Predictive neuromuscular simulation of the sit-to-walk movement for two distinct initial postures

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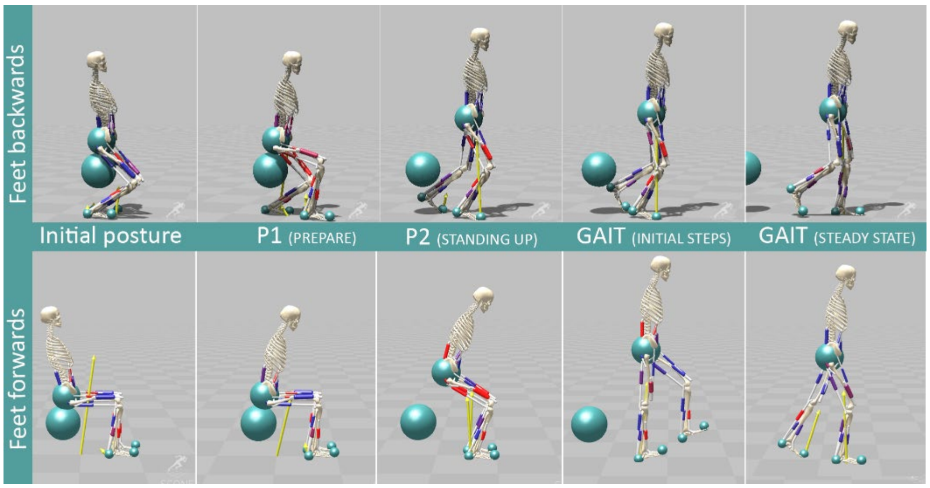

I. Background

The treatment of age-related mobility impairments is increasingly relevant in our ageing societies. Age-related progression of neuromuscular decline often lead to incorrect or insufficient compensation strategies. Predictive neuromuscular simulations can become an effective tool for discovering those strategies, enabling clinicians to design treatments that are both more effective and efficient for prolonging the mobility of the patient. The aim of this study is to develop a predictive neuromuscular model that can simulate realistic sit-to-walk movements, which is an important daily life activity.

II. Methods

The musculoskeletal model is based on an OpenSim [1] model representing a male adult with height of 1.80m and a mass of 75kg. The model has 10 DOF (2D model) and is actuated by 22 Hill-type muscle-tendon units. Contact force between the feet and the ground and between the buttocks and the chair were modelled with Hunt-Crossley force spheres (two at the foot, one at the pelvis, one at the chair). Our sit-to-walk controller consists of a gait controller (GAIT) based on [2] and a two-phase stand-up controller (P1, P2) based on proprioceptive feedback from muscle length feedback (L), tendon force feedback (F), and constant excitation (C). The delayed feedback pathways were both monosynaptic an antagonistic. The controller was developed and optimized in SCONE [3] using a shooting-based optimization method. The 152 free parameters were optimized gait velocity, while avoiding falling, ligament injury, and excessive head motion. 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 recorded kinematics (Vicon), ground reaction forces, and EMG 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 (5x) and fast speed (5x). We ran simulations for two initial postures: feet forward (knee at 90^0 flexion) and feet backwards (feet under the chair).

III. Results & Discussion

The predictive 2D lower limb model was able to simulate a sit-to-walk movement that matches real-world kinematic recordings for both initial postures. In feet backwards posture, the optimization resulted in a movement in which the model placed one foot forward (P1), stood up (P2) and then initiated gait to enter steady gait (GAIT). The model made the first step before the trunk was fully extended, which is a natural strategy in humans. The feet forward posture resulted in a simulation in which the model first performed a trunk flexion (P1), then stood up with both feet parallel (P2), followed by the unloading and stepping of one leg (GAIT) and the progression into steady walking (GAIT). Contrary to the feet backwards position, the model required a separate controller for the transition from standing to walking. This is also a common natural movement strategy in the sit-to-walk task.

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IV. References

[1] Lower Limb Extremity Model 2010, OpenSim
[2] Geyer & Herr (2010). 10.1109/TNSRE.2010.2047592
[3] Geijtenbeek, T (2019). 10.21105/joss.01421