GENERALIZATION OF MACHINE LEARNING MODEL PREDICTIONS OF KNEE JOINT FORCES TO POST STROKE GAIT

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Introduction

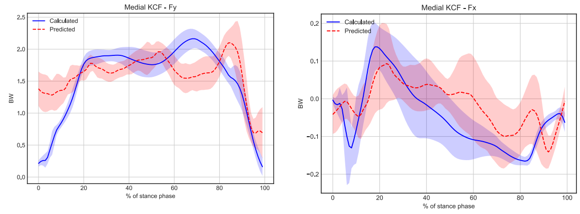
Post stroke symptoms, along with natural age-related sensorimotor decline, affect the lower limbs' soft tissue homeostasis and/or skeletal integrity, resulting in pain, muscle loss and functional decline along with elevated fall and fracture risk. Forces acting on joints and resulting bone deformation (strain) can lead to degeneration of impact-absorbing cartilage or regulate fracture-protective bone mass and shape; hence, their exploration constitutes an urgent matter for prevention stroke-induced osteoarthritis (OA) and osteoporosis. Musculoskeletal (MSK) modelling can provide such subject-specific information, although its demand for high expertise and excessive computational cost has inhibited its widespread use. Alternatively, data-driven machine learning (ML) techniques are rapidly evolving to meet such healthcare needs. However, generalization to pathological populations of such models may be restricted, due to the scarcity of relevant training data. Hence, the aim of this study is to test the generalization of a ML model trained in healthy gait data to predict knee joint forces, to corresponding post stroke data which have been collected in different settings.

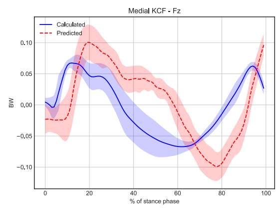
Methods

Participants consisted of fifty-four (54) healthy subjects, young and elderly, and three chronic stroke patients. Motion capture data of the healthy group were recorded at Movements and Postures Analysis Laboratory Leuven – KU Leuven, Belgium, whereas corresponding data of the stroke patients were recorded at the Biomechanics Lab – DUTH, Greece. All patients walked on a split-belt, instrumented treadmill. Healthy group walked on a range of speeds, from 3-7 km/h (~4700 gait cycles), whereas stroke group walked on preferred walking speed (10 gait cycles/each). Musculoskeletal (MSK) modelling included scaling a generic MSK model [1] to subject specific segmental dimensions, calculation of joint kinematics, muscle forces and knee contact forces (KCF) in Opensim, during stance phase. Training dataset for the artificial neural network (ANN) consisted of lower limb joint angles of both legs as inputs and six components of KCF (three for medial and three for lateral compartment) from the healthy group. Once the optimal ANN architecture was found [2] through brute-force parameterization and 3-fold cross validation, the model was trained in all healthy data. To test its generalization, we computed R-squared and root mean square error between model-predicted and calculated KCFs during stance phase of gait of three stroke patients.

Results

We present the best results of medial KCF – as more relative to knee OA - from the stroke patient most similar to the healthy group in terms of mobility, age and sex.





	R^2	RMSE
KCFx	0.53	0.09
KCFy	0.62	0.48
KCFz	0.39	0.06

Figure 1: Mean ensemble curves of the three medial KCF components of 10 stance phases of one stroke patient. Table shown mean R-squared and RMSE values between predicted and calculated curves.

Discussion

Our prediction results showed that a pre-trained ANN model on healthy data can moderately predict post stroke medial KCFs during stance phase of walking, based only on lower limb joint angles. This is comparable to results when the ANN was trained on the healthy data and all the trials of the testing subjects were excluded from the training dataset. However, generalization capability was heavily compromised when stroke patients deviated far from the training dataset (results not shown), in terms of mobility (one was hemiparetic) and sex (one was elderly male whereas the training dataset included only elderly female). Future work will research on optimal ML algorithm and architecture combined with best training scenarios that generalize sufficiently to stroke populations.

References

1 Lerner, Z.F. *et al. J. Biomech.*, 2015, 48 (4).

2 Giarmatzis, G. *et al. Sensors (Switzerland)*, 2020, 20 (23).

Acknowledgements

This work was supported by grant MIS 5047286 from Greek and European funds (EYD-EPANEK). We particularly would like to thank Sabine Verschueren and Ilse Jonkers from KUL for providing the motion capture system and offering their permission to use the motion data.