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Muscle coordination and ground reaction forces during a specific assault in world-class female sabers

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SUMMARY

The aim of this study was to determine (i) the activation timing of the lower limb muscles (ii) the relationship between muscle strength and mechanical effectiveness during a specific assault in elite fencers. Both ground reaction forces and electromyographic activity of 15 lower limb muscles were recorded during a *marché-fente* assault in 10 female sabers of the French national team. Although lower limb extensor muscles (hip, knee and ankle joints) were mainly activated during propulsive phases, determinants of the gesture performance appeared focused on the rear knee and front hip joints. These observations could be useful for muscle strengthening and prevention purposes.

INTRODUCTION

Fencing is one of the combat sports including among the shortest decisive actions, making movement speed an essential skill for fencers' performance, particularly for sabers [5]. It is well known that repeated execution of a movement task facilitates neuromuscular adaptations [4]. In this way, elite female sabers were recently showed to present specific muscle asymmetries that could be related to chronic fencing practice. However, little is known about the corresponding activation patterns of the lower limb muscles involved in fencing practice that could be responsible for these imbalances. The characterization of the muscle activities during assaults would help to better understand fencing displacement demands. Biomechanical analysis of fencing is scarce when considering saber. A recent study demonstrated relationships between kinematic strategies, upper-limb muscular activation and fencing performance [1] suggesting that further relations could exist notably between muscle activities of the lower-limb muscles, and the mechanical effectiveness of a specific gesture (i.e., lunge). Thus the purpose of the present study was (i) to investigate the activation timing of lower-limb muscles during a specific saber assault, and (ii) to determine the relationships between, muscle strength and performance criteria of the assault displacement.

METHODS

Ten females elite sabers of the French national team, including the four members of the 2010 World Championship bronze medalist team, participate in the present study (age : 22.2 ± 4.6 years, height : 170.5 ± 4.7 cm, weight : 67.3 ± 8.1 kg).

Participants performed a dynamometrical test (DT) on Con-Trex MJ dynamometer (CVHAG, Switzerland) to assess strength during maximal isometric voluntary contraction (MVC), in flexion and extension on hip, knee and ankle joints of both legs. A saber displacement test **(**SDT) was also realized. Participants were asked to perform a *marché-fente* assault (i.e. walk step followed by a lunge). The vertical and horizontal components of the ground reaction force were measured by 6 individual force platforms connected in series (Kistler 9067, Suisse). During DT and SDT and on time with mechanical data, surface electromyography was recorded with a wireless device (Zerowire, Aurion, Italy), on 15 muscles (7 muscles on both lower limbs [soleus (SOL), gastrocnemius lateralis (GL), tibialis anterior (TA), vastus medialis (VM), rectus femoris (RF), semitendinous (ST) and biceps femoris (BF)] plus the gluteus maximux (Gmax) for the rear leg). The *marché-fente* assault was divided in 4 phases (Fig. 1). The assault was mechanically characterized by the Fy component. The maximal velocity (v_{ymax}) and the total displacement (d_{ytot}) were used as performance factors for further analysis.

EMG signals were analyzed as the root mean square (RMS) amplitude and normalized by the RMS value obtained during MVC. Muscle activation timings were determine for the 15 muscles, by defining bursts of activation above a threshold of 50% of the difference between peak and baseline EMG.

One way ANOVAs (phase) were performed on three variables (i.e. impulse, d_y, v_y) calculated from mechanical parameters measured during the *marché-fente* assault. Separate two-way ANOVAs (muscle × phase) were performed on each leg for EMG data. A multiple regression analysis was performed using MVC as a dependent variable and the criteria of displacement performance as independent variables. Multiple regression analysis was set using the different impulse as independent variable and v_{ymax} and d_{ytot} as independent variables. For all tests, the significance level was set at $P < 0.05$.

RESULTS AND DISCUSSION

Two propulsion phases (phases 1 and 3) and one braking phase (phase 4) were characterized (Fig. 1). Phase 2 included either an active propulsion for some participants or a braking phase for others. Significant main effects of phases and muscles were observed on the EMG data for both legs ($p<0.05$). The muscle timing activation indicates two important bursts for rear RF, VL, SOL and GL corresponding to phases 1 and 3. For front leg, VL presents a burst in phase 4, RF is activated from phase 2 to phase 4 and GL is activated in phase 2 and 4. One way ANOVAs revealed significant phase effects ($P<0.05$) on impulse and velocity but not on displacement. The multiple regression analysis highlighted a significant positive relationship between front hip extension MVC and v_{ymax} ($R^2=0.42$, $P=0.02$) and d_{ytot} ($R^2=0.49$, $P=0.01$) and between rear knee extensors and d_{ytot} ($R^2=0.44$, $P=0.02$). The multiple regression analysis showed a positive significant relationship between the first impulse and both v_{ymax} ($R^2 = 0.25$, $P <0.05$) and d_{ytot} ($R^2 = 0.49$, $P <0.05$) and a positive relationship between the third impulse and v_{ymax} ($R^2 = 0.29$, $P=0.02$).

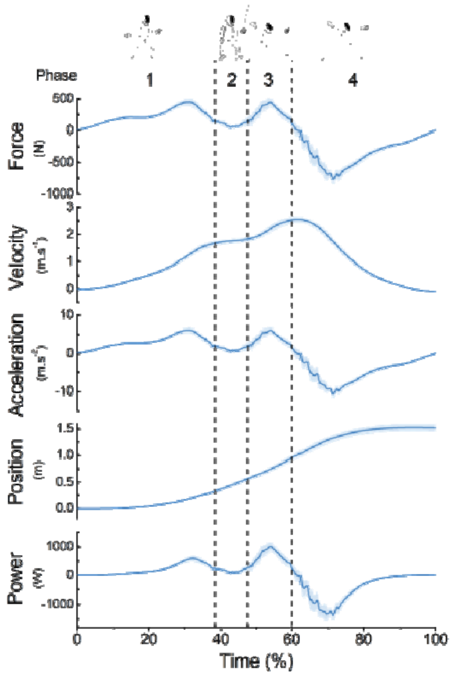

Figure 1. Mechanical parameters over the time during a *marché-fente* assault. Timing of movement is expressed as percent of the movement execution. Values are presented as mean±SD.

The standard deviation (SD) on mechanical parameters (Fig. 1) indicates a low inter-individual variability of this gesture for elite fencers. However, the neural drive used to perform the *marché-fente* assault may differ between fencers as indicates the greater scattering observed in figure 2. It seems that rear knee extensors and front hip extensors play an important role in the execution of the assault. As confirmed by figure 2 and timings of muscle activity, rear knee extensors are highly activated at the onset of phase 3. In this phase, as in phase 1, the impulse is also related to performance criteria. The analysis of the activation timing revealed that front leg extensors are activated during the braking phases (phases 2 and 4). Indeed, to decelerate the body at the end of a fast and long lunge, high-level eccentric contractions of front leg extensors are needed. Eccentric contractions are more effective at increasing strength than concentric contractions [3]. Such a finding may partly explain the greater MVCs on front leg joints compared with rear ones observed in fencers [2]. While the implication of rear and front knee extensors in the execution of a lunge could have been expected, a correlation was observed between front hip extensors and d_{ytot} and v_{ymax}. This observation could be interpreted by the fact that the higher is the reached velocity, the longer is the executed displacement, and the greater is the solicitation on the front hip extensors.

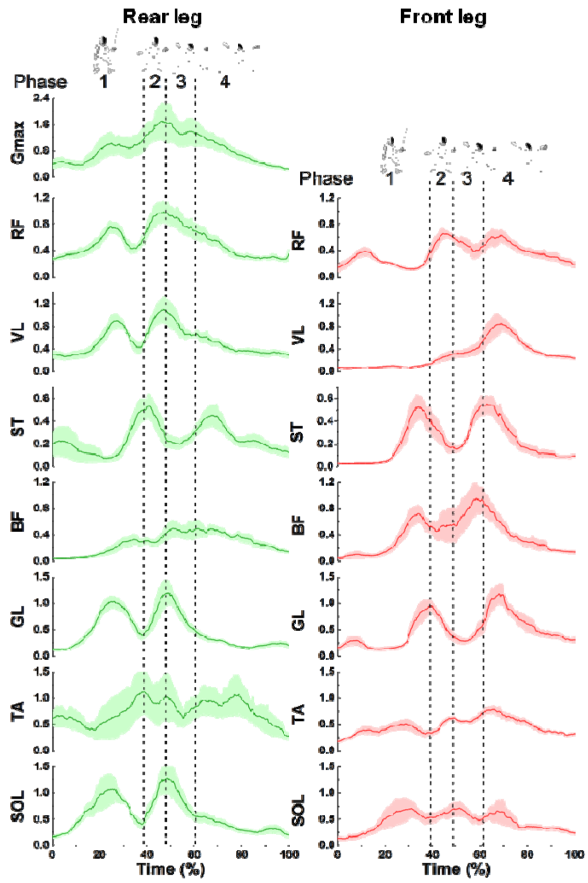

Figure 2 : Relative EMG activity of lower limb muscles during a *marché-fente* assault. Values are presented as mean±SD.

CONCLUSIONS

This study is the first to characterize the lower limb EMG activity and the mechanical aspects of a complex fencing specific gesture. It has permitted to explain some of the muscle adaptations induced by elite fencing practice.This work brings informations that could be used in the programmation of muscular training. Further analyses including upper limb observation would lead to a better understanding of the global fencing coordination.

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