A COMBINED IN-VIVO/IN-VITRO STUDY OF BIOMECHANICS OF ACL INJURY

Karla Cassidy, Preet Sabharwal, Naveen Chandrashekar
Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Canada. nchandra@uwaterloo.ca

INTRODUCTION
The mechanism of non-contact anterior cruciate ligament (ACL) injury is not well understood. It is partly because previous studies have been unable to relate dynamic knee muscle forces during sports activities such as landing from a jump to the strain in the ACL. The objective of this research was to develop and validate a unique combined in-vivo/in-vitro method to relate the muscle group forces to ACL strain during jump-landing using a newly developed dynamic knee simulator.

METHODS
A novel dynamic knee simulator system (Fig. 1) was designed and developed to study sagittal plane biomechanics of knee. The simulator is computer controlled and uses six powerful electromechanical actuators to move a cadaver knee in the sagittal plane and to apply dynamic muscle forces at the insertion sites of the quadriceps, hamstring and gastrocnemius muscle groups and the net moment at the hip joint. To validate the equipment, motion capture of a live subject landing from a jump on a force plate, was performed. The kinematics and ground reaction force data obtained from the motion capture was input into a computer based musculoskeletal lower extremity model (AnyBody modelling system, Denmark). From the model, the force-time profile of each specific muscle groups across the knee during the movement was extracted, along with the kinematics of the hip and ankle joints. This data was then programmed into the dynamic knee simulator system. Jump-landing was simulated on a cadaver knees. The programmed and actual muscle forces applied to the cadaver knees were compared. The net moment applied at the knee and calculated from inverse dynamics were compared. The ACL strain during jump-landing simulation was measured.

RESULTS
Our results show that the simulator has the capability to accurately simulate the dynamic sagittal plane motion and the dynamic muscle forces during jump-landing. The average difference between calculated and applied maximum muscle forces were 1.5±12%. The applied muscle forces resulted in similar net knee moment profiles calculated through inverse dynamics (5% difference in maximum moment). The ACL strain values (3±2% strain) were repeatable and agreed with the values reported in the literature. The joint moment profiles matched the moment profiles calculated through inverse dynamics (5% difference in maximum moment). The ACL strain values (3±2% strain) were repeatable and agreed with the values reported in the literature. Variations in the muscle forces profiles resulted in changes in the ACL strain showing the effects of various muscle forces on the ACL strain. Our results show that the knee simulator system can accurately simulate in-vivo kinematics and kinetics on the cadaver knees.

DISCUSSION & CONCLUSIONS
For the first time, we were able to simulate dynamic high-risk motion accurately on cadaver knee and study the resulting ACL strain. It was also shown that variation in muscle force profiles affect ACL strain. This combined in-vivo/in-vitro approach can be effectively used to study the relationship between sagittal plane muscle forces and ACL strain during dynamic activities. The information gained through such kind of research can give valuable insight into the neuromuscular factors that affect ACL injury. This approach could also be used to find the effects of neuromuscular training for ACL protection by performing the simulation based on motion capture on high risk athletes before and after training.

REFERENCES