Balance rehabilitation using custom-made Wii Balance Board exercises: clinical effectiveness and maintenance of gains in acquired brain injury population

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ABSTRACT

Balance disorders are a common impairment of some of the pathologies with the highest incidence and prevalence rates. Conventional physical therapy treatment focuses on the rehabilitation of balance skills in order to enhance patients' self-dependency. In the last years, some studies have reported the clinical benefits of virtual reality systems in the balance recovery. The force platform Wii Balance Board has been adopted with rehabilitative purposes by many services due to its low cost and widespread battery of exercises. However, this entertainment system is oriented to healthy people and cannot adapt to the patient's motor (and possible cognitive) deficits. In previous studies we have developed custom-made adaptive exercises that use the Wii Balance Board with promising results in acquired brain injury population. In this contribution, we present some conclusions derived from the past and undergoing clinical studies.

1. INTRODUCTION

There are multiple pathologies, such as acquired brain injury (ABI), multiple sclerosis, Parkinson and Alzheimer disease, or vestibular disorders that can induce balance complications (Cheng et al, 2012), which can directly or indirectly affect the performance of the activities of daily living (Tyson et al, 2007). The rehabilitation strategies consider specialized programs to regain balance in order to enhance the patients' self-dependency. The improvement of the balance control has been traditionally assessed by functional scales and posturography studies, which aim to objectively quantify the balance condition through measurements of the center of pressure (COP). The COP has proven to be a relevant indicator of the patients' balance condition (Ruhe et al, 2011; Terry et al, 2011). Since the COP can be directly estimated from the individuals' weight distribution on a force platform, several systems based on force plates have come onto the market in the last years. Although their initial purpose was to provide therapists with new assessment tools, some of these systems also provide rehabilitation exercises.

The Nintendo® Wii Balance Board (WBB), a peripheral of the Nintendo® Wii gaming system which was launched with entertainment purposes, has achieved a great acceptance in the clinical community, since their performance can be compared to professional systems with significant lower cost (Clark et al, 2010). In addition, the WBB is portable, works wirelessly, and its setup is not time consuming. There are an increasing number of studies involving the WBB. Most of them use off-the-shelf games with balance rehabilitation purposes (Sugarman et al, 2009). However, even though these games can be motivating, they are oriented to the entertainment of healthy population and can require motor and cognitive skills that disabled individuals can lack. The studies involving custom made rehabilitative exercises are especially interesting (Gil-Gomez et al, 2011), since they are specifically designed with rehabilitative purposes, can provide patients with contents

adapted to their particular motor and cognitive impairments, and can provide therapists with objective data of the evolution of the patients.

In previous studies we have designed and studied the clinical effectiveness of the eBaViR (easy balance virtual rehabilitation) system, a set of custom made WBB exercises for chronic ABI patients with promising results (Gil-Gomez et al, 2011). The objective of this paper is to present our experiences and conclusions in the design and in the validation of adapted balance rehabilitation exercises involving the WBB.

2. METHODS

All the clinical data presented here are extracted from two studies that involve chronic ABI patients of the neurorehabilitaion service of Hospital NISA Valencia al Mar. The first study was carried out in 2010 and the second one is being currently carried out. Both studies have the same inclusion/exclusion criteria. The inclusion criteria were: 1) age ≥16 years and <80 years; 2) chronicity > 6 months; 3) absence of cognitive impairment (Mini-Mental State Examination (Folstein et al, 1975) cut-off >23); 4) able to follow instructions; 5) ability to walk 10 meters indoors with or without technical orthopaedic aids. The exclusion criteria were: 1) patients with severe dementia or aphasia; 2) patients whose visual or hearing impairment does not allow possibility of interaction with the system; 3) patients with hemispatial neglect; 4) patients with ataxia or any other cerebellar symptom.

The objective of the first trial was to study if custom made rehabilitative exercises on a force platform could improve the balance condition of ABI patients when comparing to conventional physical therapy programs. To prove this hypothesis a randomized controlled trial was carried out. The objective of the ongoing second trial is to study if improved versions of the exercises have similar effects and if they persist in absence of the virtual training. In this case, a follow-up study was designed.

2.1 First Study

The study evaluated the clinical effectiveness of the first prototype of the system. The first version of the eBaViR system included 3 exercises to train discrete displacements of the COP in the medial-lateral plane (air hockey), and in the medial-lateral and anterior-posterior planes (Simon), and free displacements (balloon breaker) (Figure 1).

Figure 1. *Patients interacting with the first prototype of the system*

After inclusion/exclusion criteria, the final sample consisted of 20 patients, which were categorized depending on their falling risk and randomized to a control or an experimental group afterwards (Table 1). 3 participants dropped out of the treatment.

All the participants underwent 20 one-hour sessions, from 3 to 5 sessions per week. The control group underwent traditional physical therapy and the experimental group used the developed system. The balance condition of all the participants was assessed by the Berg Balance Scale (BBS) (Berg et al, 1992), the Brunel Balance Assessment (BBA) (Tyson and De Souza, 2004), the Anterior Reach Test (ART) (Duncan et al,

Proc. 9th Intl Conf. Disability, Virtual Reality & Associated Technologies
Laval, France, 10–12 Sept. 2012

1990), and by other more dynamic scales such as the Timed Stair Test (TST) (Perron et al, 2003), the Stepping Test (ST) (Fujisawa et Takeda, 2006), the 1-minute Walking Test (1MWT) (McDowell et al, 2005), the 10-meter Walking Test (10MT) (Steffen et al, 2002), the Time "Up and Go" Test (TUG) (Steffen et al, 2002) and the 30-second Sit-to Stand Test (30SST) (Verschuren et al, 2002).

Table 1. *Characteristics of the participants of the first study.*

Issue	Control group	Experimental group	Significance
Gender (n) Male Female	 5 (29.4%) 3(17.7%)	 6(35.3%) 3(17.7%)	NS (p=0.858)
Age (years)	49.13±21.18	45.78±15.38	NS (p=0.704)
Etiology (n) Stroke Traumatic brain injury Benign cerebral neoplasm	 5 (29.4%) 1 (5.9%) 2 (11.8%)	 6 (35.3%) 2 (11.8%) 1 (5.9%)	NS (p=0.657)
Time since injury (days)	675.50±283.11	478.00±324.77	NS (p=0.204)

Age and time since injury are defined in terms of mean and standard deviation. Etiology and gender are also expressed as a percentage of the total number of patients. NS: non-significant.

2.2 Second Study

The second study is currently being carried out to study the clinical effectiveness of the second version of the system and the maintenance of gains. The second version of the system includes 4 exercises that require discrete displacements of the COP and 2 exercises that require free displacements, with versions for standing and sitting position. In addition, the system includes exercises for training one-leg standing, stair climbing, one-foot rising and sit-to-stand transfer (Figure 2).

Figure 2. *Patients interacting with the second prototype of the system*

Till date, 7 participants, from an expected final sample of 21 chronic ABI patients have finished the training with the virtual system (Table 2).

The participants also underwent 20 one-hour sessions, 3 to 5 times per week. Each participant trained with the prescribed exercises that mostly fit their needs according to the therapists. A similar battery of balance scales and tests was administered to each participant at the beginning, at the end, and one month after the trial (follow-up assessment). Similarly to the first study, each participant's condition was assessed with the BBS, the ART, the ST, the TUG, and the 30SST.

Table 2. *Characteristics of the participants of the second study.*

Issue	Experimental group
Gender (n) Male Female	 6(85.7%) 1(14.3%)
Age (years)	48.08±16.03
Etiology (n) Stroke Traumatic brain injury Benign cerebral neoplasm	 7 (100.0%) 0 0
Time since injury (days)	439.86±103.99

Age and time since injury are defined in terms of mean and standard deviation. Etiology and gender are also expressed as a percentage of the total number of patients.

3. RESULTS

3.1 First Study

No significant differences in demographical (age and gender) or clinical (chronicity, etiology, and laterality) variables at inclusion were detected between groups (Table 1).

A repeated measures ANOVA revealed a significant time effect for the BBS, BBA, standing ART, ST-paretic, ST-non paretic, 1MWT, TUG and 30SST (Table 3). No group effect was detected for any outcome, which confirms the comparability of both groups. Finally, significant group-by-time interaction was detected in the scores of the BBS and the ART in standing position.

Table 3. *Clinical data of the first study.*

Scale	Group	Before treatment	After treatment	Significance
BBS	Control Trial	45.38±7.35 41.22±10.57	46.88±6.15 45.44±8.62	T**(p=0.000) GxT*(p=0.011)
BBA	Control Trial	11.00±.1.31 10.00±2.00	11.13±1.13 10.33±2.18	T*(p=0.048)
ART standing (cm)	Control Trial	25.44±9.33 24.13±7.70	25.63±9.74 27.25±10.38	T**(p=0.005) GxT*(p=0.011)
ART sitting (cm)	Control Trial	40.06±6.87 34.83±11.92	40.13±7.66 37.78±12.34	NS
ST paretic (n)	Control Trial	6.57±2.30 6.75+3.58	7.57±2.44 7.63±4.00	T*(p=0.021)
ST non-paretic (n)	Control Trial	8.17±1.72 9.33±2.81	9.50±3.39 10.50±3.02	T*(p=0.046)
TST (s)	Control Trial	14.82±9.42 15.38±9.69	12.13±4.94 13.52±9.60	NS
1MWT (m)	Control Trial	31.13±13.59 31.94±12.47	36.38±15.39 42.69±20.43	T**(p=0.007)
10MT (s)	Control Trial	14.57±10.95 13.47±8.29	14.07±9.02 13.47±10.64	NS
TUG (s)	Control Trial	24.00±14.87 20.99±15.11	19.52±10.91 18.69±13.43	T**(p=0.004)
30SST (n)	Control Trial	6.88±3.52 7.56±4.19	8.50±3.12 9.00±4.74	T**(p=0.003)

The results are given in terms of mean and standard deviation. G: group effect. T: time effect. GxT: group/time effect. * $p<0.05$, ** $p<0.01$. n represents the number of repetitions.

3.2 Second Study

A repeated measures ANOVA revealed significant time effect between the initial and the final assessment in all the measures. In addition, significant time effect was detected between the final and the follow-up assessment in the BBS, and the 30SST.

Table 4. *Clinical data of the second study.*

Scale	Initial assessment	Final assessment	Follow-up assessment	Significance
BBS	37.00±7.30	42.00±6.73	43.86±6.73	T_1**(p=0.002) T_2**(p=0.011)
ART standing(cm)	23.57±3.99	28.64±8.12	29.86±8.15	T_1*(p=0.049)
ST paretic (n)	2.86±2.19	5.14±1.95	5.71±2.43	T_1**(p=0.012)
ST non-paretic (n)	5.14±2.79	7.14±3.08	8.43±3.31	T_1**(p=0.022) T_2**(p=0.001)
TUG (s)	32.71±17.20	28.05±16.08	22.92±12.13	T_1*(p=0.045) T_2*(p=0.021)
30SST (n)	6.29±2.93	10.14±4.67	11.14±4.98	T_1**(p=0.012) T_2**(p=0.018)

The results are given in terms of mean and standard deviation. T_1: time effect between the initial and the final assessment. T_2: time effect between the final and the follow-up assessment. * $p<0.05$, ** $p<0.01$. n represents the number of repetitions.

4. DISCUSSION

The statistical analyses showed that the balance training through low-cost force platforms and custom made exercises can provide clinical benefits to ABI chronic patients. Similar results were achieved in both studies (Table 5), which confirms the effectiveness of both designs.

Table 5. *Comparison of the results of both studies between the initial and the final assessment.*

Scale	First design	Second design
BBS	T**(p=0.000)	T**(p=0.002)
ART standing	T**(p=0.005)	T*(p=0.049)
ST paretic	T*(p=0.021)	T**(p=0.012)
ST non-paretic	T*(p=0.046)	T**(p=0.022)
TUG	T**(p=0.004)	T*(p=0.045)
30SST	T**(p=0.003)	T**(p=0.012)

T: time effect. GxT: group/time effect. * $p<0.05$, ** $p<0.01$.

As shown in the first study, custom made exercises on force platforms show significant improvement in the BBS and in the ART in standing position when compared to traditional physical therapy (Table 3). This can be due to the specificity of the exercises, since they require repetitive displacements of the COP and the consequent adaptation of postural responses. The training of these tasks can lead to an improvement that can be reflected in those scales. No significant group effect or group-by-time interaction was either detected for any of the dynamic scales, which suggests that both groups improved in the same way and that the system mainly promotes the recovery of static balance, in which the system focuses on its exercises, while it has no significant effect in dynamic balance. No specific exercises for the dynamic skills of balance were included and consequently the training does not provide special benefits to conventional physical training. However, several outcomes showed significant time effect of the training in scales that focused on balance skills during gait, such as 1MWT and TUG, or other complex motor tasks, such as 30SST and ST.

According to the results of the second trial, the results show that the improvement between the initial and the final assessment lasts along time. Moreover, the participants show significant improvement in the follow-up assessment in the scales of BBS, ST (in the non-paretic side), TUG, and 30SST. The training with the virtual system could have provided an improvement in the balance condition that supported the progressive improvement of these skills after the treatment, even in dynamic activities, as shown in the TUG.

These results must be taken into account considering the limitations of the studies and the sample. However, the improvement of the patients that underwent the virtual therapy in both studies is remarkable due to the chronicity of the sample (478.00±324.77 and 439.86±103.99, respectively), which is higher that than the 6-month period which is traditionally considered as the period with maximum recovery (where spontaneous recovery takes place) (Jorgensen et al, 1995).

Acknowledgements: This study was funded in part by Ministerio de Educación y Ciencia Spain, Projects Consolider-C (SEJ2006-14301/PSIC), "CIBER of Physiopathology of Obesity and Nutrition, an initiative of ISCIII" and the Excellence Research Program PROMETEO (Generalitat Valenciana. Conselleria de Educación, 2008-157).

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