Key Gait Assistance Parameters in Lower Limb Exoskeleton Design for Elderly

Josée Mallah and Luigi G. Occhipinti
Electrical Engineering Division, Department of Engineering, University of Cambridge, Cambridge CB3 0FA, United Kingdom
Email: jm2508@cam.ac.uk, lgo23@cam.ac.uk

Summary

A comparison of spatiotemporal, kinematic, and kinetic gait parameters between older and younger adults suggests the need for kinematic gait assistance at the ankles and hips, timed kinetic assistance at the knees and hips, and balance support, highlighting opportunities for exoskeleton intervention and assistance in elderly.

Introduction

The number and proportion of older adults aged 60 years or more is expected to reach 2.1 billion by 2050 [1]. Ageing comes with a weakening of the body and muscles [2], and a higher metabolic cost of walking [3]. Balance issues are common, with 35% of adults aged 85 and older self-reporting imbalance [4]. Falling is therefore a direct consequence, and the main cause of traumatic injuries in adults over 65 years of age, with most of these incidents happening during walking [5]. Exoskeletons are promising in terms of providing effective gait assistance without requiring significant lifestyle changes.
In this work, we identify key gait parameters affected by ageing and requiring exoskeleton assistance.

Methods

Motion capture, force plate, and EMG data for 10 older (age: 78.1 ± 5.3 years, weight: 69.2 ± 10.0 kg, height: 160.0 ± 8.8 cm) and 10 younger adults (age: 26.3 ± 4.6 years, weight: 69.2 kg ± 9.0 kg, height: 167.7 ± 9.1 cm) is taken from [6].

Scaling, inverse kinematics, and inverse dynamics were executed on the Gait2392 model in OpenSim. Muscle parameters were modified for the older subjects to reflect the effects of ageing. Control constraints were used to better match the computed muscle activation to the actual EMG. Only the portion of the gait cycle between 15%-100%, during which significant ground reaction force is present, is considered.

Statistical analysis of gait parameters was evaluated using a one-way ANOVA, performed in MATLAB.

Results and Discussion

The older group has a 33.07% reduction in the ankle ROM (F=16.34, p=0.0008), with peak ankle plantarflexion decreasing by 47.87% (F=12.72, p=0.0022). A 9.02% reduction in the hip joint ROM (F=4.48, p=0.0486), with a 24.72% decrease in the peak hip extension (F=10.04, p=0.0053) are observed in elderly, in addition to a 13.79% delayed peak hip moment (F=16.89, p=0.0007) from around 50.55% to 57.52% stride. Peak knee moment was found to be on average 31.69% lower for the older group (F=6.53, p=0.0198), and more likely to be delayed (F=23.66, p=0.0001) from around 10.85% to 60.63% stride. Moreover, swing time was on average 8.35% shorter for the older group (F=11.44, p=0.0033), with 10.63% higher double support percentages (F=5.76, p=0.0274), 11.92% shorter step length (F=6.99, p=0.0165) and 11.06% shorter stride distance.

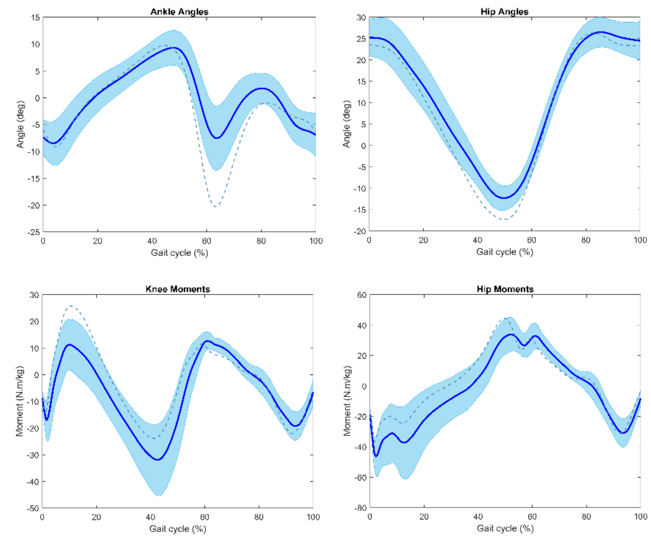

Figure 1: Ensemble averages of the ankle and hip angles, knee and hip moments for the old group normalised to gait cycle. (solid lines), along with the standard deviation (shading). Dotted lines are the corresponding curves for the young group.

These results suggest that kinematic assistance is needed at the ankle, by enhancing range of motion, in particular plantarflexion. Kinetic assistance is required at the knee, possibly using timed assistance profiles to provide assistive torques in early stance. Both kinematic (ROM – extension) and kinetic (timed, around 50% stride) assistance are needed at the hip level. The observed spatiotemporal changes suggest the need for balance and postural control support.

Conclusions

Elderly require kinematic gait assistance at the ankles and hips, kinetic assistance at the knees and hips with attention to timing, and balance support.

References

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