Assessing Improvement of Powered Wheelchair Driving Skills Using a Data Logging System

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ABSTRACT

There is currently no standard to determine if a powered wheelchair (PW) user is a safe and efficient driver. In this study, five new PW users were trained for three sessions, based on the Wheelchair Skills Training Program, and their driving skills were evaluated before and after training using the Wheelchair Skills Test (WST). Further, execution time and number of joystick movements during a subset of the WST tasks were computed using inputs from a 3D accelerometer and 2D gyroscope positioned on the PW and signals from the joystick controller. Performance-based measures were averaged over 5 trials. After training, all five participants displayed an improvement on the WST, while only three showed a global increase in number of joystick movements and decrease in task completion time. Thus, the other two participants may have increased their WST score by learning to drive more slowly and carefully.

KEYWORDS

Powered wheelchair, wheelchair skills, training, assessment, monitoring system

BACKGROUND

Powered wheelchairs (PW) are an essential tool for individuals with impairments to help them maintain their mobility and quality of life. Training is an essential component of PW service delivery, so that users can learn to properly operate their mobility device (1-3). This is important in order that PW users may learn how to navigate in various environments while avoiding collisions, as well as injury to self or others (4,5). Training may also improve satisfaction with the wheelchair and decrease abandonment (2,6). Various studies, however, have shown that both clinicians and PW users often deem training as incomplete (7-9). One possible explanation is that there currently exists no standard to determine if a PW user is safe or unsafe (5,7,9). In order to obtain such standards, it may be necessary to develop new assessment methodologies, based on the objective measurement of PW driving skills. Data logging systems, that record movement of the PW with sensors such as accelerometers (10,11), can be used to obtain such objective measurements that may complete questionnaire-based assessments. This approach may be helpful in providing a complete picture of PW use and skill level (12).

RESEARCH OBJECTIVE

The aim of this study was to determine if the objective measurements from a data logging system could be used to detect a change in PW driving skills, following three training sessions based on the Wheelchair Skills Program (WSTP) in a group of new PW users.

METHODOLOGY

Participants and Experimental Procedure

Five adult PW users were recruited for the study. Participants had less than three months of PW driving experience; they used rear-wheel traction PW with a standard joystick. During a first visit, participants underwent an initial evaluation of their PW skills. This was followed by three one-hour training sessions during a two-week interval. Training was individualized, following the guidelines of the WSTP, version 4.1 (13). PW skills were then evaluated during a final visit.

Measurements

PW skills were assessed using version 4.1 of the WST (13). The WST is a clinical and research assessment that measures both skill performance and safety in various mobility-related tasks, such as basic operation of the PW, manoeuvring and control of the wheelchair, as well as some functional tasks such as transfers and picking up objects.

In addition, some of the skills of the WST involving manoeuvring of the PW where repeated five times, while control of the joystick and motion of the chair were recorded using a data logging system (14). These tasks included: 1) driving backwards over a 5m distance; 2) 90 degree turns (left, right, forward and backwards); 3) 180 degree turns within the limits of a 1.5m square; 4) opening a door, moving through and closing the door; 5) moving sideways, from one wall to another, inside limits of a 1.5m square.

The data logging system consisted in an accelerometer/gyroscope module, as well as signals from the two axes of the joystick controller. Data were sampled at 200 Hz on a tablet PC placed inside a backpack that was attached to the PW. A second tablet PC was used as a remote display to control data collection. We also recorded errors performed by participants during those tasks; an error was defined as hitting a wall or crossing of a limit indicated on the floor.

Data Analysis

We calculated the excursion of the joystick from its center position using the vector norm of the x and y displacements. From this signal, we identified the total time needed to execute each skill. We calculated the number of joystick movements by determining the number of times, during a trial, where the excursion passed a threshold of 5% (Fig. 1).

WST Total Percentage Scores (skill and safety), number of errors, as well as mean execution time and mean number of joystick movements for each of the manoeuvring were compared before and after training. Because of the small number of participants, only a descriptive analysis was performed.

RESULTS

PW skills, as measured by the WST Total Percentage Scores (skill and safety), increased in all five subjects following training (Table 1). Mean scores for the skill performance and safety components of the WST, respectively, where 97 and 97% after training, compared to 85 and 83% before training. The error rate during the recorded PW manoeuvring trials (collisions or crossing limits) decreased from a mean of 19 to 12%. All the participants reported that the training sessions were extremely beneficial.

Figure 1 displays the signals from the data logging system recorded during the sideways manoeuvring task, for trials recorded before and after training. Comparisons indicate that the

	WST Skill		WST Safety		Errors	
Participant	**Before**	**After**	**Before**	**After**	**Before**	**After**
P1	86.7%	100.0%	86.7%	100.0%	10.2%	8.9%
P2	73.3%	93.3%	73.3%	93.3%	21.3%	17.1%
P3	86.7%	93.3%	83.3%	93.3%	30.2%	14.9%
P4	83.3%	100.0%	80.0%	100.0%	14.3%	7.5%
P5	93.3%	100.0%	90.0%	100.0%	17.9%	9.8%

Table 1: WST scores and error rate before and after training

task completion time was shorter for the trial after training. Control of the joystick during that task was also characterized by fewer and smoother joystick movements.

Average task completion time and number of joystick movements are shown on Figure 2, for two of the participants. For participant #5, task completion time and number of joystick movements decreased in all the recorded tasks following training. For participants #2, results were equivocal, generally displaying an increase in task completion time and in quantity of joystick movements. After training, three of the participants showed an overall improvement in task performance as measured by joystick control, while performance decreased or remained the same for two participants.

DISCUSSION AND CONCLUSION

The aim of this study was to verify that changes in PW driving performance following three training sessions could be observed using objective measurements from a data logging system.

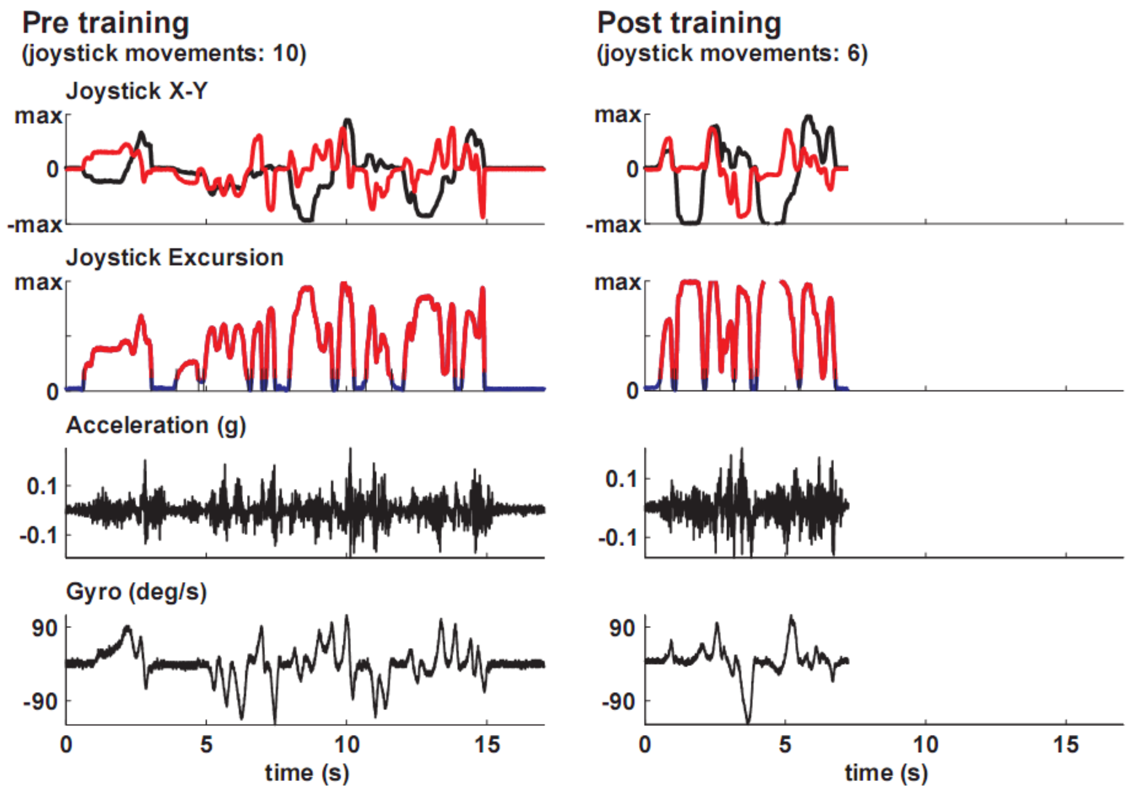

Figure 1: Data logging signals for one pre-training and one post-training trial, for

The results indicate that although all participants improved their WST Total Percentage Scores (skill and safety), changes in terms of driving performance, as measured by the data logging system, were more variable. While three participants displayed faster and smoother joystick control after training, driving performance decreased or remained the same for the other two participants.

While one must be careful about making conclusions based on a low sample, there are at least two explanations for the results of this study. The first is that the WST measures more than manoeuvring skills. A fourth of its items are related to knowledge of PW operation, such as how to turn on the wheelchair and how to select different speeds, which cannot be recorded by the data logging system. However, an examination of the WST assessment results revealed that all subjects failed some of the manoeuvring items during their first evaluation, which they then performed adequately at the final evaluation. The second explanation is that some participants may have improved their WST scores by driving more carefully, in order to avoid colliding with obstacles. This hypothesis is supported by the fact that the two participants who initially displayed the highest rate of error (P2 and P3 in Table 1) where the ones showing an increase in task completion time following training. If that is the case, then it would mean that they

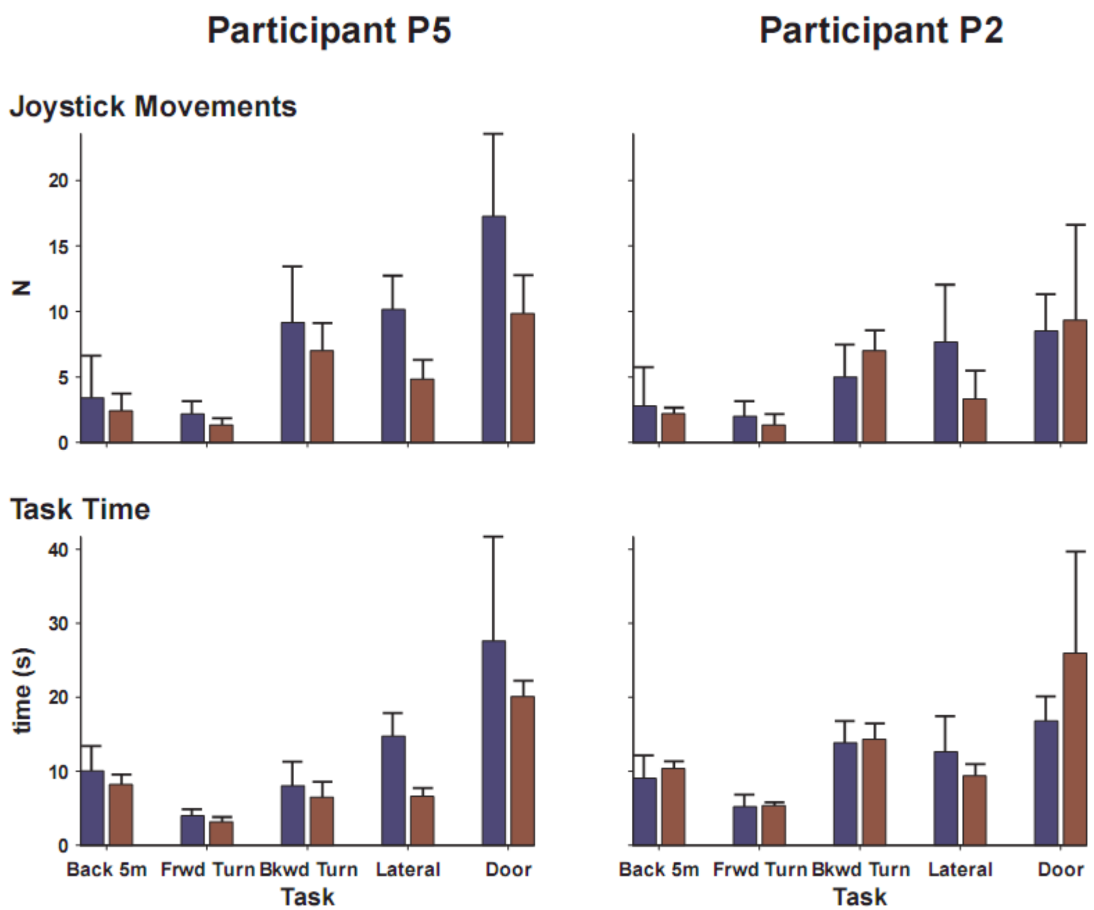

Figure 2: Change in number of joystick movements and task completion time for two participants, before training (blue bars) and after training (red bars).

increased their awareness of their surroundings, and that learning how to drive a PW may not be linear and does not necessarily lead to an improvement in effectiveness, at least in the initial stages of training. Increased awareness leads to more choices or perceived constraints in terms of planned actions, which increases reaction time (15).

It is also unknown whether the gains in either awareness or effectiveness are only to be observed in the context of a clinical assessment, or if these translate to real-life use. Our data logging system has been developed in order to allow the long-term monitoring of PW use (10,12). One objective is to quantify PW safety during daily activities using signals from the data logger, which will be critical in assessing the transfer of driving skills training.

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