INTRODUCTION: Ski jumping is a very complex skill involving several phases such as the inrun, take-off, flight and preparation for landing. The take-off requires an extension of the hip and knee joints to produce a negative aerodynamic effect (Antonio and Renato, 1987; Hubbard, et al., 1989; Komi and Virmavirta, 1996; Tveit and Pederson, 1981). It is known that a stretch-shorten cycle is used in most athletic events (Bosco et al., 1982; Wilson et al., 1991); however, there is a lack of literature concerning the possible use of a stretch-shorten cycle during ski jumping.

The purpose of this study was to investigate the relationship between the change in knee joint angle, representing the stretch-shorten cycle and the jump distance of elite ski jumpers. It is hypothesized that the stretch-shorten cycle would occur and result in a longer jump distance.

METHODS: Forty-eight competitors were filmed at 120 Hz during the first round of the Westby Continental Cup in Westby, Wisconsin on February 12, 2000. The subjects consisted of national and international elite jumpers on a (K108) jump.

The take-off was examined as a two-dimensional motion of the subjects at take-off. The jumper's body and equipment were modeled as four sections: the upper body, thigh, lower leg, and ski. This allowed hip (1), knee (2), and ankle (3) angular displacement to be measured. The change of the knee angle was used to determine the existence of a stretch-shorten cycle during the take-off motion. A Two-Tailed Pearson Correlation Coefficient was used to analyze the data with at an $\alpha = .05$.

Joint locations were estimated during digitization in accordance with the noninvasive video data collection style used by (Arndt et al., 1995). Joint centers were estimated by locating anatomical landmarks on the jumpers.

RESULTS: The average knee angle displacement was calculated by examining 44 subjects' knee angles 8 m previous to the end of the take-off table. The average distance jumped was $99.03 \pm 11.6$ m. During the apparent stretch-shorten cycle movement, the average knee flexion was $-1.1521 \pm 0.0681$ (rad) and the average knee extension was $0.1546 \pm 0.0838$ (rad). Average knee angle flexion was represented as a negative angular change due to the decrease of the knee angle at the onset of the SSC movement. The average flexion/extension ratio was $0.85 \pm 0.5$. The knee-joint extension velocity averaged $9.2$ radians $\cdot$ s$^{-1}$.

DISCUSSION: The purpose of the take-off is: (1) to give the jumper-ski system a maximum velocity, (2) to produce a favorable body position at the jump's edge, and (3) to provide an initial turning moment for the forward rotation of the body over the skis immediately after take-off (Campbell, 1980). This experiment adds another
purpose to the take-off: to perform a stretch-shorten cycle.

The data show the existence of a stretch-shorten cycle (SSC) movement 0.08 s before the edge of the ski jump lasting approximately 66 ms. An elite ski jumper must utilize the SSC movement to increase their jump distance. It is important to recall the information in Figure 2. The data demonstrate there were a significant ($\alpha=0.05$) quadratic relation between flexion of the knee joint and the jump distance. This demonstrates a relationship between optimal knee joint flexion and maximum jump distance. This suggests that when a jumper resists against and doesn’t utilize the centrifugal force entering the take-off table to flex the knee joint, they may not be harnessing the full potential of the stretch-shorten cycle movement. Also, the jump distance may be hindered if the athlete flexes the knees too much. It is possible the proper knee joint flexion angle may create a build-up of elastic energy resulting in a more explosive knee extension velocity. This is all dependent on the jumper's ability to produce a quality take-off motion followed by a stable flight phase. Therefore, the stretch-shorten cycle may be an important factor in determining the length of the jump. It is important to remember that several aspects must work together to produce a long jump distance.

Not only does the SSC movement exist, but there also may be an ideal amount of knee flexion to utilize the elastic energy in the SSC movement to produce a successful jump distance. This study concluded that when an elite jumper utilized a proper stretch-shorten movement, in combination with proper form on the take-off table and in the air, they would produce a longer jump distance.

REFERENCES: