FALL RECOVERY LIMITATIONS FOR YOUNG ADULT AND ELDERLY MODELS THROUGH COUPLED DEEP REINFORCEMENT LEARNING SIMULATIONS

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Introduction

Human locomotion is a complex task relying on neural command to initiate biological processes regulating muscle activation and contraction mechanisms. The ability of these processes to adapt to unforeseen changes in the environment at any scale may be crucial in fall recovery. We have previously used deep reinforcement learning strategies to better understand human falls in both young adults [1] and by adapting muscle parameters for the elderly [2]. We have recently developed a coupled simulation solution to analyze the physical limits for fall recovery. In this present study, we investigate the sensitivity of learned fall recovery on displacement limits and age-parameters.

Methods

A 3D musculoskeletal model was developed using OpenSim-rl and a backwards falls-driven reward function on young adult muscle parameters. This model was then tested until the center of mass (COM) exceeded the right heel position by 7cm. The position and velocity of each body segment at this point was used to initiate a second simulation which rewarded for recovery (Figure 1). The second simulation learned the muscle activations required to recover from this particular fall. The sensitivity of this recovery behavior was then tested at different displacement values: 6,7,8 and 9 cm respectively; and by testing the sensitivity to ageing (elderly model), considering age-related changes in maximum isometric force, contractile velocity, hip range of motion in extension, passive elasticity and deactivation time, as described in our previous study [2].

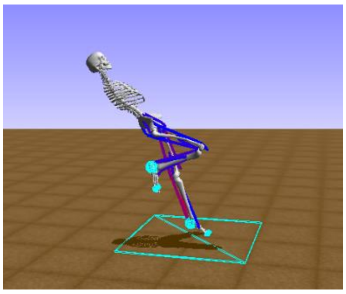

Figure 1: Image marking the final position of the first simulation of the young adult trained model with a 7cm displacement of COM relative to right heel position.

Results

The young-model-learnt muscle activations to recover from 7cm of posterior COM displacement relative to the heel position for a backward fall, marked as left foot weight bearing, and showed fall recovery at 7 cm, 8 cm and 9 cm for young muscle parameter tests. No successful recovery was simulated in any of the 5 tests completed at each interval when this learnt behavior was simulated using the elderly muscle parameters. Table 1 shows a comparison of the maximum velocity values for four body segments amongst the completed simulations.

Segment	Max Velocity (m/s^2) (Y / E)	P value (T-test)
Head	1.70 / 0.73	0.120
Pelvis	0.54 / 0.20	0.062
Right foot	2.49 / 1.27	0.109
Left foot	3.94 / 2.38	0.004*

Table 1: T-tests were completed on the mean maximum velocities (head, pelvis and each foot) over the 5 testing trials, comparing young (Y) and elderly (E) values across the 4 displacement limits.

Discussion

Simulations providing data for human falls can offer new insights into fall avoidance strategies however their limitations need to be thoroughly analysed. In this study, we investigated the sensitivity of learned behaviour to COM displacement during a fall as well as sensitivity to age-related muscle parameters. Our coupled simulation approach allows us to train models to recover from specific physical positions, such as this left-foot weight bearing backward fall example. This study also highlights a possible effect of age-related factors on the ability of the weight-bearing side to obtain a sufficient response to affect the outcome of the simulation.

References

1. Nowakowski, K. et al., Med Biol Eng Comput, 59:243-256, 2021.
2. Nowakowski, K. et al., Med Biol Eng Comput, 60:1745-1761, 2022.

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