Estimation of the clinical severity of Facioscapulohumeral Muscular Dystrophy (FSHD) using smartphone and remote monitoring sensor data

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Introduction

The slow and variable disease progression of Facioscapulohumeral muscular dystrophy (FSHD) makes the development of new treatments highly dependent on validated biomarkers that can quantify disease progression and response to drug interventions. Drug development for FSHD is expected to benefit from reliable behavioural biomarkers that can quantify the effects of (pharmacological) interventions remotely in real-time.

The objective of this study is to build a model that can identify relevant remotely monitored biomarkers that to estimate FSHD clinical severity.

Feature Category	FSHD Clinical Score	TUG
Acceleration		98% Top Acceleration Magnitude
Activity		Soft Activity Duration Moderate Activity Duration Total Steps Per Day Max Steps Per Hour Mean Steps Per Minute
Smartphone Apps	Time Spent on Tool-Related Apps (e.g. voice recording, notepads)	Number of Interactions with Social and Communication Apps
Biometric	Diastolic Blood Pressure	
Demographic		Age
Heart Rate	Percentage of Time Spent in Resting Heart Rate State	
Location	Time Spent at Health Location Time Spent at Commercial Location Time Spent at Social Location Time Spent at Leisure Location	Time Spent at Health Location
Sleep		Awake Duration Number of Aware Periods During Sleep
Social	Number of Unique Numbers Called/Called From Total Call Duration Number of Missed & Outgoing Calls	Number of Incoming Calls Total Call Duration

Table 1: Most predictive smartphone and wearables features for estimating FSHD Clinical Score and for estimating TUG in FSHD patients.

Methods

38 genetically confirmed FSHD patients were enrolled in this study. The FSHD Clinical Score and the Timed Up-And-Go (TUG) test were used to assess FSHD symptom severity at the first and last day of the trial. The remote sensor data were collected using an Android smartphone, smartwatch, smart scale, and blood pressure monitor for 6 continuous weeks.

We created two single-task regression models, one for each clinical assessment and one multi-task regression model that would estimate both clinical assessments simultaneously. For all models, linear regression, random forest regressor, and gradient boost regressor were used. For the feature selection, we compared two methods, stepwise regression and Variance Inflation Factor (VIF). The performance of the different feature selection strategies and regression models were compared. Each model was validated using 5-fold cross validation.

Results

The single-task regression models achieved an R^2 (variance explained) of 0.57 and 0.59 when estimating FSHD Clinical Score and TUG, respectively. Table 1 provides an overview of the most predictive features for the FSHD Clinical Score and TUG single-task models. The multi-task model achieved an R^2 of 0.74 and therefore outperformed the single-task models in estimating clinical severity. Fig 1 illustrates the prediction error plots for each of the predicted clinical scores for each of the regression models.

Conclusion

This study has demonstrated that remotely monitored digital biomarkers can be used to estimate FSHD symptom severity outside the clinic. Specifically, features related to physical activity, location and social activity performed were selected as predictive features. These findings warrant validation of home-based behavioral biomarkers for supporting the development of novel (pharmacological) interventions for the treatment of FSHD.

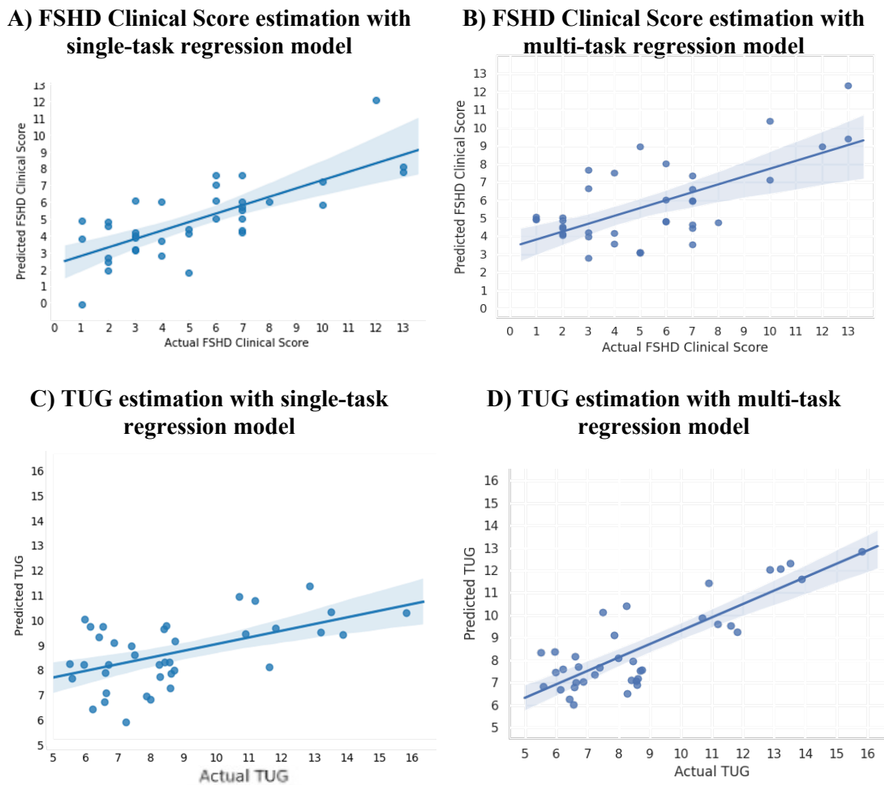

Figure 1: Comparison of the true FSHD Clinical Scores and TUGs against the estimated scores of the single and multipl task models. The blue band represents the 95% confidence interval of the mean.