Journal of Accessibility and Design for All

(CC) JACCES, 2013 - 3(2): 76-94. ISSN: 2013-7087

THE EFFECTS OF NINTENDO WII® ON THE POSTURAL CONTROL OF PATIENTS AFFECTED BY ACQUIRED BRAIN INJURY: A PILOT STUDY

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Abstract: Scientific literature demonstrates that *postural control* after suffering a brain injury can actually relate to its functional prognosis.

Postural control is a result of complex interactions of different body systems that co-operate in order to control the position of the body in the space and is determined by the functional task as well as by the environment in which it is developed. The use in rehabilitation of Nintendo's Wii® gives some results on motor functions.

Objective: Analyse the effects of the Nintendo Wii® console on *postural control* during the execution of an everyday life task consisting of getting up and walking three meters.

Range: Quasi-experimental study of a test-retest type. Not random sample of patients (n=12) affected by brain injury evaluated for the afore mentioned task with the Timed Get Up and Go Test (TGUG). Intervention and results on experimental group (n=6). Comparison of variables with respect to control group (n=6).

Results: Significant results have been obtained (p=0,007<0,05) at the TGUG of the experimental group.

Keywords: *postural control*, Nintendo Wii, ABI.

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Introduction

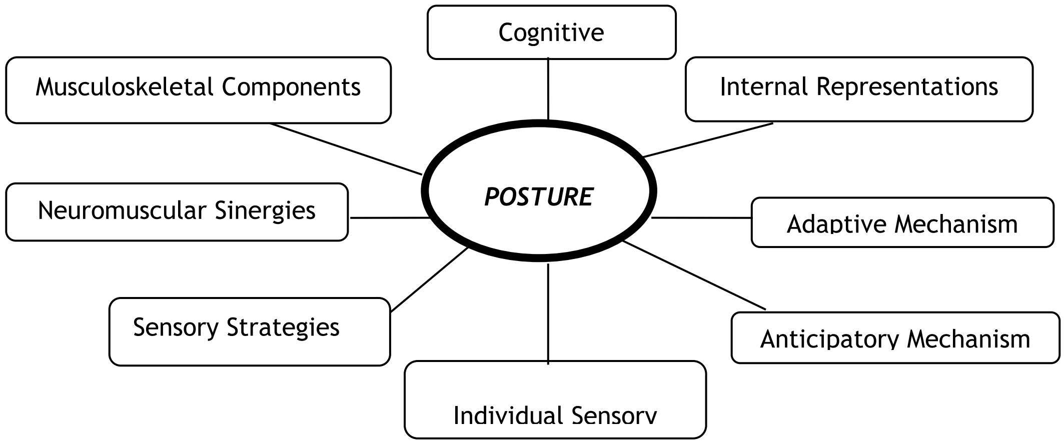
Postural control arises from the interaction between a subject, a task and the environment in which it is carried out, with the purpose of maintaining the subject stable and spacially oriented. It must ensure the control of the position of the body against gravity in all the actions that are accomplished (Shumway-Cook & Woollacott 2000; 2006).

Body orientation is defined as the ability to maintain an appropriate relationship between body segments, and between the body and the environment, while performing a particular task, maintaining a vertical orientation of the body.

In the process of maintaining stability (the ability to maintain the center of body mass (COM) between the limits of the support surface), we use multiple sensory references, including gravity (vestibular system), the support surface (somatosensory system) and the relationship of our body with objects in the environment (visual system) (Shumway-Cook & Woollacott, 2000; 2006).

Postural control requires the integration of the musculoskeletal and neural systems. The muscleskeletal components include aspects such as range of movement, muscular properties and biochemical relationships among the corporal segments involved. The neuronal components, that are essential for *posture control*, cover motor processes that include synergic neuromuscular responses, sensory processes that include vision, vestibular and somatosensory systems, sensory strategies that organize these multiple inputs, important internal representations to go from the sensation to the action, and processes of superior levels that are essential for adaptative and anticipatory aspects of *posture control* (cognitive aspects) (Shumway-Cook & Woollacott, 2006; Gallahue & Ozmun, 2006; Martín Sanz et al., 2004; Bertoti, 2004) as shown on the diagram below. These factors will depend expressly on the required task and the posture.

Figure 1. Processes necessary for postural control.



Adaptative postural adjustments imply the modification of sensory and motor systems in response to the changes on the environment and the tasks' demands. The anticipatory aspects of *posture control,* pre adjusts the sensory and motor systems for postural demands based on previous learning and experience. Other cognitive aspects that affect *posture control* include processes like attention, motivation and intention (Shumway-Cook & Woollacott, 2000; 2006).

The cycle for *postural control* consists firstly on the *input* of *sensory information,* needed to make a functional movement; it is necessary to previously analyze the data from three systems: vestibular, visual and somatosensory; in order to *assimilate this information* and receive a *respond*. When all these systems are intact, individuals show an adaptable *postural control* and are capable of finding stability and orientation goals in any context.

Standing position is characterized by small spontaneous balancing and postural oscillation (Shumway-Cook & Woollacott, 2006; Kandel, 2000), in which various factors contribute to stabilize this situation, factors such as: *body alignment*, that minimizes the gravitational forces effects with less energy waste; *muscle tone*, the muscles' resistance while being stretched and where the stretch reflexes play a feedback role during the balance position, while aiding balance control in standing position; and the *postural tone*, which is increased by the antigravity muscle activity when standing in order to control the gravitational force. In scientific literature, the postural tone acquires an important relevance, as main mechanism in the body's support against gravity. Many investigators have suggested that postural tone is the most important element for normal stability control in the erect posture (Shumway-Cook & Woollacott 2000; 2006).

In fact, researchers suggest that *postural control* includes an active sensory process that calculates the position of the body in space and predicts where it is going and what actions will be necessary to control that movement. Taking into consideration the previous experience, the object of action and the context in which it is carried out (Geurts, 1996).

An effective *postural control* requires more than the capacity to generate and apply forces that control the body's position in space. In order to know how and when to apply force, the Central Nervous System (CNS) must have an exact image of where the body is and if it is standing still or in movement (Geurts, 1996).

These factors or necessary systems to maintain an adequate *postural control* are altered in patients that have suffered an Acquired Brain Injury (ABI). "ABI is an injury produced in the brain structure as a sudden damage in people born without any kind of brain injury, who later on suffer brain injury as a consequence from an accident or illness" (Feigin, 2010; Strong, 2007; Langlois, 2006). The etiology of a sudden brain injury may be vascular (cerebrovascular accident -CVA-), traumatic (traumatic brain injury –TBI-), tumorous, by infection or anoxia (Feigin, 2010).

As for the rehabilitation in these types of patients, it is considered that after the first six months, the possibility of spontaneous recovery is very limited, therefore we can assert that improvements from this period on, will be the consequence of therapeutic act (Feigin, 2010; Strong, 2007; Langlois, 2006).

In 2008, Nintendo Wii® was the last generation of consoles in the videogame domain to include innovative characteristics that justified its position among the top ranked in sales in the US. Since it is a low cost and recreational solution, its particular form of interaction has raised interest among health professionals to be used on the field of rehabilitation. All these professionals agree in that it allows participants to forget they are working, taking their limits further. Moreover, the patients' interaction with the console also allows them to reinforce the motivational aspect and facilitates adhesion to the treatment which is an important point that influences on *postural control*.

Nowadays, the implementation of virtual therapies as a complement to the treatment of acquired brain injury (ABI) in motor and cognitive limitations, is being widely accepted in neurorehabilitation (Laver, 2011; 2012). A current revision on the subject (Laver, 2012) has obtained significant results on this kind of approach of improvement in these patients.

The object of this study is to assess the effects of a neurological rehabilitation treatment combined with Nintendo's Wii®, using Wii Fit and Wii Balance Board (WBB), on some relevant aspects of *posture control* on patients that have suffered from ABI.

On the present study, the task will consist in getting up, walk three metres, go back to the start and return to a sitting position.

Methodology

Design of the experiment

A quasi-experimental study was carried out in a test-retest format, with the objective of validating the effects of Nintendo Wii® on the *posture control* of a group of patients with ABI. The experimental and control groups were tested in parallel.

Participants were assigned in a proportion of 1:1 in both study groups, according to the subjects' schedule and the availability of the virtual hall. Patients from the experimental group couldn't be slanted in favor of the intervention.

The game system Nintendo Wii® launched in 2005, introduced a new virtual reality style through a wireless control that interacts with the player while detecting movement and its avatar performance on the video.

The WBB contains four transducers used to evaluate the distribution of the load and the resulting movements from the center of the mass. Originally designed as a videogame device, the WBB is mainly used in combination with associated software and a console. Due to its capacity to provide instant information and the possibility to improve the motivational level (Ramchandani, 2008), this system is already part of the rehabilitation programs of neurological patients with balance disorders.

The information on the screen produces a positive reinforcement and gives feedback for the patient, facilitating the execution and the progress of the task. (http://www.nintendo.com/wii/what).

The data was gathered at Centro LESCER, in Madrid, from November 2010 to January 2011.

Participants

This study was held at the Centro Lescer in Madrid, with the participation of 12 patients who have suffered from ABI and who are following individual rehabilitation programs according to their needs and involving different areas like: physiotherapy, occupational therapy, neuropsychology and speech therapy.

A not random sample was chosen: 6 patients from ischemic stroke (50%), 3 from hemorrhagic stroke (25%), 1 TBI (8.3%), 1 brain tumor (8.3%) and 1 hypoglucemic coma (8.3%), all of them already diagnosed. A high percentage of patients in this sample are vascular patients, as it occurs in ABI (Feigin, 2010; Strong, 2007; Langlois, 2006).

The 12 participants in the group were 2 women and 10 men. The mean age was of 62.17 ± 11.535, with a minimum of 39 and a maximum of 79 years old. On the other hand, according to the elapsed time since the injury, the group consisted of 4 acute patients (33.3%) and 8 chronic patients (66.7%). The first 6 subjects were included in the experimental group, while the last 6 were in the control group.

The general characteristics of the subjects are exposed in Table 1.

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Table 1. General characteristics of the subjects.

Subject nº	Gender	Age	Elapsed time since injury (months)	Diagnosis	Group
Subject 1	Male	59	4 (Acute)	Hemorrhagic Stroke	Experimental
Subject 2	Female	45	40 years (Chronic)	Traumatic brain injury (TBI)	Experimental
Subject 3	Male	39	43 (Chronic)	Tumour	Experimental
Subject 4	Male	65	28 (Chronic)	Coma	Experimental
Subject 5	Male	70	12 (Chronic)	Hemorrhagic Stroke	Experimental
Subject 6	Male	65	4 (Acute)	Hemorrhagic Stroke	Experimental
Subject 7	Male	54	43 (Chronic)	Ischemic Stroke	Control
Subject 8	Female	79	7 (Chronic)	Ischemic Stroke	Control
Subject 9	Male	60	22 (Chronic)	Ischemic Stroke	Control
Subject 10	Male	71	26 (Chronic)	Ischemic Stroke	Control
Subject 11	Male	68	6 (Acute)	Ischemic Stroke	Control
Subject 12	Male	71	6 (Acute)	Ischemic Stroke	Control

Inclusion Criteria

Among the patients with brain injury, only the ones who surpassed or leveled up to the 2nd category of the Functional Ambulation Categories scale (FAC) (Leder, 2008; Holden, 1984) were included, this means, patients who needed continuous or intermittent human support to assist balance or coordination when walking. From these, only patients who are medically stable, alert and who are capable of following simple verbal commands.

Exclusion Criteria

Patients with global aphasia, non collaborating patients like those with conduct problems, medically unstable patients or those to whom risk may be implied.

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- Study

At the beginning of the study (pre-test), 4 validated tests were administered: FAC (Functional Ambulation Categories scale), Berg Balance Scale (BBS), Barthel Index (BI) and the Timed Get Up and Go test (TGUG). These are reliable, sensitive and validated tests used to assess *postural control*, therefore adequate for this study according to the investigators criteria. Below is a brief description of these scales:

- FAC: categorizes patients according to basic motor skills necessary for functional ambulation. It does not assess endurance. Describes six categories according to the assistance required. Patients should be rated at their most independent level (Leder, 2008; Holden, 1984).
- BBS: evaluation instrument used to identify balance disorders through functional activities such as reaching over, leaning over, transferring objects, standing on one leg, and so on, until completing 14 tests. Balance is the capacity of maintaining the centre of gravity on a support base, generally on a vertical position. With a good balance a patient will be able to sit, get up or walk safely. BBS was developed in the 1990's to assess balance in elderly individuals. It has been proved to be a consistent and reliable tool. Some tasks are classified according to the performances' quality, while others are assessed by the time needed to accomplish the task (Mehrholz, 2007).
- BI: Evaluates a person's ability to independently or dependently perform 10 activities of daily living like feeding oneself, bathing, dressing, grooming oneself, bowel and bladder control, toilet use, bed/armchair transfers, mobility on level surfaces and stairs; and assigns a score according to the time and assistance needed. Designed in 1965 by Mahoney and Barthel to measure the subjects' evolution with neuromuscular and musculoskeletal processes in a hospital for chronic patients in Maryland (Berg, 2004).
- TGUG: is a mobility and locomotor performance test that includes several tasks such as standing up from a sitting position, walking, turning around, standing still and sitting. All the important tasks necessary for a persons' mobility independence are represented in

this test. The score consists of the time taken to complete the test activity (Mahoney & Barthel, 1965).

TGUG can be characterized by several non temporal criteria of postural nature (this is one of the most unknown aspects of this test) (Podsiadlo, 1991; Fife, 2000), that best define the subjects' functional capacity. Patients with balance disorders must adequately coordinate certain trunk adjustments in anteroposterior and lateral scenes (Allum, 2001).

Apart from the four quantitative tests already mentioned, the subjects were assessed every day the Wii® was used, with the consoles' test, for example, the *walking test* (walking 20 steps; gives as a result the lower body members' weight distribution percentage), the *agility test* (moving the center of gravity-represented on the screen- in a determined time), the *statue test* that consists on standing on both legs or the *one leg test*, standing in one leg (that provides the stability percentage while we continue standing on both legs or one, respectively).

All patients have been following a neurological rehabilitation program for several months, since all of them have both motor and cognitive disorders, as consequence of the ABI. This Program consists of two 45 minute daily sessions of physiotherapy, occupational therapy, speech therapy and neuropsychology depending on the patient's intrinsic goals and needs. On the experimental group, one of the weekly sessions of physiotherapy was substituted by the Wii® (45 minutes/week).

Subjects who have participated on the investigation, have worked on the WBB platform executing the different balance games of the console, once a week during 10 weeks, as well as their routinary physiotherapy and occupational therapy. The WBB and Wii Fit allow the patient to practise balance exercises in standing through the centre of gravity monitoring and visual feedback.

You can see the results of each test on the following table.

Table 2. Results of pre-test and post-test (Functional Ambulation Categories scale, Berg Balance Scale, Barthel Index, Timed Get Up and Go test) of the subjects.

TEST	FAC[1]		BBS[2]		BI[3]		TGUG[4]	
Subject nº	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Subject 1	3	4	34/56	47/56	35/100	75/100	23.02	13.85
Subject 2	5	5	52/56	53/56	95/100	95/100	7.72	5.40
Subject 3	5	5	51/56	52/56	100/100	100/100	10.09	7.72
Subject 4	5	5	44/56	48/56	95/100	95/100	20.47	14.32
Subject 5	4	5	43/56	53/56	100/100	100/100	13.97	11.40
Subject 6	5	5	51/56	54/56	100/100	100/100	8.87	6.31
Subject 7	4	4	38/56	38/56	85/100	90/100	27.94	20.50
Subject 8	2	3	13/56	33/56	15/100	55/100	65.54	36.15
Subject 9	4	4	45/56	50/56	95/100	95/100	12.22	9.40
Subject 10	4	4	51/56	52/56	85/100	85/100	20.83	18.37
Subject 11	5	5	50/56	52/56	90/100	90/100	7.40	6.41
Subject 12	4	5	38/56	55/56	85/100	95/100	17.23	12.30

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Table 3. Comparison of parameters before the treatment.

Test	Control	Experimental	P - value
FAC[1] Pre	3.83 ± 0.983	4.50 ± 0.837	0.022
BBS[2] Pre	39.17 ± 13.992	45.83 ± 6.97	0.200*
BI[3] Pre	75.83 ± 30.069	87.50 ± 25.836	3.022×10^{-5}
TGUG[4] Pre	25.19 ± 20.99	14.02 ± 6.39	0.39

[1] Functional Ambulation Categories scale

[2] Berg Balance Scale

[3] Barthel Index

[4] Timed Get Up and Go test

Statistical Analysis

The statistical software SPSS v.17.0 was administered. The descriptive data is expressed as average ± standard deviation. The statistical inference was based on the *t of student* and non-parametric tests on two associated samples (*Wilcoxon test*), to compare the initial and final values of every scale in each separate group. Non-parametric tests were also administered on two independent samples (*Mann-Whitney U test*) with the purpose of comparing the scale difference (final value minus initial value for each scale) on the control and experimental group. The *Kolmogorov-Smirnov test* was carried out as test for normality (with the correction of the Lilliefors significance). The level of statistical significance gathered in the study was of 95% (p≤ 0. 05).

All 12 patients were evaluated; therefore there weren't any lost values.

Results

In view that the TGUG represents the task presented throughout this study, the analysis began by verifying differences in the initial *TGUG*, according to the group they were in, control or experimental. With a confidence index of 95% [9.50 – 29.71], no relevant statistical differences were found among this two groups, therefore we can't discard the possibility that it may all be down to chance (p=0.39). (Table 3)

The neurological rehabilitation program isolated or associated to the Nintendo Wii® console contributed to substantial improvement while comparing the FAC (functional walk) test results, before and after the treatment on both; the control group, (4.17 ± 0.753 compared to 3.83 ± 0.983; p=0.02) as on the experimental group (4.83 ± 0.408 compared to 4.50 ± 0.837; p= 0.02). The 95% Confidence Index on the pre-post score difference for both groups is of: [(-0.21) – 0.87]. (Table 4)

As for the balance test (BBS): an improvement has been made in both treatment groups, even though it has not been statistically significant in neither (7.5±8.734; p=0.157 >0.05 in the control and 5.33±5.006; p=0.189 >0.05 in the experimental). In the first, the 95% CI of the remainder from the final minus the initial score is of: [(-1.67) – 16.67)], while in the second, the 95% CI is of [0.08 – 10.59]. (Table 5)

Regarding the daily living activities (ADL), the experimental group displayed a significant improvement in the final measurements (94.17 ± 9.704) compared to the 87.50 ± 25.836 from initial measurements, p= 4.6x10-5 <0.05; CI 95% [(-10.47) – 23.80]; while in the control group, (85.00 ± 15.166 compared to 75.83 ± 30.069), p= 0.069 >0.05; CI 95% [(-7.23) – 25.56], even though there was improvement, it was not significant. (Table 6)

Finally, in order to evaluate the task suggested in this study, we will analyze the results that reflect this activity on the TGUG. We noticed that the time was significantly reduced (p= 0.007 <0.05) in participants who used the Nintendo Wii® console (9.83 ± 3.88 compared to 14.02 ± 6.39) as well as in those who only received conventional rehabilitation (17.19 ± 10.70 compared to 25.19 ± 20.99), p= 0.018 <0.05). The 95% CI is of [(-7.1853) - (-1.1947)] and [(-19.25) – 3.24], respectively. (Table 7)

As statistical method to determine clinical significance, it follows the standard error of measurements (SEM) used to calculate the minimum detectable change. This was calculated as the standard deviation by taking the square root of the sample size.

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Table 4. Comparing the FAC test results, before and after the treatment on both group.

Test group	Prior	SEM[2]	Post	SEM[1]	Difference and Probability
FAC[1] Control Group	3.83 ± 0.98	0.401	4.17 ± 0.75	0.307	0.33 ± 0.51 p=0.02 p<0.05
FAC Experimental Group	4.50 ± 0.84	0.341	4.83 ± 0.41	0.167	0.33 ± 0.51 p= 0.02 p<0.05

[1] Functional Ambulation Categories scale

[2] Standard error of measurements (SEM)

Table 5. Comparing the Berg Balance Scale test results, before and after the treatment on both group.

Test group	Prior	SEM	Post	SEM	Difference and Probability
BBS[1] Control Group	39.17 ± 13.99	5.712	46.67 ± 8.94	3.649	7.5 ± 8.734 p= 0.157 p>0.05
BBS Experimental Group	45.83 ± 6.97	2.845	51.17 ± 2.93	1.196	5.33 ± 5.006 p= 0.189 p>0.05

[1] Berg Balance Scale

Table 6. Comparing the Barthel Index test results, before and after the treatment on both group.

Test group	Prior	SEM	Post	SEM	Difference and Probability
BI[1] Control Group	75.83 ± 30.07	12.2 75	85.00 ± 15.17	6.1 93	9.166 ± 15.625 p= 0.069 >0.05
BI Experimental Group	87.50 ± 25.84	10.5 47	94.17 ± 9.70	3.9 6	6.667 ± 16.329 $p= 4.6x10^{-5}$ <0.05

[1] Barthel Index

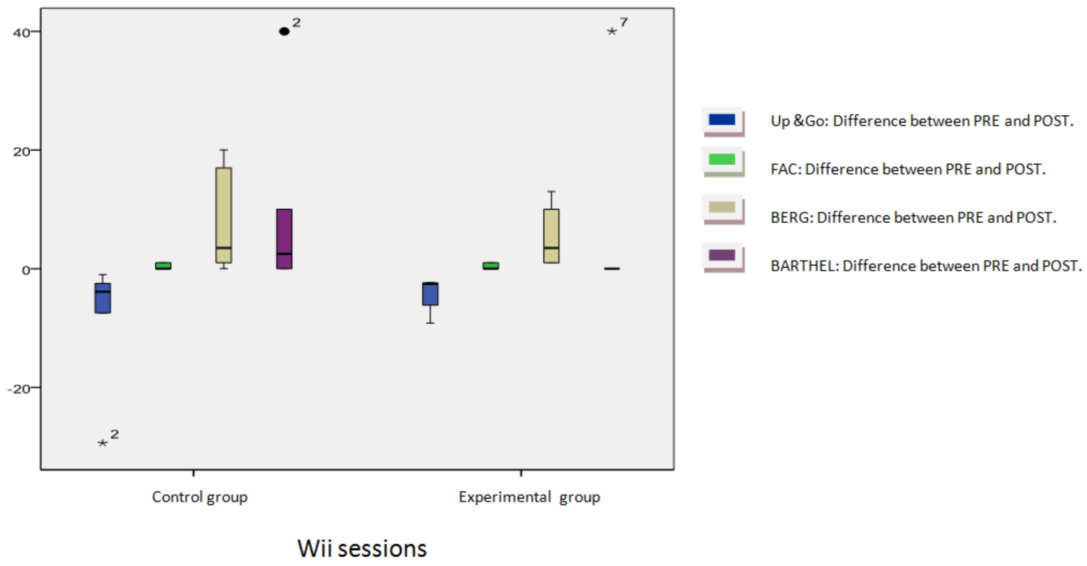
Table 7. Comparing the Timed Get Up and Go test results, before and after the treatment on both group.

Test group	Prior	SEM	Post	SEM	Difference and Probability
TGUG[1] Control Group	25.19 ± 20.99	8.569	17.19 ± 10.70	4.368	-8.00 ±10.71 p= 0.018 <0.05
TGUG Experimental Gr.	14.02 ± 6.39	2.608	9.83 ± 3.88	1.584	-4.1900 ±2.85 p= 0.007 <0.05

[1] Timed Get Up and Go test

The graph below shows the resulting values of the difference between the pre and post scores of each test, from both the experimental and the control group:

Figure 2. Resulting values of the difference between the pre and post scores of each test on both group



Discussion

Even though there has been a great improvement in all the tests administered to each patient, and as a result an improvement on the performance of the suggested task, not all have been statistically significant. Hence, and although there was a p=0,02 on the *FAC*, the confidence index of

95% holds the value zero, indicating that this improvement on the score is not statistical significant. As well as occurring in the BI scores of the experimental group ($p<0.001$) once again, we find a 95% CI that holds value zero, making it impossible to reject the invalid hypothesis. This also happens on the *TGUG* from the control group.

However, as it has been also stated in other researches (Gil-Gómez, 2011), the virtual rehabilitation provides significant improvements in *postural control* and balance. Regarding the ADL, the positive significant differences are also demonstrated in a recent virtual reality review (Laver, 2011).

Nevertheless, we found significant results while discarding the possibility that chance might explain the results, on the *TGUG* of subjects who benefitted from the Nintendo Wii® console ($p=0.007$). We found that when performing the task of standing up, walking three meters, turning around, walking back three meters and sitting down, the time used in this activity will diminish 1.19 and 7.18 seconds, with a confidence of 95%.

Although this research represents a small step, the investigation should ideally continue with a bigger and more homogenous sample to avoid slants. Also, the elapsed time since the injury has varied significantly from one individual to another, influencing to a large extent on the statistical analysis. As for the distribution of patients on both groups, a randomization process must be fulfilled, in order to have the lowest influence on the results.

An important limitation in this study has been the time at hand to collect data (November 2010 – January 2011), and the limited availability to the console (if it was being used by another subject), leaving each individual from the experimental group, with 10 sessions of 45 minutes. Therefore a continuation of the investigation searching long-term results is recommended.

Nevertheless, it would be useful to continue this line of study, by separately analyzing the effects of the different treatments, for example, the console with physiotherapy, or console with occupational therapy, or the Wii® alone.

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Future lines should also consider larger samples and random assignment.

Apart from its usage as a feedback and amusement tool, the WBB can also be used by healthcare professionals to compile and analyze balance data, by using techniques and precise measurement results for targeted patients. The WBB is a small fraction of the cost of a dynamic posturography laboratory, it is commercialized in large scale and portable, therefore it has the potential of turning into a key component of tests, given it is possible to demonstrate that liable and valid results can be generated.

Conclusions

The effects of a neurological rehabilitation treatment in addition to Nintendo Wii have been shown to provide benefits to our sample of ABI patients related to *postural control* and balance. This was reflected on a task evaluated through TGUG, demonstrating that the time used to achieve the objective has diminished significantly on the experimental group.

The sensory process of the visual system needed to obtain *postural control*, took place thanks to the feedback displayed on the screen, the patient needed to calculate the body's position in space and accomplish the necessary actions to control the required movements.

Moreover, it could be concluded that the patients with virtual therapy included in their neurorehabilitation program, obtained significant improvements in their ADL and, therefore, in their *functionality*. Although the Barthel Index revealed improvements in the control group, these have not been statistically significant.

Due to the characteristics of this device and the positive results obtained, it seems to be of great utility as a complement to the traditional rehabilitation therapy for patients with ABI.

This highlights the need to create an available low cost, portable system to evaluate balance. The Wii Balance Board (WBB) part of the popular videogame Wii Fit, accomplishes all these criteria.

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In short, by improving *postural control* these patients can obtain a higher functionality.

Acknowledgements

As author of this article I'd like to express my greatest thanks to the patients and therapists from the Centro Lescer for their participation.

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