Quantifying Electric Powered Wheelchair Users' Driving Skills using an Inertial Measurement Unit

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Introduction: Electric Powered wheelchairs (EPWs) are key assistive technology devices that encourage safe mobility and social participation of people with disabilities. Proper EPW driving skills allow users to navigate different environments and promote independence. However, evaluating EPW users' driving skills in the clinic has been a challenge due to the lack of objective measures that can quantify differences in skills between drivers and provide evidence-based training that can improve EPW driving skills. The aim of this pilot work is to (1) evaluate the feasibility to gather objective movement data from the EPW and (2) evaluate the content validity of quantitative variables from the movement data to serve as objective driving metrics of EPW users' driving skills.

Materials and Methods: A driving course was constructed in a laboratory space consisting of 9 different driving tasks from the Power Mobility Clinical Driving Assessment (PMCDA) tool, an EPW driving evaluation tool commonly used to evaluate driving skills in the clinic. Tasks included common maneuvers performed by EPW users such as driving forward, driving backward, turning 180 degrees in place, turning left and right while driving forward, turning left and right while driving backwards, and driving up and down a 6° incline. The dimensions of each task were defined according to the Standards for Accessible Design by the Americans with Disabilities Act. Three researchers without disabilities drove a front-wheel drive EPW through the obstacle course, five times each. A physician administered the PMCDA using standardized verbal commands to indicate the beginning and end of each task. The driving trials were audio and video recorded for review. An inertial measurement unit (IMU) embedded with 9-axes motion sensors (UDOO NEO Extended, Freescale®, USA) was placed on the frame of the EPW to collect acceleration and angular velocity data at a sampling frequency of 100Hz (Fig.1a). A binary signal generated by a toggle switch was delivered to the UDOO board via Bluetooth from an application on the physician's Android phone to indicate the beginning and end of each task in the raw data in-sync with the verbal commands. This data was then processed in Matlab® using a low-pass filter to plot graphs and compute variables representative of the movement of the EPW for each task. Three researchers familiar with signal processing and EPW mobility evaluated the processed data independently in order to identify variables that were clinically meaningful for each task. A percent agreement between the three researchers was computed for each variable. Variables that had 100% agreement for a task were identified to serve as objective driving measures for that particular task.

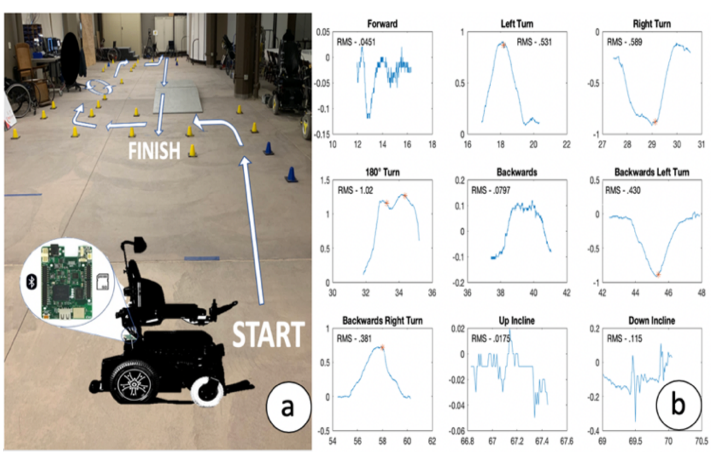

Fig.1: A graphical illustration of the data collection protocol; 1a: Driving course illustrating path of driver; 1b: Angular velocity in the z-axis (upward) direction of one participant

Results and Discussion: The three researchers (Ave. age: 28 ± 7 Yrs.) had varying levels of experience driving an EPW (0-10Yrs). The UDOO was successful in gathering raw data for all the tasks without any attrition. Task time, velocity, jerk, root mean squared (RMS) deviation, Min. & Max. peaks computed using change in acceleration and angular velocity data from the Z-axis (forward) were in 100% agreement among the researchers. The number of distinct peaks in a task closely matched the smoothness of the turn, and a lack of marked peaks indicated a straight path of motion (Fig.1b: Compare forward to left turn). For straight tasks, the RMS can then be used to determine how well the driver maintained a linear path.

Conclusions: This pilot protocol demonstrated the feasibility to gather movement data of an EPW from an IMU and establish content validity of the objective driving metrics. Further studies will be conducted in a clinic to gather larger datasets that can identify patterns representative of novice, moderate and expert users, which can enable development of novel training programs.