3-D INVERSE DYNAMICS ANALYSIS OF MARTIAL ARTS CIRCULAR KICK

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INTRODUCTION

This project investigated the kinetics of the lower limbs during the martial arts circular kick. Patterns of the net moments of force and powers were computed three-dimensionally. Due to the lack of three-dimensional kinetic investigations of the circular kick, this paper attempted to establish a basic outline of the recruitment patterns seen in this particular kick. The kinetic data were compared with similar powerful kicking activities from the literature such as soccer kicking [1] and *karate* front kicks [2]. Our hypothesis was that the circular kick requires similar kinetic patterns as other kicking modalities but possesses distinct features such as significant abductor power recruitment at the hip, limited pre-stretch and reduced follow-through.

METHODS

One subject performed a total of 15 trials of the circular kick delivered with maximal force into a stationary pad. The subject was an elite-level combat athlete competing internationally at 80 kg. A Vicon Motion Analysis system recorded the trajectories of 42 markers using seven MX-13 cameras at 200 Hz (see Figure 3). The marker coordinates were filtered using a Butterworth lowpass digital filter with cutoff of 6 Hz. Two Kistler force platforms measured the ground reaction forces of stance and kicking legs. Analog signals were filtered at 20 Hz. Visual3D computed the angular velocities, moments and powers for the ankle, knee and hip of both lower limbs using inverse dynamics. Only the kicking leg's results will be reported.

RESULTS AND DISCUSSION

Figure 1 holds the sagittal plane ensemble averaged (15 trials) angular velocities, moments and powers of the kicking leg's ankle, knee and hip joints. The results start 0.43 seconds before pad contact when some of the markers of the kicking leg become occluded. Negative values of the angular velocities and moments of force are plantiflexor at the ankle,

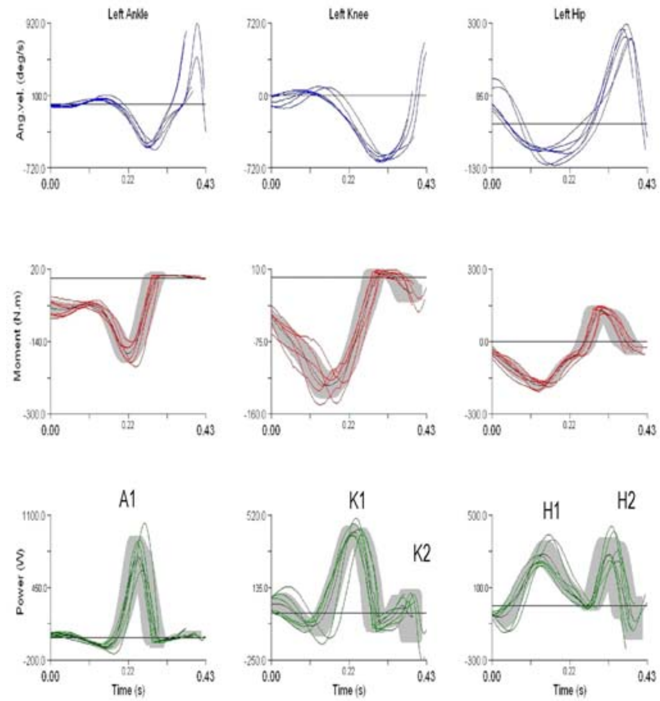

Figure 1: Flexor/extensor angular velocities (top), moments (mid) and powers (bottom) of ankle (left), knee (mid) and hip (right) of the kicking leg.

flexor at the knee and extensor at the hip. Positive powers indicate the rate of work done by the associated moment of force.

As the kicker begins the kicking motion, the hip extensors of the kicking limb (H1 in Figure 1) work positively to extend the hip until toe-off at t=0.28 s. After slight delays, both the ankle plantiflexors (A1) and knee flexors (K1) performed positive work to push away from the floor and simultaneously actively flex the knee, respectively.

After the leg is in swing (at t=0.28), the hip flexors acted to flex the hip (H2) and then immediately before contact the hip extensor moment dominated to stop hip flexion and extend the knee and foot towards the pad. In contrast, the knee flexors transition briefly to eccentric work to prevent hyperextension of the knee [*cf*. 2].

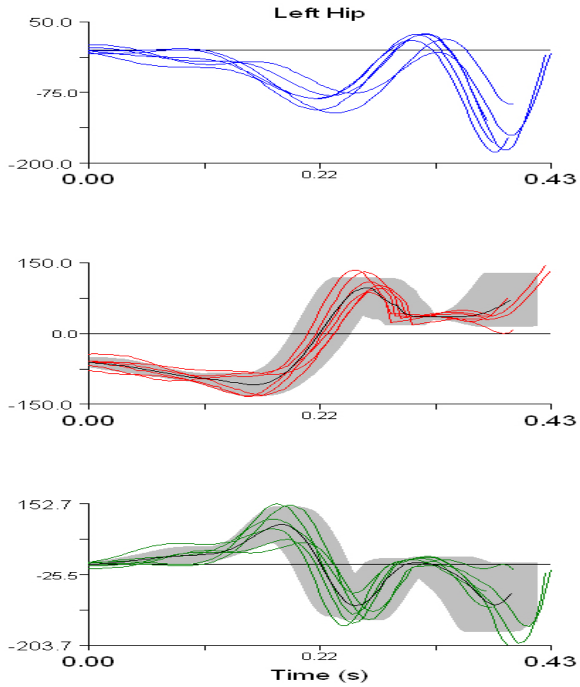

Figure 2: Ab/adductor angular velocities (top), moments (mid) and powers (bottom) of the hip of the kicking leg.

Figure 2 holds the frontal plane ensemble averaged (15 trials) angular velocities, moments and powers for the hip of the kicking leg. Negative velocities and moments indicate abduction.

Notice in Figure 2 the abductor moment is initially acting isometrically. The abductor moment quickly begins positive work to elevate the kicking limb to the maximum kicking height. Then, the adductor moment works eccentrically to stop the elevation of the limb. Prior to impact, the adductors briefly act isometrically and then eccentrically to control the rates of abduction. Note prior to impact, the kicker is rotating towards the pad on the stance leg. As well, the trunk is substantially hyperextended as the kick is delivered.

This circular kick did not exhibit identical recruitment patterns as soccer kicking or the *karate* front kick. The circular kick differs from a soccer kick because it is delivered from a stationary stance, has no approach run and has no follow-through. As well, martial arts kicks are delivered so an opponent cannot anticipate the time of execution. As result, the pre-stretch–while it does occur–is not as dramatic or pronounced as in soccer kicking where a large wind-up precedes a maximal kick. It appears being fast and accurate with the circular kick is more valuable than maximal power. Additionally, soccer kicks and *karate* front kicks use different surfaces for contact with the ball or opponent. In the circular kick, the athlete uses the anterior surface of the tibia as the contact surface; whereas, soccer kicking uses the instep and the *karate* front kick uses the ball of the foot. As a result, the knee flexor moment of the circular kick activates earlier in the motion to resist extension of the knee and to ensure that proper contact is made with the pad. This accounts from the lower hip extensor activity compared to soccer and *karate* front kicks.

CONCLUSIONS

The martial arts circular kick exhibited pre-stretching, large concentric flexor and extensor hip powers, large ankle plantiflexor power at push-off, substantial hip abductor and adductor moments and powers as well as protective or breaking behavior at the knee joint. These results demonstrate the martial arts circular kick has distinctly different kinetic characteristics than either the soccer kick or the *karate* front kick.

REFERENCES

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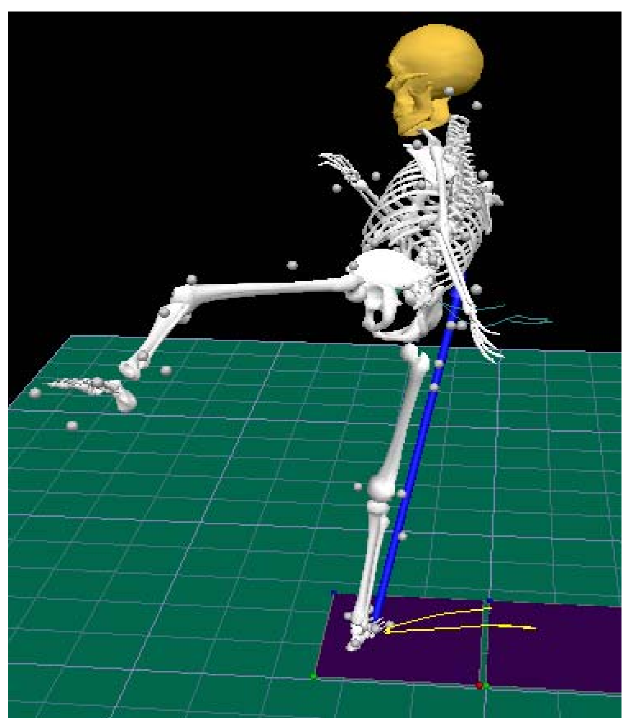

Figure 3: Model immediately before impact.