Predicting the effects of knee extensor muscle weakening and strengthening on a post-stroke gait
Gilmar Santos, Eike Jakubowitz, Nicolas Pronost, Thomas Bonis, Christof Hurschler

To cite this version:
Gilmar Santos, Eike Jakubowitz, Nicolas Pronost, Thomas Bonis, Christof Hurschler. Predicting the effects of knee extensor muscle weakening and strengthening on a post-stroke gait. XXVIII Congress of the International Society of Biomechanics (ISB), Jul 2021, Stockholm, Sweden. hal-03542694

HAL Id: hal-03542694
https://hal.archives-ouvertes.fr/hal-03542694
Submitted on 25 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Predicting the effects of knee extensor muscle weakening and strengthening on a post-stroke gait

Gilmar F. Santos1, Eike Jakubowitz1, Nicolas Pronost2, Thomas Bonis2, Christof Hurschler1
1Laboratory for Biomechanics and Biomaterials, Department of Orthopedics, Hannover Medical School, Hanover, Germany
2Université de Lyon, Université Claude Bernard Lyon 1, CNRS LIRIS, Lyon, France
Email: FernandesdosSantos.Gilmar@mh-hannover.de

Summary
Stroke may cause different gait abnormalities, such as knee hyperextension and stiff-knee gait. This study used predictive simulation to investigate how the weakening and strengthening of the knee extensor muscles affect the gait pattern of a post-stoke patient. The prediction result showed impairments similar to those observed in the gait obtained by the inverse dynamics. While the predictive simulation of muscle weakening corrected the stiff-knee gait, the gait prediction of muscle strengthening decreased the knee hyperextension exhibited in the gait pattern of the patient.

Introduction
Individuals who suffered stroke may present impaired gait. Knee hyperextension and stiff-knee gait (SKG) are deviations commonly exhibited by this population, but these gait patterns could have different causes [1]. Understanding how to improve these impairments may support the rehabilitation. Predictive simulation was used in order to investigate the cause-effect relationship between changes in the musculoskeletal system and the observed gait abnormalities in a typical post-stroke patient. In a simplified approach, the purpose of this study was to predict the effects of the weakening and strengthening of the knee extensor muscles on pathological gait, and to investigate whether the specific changes could improve the gait pattern of the patient.

Methods
The gait analysis was performed for a female patient (age: 46 years; height: 1.60 m; mass: 63.8 kg) walking overground at a self-selected gait speed (0.55 ± 0.04 m/s). Inverse dynamics (ID) results were obtained using a scaled lower body model (gait2392) and the tools available in OpenSim (v. 3.3). The 3D musculoskeletal model used for predictive simulations (PS) was based on the one used in ID. The PS was formulated as an optimal control problem [2]. The observed speed in the gait analysis was imposed. Personalized muscle-tendon parameters (optimal fiber length, maximal isometric force and tendon slack length) were used for PS. An optimal control problem was solved using the ID joint moments to estimate the personalized muscle-tendon parameters [2]. With this parameter set, it was possible to predict a pathological gait without directly relying on the kinematics and kinetics of the collected gait data. In order to investigate the effect of muscle weakening (PS-weak), maximal isometric force of the knee extensor muscles in PS was decreased by 50%. Similarly, muscle strengthening (PS-strong) was predicted by increasing maximal isometric force by 50%.

Results and Discussion
The knee hyperextension and SKG in the ID were predicted, but PS resulted in less knee extension during the stance phase than the ID (Fig. 1A). PS-weak increased knee hyperextension and corrected the SKG, while the opposite was observed for PS-strong (Fig. 1A). These results indicate that weak knee extensor muscles is related to knee hyperextension in this patient, as also reported by Mulroy et al. [3]. The decreased peak of knee flexion in the swing phase was accompanied by low knee flexion velocity (Fig. 1B), which has been identified as a cause of SKG [4]. The change of dominance from knee flexion to extension moment in early stance phase in PS-strong (Fig. 1C) allowed knee flexion, which corrected knee hyperextension.

Conclusions
The alteration of the knee extensor muscle strength predicted improvements in the post-stroke gait and identified possible causes of the knee hyperextension and SKG. Future studies may investigate other gait abnormalities and should include more patients in the analysis.

Acknowledgments
This study is part of the OMEGA project funded by DFG (316739714) and ANR (16-CE92-0042).

References