Machine learning-based prediction of upper limb rehabilitation outcomes in multiple sclerosis: a preliminary analysis

Other Conference Item

Author(s):
Josse, Eva; Sylvester, Ramona; Gonzenbach, Roman; Lambercy, Olivier; Kanzler, Christoph

Publication date:
2021-07-01

Permanent link:
https://doi.org/10.3929/ethz-b-000501106

Accepted at IEEE International Conference on Biomedical and Health Informatics 2021

Machine learning-based prediction of upper limb rehabilitation outcomes in multiple sclerosis: a preliminary analysis

Eva Josse[1], Ramona Sylvester[2], Roman Gonzenbach[2], Olivier Lambercy[1,3], Christoph M. Kanzler[1,3]*

Abstract— **Upper limb rehabilitation outcomes in persons with multiple sclerosis (pwMS) are highly variable, highlighting the need for quantitative models predicting therapy outcomes and accordingly personalizing therapy content and intensity. In this work, we define and validate a machine learning-based model for predicting rehabilitation outcomes in 89 pwMS by relying on multi-modal data collected at the admission of a 3-week inpatient rehabilitation program. Based on a random forest model, we could accurately predict Box and Block Test outcomes with a cross-validated root mean squared error of 6.3±4.0 blocks.min^{-1}, which is well below the minimal detectable change of the clinical scale. This provides the basis for stratifying pwMS into subgroups receiving dedicated, optimized rehabilitation protocols.**

I. Introduction

Persons with multiple sclerosis (pwMS) often present with upper limb impairments that negatively affect their independence. While rehabilitation programs promise to improve upper limb function, therapy outcomes remain highly variable [1]. An accurate prediction of rehabilitation outcomes in pwMS should help to optimize the allocation of therapy content and resources. A previous pilot study in 11 pwMS indeed suggested that multi-modal data, collected before rehabilitation, and machine learning (ML) can be used for predicting binary rehabilitation outcomes [2]. Building upon this preliminary work, we aim to develop and validate a more representative and sensitive regression-based ML model for the prediction of rehabilitation outcomes in pwMS.

II. Methodology

PwMS underwent a comprehensive assessment battery before and after a 3-weeks neurorehabilitation program at the Rehabilitation Center Valens (Valens, Switzerland). The assessments included clinical scales, such as the Box and Block Test (BBT), the Functional Independence Measure, the Expanded Disability Status Scale, and grip strength, as well as a technology-aided assessment, the Virtual Peg Insertion Test, providing ten digital health metrics (M1-10) on upper limb movement patterns and hand grip forces [2]. In addition, standard clinical data such as chronicity, gender, age, and type of MS were obtained. If possible, both body sides were tested. In total, 18 measures, collected at admission to the clinic, were used as independent variables for a Random Forest regression model predicting outcomes of the BBT (dependent variable) at discharge from the rehabilitation program. During training of the model, class balance was restored using minority oversampling. The accuracy and generalizability of the model was evaluated using a leave-one-out cross-validation and compared to the minimal detectable change (MDC) of the BBT (8.11 blocks.min^{-1}) [1]. Procedures were approved by the local ethics commission.

III. Results & Discussion

We obtained 165 observations from 89 pwMS (62 female, 52±11 age, 55±11 blocks.min^{-1} for BBT admission). Rehabilitation outcomes were highly variable, with only 30 observations indicating BBT improvements beyond the MDC. The cross-validated root mean squared error for predicting BBT outcomes based on data collected at admission was 6.3±4.0 blocks.min^{-1} (Fig. 1A), thereby being well below the MDC of the clinical scale. However, the prediction error moderately increased with larger changes in BBT during rehabilitation ($r=0.43$, $p<0.05$). The most important predictor was the admission BBT score (Fig 1B).

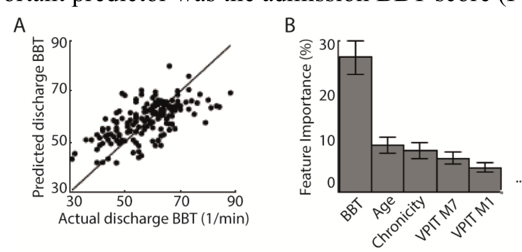

Fig. 1: Predicted and actual BBT at discharge (A) and feature importance (B).

This study demonstrates that regression-based ML can be used to predict upper limb rehabilitation outcomes in pwMS with data collected before the intervention. Further work is warranted to improve the accuracy for pwMS exhibiting large changes between discharge and admission, and to include therapy parameters in the model, thereby promising the implementation of in-silico clinical trials.

Acknowledgment

This research is supported by the National Research Foundation, Prime Minister's Office, Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.

References

[1] Lamers, I. et al. (2014) 'Upper limb assessment in multiple sclerosis: A systematic review of outcome measures and their psychometric properties', Arch Phys Med Rehabil, 95(6), pp. 1184–1200.
[2] Kanzler, C. M. et al. 'Personalized prediction of rehabilitation outcomes in multiple sclerosis: a proof-of-concept using clinical data, digital health metrics, and machine learning', Med. Biol. Eng. Comput., under review.

[1]Rehabilitation Engineering Laboratory, Department of Health Sciences and Technology, ETH Zürich, Switzerland. [2]Rehabilitation Center Valens, Valens, Switzerland. [3]Future Health Technologies, Singapore-ETH Centre, Campus for Research Excellence And Technological Enterprise (CREATE), Singapore. *Corresponding author: (christoph.kanzler@sec.ethz.ch)