Sharing the load: Strategies for modelling loads in OpenSim simulations of two-handed lifting

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Summary

Appropriately modelling the interaction between the hands and external loads in OpenSim simulations of lifting is a difficult yet important problem. In this work, we introduce and compare five approaches of varying complexity. Approaches 1 and 2 have been employed in previously published research; Approaches 3–5 were developed as part of the current work. These modelling approaches were tested using a two-handed lifting scenario. We demonstrate that the modelling approach may result in considerably different spinal forces and, thus, must be chosen carefully in computational studies of lifting.

Introduction

Musculoskeletal models are commonly used to estimate spinal loads using Static Optimization (SO) [1]. The external load contact forces and moments (LCF&M) acting on the hands have a substantial effect on the results of SO during lifting tasks. LCF&M are often oversimplified in computational studies of lifting and the effect of various LCF&M modelling approaches on spinal loads has not been investigated. This study explores five approaches to model LCF&M in OpenSim [2] and evaluates the effect of these modelling approaches on the predicted spinal loads for one participant during two-handed lifting tasks.

Methods

Experiment: One male participant (20 yr, 185 cm, 73.9 kg) performed various symmetric stoop and squat lifting/lowering tasks with different speeds of movement and different loads in the hands. Marker data were collected for the participant and the load (Box) at 120 Hz using 10 Vicon Vantage V5 cameras. Motion cycles were cropped to begin and end when the load lifted off and returned to the floor, respectively.

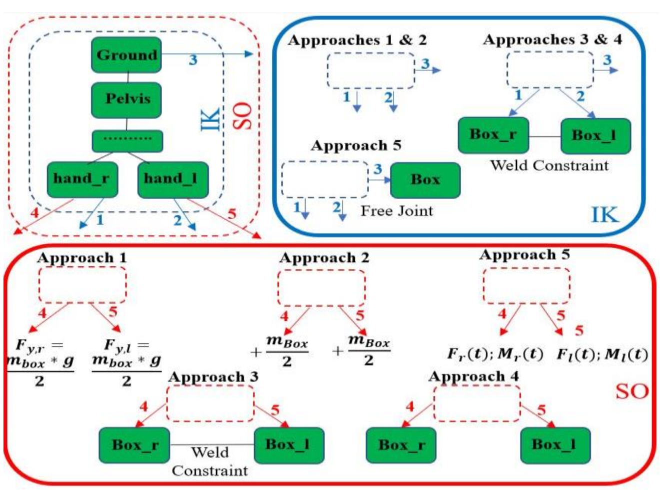

Figure 1. Topology of the model. Blue and red borders indicate the methods used for inverse kinematics (IK) and static optimization (SO) calculations, respectively. Green denotes OpenSim bodies.

LCF&M Modelling Approaches: Although the validated spine model from Bruno et al. [3] was used in this study, the presented LCF&M modelling approaches (Figure 1) are generalizable to other OpenSim lifting models. Approaches 1 and 2 do not consider the box kinematics. In Approach 1, a gravity-oriented half-load was applied to each hand; in Approach 2, the mass of each hand was increased by half of the box mass. In Approaches 3 and 4, a closed kinematic chain was formed for the IK analysis, but for Approach 4, an open-tree structure was used in SO to reduce the computational cost. In Approach 5, the kinematics of the body and box were calculated separately, and LCF&M were calculated as a function of time using an optimization procedure.

Results and Discussion

During stoop lifting with 20 kg, the maximum difference in the maximum L5/S1 resultant force was found between Approaches 1 and 5 (582 N). When lowering the load, the difference between Approaches 1 and 2 was greater than other approaches (539 N). Modelling Approaches 3–5 suggest that, during lifting, the maximum loads on the spine do not necessarily occur at maximum upper body flexion, which corroborates *in vivo* measurements [4]. However, Approach 1 cannot capture this phenomenon because it does not consider any acceleration of the load. Nevertheless, Approach 1 has been used in many lifting studies due to the ease of application, or because the simulated tasks were static.

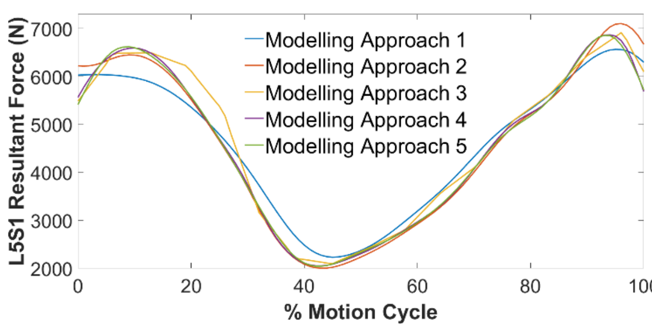

Figure 2. L5/S1 resultant forces during 20 kg stoop lifting.

Conclusions

LCF&M modelling approaches alone can substantially affect the estimated spinal loads during lifting tasks in OpenSim models. The comprehensive evaluation of our modelling approaches during stoop and squat, three speeds of movement, and two lifting loads will be presented at the conference.

References

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