3	-2±1	-18±3	5.9*
Unarmed Arm Max. Extension Vel. (°/s)	518±76	497±95	0.2	641±18	405±62	3.6*
Unarmed Arm Elbow Flex.-Ext. Range (°)	108±8	120±17	0.7	140±10	96±4	4.4*
Unarmed Arm Shoulder Flex.-Ext. Range (°)	85±6	82±4	0.4	83±7	84±4	0.1
Unarmed Arm Shoulder Abd.-Add. Range (°)	56±3	64±4	1.5	59±2	62±5	0.4
Max. epee tip velocity (m/s)	5.2±0.3	3.2±0.6	2.8*	3.4±1.1	4.5±0.5	0.9

Legend: Flex.-Ext. = Flexion-Extension; Abd-Add = Abduction- Adduction; Pron.-Sup = Pronation-Supination; Uln.-Rad. Dev. = Radial-Ulnar Deviation; $H_{S\text{-}W}$ = relative position between UA wrist and shoulder at the beginning of attack (negative values mean wrist bellow shoulder); CM = center of mass (anterior-posterior, AP; medial-lateral, ML; vertical, V); IAEE, IUAE and IFE = respectively, the instant of armed arm, unarmed arm and foot elevation start.

The fact that we observed significant differences in the UA initial position and elbow extension when comparing the best trials and the others highlights the importance of the UA movement to improve the athlete’s performance. In addition, the more straight AA elbow extension (resulting in a lower elbow flexion-extension range of motion) observed in the best-performed trials, rather than the sudden extension after a small flexion, observed in the other trials (see figure 1), may also contributes to increase the efficiency of the attack.

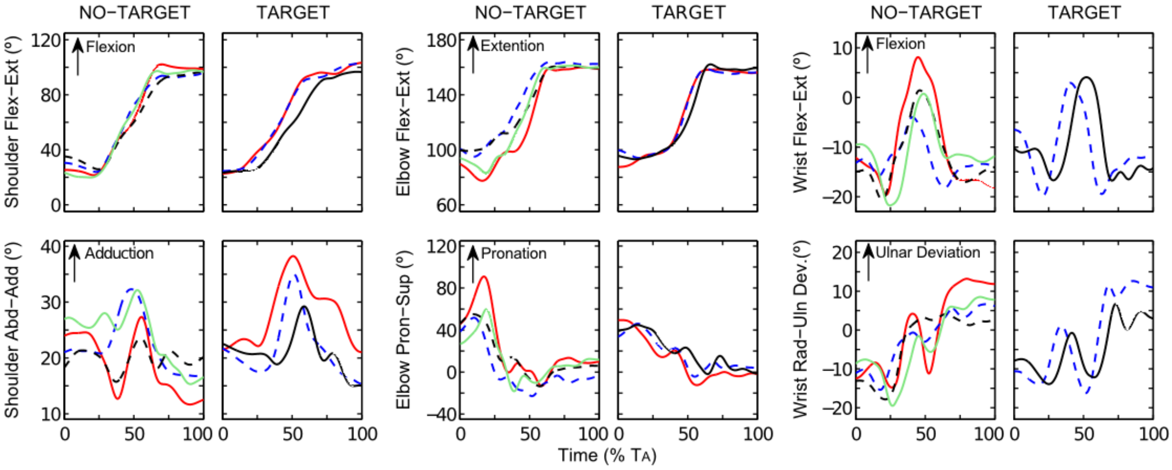

Figure1: Armed arm shoulder, elbow and wrist joint displacement during the period of attack (T_A). The uninterrupted lines indicate the best performed trials in each target condition. Flex.-Ext. = flexion-extension; Abd.-Add. = abduction-adduction; Rad.-Uln. Dev. = radial-ulnar deviation; Pron.-Sup. = pronation-supination.

CONCLUSION: Although this analysis is based on an one-subject, few-trials data acquisition and may reflect subject specific responses, those observations corroborate the idea that the presence of a target may affect the motor strategy adopted during the lunge execution. In the case of the studied athlete, the target seems to positively affect his performance, probably by increasing motivation. Such results have two main implications. The first for children coaching, since they suggests that training with and without the use of a target may improve different motor abilities, and the second for fencing kinematic analysis, since the usage of a target may affect the obtained results. Our observations also support the idea that a proper synchronization between upper and lower limbs, as well as a proper unarmed-arm posture and gesture, can improve the fencing performance. Equally important, this study shows that it is possible to establish a good relationship with coaches, bringing them to the laboratories in order to solve their daily coaching problems without losing the academic view.

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Acknowledgement

The authors would like to thanks the CNPq for the financial support.