INTRODUCTION
In hula hooping an unstable object is kept in steady oscillation parallel with the ground by means of coordinated oscillations of the body [1]. The physical basis of the skill is the conservation of angular momentum, whereby carefully regulated impulses create a state of dynamic equilibrium. A vertical component of the exerted impulse opposes the force of gravity, whereas a horizontal component maintains the angular motion of the hoop. Previous research argued that concurrent oscillatory motions of the hips and knees create these impulses thereby satisfying the functional constraints that characterize the skill [1]. The purpose of the present research was to conduct an inverse dynamic analysis to determine whether the mechanics of hula hooping generated conclusions similar to the decompositional kinematic analysis previously reported [1].

METHODS
Three females voluntarily participated in the experiment. All participants were intermediate-level hula hoopers with no competitive experience. The age range was 16-23 years, with a mean of 19.3 years and heights ranging from 164-168 cm (mean of 165.3 cm). None of the participants reported any recent injuries or longstanding musculoskeletal conditions that would impair their ability to hula hoop. The subjects were selected based on the criterion that they could comfortably (in terms of speed, smoothness and stability) sustain hoop oscillations for a period of 30 s.

Kinematic data were collected with six infrared Vicon MX13 cameras sampled at 200 Hz. Reflective markers were affixed bilaterally to the subjects’ lower extremities according using the uOttawa marker set. Two adjacent force platforms (Kistler) sampled ground reaction force data at 200 Hz. Both the kinematic and kinetic data were filtered with a 4th-order zero-lag Butterworth low-pass digital filter [2]. The cut-off frequency for force data was 20 Hz; kinematic data were cut-off at 4 Hz due to the low frequency content of the data.

The subjects balanced a large diameter hoop (80.4 cm) at a pace most comfortable to them for 30 s. Data collection began when the participant expressed that hoop oscillations comfortable in terms of speed, smoothness and stability. This speed was considered their resonant frequency. Five trials were collected per participant at this frequency. Next, five trials were collected per participant for both large (80.4 cm) and small (70.4 cm) diameter hoops for a total of 10 trials. Lastly, the participants were instructed to oscillate the hoop at two frequencies 10% faster and slower than their self-selected speed paced by a metronome using the large diameter hoop.

RESULTS AND DISCUSSION
The results of this study suggest that the involvement of the hip abductors was fundamental to the skill of hula hooping.

Figure 1: Abduction/adduction moment about the left hip during the skill of hula hooping (Subject 1). Error bars represent ±1SD.

Figure 1 shows the moment of force of the left hip averaged across five trials of three hoop revolutions. The abductor moments and powers about the hip revealed these muscles were recruited 180° out-of-phase with one another. These results were consistent across subjects. Thus, two abductor bursts were necessary to maintain the horizontal regulatory component of the angular momentum—a burst from the abductors of the hip with a simultaneous eccentric burst of the contralateral adductors. While the knee extensors contributed to the vertical regulatory component, their involvement was inherently variable among the subjects. Similarly, the ankle contribution was variable and inconsistent among the subjects. Inverse dynamics revealed the three subjects utilized three distinct strategies while successfully maintaining hoop oscillations; an hip-knee strategy, a hip strategy and a hip-knee-ankle strategy.

CONCLUSIONS
The two theories were in agreement with respect to the involvement of the abductors of the hip. This research demonstrated that all subjects consistently relied on the hip abductors to maintain hoop oscillations. Similarly, Balasubramaniam and Turvey [1] demonstrated that the side-to-side motion of the hip accounted for the greatest proportion of the variance of the K-L transformation. However, discrepancies were noted in terms of the contributions of the ankle and knee musculature to the vertical requirements necessary for dynamic equilibrium.

REFERENCES