Tablet Technology for Rehabilitation after Spinal Cord Injury: a Proof-of-Concept

Gabriella FIZZOTTI¹, Carla ROGNONI²,³, Arianna IMARISIO⁴, Alessandro MENEGHINI⁴, Caterina PISTARINI⁴, Silvana QUAGLINI²

¹ Spinal Unit, Maugeri Foundation IRCCS, Pavia, Italy
² Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Pavia, Italy
³ Centre for Research on Health and Social Care Management (CERGAS), Bocconi University, Milan, Italy
⁴ Physiotherapy, Faculty of Medicine and Surgery, University of Pavia, Pavia, Italy

Abstract. Spinal cord injury (SCI) is a damage to the spinal cord resulting in a change, either temporary or permanent, in motor, sensory, or autonomic functions. Patients with SCI usually have permanent and often devastating neurologic deficits and disability. Trunk motor control is crucial for postural stability and propulsion after low thoracic SCI and several rehabilitative strategies are aimed at trunk stability and control. Tablet technology and gaming systems are novel and potentially useful strategies that apply relevant concepts in rehabilitation for these patients. In this study we combined the traditional training of trunk control with exercises administered through two iPad games apps, 2 or 3 times a week. All the participant patients showed increasing game scores during the treatment, as well as increasing Trunk Recovery Scale scores, showing a significant improvement in trunk control. Also the personal judgment of the patients, collected through evaluation questionnaires, was very positive.

Keywords. Spinal cord injury, tablet technology, rehabilitation

Introduction

Over the last few years tablet computers have become very popular, allowing several tasks to be done outside home or office. In many hospitals they start being used to access patients’ electronic medical records, X-rays and other diagnostic tests at bedside, and to search for information or make statistics without needing to seat at a workstation.

There are many tablet applications (apps) designed specifically for rehabilitation tasks, ranging from cognitive rehabilitation, speech acoustics, to purely motor activities. In general, apps can assist and motivate independently living and healthy older adults to autonomously perform strength-balance exercises [1], or implement new support systems for assisting elderly people communicating by telephone and e-mail [2]. Assistive technology performed by cell phones or tablet computers has been shown to increase functional independence of severely disabled individuals providing a mechanism to extend therapeutic practice beyond the traditional therapy days [3].

¹ Corresponding Author: Gabriella Fizzotti, Spinal Unit, Maugeri Foundation IRCCS, Pavia, Italy, Via Maugeri 4, 27100 Pavia, Italy, Gabriella.fizzotti@fsm.it
Among these possibilities we have considered those targeted for the rehabilitation of the motor control of the trunk in patients with tetraplegia or paraplegia after a spinal cord injury (SCI).

The strategies that a person with SCI must take in order to manage sitting position depend strongly on the level of the lesion and the residual motor capacity. As a matter of fact, SCI is extremely variably expressed with a transversality of symptoms and signs, with a demarcation, more or less evident, depending on the severity between the regions above and below the lesion [4]. Transversality is not only in terms of loss of muscle activation and strength, but also involves superficial and deep sensitivity.

Trunk instability is a major concern for people with SCI; it not only limits their independence, but also leads to secondary health complications such as kyphosis, pressure sores and respiratory dysfunctions. Since trunk motor control is crucial for postural stability and propulsion after low thoracic SCI, several rehabilitative strategies are aimed at trunk stability and control.

This paper describes a feasibility study of the introduction of a new modality to reinforce patients’ attitude toward trunk rehabilitation, transforming methodical therapeutic exercises in captivating and educational games performed with a tablet. The study is preliminary to a future clinical trial that will test the effectiveness of the game-based rehabilitation as a reinforcement of the traditional one. It is also the first step to promote a future rehabilitation project, self managed at home, in which the patient could verify its own improvements through the game results.

1. Methods

The extent of injury and the degree of trunk control have been estimated through ASIA (American Spinal Injury Association) Impairment Scale modified from the Frankel classification [5] and the recent Trunk Recovery Scale (TRS) [6] developed at Maugeri IRCCS Maugeri Foundation, respectively.

ASIA is defined by four categories: A (Complete) = no sensory or motor function is preserved in sacral segments S4-S5; B (Incomplete) = sensory, but not motor, function is preserved below the neurologic level and extends through S4-S5; C (Incomplete) = motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a grade <3; D (Incomplete) = motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a muscle grade >= 3; E (Normal) = sensory and motor functions are normal.

TRS specifically evaluates the trunk in patients with SCI. It aims at improving personalized physiotherapy and occupational therapy, by facilitating the monitoring of autonomy achieved during the rehabilitation process in both acute and chronic phase. This scale consists of a first section which contains patient demographics, the level and the date of injury and the use of the upper limbs. The second section contains specific evaluation items for the recovery of the trunk and each item has a different score: ITEM A considers the wheelchair model adopted by the patient, which could depend on the trunk control (score 0-2); ITEM B evaluates the passage supine-seated considering the use of the upper limbs and the management capacity of the lower limbs (score 0-6); ITEM C evaluates, ex novo, the passage sitting-supine and analyzes it as the previous item (score 0-4); ITEM D evaluates the static balance control in a sitting position and takes into account the help offered by the upper limbs (score 0-6); ITEM E evaluates
the dynamic equilibrium by sitting and the ability to decouple the upper limbs to perform multi-directional movements (score 0-4).

The total score (sum of the different items scores) ranges from 0 to a maximum value (22) depending on the patient’s performance and higher the score better the capacity of trunk control.

In this study we have evaluated 15 patients (12 males, 3 females, mean age 37 years, range 19-66 years) admitted to the Spinal Unit of IRCCS Maugeri Foundation in the period between February 2014 and September 2014. They were selected according to the following criteria: TRS minimum score of 2 for item D and E and ASIA grade ranging from A to C. In particular 12 out of 15 patients reported a complete SCI and the remaining an incomplete SCI (two ASIA B and one ASIA C).

Each patient received an individual rehabilitation program including traditional neurologic exercises and an innovative sequence of tablet games, related to his own functional abilities.

An Apple iPad 2 was used for the exercises; the device, in relation to the games used, exploits mainly two functions: KODAK Front (anterior) 640x480 VGA camera and a sensor of movement, namely capacitive accelerometer.

The iPad is placed in front of the patient at a variable distance (from 50 cm to 1.5 m) in vertical or horizontal position (depending on the game) with the front camera facing towards the patient; the camera captures the image of the patient and his/her movements, giving to him/her an immediate visual feedback.

The iPad games used in the rehabilitation program were “Ball Strike” and “Pop Flux”. In the first one the image of the patient appears on the screen and the objective is to hit moving coloured balls (red-large, blue-medium, green-small), avoiding gray or other coloured balls, moving the trunk, upper limbs, head and shoulders. Hitting coloured balls accumulates points (red: 1 point, blue: 2 points, green: 3 points), while hitting others objects reduces the total score. The game consists of 12 levels of increasing difficulty and the therapist decides how many levels the patient has to perform accordingly to the improvement obtained. A good strength and aerobic capacity are required to get to higher levels since the movements required are much more selective and faster and need adequate alertness.

In the “Pop Flux” game the image of the patient is projected on the screen and the objective is to blow soap bubbles that fall from the sides of the screen, avoiding and dodging bombs, rockets, knives and other objects. To play this game a good dynamic balance of the trunk, greater selectivity and speed of movement are requested.

Patients performed the two iPad games, with a frequency of 2 or 3 times per week before or after the standard rehabilitation treatment, for a period ranging from 3 to 12 weeks. The iPad applications have different grades of difficulty so that the patients could overcome them gradually, depending on the skills achieved during the hospitalization period. Traditional exercises for trunk control were not replaced by iPad games because they were considered preparatory.

At the end of the rehabilitation programme, all patients completed an anonymous questionnaire to evaluate their satisfaction with regard to the iPad games and an objective evaluation was performed. In particular, patients’ trunk control was evaluated comparing initial and final TRS scores and the scores obtained with iPad games. Correlations among the different parameters were also tested.
2. Results

Patients played iPad games for a mean time of 5 weeks. Concerning TRS, the study highlighted that 5 patients achieved improvements in item D and 8 patients in item E and for the latter the improvements were statistically significant (Paired sign test \( p=0.013 \)). The patients who didn’t show any improvement in trunk control have anyway maintained their motor ability preventing a possible worsening. These patients can benefit from training and regular exercises which help them to preserve their health in order to maintain the bodily control in general and in self-management situations.

![Figure 1. TRS item D, E and games scores.](image)

All patients increased significantly their game scores from the beginning to the end of the treatment (Wilcoxon paired test \( p=0.0006 \) for Ball Strike and \( p=0.001 \) for Pop Flux). This result may be due to different factors: 1) Improvement of patients’ ability to control the trunk as measured by the TRS and 2) Improvement due to increased familiarity with the games proposed. Figure 1 summarizes baseline and final scores distributions for both TRS items and games.

No statistically significant correlation was found neither between the age of the patients and the difference between final and baseline scores of the games nor between the age of the patients and TRS items E and D scores, showing no particular difficulties in performances for older patients with respect to younger ones. After few days of performing the new rehabilitation treatment, the patients “entered” in a different reality, finding strategies to deal with it. Each game had an exciting, relevant theme and was easy enough for most patients to understand how to interact with. Finally, each game was so sturdy that it could be played many times, without wearing out.
The personal judgment of the patients, collected through the evaluation questionnaire, was positive. In particular, 67% of patients self-reported considerable or sufficient improvement in trunk control and 53% of patients stated a very high satisfaction regarding the performance achieved. All patients showed curiosity and interest regarding this new rehabilitation approach declaring satisfaction for the results obtained.

3. Conclusions

Even if, given the absence of a control arm, this study did not evaluate the true impact of the game-based rehabilitation, it showed the feasibility of integrating conventional exercises with tablet-based educational games to recover trunk control. From patients’ self-perception, this helped them either to achieve rehabilitation outcomes or to improve the relationship with themselves by raising abilities awareness.

Training was not operator-dependent: during the course of the games the supervision of the physiotherapist was not strictly necessary and so the patient could manage himself. This advantage can be exploited in hospital but especially at home.

The same applications used for the rehabilitation of the patients with SCI may be extended to other outcomes. The same games suggested to patients in upright position can became exercises to improve balance and proprioception in case of orthopedic problems and/or other kind of neurologic diseases.

Moreover, adapting skeletal tracking technology used in gaming software could automate exercise tracking, documentation and feedback for patient motivation and clinical treatment planning and interventions. The research could be progressed by developing softwares for platforms that support interoperability between these applications and provide analysed data to track patient’s progress.

This method has an affordable cost since the apps used are free of charge. However, to continue exercising at home, the patient needs an iPad, since these applications are exclusively available for Apple tablets. Their porting on other operating systems or other gaming consoles (i.e. Microsoft Xbox Kinect) could give opportunity to a bigger number of patients to continue the training at home.

References