2014 WORLD CONGRESS ON BIOMECHANICS

Comparisons of Knee Joint Loading Between Forward and Backward Pedaling on an Instrumented Cycling Ergometer Using 3D Fluoroscopy Method

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INTRODUCTION: Backward pedaling has been suggested for the rehabilitation of patients with knee injuries. However, no study has compared the biomechanics of the knee between forward and backward pedaling. Measurement of knee loadings using skin marker-based motion analysis is subject to soft tissue artifacts, making it difficult to reveal potentially subtle differences between pedaling conditions. The current study used 3D fluoroscopy method to get accurate knee kinematics and joint center positions for studying the effects of pedaling direction on knee loadings.

MATERIALS AND METHODS: Five healthy young adults pedaled forward and backward on an ergometer with instrumented pedals at an average resistance of 20 Nm mimicking rehabilitation conditions. During the tests the subject wore 30 skin markers on the pelvis and the left lower limb while the marker trajectories were measured using a 12-camera motion capture system, and the knee was imaged at 30 Hz by a bi-plane dynamic fluoroscopy system. The knees of the subjects were also CT scanned and used to construct CT-based bone models, which were then registered to the fluoroscopy images using a fluoroscopy-to-CT registration method, giving the poses of the femur and tibia, and knee joint center positions. Knee moments were calculated using the measured motion data and pedal reaction forces. A paired t-test was used to analyze the pedaling effects for each of the variables (α=0.05).

RESULTS AND DISCUSSIONS: Accurate 3D skeletal kinematics of the knee during cycling was measured so that accurate knee joint forces and moments could be calculated. During forward pedaling, the peak extensor moment (41.96 Nm) occurred at 5.6% cycling cycle, producing a crank torque of 20.11 Nm. The values

during backward pedaling were 47.42 Nm at 19.72% cycling cycle with a crank torque of 35.16 Nm. The results showed that extensor moments contributed more to the crank torque during backward pedaling. Backward pedaling experienced increased anterior shear force (143.4 N) than forward pedaling (125.5 N). However, the peak internal rotator moments (15.32 Nm) during the forward pedaling were greater than those during backward pedaling (13.52 Nm). Knee abductor moments (5.7 Nm) at most extended knee position during forward pedaling were also significantly greater than those for backward pedaling (-1.5 Nm). Backward pedaling was found to generate higher knee extensor moments for greater pedaling torque but decreased abductor and internal rotator moments, which may reduce the risk of injury during backward pedaling.