KINETIC ANALYSIS OF THE LOWER LIMB DURING THE PIROUETTE IN BALLET

Cristina Fulop, Tama Davis, Courtney Timm, D.G.E. Robertson
School of Human Kinetics, University of Ottawa
email: dger@uottawa.ca

INTRODUCTION
The purpose of this research was to quantify and contrast the moments and powers produced bilaterally at the joints of the lower extremity during the ballet pirouette. One-half, full and two-turn pirouettes were investigated.

METHODS
One experienced dancer with 10 years of training performed the various pirouettes. The female subject wore dark, tight fitting clothing with no reflective material to eliminate obstruction of the markers during recording. The University of Ottawa marker set (49 markers in total) was placed on important anatomical landmarks. The pirouettes were performed on two Kistler force platforms while seven infrared Vicon MX13 cameras sampling at 200 Hz recorded the movement data. Both the kinematic and kinetic data were filtered with a 4th-order, zero-lag, Butterworth, low-pass filter. Moments and their powers were computed using Visual3D [2]. The kinetic data were then ensemble averaged from the start of the pirouette until the required rotation was completed. The start was identified by the countermovement or plie immediately preceding the pirouette.

RESULTS AND DISCUSSION
Figure 1 shows the results from the five two-turn pirouettes. The top three curves are the moments of force at the ankle (left), knee (middle) and hip (right) for the lead (or swinging) leg. The second row of figure 1 are the moment powers at the three joints. Figure 2 has the same data for the stance leg.

The pirouettes in all cases started with simultaneous strong knee extensor and hip flexor moments of force from the lead (swinging) leg. The hip flexors performed positive work to flex the hip and knee joints while the knee extensors worked eccentrically to restrict the amount of knee flexion. About 250 ms later, plantar flexors of both legs produced nearly equal amounts of work causing a force couple-like action to promote rotation about the vertical axis. Notice that as the plantar flexors start producing positive work, the lead knee extensors switched briefly to extending the knee before the knee flexors began a period of positive work or isometric contraction to maintain the lead knee in a flexed position.

The stance leg’s knee moments while switching back and forth from weak flexor to extensor moments several times only produced one significant burst of positive work. This occurred after the lead leg’s toe-off and was almost simultaneous with a larger burst of power by the stance leg’s hip extensors. Presumably the hip extensors were recruited to extend the hip and straighten the stance leg to minimize its rotational inertia. This contraction was followed by hip flexor and then extensor activity that produced little work during the period of maximum rotation.

Notice that all of the major work bursts terminate quite early, at about 50% of the entire duration of the pirouette, so that little work was done during the second turn. During the latter half of the pirouette conservation of angular momentum was the dominant principle whereby increased angular rotation was due to the upper body and lead leg moving closer to the axis of rotation as necessary.

CONCLUSIONS
The lead-leg hip flexors performed more work as the number of turns increased while the hip extensors increased the most for the stance leg. The ankle plantar flexors performed approximately the same amounts of work regardless of the number of turns. The knee moments of the stance leg performed relatively the least amount of work; however, the lead-leg knee extensors dominated throughout the drive phase producing approximately equal amounts of first negative work than positive work. As this research only focused on en dedans pirouettes, future directions should focus on the power analysis of other styles of turns. In addition, research should examine the upper extremities’ functions in initiating and sustaining various types of turning movements in dance.

REFERENCES