VALIDATION STUDY OF A LOWER EXTREMITY MUSCULOSKELETAL MODEL FOR DROP LANDING AND STOP JUMP TASKS

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Introduction: Musculoskeletal modeling is used to estimate muscle forces and activation patterns. To gain confidence of utilizing musculoskeletal models, validation studies must compare experimental and simulated data. The purpose of this study was to validate a musculoskeletal model of the lower extremity for drop landing and stop jump tasks to obtain estimates of muscle activity from motion analysis data. We hypothesized that the model would be validated for both tasks.

Materials and Methods: Five male and five female healthy and recreationally active subjects (age: 25.1 ± 2.6 years, ht: 171.9 ± 78.9 cm, wt: 681 ± 11.4 kg) were recruited for the study. Lower extremity kinematic data were collected using an eight camera 3-D optical motion capture system (200 Hz) with two forces plates (1200 Hz). Muscle activity was collected using an eight channel telemetric electromyographic (EMG) system (1200 Hz). Surface EMG was used to collect muscle activity from the the vastus lateralis, vastus medialis, rectus femoris, medial and lateral hamstrings, anterior tibialis, and medial head of the gastrocnemius. Subjects performed single-leg drop landing and stop jump tasks using their dominant (test) leg. Three trials of each task were collected. Subject specific musculoskeletal models of the lower extremity were generated based on the Generator of Body Data (GeBOD) using Lifemodeler software. Models consisted of seven segments with 24 degrees of freedom and 45 muscles on the test leg. Muscles were modeled using Hill-based elements consisting of contractile and parallel elastic elements. Default muscle model parameters were used for all models and ligaments were not included. Experimental *(in vivo)* joint angles were computed using inverse dynamics. Enveloped EMG signals were normalized by the peak values recorded from each muscle over all testing. Simulated joint angles and muscle activities were estimated using the subject specific musculoskeletal models in Lifemodeler. Marker trajectories and ground reaction forces were imported into the model and inverse solutions were used. Experimental and simulated time histories of the joint angles and muscles activities were compared for the landing phase of the drop landing and stop jump tasks using mean absolute error (MAE) and Pearson's product moment correlation (ρ). Validation criteria were set as MAE < 5° and ρ > 0.60 for angles and MAE < 0.3 and ρ > 0.60 for muscle activities [1].

Results and Discussion: For the drop landing task, the joint angle MAE ranged 6.0–19.1° and the joint angle correlations ranged 0.16–0.95. The muscle activation MAE ranged 0.21–0.59 % peak and the correlations ranged -0.43–0.48. For the stop jump task, the joint angle MAE ranged 5.8–24.5° and the joint angle correlations ranged 0.41–0.93. The muscle activation MAE ranged 0.26–0.39 % peak, and the correlations ranged -0.22–0.46. The purpose of this study was to validate a musculoskeletal model of the lower extremity for drop landing and stop jump tasks to obtain estimates of muscle activity from motion analysis data. Previous studies have validated models for dynamic tasks [2], but are not available. The subject specific lower extremity musculoskeletal models were not validated using default muscle model parameters. A prospective study of female athletes found an increased knee valgus angle of 8° at landing in those who had an anterior cruciate ligament (ACL) injury as compared to non-injured [3]. With a knee valgus/varus MAE of 6–11°, the model will not be capable of discerning individuals at greater risk of ACL injury due to greater knee valgus angles. For muscle activity, de Zee, et al. [1] found an average MAE of 0.11 and correlation coefficient of 0.58 compared to 0.32 and 0.14, respectively, in this study. The differences are likely due to the large impact forces and segmental decelerations that occur during landings.

Conclusions: The results of this study indicate that the musculoskeletal model was not validated utilizing default muscle model parameters. Additional refining of model parameters and utilizing optimization techniques are necessary to obtain valid muscle activity from motion analysis data.

References:

1. de Zee M, et al. *J Biomech* **40**, 1192-1201, 2007.
2. Erdemir A, et al. *Clin Biomech*. **22**, 131-154, 2007.
3. Hewett TE, et al. *Am J Sports Med* **33**(4), 2005.