



## AI Classification of MS Disability with the Utilization of a Mobile App

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### Abstract

**Background:** Lack of access to MS specialty care, exacerbated by the COVID-19 pandemic, has prevented many patients suffering from Multiple Sclerosis (MS) and other neurodegenerative diseases from receiving timely in-person care, resulting in less optimal care. As a result, there has been an increased adoption of remote patient monitoring, often employing machine learning as a tool.

The BeCare MS Link mobile app collects quantitative measurements of neurologic function as users perform different activities on the mobile app. The app was designed to monitor changes in neurologic function and patient-reported symptomatology. The intention is for the app to serve as a remote equivalent of the Expanded Disability Status Scale (EDSS) and other standard clinical metrics of MS progression.

**Methods:** In total 26 subjects were enrolled in the study over a period of 6 months. The study was concluded early because of the COVID-19 pandemic. Our research compiled MS disability categorizations of 15 subjects obtained by the BeCare MS Link MLA (Machine Learning Algorithm) and by 2 MS neurologists at Yale New Haven Hospital MS Clinic. The machine learning inputs were derived from data collected by specialized mobile app activities incorporated into the BeCare MS Link app.

**Results:** Each participant was categorized by their Clinical EDSS score into one of these categories: Normal (<1.0), Mild (1.0- 3.0), Moderate (3.5 – 6.0) or Severe [6.5 – 9.0]. These clinical classifications were compared to MLA classifications that were obtained using only BeCare MS Link-derived data corresponding to each subject's visit. To increase the number of available data points, subjects were evaluated in an initial study visit and at a follow-up visit at least three months later. Of the 26 enrolled subjects, 15 subjects complied with the study protocol at the time of their initial visit by using the BeCare App with sufficient frequency and completing sufficient activities to generate MLA-calculated EDSS classifications. Seven of the 15 initial study visit subjects returned for a second visit as part of this study. The study population included 15 patients, between the ages of 39-72 years old, and with 13/15 being female.

The clinical categorization of disability as normal, mild, moderate, and severe were compared to the BeCare MS Link categorization. The clinical and BeCare MS Link categorizations were in perfect agreement 86% of the time. BeCare MS Link categorization differed from the clinical categorization by no more than 1 category (e.g. Mild instead of Normal or Moderate) in 100% of assessments. The EDSS score difference between clinician calculation and BeCareLink machine learning (MLA) was less than one point 91% of the time and less than 1.5 points 95% of the time.

**Conclusions:** The BeCare MS Link categorization of MS patients as having no disability or mild, moderate, or severe disability and the calculation of EDSS demonstrated high correlation to clinical categorization of disability in MS patients.

**Keywords:** Machine Learning; Evaluation; MS Patients; COVID

## Introduction

The increasing shortage of doctors in general practice and neurologists, in particular, is greatly limiting access of MS patients to specialists. Such lack of access is accentuated by transportation issues and financial concerns and most significantly by the COVID-19 Pandemic. The need for remote assessments of neurologic function has never been more compelling. Quantitative assessments of cognition, sensory and motor functions are central to clinical decision making for patients with MS. The Expanded Disability Status Scale (EDSS), performed in clinic by a MS specialist, is the current gold standard of metrics for MS. There are other measures such as the Timed-Up-and-Go and neuroophthalmological testing that improve monitoring of MS patients further. However, there are limitations to the clinically derived EDSS as there is significant interrater variability in the assessment and calculation, reducing the utility of this measure of disability.

BeCare Link was developed in response to the glaringly delayed diagnosis and detection of progression of MS due to lack of access to specialty care, which results in poor clinical outcomes. The BeCare MS Link app has been designed to quantify neurologic function, enhanced by Machine Learning and AI. The goal was to create a remote tool with excellent user-experience to increase patient compliance for evaluation of the symptomatology and neurologic function of patients with MS. The intent was to not only become a digital equivalent for the EDSS, but to also incorporate other measures of neurologic function particular to MS patients which would result in an even more robust evaluation than the EDSS alone. Further, given the greater quantification by the accelerometer and gyrometer in the mobile phone and the lack of interrater variability, we aim to produce an even more accurate EDSS and an overall snapshot of neurologic function at different points in time.

BeCare MS Link collects data as users complete different app-provided activities measuring different functional neurologic systems such as cognition, gait, cerebellar function, vision, and ambulation. This data is then analyzed by several MLAs that collectively produce an EDSS. The primary objective of this study was to demonstrate a convergence validity between the BeCare MS Link and the clinician designation of patients' disability as normal, mild, moderate, or severe. The secondary objective was to explore the correlation between BeCare MS Link's calculated EDSS with the EDSS calculated by the clinician.

## Methods

Each participant was categorized by their Clinical EDSS score into one of these categories: Normal (<1.0), Mild (1.0-3.0), Moderate (3.5 – 6.0) or Severe [6.5 – 9.0]. These clinical classifications were compared to MLA classifications that were obtained using only BeCare MS Link-derived data corresponding to each subject's visit. To increase the number of available data points, subjects were evaluated in an initial study visit and at a follow-up visit at least three months later. Of the 26 enrolled subjects, 18 subjects complied with the study protocol at the time of their initial visit by using the BeCare App with sufficient frequency and completing sufficient activities to generate MLA-calculated EDSS classifications. Seven of the 15 initial study visit subjects returned for a second visit as part of this study. The study population included 18 patients, between the ages of 39-72 years old, and with 13/15 being female.

Our study compared the categorization of disability in MS patients into the categories of normal, mild, moderate, and severe based on ranges of EDSS scores derived from the BeCare MS link app to EDSS scores calculated by clinicians from neurologist assessment and compared the exact EDSS score calculated by clinicians with the EDSS score calculated by BeCareLink AI for a cohort of 15 patients diagnosed with MS. The trial is registered on ClinicalTrials.gov as Validation of the BeCare Multiple Sclerosis Assessment App (<https://classic.clinicaltrials.gov/ct2/show/NCT04288011>).

## Inclusion and exclusion criteria

The inclusion criteria consisted of patients aged 18 to 75 years with clinically definite MS based on the revised McDonald criteria (Spain, et al). Included patients had normal, mild, moderate, or severe disability in one or more of the modalities assessed by the BeCare MS Link app and a baseline clinically-derived EDSS score of 0.0 to 6.5, understood and spoke English, and provided informed consent. Patients were excluded if they had a clinically derived EDSS score higher than 6.5, were unable to provide consent, had congenital or traumatic loss of index finger or thumb, had impaired mobility or function owing to rheumatologic or other illnesses, or had neurologic impairment due to an illness other than MS.

## Informed consent

The details of the study protocol were reviewed with each patient and all questions were addressed. If a patient agreed to enroll in the study, an informed consent form was signed. The

informed consent was kept in a study binder and a digital copy was made and stored on a secure server in compliance with the Health Insurance Portability and Accountability Act.

**Assessments**

Patients were evaluated by one of two MS neurologists at the Yale MS Center and a clinically derived EDSS score was obtained. Additionally, patients were trained by clinical research assistance to use the BeCare MS Link app on their mobile devices and obtained their first set of scores by completing enough app assessments. The BeCare MS Link app assessments included: Arm Elevation, Path, Transcription Test, Contrast Sensitivity, Timed 25-Foot Walk (T25-FW), 6-Minute Walk, Time Up and Go (TUG), Tap Task, Stroop Test, Code Test and Memory Test. The composite of this data measured motor mobility, fine motor function, upper extremity coordination, auditory comprehension, ambulation, color blindness, cognitive function, memory, reaction time, information processing speed and vibration sense.

The app-based assessments were designed to correspond to testing routinely performed on a standard neurologic exam. The app uses the accelerometer, gyroscope, and magnetic sensor in

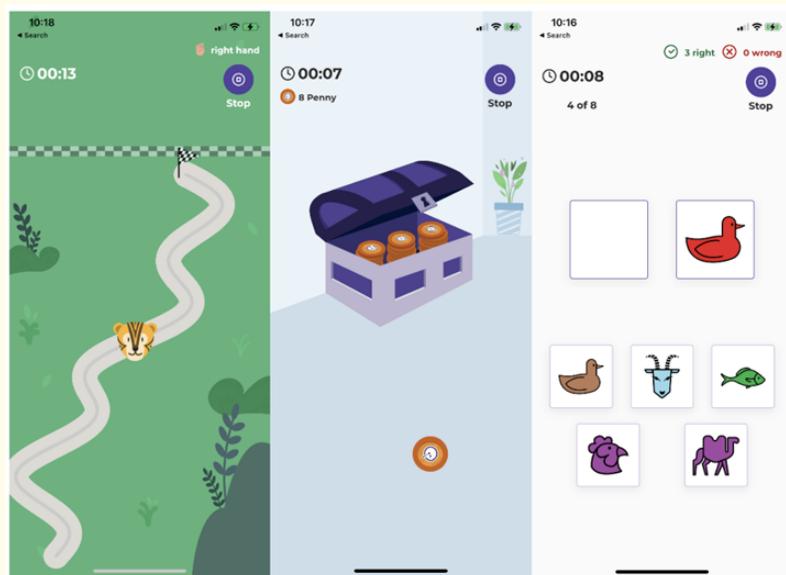
the patient’s phone to determine when they take a step, make a transition to a different position or orientation, and/or move their arms.

After an assessment was completed, the data was sent to the BeCare Link cloud via the mobile app. After the assessment data was stored in the BeCare Link cloud, the MLAs produced an app derived EDSS score if enough activities were included.

The app-derived EDSS scores were then used to categorize the patient’s disability as normal, mild, moderate, or severe and compared to the categorization by clinically derived EDSS scores.

**Statistical analysis**

An agreement between BeCare MS Link EDSS and MS Neurologist-derived EDSS is desired to make the claim that BeCare MS Link data may be used interchangeably with in-clinic assessments. A Bland-Altman analysis was identified as the most appropriate statistical tool to demonstrate whether agreement was achieved (Collins, et al). This tool provides a pictorial estimate of the differences between BeCare MS Link and neurologist derived EDSS scores and their 95% limits of agreement.

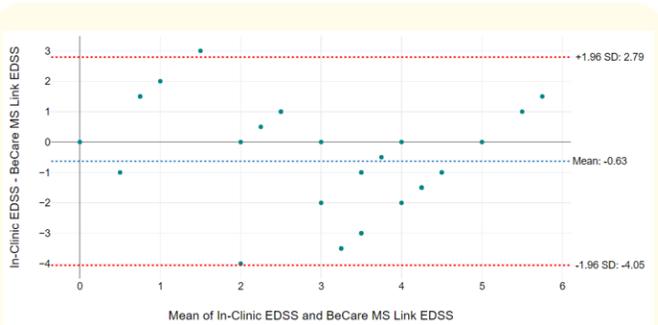


**Figure 1:** The BeCare MS Link mobile applications assesses functional system ability/disability through the use of gamified activities. Shown above are the Path (left), Tap (center) and Memory (Right) activities.

**Results**

BeCare MS Link and the in-clinic EDSS scores were translated into MS categories according to the following intervals

- Normal: EDSS <1.0
- Mild: EDSS 1.0-3.0
- Moderate: EDSS 3.5-6.0
- Severe: EDSS 6.5-9.0



**Figure 2:** This Bland-Altman Plot suggests that there is sufficient agreement between the BeCare MS Link and In-clinic EDSS scores to use them interchangeably, with all data points remaining [on or within] the limits defined by the 95% confidence intervals.

The In-Clinic categories were then compared to the BeCare MS Link categories, and both were in perfect agreement 86% of the time, with BeCare MS Link differing from the In-Clinic assessment by no more than 1 category (e.g., Mild instead of Normal or Moderate) in 100% of assessments.

	# of Subjects (N)	% of total N
<b>Exact Agreement</b>	16	86%
<b>Within 1 label</b>	30	100%
<b>Within 2 labels</b>	31	100%

**Table 1:** Category agreement between BeCare MS Link and in-clinic categorizations.

**Discussion**

The BeCare MS Link app can replicate the clinician’s categorization of disability and calculation of EDSS scores with a high degree of convergence validity. The percent agreement will surpass that of two clinicians, who average 1.5 points on the EDSS 85% of the time, because of the elimination of interrater variability (Francis, et al). Further, because more quantitative and objective data points are recorded by the BeCare MS Link app, it is conceivable that the accuracy will exceed that of repeated scoring by a single clinician.

The BeCare MS Link app is novel in its ability to measure neurologic dysfunction objectively, rather than relying on patient-reported symptoms, and in its use of MLAs to calculate EDSS scores that can mimic clinically derived EDSS scores. Additionally, the BeCare MS Link app can reduce the problematic interrater

variation between 2 clinician assessments of the same patient, benefiting outcomes in clinical care as well as in clinical trials.

Importantly the increased patient access to quantifiable assessments that can be performed at home via a mobile app will result in greater patient compliance of seeking follow-up evaluations and a greater amount of data tracking neurologic function to direct patient care. The BeCare MS Link’s MLAs can detect subtle changes in patient performance that may elude physicians and even patients themselves. The result can be earlier intervention with improved patient outcomes. This is increasingly important as our therapies improve because more patients have a disease course characterized by gradual progression rather than the historically more prevalent relapsing-remitting course. The BeCare MS Link measurements make possible the study of the relationship between real-time assessments, such as medication changes, dietary changes, and rehabilitation, with changes in the BeCare MS Link-derived EDSS score over time.

This study does have limitations. Despite confirming the equivalence of clinically derived and app-derived categorization of degree of disability, several app-based assessments were excluded from the final analysis because many patients did not complete app-based assessments due to time constraints. Additionally, because of the pause placed on studies during the pandemic, the cohort number is small. In future studies, we hope to have a greater number of subjects performing all activities on a longitudinal basis to prove that the BeCare MS Link app can reflect clinical changes over time that are found by their clinical assessments. Finally, in future studies, we intend on including greater numbers of patients in each of the categories of disability severity [1-11].

**Conclusion**

The potential ramifications of using the BeCare MS Link app are profound. First, patients will have greater access to assessment of their neurologic function which will inform them and their physicians when treatment modifications need to be made. Secondly, as approximately 75% of MS patients are treated by primary care doctors, the BeCare MS Link app can act as a tool for non-neurologists to make informed and data-based treatment decisions. Third, the use of the app remotely or advanced practice providers can result in significant cost savings to society. Fourth, the BeCare MS Link app can be used in clinical trials, helping new drugs come to the market more expeditiously and at less expense, unencumbered by the interrater variability that plagues multi-center trials. Most importantly, by empowering patients to partner with their physicians in collecting and analyzing data on their clinical function, patient outcomes will improve.

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