UNRAVELLING ADAPTATION STRATEGIES IN SIT-TO-WALK USING PREDICTIVE NEUROMUSCULAR SIMULATIONS

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Introduction

Standing up from a chair is a key daily life activity (>60x per day) that is sensitive to functional limitations as we age. Most stand-up movements transfer directly into walking (sit-to-walk). The aim of this study was to develop and validate a neuromusculoskeletal model with reflex-based muscle control to simulate the sit-to-walk movement, under various conditions (seat height, foot placement), reduced muscular capacity, reduced neural capacity, and altered movement objectives (pain). In this abstract we demonstrate how different seats and initial postures affect the sit-to-walk biomechanics and adaptation strategies from a lower seat (height = 35cm), and with asymmetrical foot placement (anterior-posterior position).

Methods

We developed a planar sit-to-walk musculoskeletal model (11 degrees-of-freedom, 20 muscles) and neuromuscular controller, whose parameters where optimized using a shooting-based optimization method [1]. The sit-to-walk controllers consist of a two-phase stand-up controller (P1, P2) and a reflex-based gait controller [2]. The stand-up controller uses delayed proprioceptive feedback from muscle length, force, velocity, and upper-body orientation. Both monosynaptic an antagonistic feedback paths are included in the controller. Control parameters were optimized to minimize the cubed muscle activation and gross cost of transport, at a prescribed minimum gait velocity, while avoiding falling, and excessive ligament stretch forces. We ran multiple parallel optimizations with the same initial guess and used the best set as start for the next set of optimizations. Final results were compared to a subset of recorded kinematics, ground reaction forces (GRF), and muscle activation (sEMG) from young (18-35 year) and older (>65 year) adults (n = 50), in which participants were asked to stand up and walk to a table at self-selected speed [2].

Results

When the height of the seat was reduced, the model showed a larger trunk angle in P1, which is in line with human motor control [3]. As expected, overall the lower seat requires higher muscle activations and results in higher joint loads: higher peak knee (+25%) and hip (+22%) loading in stance leg, and +10% in the stepping leg, and bilateral increase in peak load of the ankle (+12-16%). The biggest differences in muscle activation is bilateral less activation in the BFSH, and higher activation in the PSOAS and TA. For the stance leg, HAM and GMAX are more activated compared to a normal seat height.

In the asymmetric foot condition, the trunk was kept more upright. This posture results in a large reduction of hip load in the stepping leg compared to the normal condition (-48%). The bilateral knee loads are also slightly reduced (-5-7%), whereas the ankle load in the stepping leg is higher compared to the normal condition (+62%). There is less activation for HAM in the stepping leg, and RFEM and GAS have a longer activation on this side, and the peak VAS activation in is higher.

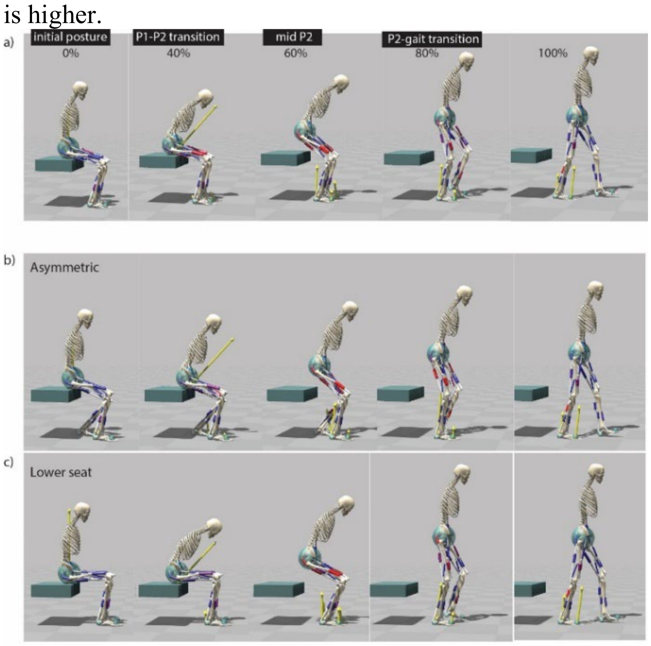

Figure 1: a) STW simulation with normal seat (44cm). b asymmetric foot position; c) lower seat height (35 cm);

Discussion

The predictive planar lower limb model was able to simulate sit-to-walk movements that match real-world kinematic and kinetic recordings. We demonstrated that the model can realistically simulate compensation strategies due to alteration in the neuromuscular system and alternative conditions such as seat height and foot positioning. Asymmetric foot positioning in which the stepping leg was placed backwards, leads to a large reduction of peak hip load in the stepping leg with the drawback of increased ipsilateral peak ankle load. This is relevant for clinic in for example hip arthroplasty rehabilitation to advice on the best sit-to-walk strategy during recovery.

References

1. Geijtenbeek, T JoOSS 38: 1421, 2019.
2. Geyer, H., & Herr, H. 18(3): 263-273, 2010.
3. van der Kruk, E., et al. npj Aging, 8(1), 13, 2022
4. van der Kruk, et al. J Biomech 122: 110411, 2021