Physical Therapy Intervention Through Virtual Reality in Individuals With Balance Disability: a Case Study

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***Abstract*—Balance is an ability found in most of the human activities and it is essential under a functioning view. When balance is impaired due to any brain injury, several tools may be used for its treatment. One of them is virtual reality, a tool which allows individuals to make use of their senses and natural movements during virtual games in order to promote interaction on a virtual environment. This study was performed with a volunteer from the neurology section of Universidade de Marília (Unimar) physical therapy clinic under ethics parameters, and its purpose was to measure the balance of an individual with traumatic brain injury who was involved in a treatment with use of virtual-reality games. An Xbox kinect® console was utilized for this intervention, and the selected games required the use of many physical abilities, including balance. The tests were recorded on video, and pictures were analyzed by two researchers and three evaluators. Score data from each game were obtained during the process. The data analysis was quantitative in relation with game scores and qualitative in relation with the test pictures. The results obtained from the analysis of the balance tests were: (a) in romberg's test with eyes open and eyes closed there were not significant changes; (b) in sensitive romberg's test there was improvement in balance with support in both legs; (c) in dynamic balance test there was improvement in balance during the straight-line walk. In the statistical analysis of game data friedman's variance was found in three levels of significance (p): for each sequence in the seven days of attendance the results were p=0.0367, p=0.0281 e p=0.0136; it was considered as p<0.05 what affected significantly the performance of the volunteer. According to the results observed in the study, it was concluded that virtual reality as a therapeutic media provided improvement of the volunteer's physical balance.**

Keywords-physical therapy; balance; virtual reality.

I. INTRODUCTION

The balance or postural stability is the condition in which every force acting over the body is balanced so that the center of mass stays within the stability borders in the limits of the bases of support [1]. Balance is a sensorimotor function that ensures permanently the dynamic postural stability [2]. In the opinion of postural stability, also defined as balance, is the ability of having control over the center of mass in relation with the base of support [3].

Balance can be static, when a body stays stable in a given position, or dynamic, when it is able to advance through an intentional movement without losing balance [4].

In order to obtain postural control and then postural stability, a body needs to create and apply forces. However, the central nervous system (CNS) requires an exact image of where the body is in the space and if it is still or in movement. The nervous system performs that through the following systems: vestibular, visual, and somatosensory, primarily proprioceptive mechanism and cerebellum which manages constantly every motor activity of the body and compares movements intended by the motor cortex with the updated sensory information that receives and regulates the quality of motor movements [5].

That instability is the lack of ability for correcting the displacement of a body during its movement in space [6]. There are three media in daily life in which balance can be disturbed: by an external force applied to the own body through the movement of the base of support, or by internal forces applied during a self-initiated movement [7]. Any obstruction at controlling the segmental alignment and activating, coordinating and measuring muscular activity effectively can impair postural stability.

Balance is essential for independence in daily activities. Impairments in postural control that produce loss of stability has a profound impact in daily life for individuals with neurological pathology. The consequences of impairment on stability include loss of functional independence, increase of disability prevalence, and falls [3][7].

The ability of keeping a static position provides a lesser challenge for a patient's balance, whereas dynamic activities are more challenging since the center of mass is more displaced. Therefore, the program of rehabilitation for balance training must have exercises with progression of kinetic chain, exercises with eyes open and closed, progression of stable-to-instable bases, self-perturbation by external perturbation, single-to-multiple plans, and single-to-multiple movements [8].

There are also studies that demonstrate the benefit of other therapies in the treatment of balance disorders such as hydrotherapy [9], equine therapy [10], isostretching [11], pilates [12].

Studies on virtual reality (VR) took place in the 1960s, not successfully, then since 1980 they began to be strengthened and became even more popular in the beginning of 1990 with digital technology and the popularization of digital games [13].

The term VR was created to define virtual worlds developed with the utilization of high technology in order to convince users that they are in another reality. It enables the integration between user and virtual environment. So, there is an experience of immersion and interaction based on tridimensional graphic images generated by computer. The VR allows a user to utilize perceptions from our five senses [14].

VR can be defined as a computing simulation that enables to re-create real environments where a subject is able to interact with the game, to experience and simulate a real environment [15].

VR provides a unique media appropriate for the creation of several requirements for an effective intervention of rehabilitation, and can be provided in a functional, intentional and motivating context [16].

Virtual environments are created with the purpose of rehabiliting individuals with disabilities, and it aims to recover the motor ability and cognitive functions. It is a therapy provided for patients who have some brain injury, phobias, autism, traumatic brain injuries, brain paralysis, and in the prevention of falls and accidents with the elderly [17].

It is Schiavinato et al. [18] have reported an important effect in the rehabilitation provided by VR, i.e., a possibility where the patient interacts with a virtual environment, and this interaction provides an immediate feedback by the patient, because he has positive immediate responses of the efficacy of his/her movements. Then his/her brain is stimulated to be adjusted to the game, and makes the corrections necessary so that the patient has a good performance in the game. This enables competitivity, and the patient begins to make good efforts.

The Balance Rehabilitation Unit (BRU) is an equipment which allows handling balance disorder, primarily the vestibular ones. It utilizes 3D glasses that re-create situations that cause dizziness in the user and work on visual stimulation, perception of deepness, direction and movement speed, stimulating the maintenance of body balance [19].

The utilization of VR in rehabilitation, when compared with treatments using other technologies, has several advantagens such as the opportunity of experience of real situations in an illustrative environment that encourages the active and individualized participation of a subject who practice movements being performed later in the real world. It also provides an amusing environment that creates a high level of motivation for the acquisition of knowledge and learning [17].

The VR can be utilized in the treatment of vestibulopathy since the physical movements performed during the therapy reorganize the harmonious functioning between visual, vestibular and somatosensory systems, promoting visual stabilization during the movements of the head. This repetitive training associated with neuronal plasticity makes the recovery of body balance and vestibular compensation possible [20].

The purpose of this study was to measure balance of an individual with traumatic brain injury who underwent a treatment with virtual-reality games.

The present work is subdivided in sections. Section II contains the research methods used. Section III presents how the procedures were realized and which materials were utilized. Section IV presents the results and explains the way they were analyzed. In Section V, we present the discussion, comparing with the results from other authors. And, finally, Section VI presents the conclusion of this work.

II. METHODS

The study was issued and approved by University of Marilia (UNIMAR) Research Ethics Committee, and followed Brazilian and International Regulations and Guidelines, especially Brazilian Health Board Resolutions no. 196/96 and Supplementary, protocol no. 341.

A volunteer from neurology section at UNIMAR Physical Therapy Clinic, male, 30 years, who underwent a conventional physical therapeutic assessment performed by researchers in the last term of Physical Therapy undergraduate course, took part in the study. The volunteer had a clinical diagnosis of traumatic brain injury secondary to a car accident.

The accident occurred in January 31st, 2010, and the volunteer was hospitalized during 48 days, from which 31 days he was in an Intensive Therapy Unit (ITU), and 17 days in an outpatient room. While at ITU he had been into a coma and underwent a procedure with invasive mechanical ventilation. During the period of hospitalization he was put a cervical collar due to a fracture in the third cervical vertebra, underwent a facial drainage, had bronchoaspiration, and had two episodes of pneumonia. The patient had a hospital discharge in March 19th, 2010.

One month after the discharge the patient initiated a therapeutic treatment at UNIMAR Physical Therapy Clinic, where he followed attending up to later April 2011. In this period there was a significant progression in sequels. The patient has any former pathology, has no use of medication, no use of tobacco or alcohol. He has a moderate limitation in daily activities which require a higher level of body balance such as play soccer. The volunteer is a college student and he is temporarily retired from his professional activities.

There were not found force, skeletal or joint changes, muscular atrophy, tonus, profound or superficial sensitivity, or rough coordination at the physical examinations. Changes in static and dynamic balance, and dysdiadochokinesia in the right upper member were the only motor alterations.

The volunteer underwent magnetic resonance imaging examinations through which a small area of gliosis by brain contusion in the right temporal-occipital transition, and sequels from diffuse axonal injury in brain regions (corpus callosum, bilateral brain peduncle, and right lower brain peduncle) were diagnosed in the outcomes from recent examinations, previous to the beginning of the therapy.

A LG 29’’ TV, a Xbox 360° Kinect console and Kinect Adventures game, a Sonic 12.1 megapixels digital camera, a support tripod and simetrograph were utilized in the therapy.

III. PROCEDURES

The procedures of this case study were divided into stages consisting of: First Assessment, Therapeutic Intervention Protocol, and Final Assessment.

The volunteer was assessed initially through Romberg’s test as per O’Sullivan, which is used to evaluate static balance. In this test, the patient was instructed to stand erect and feet positioned together, arms hanging along the body. The patient had three minutes before the beginning of the test for postural adjustment. The test was performed in three stages: with eyes open, with eyes closed, and unipedal right stance, then left stance, hereby called Sensitive Romberg. A simetrograph was used in order to support the test.

A straight-line walk test was used to assess dynamic balance. This test was performed by the patient walking over a 5.7 m straight line in the floor so that the calcaneus of one foot was in front of the ankle of the other foot. He walked the line three times, back and forth; the first time was not considered for analysis.

All tests were recorded in video with a digital camera supported by a tripod. The camera was in a position 2.50 meters of length away from the simetrograph and at 79 cm of height in the Romberg’s test. In the walk test it was at 80 cm of length and 79 cm of height.

In relation to therapeutic intervention protocol, an Xbox Kinect console with Kinect Adventures game and a 29’’ TV were used for the intervention. This console captures movements performed by the user, reads them and then sends kinetic movement signs to the virtual reality; this console does not require joypads or any device to play. Games were not therapeutic and had background music. The distance between the console and the participant were always the same, adjusted by the console sensors. Two games were selected for the therapy: Reflex Ridge, where the virtual scenario was a platform running through trails, and the participant was required to jump, knee and avoid obstacles in the way; and Rally Ball, where he should make movements to catch balls using hands and legs along with side displacements as a goalkeeper. He also should destroy floating boxes with the same balls.

Both games have basic, intermediate and advanced levels. Each level had three different game, i.e. each game had a total of nine mini-games. At each attendance the volunteer played Reflex Ridge first, then Rally Ball. He was requested to play one basic-, one intermediate-, and one advanced-level mini-game from each DVD. Twenty one attendances were performed, with a sequence of three different games in each attendance. After three days the sequence was repeated, in a total of 7 attendances with each sequence. The sequences were: Mover, Dodger and Olympian; Collector, Wrangler and Shapeshifter; and Cruiser, Slingshotter and Speedster.

The game that provided more data for the collection was selected for data analysis: Reflex Ridge. Data were collectedon number of total obstacles, number of fails at trying to overcome obstacles, game time and score. The intervention lasted one month and two days, and four attendances per week were performed in this period, with therapy time of approximately 25 minutes. Initial and final blood pressures were measured in every attendance, since it was a therapeutic attendance. There were not intervals during each therapy, and the volunteer had only short rests due to the time spent to select a new game.

The volunteer underwent the same tests of first assessment one day after the end of attendances, performed in the same site and with the same equipment.

The data analysis was quantitative in relation with game scores and qualitative in relation with the test pictures. The results obtained from the analysis of the balance tests were: (a) in Romberg’s test with eyes open and eyes closed there were not significant changes; (b) in sensitive Romberg’s test there was improvement in balance with support in both legs; (c) in dynamic balance test there was improvement in balance during the straight-line walk.

IV. RESULTS

An imaging qualitative analysis was performed by recording for static and dynamic balance tests, as per table 1. Tests were recorded on video at assessment and reassessment. Then relevant parts were selected and edited for analysis. Both researchers assessed individually the edited parts and took notes considering parameters that aimed the purpose of the study. Following this analysis, they observed common findings and found some conclusions. In order to assure the common outcomes obtained, the video recordings were submitted to three evaluators who were not informed about the study, and the validation of the conclusions obtained by the researchers was accepted if most of the evaluators observed the same outcomes.

TABLE 1. IMAGING ANALYSIS OF BALANCE TESTS THROUGH

CATEGORY	SUBCATEGORY		OUTCOME
STATIC BALANCE	ROMBERG WITH EYES OPEN	ASSESSMENT	“mild deviation”
		REASSESSMENT	“mild deviation”
	ROMBERG WITH EYES CLOSED	ASSESSMENT	“mild deviation”
		REASSESSMENT	“mild deviation”
	SENSITIVE ROMBERG	ASSESSMENT	“left leg: regular balance right leg: poor balance”
		REASSESSMENT	“left leg: fairly normal balance right leg: good balance”
DYNAMIC BALANCE	STRAIGHT-LINE WALK	ASSESSMENT	“regular balance, high deviation”
		REASSESSMENT	“good balance”

In the statistical analysis of game data, Friedman's variance (Fr) [21] was found in three levels of significance (p): for each sequence in the seven days of attendance the results were p=0.0367, p=0.0281 e p=0.0136; it was considered as $p<0.05$ what affected significantly the performance of the volunteer, as per Table 2.

TABLE 2. PATIENT'S SCORE IN EACH SIMULATION GAME IN 7-DAY PERFORMANCE ASSESSMENTAND FRIEDMAN'S VARIANCE (FR)

Game	Level	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Statistical Outcome
Mover	Basic	90	131	109	144	141	134	133	Fr=13,428 p=0,0367
Dodger	Intermediate	124	204	214	256	237	284	280	
Olympian	Advanced	159	196	286	271	238	325	358	
Collector	Basic	218	217	246	243	224	239	259	Fr=14,142 p=0,0281
Wrangler	Intermediate	443	454	489	456	535	538	558	
Shapeshifter	Advanced	455	494	491	531	528	563	564	
Cruiser	Basic	176	202	183	219	217	234	253	Fr=16,035 p=0,0136
Slingshotter	Intermediate	204	187	228	241	259	266	266	
Speedster	Advanced	265	294	307	328	340	350	329	

The results showed a progressive increase in the score in the proposed games every day, noting improvement of the individual's performance.

V. DISCUSSION

The balance disability indicated in volunteer's outcomes is due mostly to a TBI affecting one of the areas responsible for balance control, the cerebellum. It can be observed through the diagnosis of the imaging magnetic resonance, previously addressed in methodology. However, as the cerebellum was not the only structure affected, according to the diagnosis, it was decided to adopt an overall treatment for balance disorders and TBI.

Physical therapy for patients with TBI shall be instructed for a functional performance of concrete tasks in daily life, as well as leisure activities. In this study games were utilized requiring from the player the execution of activities similar to daily life activities, leading him to carry them out in a pleasurable way [7].

One of the main purposes of rehabilitation by using VR is to provide tasks which require from patient repeated movements involving processes of different sensory modes, such as sight, touch, hearing, and proprioception. They provide quantitative and qualitative improvements in daily activities, and increase its functions, improving independent quality of life [16].

The games selected for the volunteer had many repeatable movements, such as jumping, avoiding obstacles, kneeing and making side evasions. At each therapy the volunteer himself observed he could perform a new movement, unable in the previous attendance. In addition, he better performed a given movement in the end of treatment due to repeatability. Repeatability has shown a strong aspect in this kind of therapy.

The adaptation with movements required in the game occurred quickly because the movements were similar to those required in the volunteer's daily life, besides being repeatable. The difference was that, in the game, the movements were reproduced in a virtual scenario, a new situation for the volunteer, and they required a high level of attention, concentration and effort. The adaptation with the console system, which does not require devices, was very good; it was also one of the factors that attracted the volunteer, since it was a different resource for someone who had been performed physical therapy one year ago and was used to traditional equipment.

The exploration of virtual environments by individuals with different disabilities provides new approaches that are impossible to be performed usually. Even the volunteer stated in an interview that he liked the therapy because, besides using the mind, he had to do movements with his own body [17].

The adaptation of games and its accessories by the patient in order to fulfill the purposes given in the routine of a rehabilitation process is a decisive factor for the success of this approach. By submitting the patient to a game as a part of his/her treatment, we assure a continuing involvement between the patient and his/her routine of rehabilitation [22].

The significant involvement of the volunteer with the therapy was also a positive factor for the improvement. Every time he could not perform a given movement or achieve a score, he turned that into an encouragement for the next session. And every time he could improve his results, it was a point of overcome. Many applications utilizing VR provide opportunities for individuals to take part in new and rewarding experiences [16].

The VR can promote the recovery of body balance through a program of repeatable and active physical exercises which involve the eyes, head, body, or physical maneuvers performed by the patient. It aims to stimulate the vestibular system and to enhance CNS neuroplasticity. The virtual reality games chosen for the therapy involved repeatable movements of the eyes, head, and body, improving balance [23].

A study of four cases of spinocerebellar ataxia showed improvement in motor coordination and postural balance with virtual reality use [26].

The study of nine children, aged 4 to 6 years, referred to physical therapy with developmental coordination disorder, participated in 10 game-based intervention sessions, it was concluded that children seemed to be motivated and to enjoy the interaction with the VR environment and VR games seemed to be beneficial in improving the children's motor function[27].

A study performed by Schiavinato et al. [18] that utilized Nintendo Wii as a VR tool with a 24-year female patient with early onset cerebellar ataxia, gait ataxia, and balance deficiency has shown results such as improved balance and higher independence in her daily life activities.

The study showed that the equilibrium, distribution plantar pressure and the teste Time Up and Go (TUG), measured the patient with cerebral palsy spastic diparesis the participant type this case study, were influenced positively the Nintendo Wii game systems with accessory Balance Board [28].

Another study performed by Doná, Santos & Kasse, with an 82-year female diagnosed with right-deficient vestibular syndrome, multisensory changes, sudden deafness, complaints on lack of balance, chronic vertigo, history of falls, who underwent a therapy with BRU has shown results such as improvement in functional body balance, quality of life, and functional ability [19].

The aim of this study was to investigate the role of VR using video game to the improvement of postural control in a chronic stroke survivor and the protocol resulted in higher amplitude of sway in x and y for both eyes open and eyes closed condition, and a higher area of sway in both conditions too [25]. That is consistent with the study performed.

It is Barcala et al. [24] performed a study in which balance was assessed in 12 hemiparetic patients who underwent a balance training with Wii Fit software. They were divided into two groups: a control group had only conventional physical therapy for one hour, and the other group had physical therapy for thirty minutes and thirty minutes of Wii Fit training. Results indicate that either the control group or the Wii Fit group had a better control of static and dynamic balance, and the researchers concluded that the use of devices had significant outcomes in balance rehabilitation for hemiparetic individuals, what may represent one more therapeutic resource.

According to the studies mentioned above, the utilization of VR brought good outcomes to the participants. This was also observed in this study since the volunteer had improvement in his body balance.

VI. CONCLUSIONS

According to the results observed in the study, we concluded that VR as a therapeutic media has made improvements in the volunteer's body balance possible.

The participant showed increased scores in all games proposed, improving their performance.

At our clinical practice, the use of VR has demonstrated itself successful.

Since it is still considered a new therapy in the rehabilitation, several studies can be exploited, in relation to motivational aspects, appropriate therapy time, data about the participant's functional performance, if the VR is most effective when applied alone or in combination with other conventional therapies.

Finally, a broad research field can be explored to the continuity of this work.

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