MODELING THE EFFECTS OF FOOT PLACEMENT DURING SIT-TO-STAND USING A STABILIZATION STRATEGY

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INTRODUCTION

Sit-to-stand movements are required for initiation of gait, upright reaching, and self-care tasks. Older adults with osteoarthritis may find sit-to-stand difficult or impossible without external assistance. It remains unknown how to systematically recommend an optimal seated posture based on individual physical capability.

Reduced strength and increased pain in the lower extremity joints are barriers to the completion of sit-to-stand transfers. Individuals who are unable to perform sit-to-stand without assistance or who perform sit-to-stand slowly (> 2 s) have greater than two times the risk for falls (Nevitt et al., 1989). Arthritic pain was another factor that appeared to compound the risk of falls.

The effects of foot placement on lower joint torques when using a momentum strategy have been simulated (Gillette et al., 2005). We are developing a technique to optimize foot placement using individualized measures (Gillette and Stevermer, 2006). However, if video/force platform data are not available, then the optimization needs to consider multiple sit-to-stand strategies.

Our long-term goal is to extend sit-to-stand optimization to a clinical environment. Individualized measures would include strength, anthropometrics, and sit-to-stand time. Specifically, this study focuses on simulating the effects of foot placement on sit-to-stand when using a stabilization strategy (Scarborough et al., 1999).

METHODS

The stabilization strategy was simulated with no upper body momentum generation. The initial knee flexion was 90° for foot-back and 106° for foot-neutral, trunk flexion was 135° for both, and ankle dorsiflexion was determined geometrically. Knee extension was initiated at 10%, hip extension at 12%, and ankle plantar flexion at 30% of the sit-to-stand cycle (STS).

Seated forces were simulated by unloading the upper body and thighs at 12% STS for seat-off. Hand support forces were applied, then unloaded at 30% STS if needed to maintain the center of pressure within the base of support. Ground reaction forces were calculated using segment inertias, seated forces, and hand support forces.

For comparison, a female older adult (75 yr) with bilateral total knee replacements performed sit-to-stand transfers from a 41 cm bench. She was observed utilizing a stabilization strategy from foot-back and foot-neutral placements. An eight-camera system tracked reflective markers, and each foot was placed on a separate force platform.

RESULTS

Hand support forces were not needed to complete the sit-to-stand from the foot-back placement. However, hand support forces at 40% body weight (BW) were required to maintain the center of pressure within the base of support for foot-neutral.
Maximum simulated ground reaction forces were greater with the foot-back (108% BW) than with the foot-neutral placement (101% BW). Maximum experimentally measured ground reaction forces were 100% BW for both foot placements (Figure 1).

Maximum ankle plantar flexion (37 Nm vs. 1 Nm), knee extension (61 Nm vs. 16 Nm), and hip extension torques (48 Nm vs. 45 Nm) were greater with foot-back (0% hand support) than with foot-neutral (40% BW hand support) placement (Figure 2).

DISCUSSION

There were several differences between the simulated and experimentally measured sit-to-stand movements. First, the older adult did not achieve full extension during upright standing (38° final experimental knee flexion). Second, the ground reaction forces did not change appreciably during the experimental trials. It appeared that the older adult used a similar amount of hand support force regardless of foot placement.

Using the stabilization strategy, high hand support forces were required to complete the sit-to-stand movement with foot-neutral. Previous simulations using the momentum strategy did not require hand support forces with foot-neutral, but high hip extension torques resulted instead. Therefore, an older adult would need either sufficient upper body strength or hip extensor strength depending upon movement strategy.

These results imply that an intermediate foot placement with moderate joint torques and hand support forces may be preferable. The next analysis step toward foot placement optimization would be to compare sit-to-stand torque requirements with strength capability (Gillette & Stevermer, 2006). Since the ground reaction forces displayed left-right asymmetry, staggered foot placement options also merit further consideration.

REFERENCES


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