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INVESTIGATION OF THE MOMENT OF INERTIA AND THE BIOMECHNICAL INTERNAL FORCES ACTING ON THE KNEE DURING HIKING

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The purpose of this study is to use three-dimensional (3D) motion capture data together with the computer software for analysis of the human body, Anybody Technology[1], to perform inverse dynamics and quantify the biomechanical internal forces acting on the knee joints, particularly, the tibiofemoral and patellofemoral. The experiment will be conducted on-land, within a controlled environment. A customized hiking bench, designed and constructed to be identical to the deck of a Laser Standard dinghy will be used to simulate sailing conditions. From the results analysis, we can address deficiencies in the sailing techniques of sailors thereby minimizing the occurrence of knee injury during sailing. We have also investigate on the moment of inertia generated by the human body during the hiking action to explore the most effective sailing posture to be adopted.

KEY WORDS: Laser sailing, hiking, Anybody Technology, C3D, force plate, inverse dynamics, biomechanics.

INTRODUCTION: Sailing is a vigorous and dynamic sport that requires precise techniques and superior physical fitness. During upwind sailing, the aerodynamics forces acting on the sail will cause the deck to heel - the stronger the wind and the higher the sailing angle to the wind, the greater the heeling force. Water currents and waves can also contribute to the heeling force. Sailors perform many sporadic and sudden body movements to counteract these forces and prevent the vessel from capsizing. Such movements, together with poor hiking technique and insufficient physical strength can cause severe injuries to the spine and knees. Numerous studies have quantified the occurrence of injuries during sailing. According to a review by Moraes *et al* (2002)[1], most injuries occurred in the lower back (52.9%), followed by other back areas (41.2%), knees (25–32%), right thigh (26.5%), neck (23.5%), right shoulder (23.5%), and forearm or elbow (20.6%). Another study by Legg *et al* (1997)[2] revealed that 57% of New Zealand Olympic sailors reported injury in the preceding three years, including the lower back (45%), knee (22%), shoulders (18%), and arms (15%).
The objective of this research is to quantify the biomechanical internal forces acting on the knee joint during hiking and the moment of inertia generated by the human body during the hiking motion. Using the data, we hope to obtain the most effective hiking posture. We have defined effectiveness in terms of reducing the occurrence of knee injuries during sailing yet obtaining the maximum moment of inertia.
In this preliminary study, we will base our experiment on the Laser Standard dinghy, a popular single handed dinghies accepted by the International Olympic Committee. The hiking trails will be conducted on a customized bench with dimensions identical to the Laser Standard dinghy called a “hiking bench”.

METHODS: Using Anybody Technology[TM], we first structured a modelling system that is similar to the hiking motion of a typical sailor while sailing. The modelling system consisted of the human body and simulated the hiking motion through the use of the hiking bench stimulator customized for this test. Using the Computer Aided Design, we will load the hiking bench environment and synchronize it with the human body.
Using 3D motion capture data software, we will record two sets of kinematic data. The first set data will be used to investigate the moment of inertia while holding the hiking position of the sailor. The subject will go from rest to three different hiking positions, and hold the

position for 10 seconds. In all three positions, a 140^0 between the the femur and tibia will be maintained while the angle between the hip and the lower spine will be increased as follows: i) 110^0 in the first position, ii) 130^0 in the second position and iii) 150^0 in the third position.

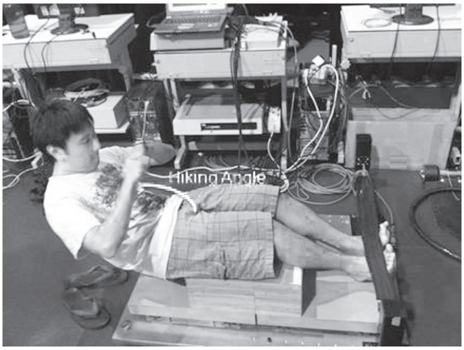

Figure 1: Subject on hiking bench, keeping a 130^0 hiking angle.

The second set of data will be used to investigate the internal forces acting on the knee of the sailor when he moves to a full hiking position. This protocol will be used to stimulating the sailor's sudden response to gusts. The subject will move from rest to maximum hiking position and hold this in the position for 10 seconds before going back to rest again and immediately to the maximum hiking position again. This action will be performed six times, totally to 60 seconds of dynamic hiking motion.
The marker system we will be using for this experiment is the plug-in-gait marker system[4]. An inevitable error of using 3D motion capture data is that the markers are placed directly on the skin. Depending on the size of the muscles, the marker positioning can be substantially distant away from the bones and joints. Hence, such errors must be addressed and compensated for when using the motion data.
During the data capture, the forces generated will be captured by two separate force plates, one for each of the femur and the tibia. The force data, together with the motion capture data will be loaded to the Anybody Model to perform the biomechanical inverse dynamics, thereby obtaining the individual forces acting on the knee joint. We will also place non-invasive wireless Electromyograph (EMG) receivers on the Rectus Femoris, Vastus Laterialis and the Tibialis to measure the signalling activity of the muscles. This additional data can assist in determining the percentage of maximum strength used by the subject during the test. We will first perform a base-line test on the maximum strength of the muscle and we can then determine the percentage of the muscle activity during hiking motion.
The moment of inertia generated by the subject will then be manually calculated using the aforementioned data acquired.

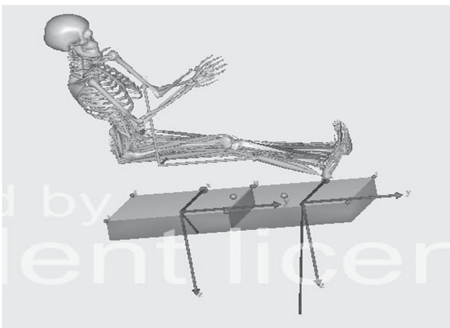

Figure 2: Model system in Anybody Technology.

RESULTS: We have performed a preliminary test with the methodology using one subject and we have run the modelling system for the 110^0 degree hiking position. We have performed the inverse dynamics through the modelling system and the results are as follows. The direction of the action is defined in modelling system shown in Fig. 2
The force (N) vs. time (t) graph shown below is the internal load acting on the right knee joint during the hiking experiment.

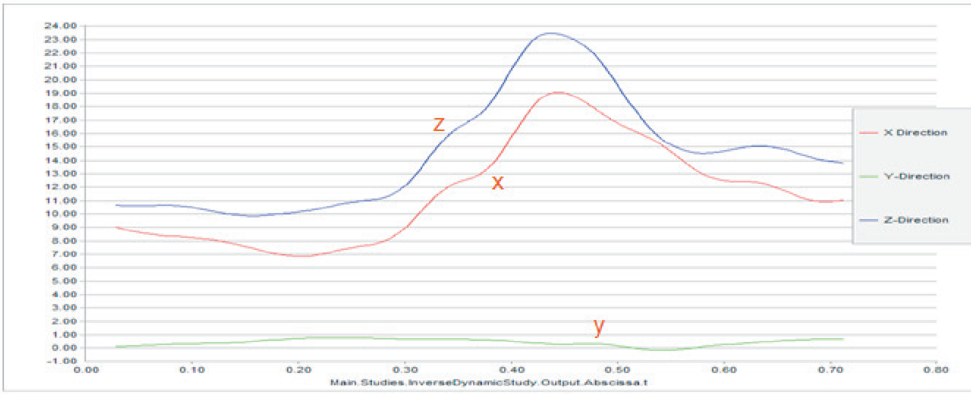

Figure 3: Internal force of right knee during hiking.

The following moment (Nm) vs. time (t) graph shown below is the moment of inertia acting on the right knee joint during hiking.

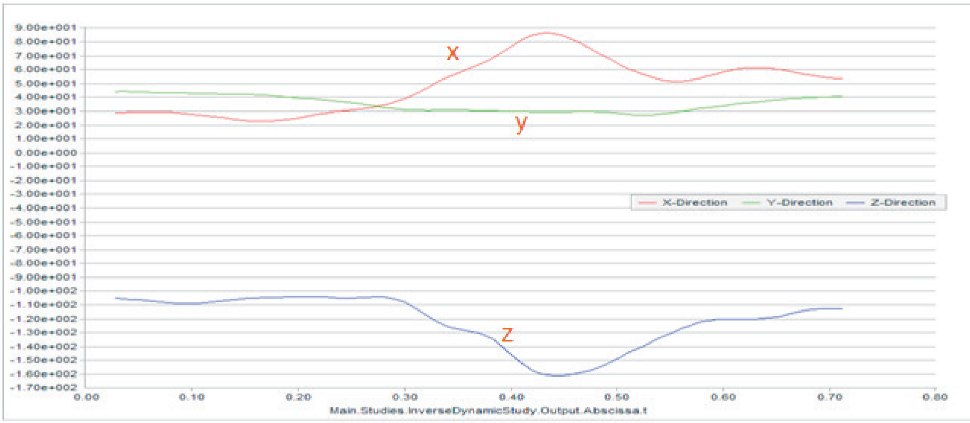

Figure 4: Moment of inertia on right knee during hiking.

DISCUSSION: From this initial test result, we can see that even when a sailor were to hike at a 110^0 angle, the internal load on the knee peak at a value double that of the resting position at the X and Z direction. We can then predict that if a sailor were to high at an even greater angle, the internal load on the knee will increase exponentially. From this initial results, we can proceed on and perform an in-depth analysis of the injury report
We are currently performing the modelling system for the 130^0 and 150^0 degree hiking angle as well as analysing the EMG data with the base-line data. We believe that with time, this research experiment can serve a great deal of information to sailors with regards to injury analysis, especially when such sailing injury analysis are not commonly done.

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