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Original Article

Joystick-controlled video console game practice for developing power wheelchairs users' indoor driving skills

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Abstract. [Purpose] This study aimed to determine the effectiveness of joystick-controlled video console games in enhancing subjects' ability to control power wheelchairs. [Subjects and Methods] Twenty healthy young adults without prior experience of driving power wheelchairs were recruited. Four commercially available video games were used as training programs to practice joystick control in catching falling objects, crossing a river, tracing the route while floating on a river, and navigating through a garden maze. An indoor power wheelchair driving test, including straight lines, and right and left turns, was completed before and after the video game practice, during which electromyographic signals of the upper limbs were recorded. The paired t-test was used to compare the differences in driving performance and muscle activities before and after the intervention. [Results] Following the video game intervention, participants took significantly less time to complete the course, with less lateral deviation when turning the indoor power wheelchair. However, muscle activation in the upper limbs was not significantly affected. [Conclusion] This study demonstrates the feasibility of using joystick-controlled commercial video games to train individuals in the control of indoor power wheelchairs.
Key words: Joystick, Video games, Power wheelchair

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INTRODUCTION

Power wheelchairs (PW) are essential for many individuals who have mobility impairments and locomotion restrictions. Those who benefit from power wheelchairs improve and satisfy their functionality, increase participation in healthcare, education and social activities[1]. Most wheelchair use occurring at home in a limited space is vulnerable to collisions[2, 3]. To use power wheelchairs safely and effectively, skill-training for the wheelchair user has been recognized as an important component of power wheelchair provision[4, 5], and learning in an indoor environment is critical for wheelchair driving. A series of driver skill-training sessions for power wheelchair users was conducted by the Kirby and Mountain Group in which wheelchair-skills assessment and training was given to teach power wheelchair driving skills to long-term wheelchair users as well as subjects suffering from stroke[6–8].

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Training for power wheelchairs is usually practiced in realistic situations, to avoid leaving inexperienced users susceptible to collisions and other accidents. As Jipp noted, PW users' aiming, precision, and arm/hand speed contribute significantly to both safety (numbers of collisions) and efficiency (time required to reach certain goals); i.e. those with lower fine motor abilities have more collisions and require more time to reach certain goals[9]. Performance in the driving of power wheelchairs, as Massengale reported, is strongly associated with visual perception, ocular motor function, stereo-depth perception, and alertness to the environment[10]. Virtual reality programs have been developed for training driving skills to improve the use of a mobility device[11]. In a 90-second session of 3D immersion video game training, 10 of 13 participants with mild-to-moderate brain injuries showed improvements in game performance time and precision, and arm movement through adaptation of arm-postural coordination strategies, and also displayed an immediate increase in arm forward reach and single-leg stance time[12].

Power wheelchairs are commonly operated using a joystick similar to those used by video game consoles. The provision of contact and interaction to facilitate object manipulation is an important strategy for nurturing learning performance[13]. Computer gaming develops skills such as decision-making, resource management, visual acuity, memory, and motor skills[14]. Hungspreugs and Poon designed computer games specifically to develop skill in using joysticks, including “Catch the Butterfly” and “Bump & Go”[15]. Children in particular could learn how to operate a joystick prior to trying a power wheelchair, while simultaneously having fun. A variety of games that use joysticks are available for computers or video game consoles, making them cost-effective and user-friendly. This study sought to overcome the lack of research on whether commercial video console games can provide effective practice in joystick control in preparation for driving an indoor power wheelchair. Moreover as our previous study showed, the muscle effort needed for driving an indoor power wheelchair is an important issue for clinicians and could be useful as a reference for prescription. Thus, the purposes of this study were to determine whether the subjects who played joystick-controlled video console games showed better performances in indoor driving a power wheelchair, as well as greater muscle activity in the upper limbs during driving.

SUBJECTS AND METHODS

A convenience sample of healthy young adults was recruited with the inclusion criteria that the participants had no prior experience in the use of power wheelchairs or the specific video console games. Individuals with orthopaedic or neurological disorders that might have influenced joystick control were excluded from this study. All the subjects were self-reported as right-handed. The Institutional Review Board of Chang Gung Medical Foundation, Taiwan, approved this study and written informed consent was provided by each subject.

A joystick modelled as a toy doll, in which there are four built-in commercial video console games (©2006, JAKKS Pacific, Inc., Malibu, CA, USA), was used for joystick training in this study. Activities in these games included: attempting to cross a river, floating a boat on a river, catching objects falling from the second floor, and a maze. The games test medio-lateral control through catching falling objects and crossing a river, as well as forward movement by tracing the routes while floating on the river or navigating through the garden maze. A projector was used to display the games on the wall. The joystick could be operated in four directions, forward, backward, left and right, similar to the typical joystick control for a power wheelchair. The power wheelchair (EB-2111, Comfort Co., Taiwan) used in this study to test driving performance is equipped with a conventional right-hand short-handle joystick.

A Bluetooth telemetric EMG system (DELSYS® Trigno™ Wireless EMG System) was used to record the muscle activities of the upper limbs (biceps brachii, BB; triceps brachii, TB; flexor carpi radialis, FCR; and extensor carpi radialis, ECR). EMG electrodes were placed 2 cm proximal to the distal tendon and parallel to the muscle fibre of the biceps brachii, midway between the posterior fold of the axillar and lateral epicondyle of the humerus of the triceps brachii, 5 cm from the medial epicondyle along the longitudinal axis of the forearm for the flexor carpi radialis, one-third of the distance from head of the ulna to the olecranon of the wrist and finger extensor muscles, and over the left wrist ulnar styloid for the extensor carpi radialis[16]

Data were acquired at a sampling frequency of 1,000 Hz. Analogous signals were processed using a differential amplifier (bandwidth = 50–500 Hz, input impedance = 1 GΩ, common mode rejection ratio = 95 dB at 60 Hz, and gain = 1,000). The mean RMS value was normalized using recordings of maximum voluntary contraction (MVC). Prior to the experiment, the MVC of each muscle was obtained using a procedure in which each subject performed two 5-second MVCs at a 90° elbow angle with a 45-second rest period between contractions.

The driving test in this study was performed in a rectangular indoor space (6.60 m × 5.10 m), a driving route of 5-meter straight lines and right/left turning points. The driving test required the participants to: (1) drive in a straight line, (2) perform a left turn, and (3) perform a right turn in a random order. A total of three trials were performed. Participants were encouraged to try to complete the course as quickly as possible. The experimental protocol was as follows: (1) EMG recording of MVC, (2) EMG recording at rest, (3) driving performance test with EMG recording, (4) joystick practice using four video console game programs in a random order, (5) driving performance re-test. The video console game practice was carried out for 10 minutes.

The lateral deviation during driving was determined as the average root mean square value of the perpendicular distance from the middle line of the test track, according to a laser marker recorded with a webcam. A webcam (QuickCam® Ultra Vision Logitech, Silicon Valley, CA, USA) and a laser pointer were installed beneath the seat of the power wheelchair at a height of 0.4 m from the ground in order to record the pathways driven in the tests in order to evaluate the deviation while driving. The software “Extra.Movie to Gif” was used to edit the laser recording at a 20 Hz sampling rate. The images were saved using Adobe Acrobat which has a built-in function to measure the lateral deviation distance which was converted to the root mean square value in Excel. Deviations were collected as performance measurements, and the time required to complete the task was included.

Statistical analysis was performed using SPSS for Windows 10.0 (SPSS Inc., Chicago, IL, USA). The means and standard deviations were the main descriptive measurements. The paired t-test was used to determine the significance of differences in performance measurements (practice time, completion time, driving deviation, and muscle activities of the upper limbs) before and after the joystick practice. Before using parametric testing, the assumptions of normally distributed data and homogeneity of variance were checked. Significance was accepted for values of $p<0.05$.

RESULTS

Twenty subjects (13 males and 7 females) between 19 and 21 years of age were recruited. All the participants completed the joystick practice as well as the indoor driving test. The results of the indoor driving test are presented in Table 1. The time spent turning and deviations in overall turning were reduced after joystick practice ($p<0.05$). However, no statistically significant change was observed in the activation of upper limb muscles after joystick practice.

Table 1. Driving performance and muscle activities of the upper limb (%MVC) before and after video game practice

	Straight			R turn			L turn		
Driving performance	Pre	Post	Effect size	Pre	Post	Effect size	Pre	Post	Effect size
Completion time (sec)	6.8±0.6	6.5±0.2	0.671	9.4±1.5	8.6±1.3*	0.570	8.7±1.0	8.2±0.8*	0.552
Lateral deviation (cm)	2.1±1.3	1.6±0.7	0.479	6.5±0.8	4.7±1.1*	1.872	6.1±0.8	4.4±1.1*	2.080
Muscle activity									
Biceps (%)	0.5±0.8	0.8±1.6	0.237	0.5±0.8	0.7±0.7	0.266	0.9±1.0	0.9±1.3	<0.001
Triceps (%)	1.6±1.8	2.7±4.8	0.303	3.8±5.7	4.2±0.5	0.099	4.1±5.8	4.8±8.1	0.099
Flexor carpi radialis (%)	5.8±4.3	5.5±5.1	0.064	7.3±4.8	9.6±9.5	0.306	13.5±9.2	13.8±10.2	0.031
Extensor carpi radialis (%)	4.1±3.1	3.7±2.5	0.142	6.0±5.3	5.9±3.7	0.022	4.8±3.0	3.9±2.9	0.305

* indicates a significant difference between pre- and post-practice

DISCUSSION

Commercial video console games are a feasible option for simulating the joystick manipulation required for driving power wheelchairs, as an alternative to training in the field for collision avoidance. The effectiveness of this approach was demonstrated by the reduction in driving deviation and time to complete left turns. However, muscular effort remained the same in the upper limbs after the training. Joystick manipulation skills learned while playing video games can translate to driving an actual power wheelchair, making this a viable approach to the training and assessment of performance in the use of power wheelchairs prior to on-site clinical practice.

The muscle activity during the driving test showed that the elbow extensors and the flexors of the wrist and hand contributed more to joystick control. When turning to the left, the flexors of the wrist and hand showed greater effort in control of the driving direction through wrist and hand flexion. The video console game practice was completed in just 10 minutes, which may have been too short to alter muscular activity. Future research should include kinematic measurements in conjunction with the recording of muscle activation to determine the smoothness of joystick operation. In addition, the EMG recording of the FCR and ECR may be measuring both wrist and hand muscles as the anatomical alignment is close.

This study had several limitations. First of all, this was a study with within-subject design since only novice young adults participated. We did not provide any control participants, who did not practice the video console games. In other words, the healthy individuals participating in this study demonstrated how visual attention, muscle activities of the upper extremity, and operation of an electric wheelchair are affected by practice of video games as a reference for further clinical assessment and planning of power wheelchair prescriptions in clinical settings. In the future, the results of this study could be used for comparisons with the performances achieved by patients with motor impairments who practice video console games.

The results of this study were also limited to immediate effectiveness. Therefore, to improve PW maneuverability in a real environment, a practice protocol should be devised for more systematic training. Moreover, a large-scale randomized clinical trial to evaluate the long-term effects of this kind of intervention practiced in multiple sessions on the driving performance of joystick maneuver is warranted. Furthermore, although the use of assistive devices has been reported for personal activities of daily living and mobility, the design of video games considering social participation is also desirable[1]. The concepts of client-centered task-oriented training[17] could also be applied to the development of video console games for personal activities of daily living and social participation.

Video console games are a popular recreational activity for both children and adults, and can be used to train the skills required to drive power mobility devices. Such practice might also benefit the elderly population who require power wheelchairs for mobility.

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