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Predicting the influence of hip and lumbar flexibility on lifting motions using optimal control

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Abstract

Computational models of the human body coupled with optimization can be used to predict the influence of variables that cannot be experimentally manipulated. Here, we present a study that predicts the motion of the human body while lifting a box, as a function of flexibility of the hip and lumbar joints in the sagittal plane. We modeled the human body in the sagittal plane with joints actuated by pairs of agonist-antagonist muscle torque generators, and a passive hamstring muscle. The characteristics of a stiff, average and flexible person were represented by co-varying the lumbar range-of-motion, lumbar passive extensor-torque and the hamstring passive muscle-force. We used optimal control to solve for motions that simulated lifting a 10kg box from a 0.3m height. The solution minimized the total sum of the normalized squared active and passive muscle torques and the normalized passive hamstring muscle forces, over the duration of the motion. The predicted motion of the average lifter agreed well with experimental data in the literature. The change in model flexibility affected the predicted joint angles, with the stiffer models flexing more at the hip and knee, and less at the lumbar joint, to complete the lift. Stiffer models produced simi-

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