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KINETIC ANALYSES OF TWO FENCING ATTACKS – LUNGE AND FLECHE

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Two fencing attacks – the lunge and the fleche – were investigated to determine the moments and powers of the joints of the lower extremity. A Vicon MX system recorded the motion while four force platforms simultaneously recorded the ground reaction forces. Inverse dynamics was used to calculate the moments and powers produced at the hip, knees and ankles of both legs. Results showed that during the lunge, the commonest attack, only the trail leg's extensors and hip abductors contributed significantly to the attack. On the other hand, for the more dynamic and risky fleche, extensors of the ankle, knee and hip and the hip abductors for both legs contributed significantly to the attack.

KEY WORDS: inverse dynamics, mechanical power

INTRODUCTION: Fencing is an Olympic sport and has been since the first modern Olympics in 1896. Today the sport has many practitioners, with over 20 000 registered fencers in the United States alone. Despite having a long history and numerous participants, scientific knowledge of fencing is still limited, especially in the realm of biomechanics. To date there have been few biomechanical studies that use 3D-motion capture devices to analyze the sport. The knowledge obtained from this study will help coaches and practitioners improve technique, select proper cross-training routines, identify possible areas of injury, and have better general understanding of the nature of attack movements. The purpose of this study was to compare two different attack strategies: the lunge and the fleche. The lunge is performed propelling forward by fully extending the rear leg from the *en garde* position (feet shoulder width apart, legs in perpendicular planes, with the lead leg facing forward), and landing on the lead leg. The fleche is performed by crossing the rear leg over the lead leg and then driving forward with lead leg in a sprint-like motion until the opponent is passed.

METHODS: Seven Vicon MX cameras and four force platforms were used to collect the movement kinematics and the ground reaction force datas at 200 Hz. The subject was an internationally competitive male fencer. The subject was outfitted with 42 reflective markers based on a modified plug-in-gait marker set; the foil (sword) and right finger were also outfitted with markers to complete the set. The subject did a number of trials (3-5) of both fencing attacks; of which three trials of each attack were analyzed. Trials where the subject missed the force platforms were not selected for analysis. The data were smoothed using a Butterworth, low-pass filter with 6 Hz cutoff frequency for the marker trajectories and 10 Hz for the force signals. Inverse dynamics and moment powers were computed using Visual3D.

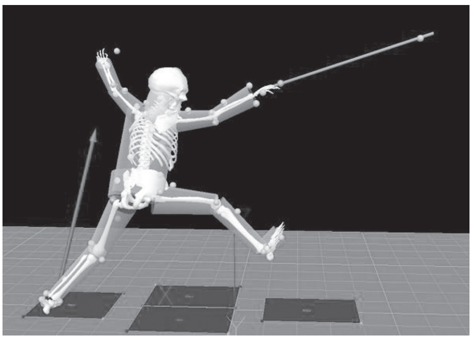

Figure 1: Model and marker locations of the fencer at the end of an attack

RESULTS: Figures 2 and 3 hold the results from the lunge and fleche attacks, respectively. The top rows are the angular velocities (rad/s), the middle rows are the net moments of force normalized to body mass (N.m/kg) and the bottom rows are the powers of the moments of force normalized to body mass (W/kg). Solid coloured lines are the results for the trail (left) limb while the dashed black lines are for the lead (right) limb. The shaded areas show +/–1 SD about the mean values. Positive moments are dorsiflexor, knee extensor, hip flexor and hip adductor moments; negative moments indicate plantiflexor, knee flexor, hip extensor and hip abductor moments. For comparitive purposes the scalings are the same across quantities and the ordinates are normalized to the duration of the attack. The attack is defined as starting from a static position and finishes when the fencer becomes airborne.
Upon analysis of the lunge (Figure 2), it was found that power production of the lower limbs occurred almost exclusively from the trail or left side of the body. The most work done was by the trail limb's ankle plantiflexor moment followed by its knee extensor moment. The trail hip's extensor moment produced little positive work but its hip abductor moment after a brief burst of negative work also contributed significant positive work. The attack started with flexing the lead knee and positive work done by the trail leg's knee extensors. This causes the lead foot to leave the ground. Once the lead leg is off the ground, the ankle plantiflexors and then knee extensors provided positive work to drive the body forward while small amounts of positive work were done by the leading knee's extensors and hip flexors to lift and extend the leading leg forward. The trail leg's hip extensors and flexors were active but produced relative small amounts of positive work, whereas this hip's abductor moment performed first negative then positive work at the end of the lunge.

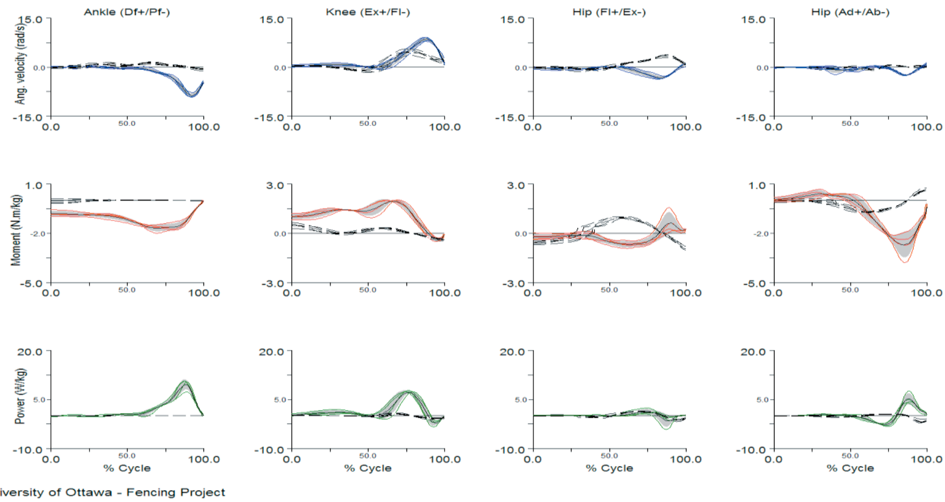

Figure 2: Angular velocities (top row), moments of force (middle) and powers (bottom) of the ankles (left), knees, and hips for the lunge attack. The final column shows hip adduction (+ve) / abduction (-ve) direction while the other columns are for the sagittal plane. The solid coloured lines are of the trail leg; the dashed black lines are of the lead leg.

During the fleche (Figure 3) power was provided by moments of force from both sides; first from the trail limb then the lead in a sprint-like action. The trail leg provides the initial thrust while the lead limb passively flexes at the ankle and knee and to a lesser extent the hip. The trail leg's plantiflexors and knee extensors provided the majority of the power with a small contribution by the hip extensors and abductors. After the leading leg has stepped forward its plantiflexors and knee extensors provided a second thrust to continue the attack.

Simultaneously, the trailing leg's hip flexors acted concentrically to start the next running cycle (i.e., 2nd step).

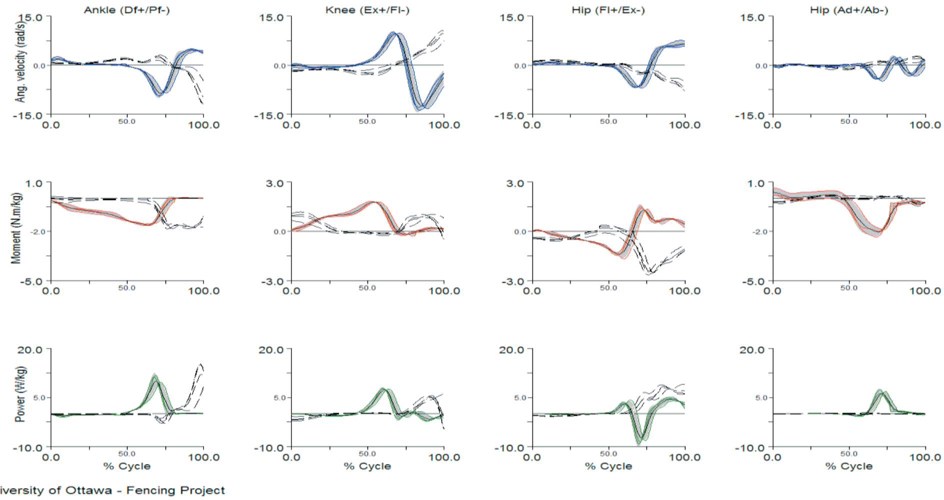

Figure 3: Angular velocities (top row), moments of force (middle) and powers (bottom) of the ankles (left), knees, and hips for the fleche attack. The final column shows hip adduction (+ve) / abduction (-ve) direction while the other columns are for the sagittal plane. The solid coloured lines are of the trail leg; the dashed black lines are of the lead leg.

DISCUSSION: Power production of both the lunge and fleche show a pattern originating almost simultaneously from the ankle and knee and to a lesser extent the hip of the trail limb. During this thrust the lead limb moments do surprisingly little work; their only functions being to lift the hip slightly, and flex and then extended the knee into the first landing. The timing of the concentric work of the extensor moments of the trail limb were highly coordinated, occurring almost simultaneously and not in a distal to proximal pattern as happens with throwing or horizontal jumping skills. Such a pattern is typically of vertical jumping (Stefanyshyn & Nigg, 1998) but in fencing attacks resulted in a horizontal thrust in the attack direction, indicating the need for a highly developed motor patterns to maximize horizontal impulse (Gebhard, 1981).

One limitation with this study was the requirement of a relatively static position prior to force production. Fencing is a highly dynamic sport in which the athlete rarely or never begins from a stationary position, however, because of the limited size of the force platforms a static start was necessary. Nevertheless, the lunge is a primary mode of attack and its initiation can be very abrupt and implemented quickly upon recognition of opportunity.

The fleche is a very fast and explosive movement in fencing, used sparingly as a surprising and overwhelming hit. One reason for this, as shown in Figure 3, is the number of joints involved. In the lunge the only powers generated to propel the athlete came from the plantiflexors, knee extensors, and hip abductors of the trail leg. Though the powers produced were strong, they were unilateral. By changing the fencer's body position to face forwards, and by using both legs in a sprint-like motion, the fleche utilizes powers generated at every joint in the lower limbs. This adds additional power from plantiflexors, knee extensors, and hip extensors of the lead leg, as well as hip extensors and flexors of the trail leg, which are not found in the lunge. In this way, the fleche doubles the amount of work produced.

When compared with other sports, the fleche displayed similar biomechanics to those found in sprinting. When compared to a study by Bezodis, Kerwin, and Salo (2008), the plantiflexor power of sprinting looks similar to that exhibited at the beginning and middle of the fleche.

Two differences, however, are that in fencing the lead knee is extended to yield a greater step distance whereas in sprinting the knee flexes in preparation for the next step and in a sprint start the lead leg provides the majority of the thrust rather than the trail leg in fencing attacks.

CONCLUSION: Fencing is a very unilateral and unique sport. It relies heavily on the trailing leg as its main power supply during the lunge, the sport's primary attack. In the lunge, most of the power comes from the plantiflexors of the rear leg, followed by power from the knee extensors and then the hip abductors. The fleche was a more complex attack with power coming from moments of force of both legs. We conclude that fencers wanting to improve their attack effectiveness should focus primarily on their plantiflexors, as well as hip abductors and hip and knee extensors. This is because ankle plantiflexors and knee externsors contributed the larger amounts of power to both movements and were the primary sources of power for the lunge, the more common attack.

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