ORIGINAL ARTICLE

Comparison of scores obtained in videogame with biomechanical variables in stroke

Fernanda Botta Tarallo[1], Jéssica Santos da Silva[1], Mayara Luz Alcantara dos Santos[1], Pedro Claudio Gonsales de Castro[2], Maria Cecília dos Santos Moreira[3]

ABSTRACT

Virtual reality (VR) promotes intensive training of a single task, enabling the motor learning, thereby affecting the recovery of postural control (PC) in individuals with stroke. Video game with balance platform are used as a form of intervention and, at the end of the game, a score is provided, but there is no evidence that it can be used as a quantitative parameter of PC. **Objective:** To determine whether there is a correlation between the score obtained by a video game and stabilometric variables. **Methods:** Nine individuals with stroke participated in an experimental protocol using the game Penguin Slide as intervention. The score was collected in the first and last sessions. The 2.0 AMTI force platform was used, with an acquisition frequency of 200Hz for evaluating before and after intervention. The volunteers were positioned with open eyes (OE) and closed eyes (CE) in the upright position for 1 minute, with one foot on each platform. Using the Matlab software, the variables of center of pressure (COP) were obtained: total COP area (ACOPt), COP area on the mediolateral (ACOPx) and anteroposterior (ACOPy) axis, average speed of COP (VCOP). The non-parametric paired Wilcoxon test ($p < 0.05$) was used to compare the initial and final results of Penguin Slide game score and the pre and post intervention data obtained by the force platform in the OE and CE conditions. The analysis were done with the software R. **Results:** Comparison of initial and final score ($p = 0.003$). In OE condition, the initial and final comparison: ACOPt ($p = 0.91$), ACOPx ($p = 0.57$), ACOPy ($p = 0.49$), VCOP ($p = 0.09$). In CE condition, the initial and final comparison: ACOPt ($p = 0.73$) ACOPx ($p = 1.0$), ACOPy ($p = 0.73$) VCOP ($p = 0.73$). **Conclusion:** The VR did not provide PC improvement of the patients despite the score of the Penguin Slide game have increased significantly at the end of the protocol. Thus, there was no correlation between the score obtained by video game and the stabilometric variables.

Keywords: Stroke/rehabilitation, Video Games, Postural Balance

[1] Physiotherapist, Professional Development Program, Institute of Physical Medicine and Rehabilitation - IMREA HCFMUSP.
[2] Physiotherapist, Institute of Physical Medicine and Rehabilitation - IMREA HCFMUSP.
[3] Physiotherapy Director of the Institute of Physical Medicine and Rehabilitation - IMREA HCFMUSP.

Mailing address:
Instituto de Medicina Física e Reabilitação HCFMUSP
Serviço de Fisioterapia
Pedro Claudio Gonsales de Castro
Rua Domingos de Soto, 100
CEP 04116-040
São Paulo - SP
E-mail: pedro.castro@hc.fm.usp.br

Received on October 17, 2015.
Accepted on September 21, 2016.

DOI: 10.5935/0104-7795.20160027

INTRDUCTION

The cerebrovascular accident (stroke) is characterized by a sudden establishment of a neurological deficit that may cause, depending on the area of the injury, relative clinical conditions, among them hemiparesis is the most common. There are, however, motor, sensitive, cognitive, and perception related deficits,[1] which bring about important alterations in postural control (PC).[2] Falls are one of the most relevant complications of patients with stroke and interfere in their functional recovery,[3] causing the balance retraining to be an important approach in the rehabilitation of these patients. In 2009, 160,121 hospitalizations due to cerebrovascular diseases were registered, with a mortality rate of 51.8 per 100,000 individuals,[4] what confirms the relevance of researches focused on advances for the rehabilitation of these patients.

The PC covers the body positioning in the space, with the objective to maintain it stable and oriented, whereas the stability is characterized by the individual capacity to hold the center of mass (CM) projected inside the limits of the base support.[5] There are three sources engaged in the PC: the somatosensitive afferences, the vestibular afferences and the visual afferences. Their integration combined with the ability to choose and use the most adequate sensorial input is crucial to the suitable PC.[6] Maintaining the balance, even in a static posture, is a dynamic process in which forces interact with the body and the vertical projection of these forces impacts the center of pressure (COP). The COP oscillation is inversely proportional to the postural stability, in other words, the bigger the COP oscillation, the lower postural stability, once the CM is the closest to the stability limits.[7]

The treatment methods for rehabilitating patients with stroke are based on the motor learning principles, in which the repetitive and intensive practice of a specific task induces cerebral plasticity modifications and influences the functional recovery of the deficits.[8,9] It is known, however, that the conventional therapies promote a limited amount of repetitions,[9] whereas therapies with virtual reality (VR)[10-12] have become promising, once they allow intensive and repetitive training of one single task.[8]

VR is described as form of interface between the user and the computer that simulates a real environment and that allows the patients to interact with it.[13]

It is a resource that assures visual feedback as an opportunity for the patients to observe their own movements in real time, facilitating the training and activating mirror neurons.[9] The mirror neurons aid the cortical reorganization and the learning facilitation, therefore contributing to the functional recovery.[14]

In November 2006, Nintendo® released the seventh-generation videogame console Nintendo Wii®, a non-immersive VR device.[15] With the Wii Remote is possible to recognize gestures in an envonment[16] and, with the use of a balance platform, connected to the console via Bluetooth, the user on the platform can control a virtual character (avatar) by using the movements of the trunk, upper limbs and lower limbs. Considering the potential benefits of this new tool in rehabilitation of patients with neurological alterations, in 2008 the first case report of the use of Nintendo Wii® as a tool for neurological rehabilitation of a patient with cerebral palsy was published[17] and many other studies were performed ever since.

Among the games proposed by Nintendo Wii® there are the ones named "balance games". Such games use balance strategies to control a virtual character (avatar) that is shown on the TV screen, by which the patient can actively interact with the game. At the end of each game, the console releases a score, however it is not known whether it can be rated as a quantitative parameter for the balance evolution.

Thus, evaluating the use of VR as a tool for the balance retraining as a mean to verify if it is an effective therapy, capable of enhancing the PC of patients with stroke sequelae have become a request. This verification will allow the inclusion of this videogame console as a therapy program.

OBJECTIVE

The objectives were to compare the score released by the videogame in the first and last virtual therapy and to compare the data collected at the force platform before and after the intervention. Verifying whether there is a correlation between the average score obtained in a single game with the kinetic variables collected in the force platform of the patients with stroke sequelae completed the objectives.

METHODS

This study was performed in the Institute of Physical Medicine and Rehabilitation of the General Hospital of the Medical of the University of São Paulo (IMREA - HCFMUSP). Nine subjects of both genders, five male patients, with sequelae of stroke, were included. The mean age was 50.88 years (± 11.63), and seven of them had right hemiparesis. The subjects consented their participation signing the informed consent form. Their participation was mediated by the Ethics Committee of the General Hospital of the Medical School of the University of São Paulo, whose approval registration was 0735/10.

The exclusion criteria were muscle tonus higher than 1+ in the Modified Ashworth Scale[18] of the soleus, gastrocnemius, tibialis anterior, quadriceps, and hamstring muscles, once they are considered highly important for the maintenance of balance and PC; muscle strength lower than 3 in the mentioned muscles; atrophies and deformities in the lower limbs that could limit the movement range of waist, knee and ankle; cognitive deficits and psychiatric alterations that could hinder the application of the proposed therapy; visual loss that could jeopardize the performance of the therapy; previous diseases that could interfere in the evaluations; cerebellar or vestibular system compromised; obesity.

Equipment for the biomechanics analysis

The data collection was done in the Movement Laboratory of IMREA-HCFMUSP with its three force platforms AMTI 2.0/2004, model OR6-7 (1000). With these platforms, it was possible to measure the tridimensional forces of the patients in the axis x (medial-lateral), y (antero-posterior) and z (vertical) as assisted by the reference system of the laboratory. Although the platforms have a frequency of data collection of 1000Hz, this study used the frequency of 200Hz, and the platforms 2 and 3 were the ones used. They were calibrated prior to the experiment.

Evaluation

After the selection, the patients were evaluated in the Movement Laboratory of the IMREA - HCFMUSP before and after the end of the experimental protocol, which lasted 24 weeks, under the same conditions: The sub-

jects were positioned in an erect posture with the arms to the side of the body; Each foot laid on one platform, the left foot on the platform 2 and the right foot on platform 3. This way, the x-axis represented the medial-lateral (ML) position and the y axis the antero-posterior (AP). The task was performed as follows: a) opened eyes (OE), in which the patient looked at a fixed mark on the wall of the Movement Laboratory; and b) closed eyes (CE), when the patient wore dive goggles filled with cotton to eliminate any visual sensorial information. The task was previously explained to the patient, and a researcher supported the subject along the task for safety. Three attempts of one minute each was performed. The first attempt was for adapting the patient to the task, the second was the valid one for the data analysis, and the third was done for data safety, in case there was experimental error. Between the attempts, the patients could sit and rest for 1 minute.

Therapy intervention materials

For performing the research, the videogame Wii® was used. A console, a wireless manual control, and a balance board are parts of the videogame. The manual control and the balance board are responsible for the interface between the patient and the virtual environment. The console and the balance board are connected via Bluetooth.

In this study, the wireless manual control was used solely for accessing the videogame menu. The balance board was positioned two meters away from the TV screen, which in its turn was 90cm above the ground. Bedrolls were placed around the balance board of the videogame as to protect the patients in case of any falls, which was prevented by a researcher that stayed next to the patient during the task. The score accounted in the study was collected during the Penguin Slide game, once it presents the same degree of difficulty, therefore allowing the comparisons of the score before the first and after the last session of the experimental protocol.

The Penguin Slide is a game in which, for 90 seconds, a penguin must move over an iceberg trying to catch the fish that are tossed from one side to another. For doing so, the patient must move over the platform, from one side to another without letting the avatar slip and fall in the sea. This activity requests medial-lateral movements and the patients skill to quickly shift their body weight from one side to another.

Protocolo experimental

The research protocol consisted of five balance games of a videogame played twice a week for 24 weeks. In the protocol, Penguin Slide was the chosen game in the weeks 1, 3, 6, 8, 11, 14, 17, 20 and 23. In each session, the same game was repeated five times. All the patients had physiotherapy sessions twice a week, which consisted of global stretching, muscle strengthening, balance and proprioception training, gait training, daily life activities orientation, and, in some cases, physical resources. Each session lasted around one hour approximately.

Data collection and processing

The scores from the first and the last day of the protocol were the only ones collected; this way, in these days, at the end of each repetition of the Penguin Slide game, the score given by the videogame was collected. Also, the data obtained in the Movement Laboratory before the beginning and after the end of the experimental protocol were collected. The kinematic variables were processed by the software EVArT 5.0 and the Ortotrack 6.6.4, and calculated with the Matlab® 7.0 (high performance and interactive statistical analysis software for numeric calculation that integrates numeric analysis, matrix calculation, sign processing and graphic construction).[19]

Variable description

Among all available variables of the software, the chosen ones were:

a) Total area of center of pressure (ACOPt): it represents the area of the transit of the center of pressure (COP) along AP and ML axis.
b) Area of COP in x axis (ACOPx): it represents the roaming of COP transit the ML axis;
c) Area of COP in y axis (ACOPy): it represents the transit of COP along the AP axis; ACOPy
d) Average velocity of COP (VCOP): the velocity of the COP movements determines how fast the movements were.

Statistical Analysis

The software R was used for verifying whether there were any changes in the score Penguin Slide game and whether there were changes in the analyzed variables of the force platform, either with the open eye condition (OE) or with the closed eye condition (CE), and the statistical test was the non-parametric paired Wilcoxon, at a significance level of $p < 0.05$.

RESULTS

The score data are described in Table 1. The comparison of the Penguin Slide game score in the beginning and the end of the intervention has shown that there as a statistically significant difference ($p = 0.003$) of the results after the intervention.

The comparison of the variables ACOPt, ACOPx, ACOPy, and VCOP collected in the initial and final evaluations, with OE (Table 2) and CE (Table 3) conditions have shown that their central tendency measures have no difference. Therefore, the results suggest that the game did not interfere in the balance improvement, once the Penguin Slide score increased, but the variables that evaluated the PC did not outcome as statistically different. Thus, no correlation was observed between the Penguin Slide score and the improvement of PC.

DISCUSSION

Trials investigate VR once it allows a computer interface that involves real time simulation of movements that stimulates the user to react towards what is shown on the screen. As the balance rehabilitation require motor learning and, therefore, is dependent on the practice and the feedback,[19] the virtual therapy could be a promising instrument in the rehabilitation of neurologic patients.

However, the results of the present study have shown that, even with statistically significant increase in the score of the game Penguin Slide of the Nintendo Wii® videogame (Table 1), which could be an evidence of improvement of the postural control (PC) of the patients, there were no statistical differences between the results after the intervention concerning the conditions OE (Table 2) and CE (Table 3), suggesting that the applied virtual therapy protocol was not satisfactory for the improvement of the (PC) of patients with stroke sequelae.

In the study by Cho, Lee and Song,[10] patients with stroke sequelae were evaluated on static balance (postural oscillation speed) and dynamic balance (Berg balance scale - BBS, Timed Up and Go - TUG), and were randomized

Table 1. Score in the first session (initial) and the fourty-sixth session (final) for each patient in the Penguin Slide game

Randomization	Initial score Penguin Slide	Final score Penguin Slide
IND. 1	42.8	52
IND. 2	37.8	66.4
IND. 3	43.4	74.8
IND. 4	52	84.8
IND. 5	39	68
IND. 6	47.6	68.2
IND. 7	32	65.2
IND. 8	60.6	74.4
IND. 9	57.6	88.8
Mean	45.8*	71.4*
Standard Deviation	9.45	10.97

* Statistical difference ($p = 0.003$).

Table 2. Mean of the variables analyzed in the force platform and the *p*-value

	Before-OE	After-OE	*p*-value
ACOPt	382.26	281.15	0.910
ACOPx	11.84	13.29	0.570
ACOPy	28.83	27.39	0.496
VCOP	2.14	1.58	0.097

Open eyes condition.

Table 3. Mean of the variables analyzed in the force platform and the *p*-value

	Before-CE	After- CE	*p*-value
ACOPt	494.50	458.62	0.734
ACOPx	23.65	14.17	1.000
ACOPy	33.62	29.23	0.734
VCOP	2.76	2.28	0.734

Closed eyes condition.

to control group (physiotherapy only) and experimental group (physiotherapy combined with virtual reality). The results indicate there was a considerable increase in the dynamic balance skills of the experimental group when compared to the control group. However, when the antero-posterior (AP) and medial-lateral (ML) postural oscillation speed in open and closed eyes conditions (OE and CE) were analyzed, no statistical difference was found in the groups, what suggested there was no static balance improvements in any of the groups. It was expected that, in the CE condition, the patient would gain more postural oscillation speed due to the loss of the visual afference. This result agrees with the results of the present study, once the force platform was used, a device commonly applied for evaluating the static balance and he postural oscillation.

Barcala et al.[11] used the Berg scale and the stabilometry which measures the oscillation of the COP in the axis AP and ML by a pressure platform in the conditions OE and CE. The results found by Barcala et al.[11] suggest that, after the experimental protocol, there was a decrease in the ML oscillation and an improvement in the Berg score in both groups, but the AP oscillation was reduced only in the group that used the VR therapy, indicating that RV may influence the balance recovery, especially in the AP strategies. This result is opposed to the ones found in the present study, in which no statistical difference was found in the total corporal oscillation, neither AP nor ML.

Gil-Gómez et al.,[8] however, found improvements of the static balance of stroke patients after undergoing virtual therapy combined with conventional therapy. Morone et al.[12] achieved, in their findings, balance and independence for daily life activities improvements in subacute stroke patients who performed physiotherapy associated to balance training at Wii fit, as compared to those who performed physiotherapy combined with conventional balance training.

The results presented in the previous studies,[8,12] which applied only scales as tools for evaluating the balance, indicated the improvement of PC after the intervention with Wii Fit, however the studies which applied the posturography for evaluating the PC did not find significant statistical differences in the variables analyzed in the force platform, except for Barcala et al.[11] study, in which the six patients of the experimental group presented AP reduction of the COP, whereas the Berg scale score and the medial-lateral oscillation of the COP did not have significant difference when compared to the patients of the control group.

The authors Goble, Cone and Fling,[20] performed a review on the use of Wii Fit as a tool for evaluating the balance and neurological rehabilitation and concluded the interventions of Wii Fit are effective, evidencing balance improvement when measured by instruments as the Berg scale and the TUG which evaluate dynamic components. They concluded, however, that there is a gap in the scientific researches that evaluate the recovery of CP based on virtual therapy due to the lack of convincing statistical significance, once most of the studies assessed narrow samples of training patients, with as many as 40% of the studies being performed with sample sizes of five or less patients.

CONCLUSION

Thus, it is possible to conclude that the proposed intervention did not significantly change the data of the variables collected during the evaluation of the force platform, suggesting the patients with sequelae of stroke had no improvements of postural control after receiving a virtual therapy protocol composed of five balance games of a videogame, however, other studies, with broader sample sizes, could be performed to test this hypothesis, and function scales as Berg and TUG should be used, once, per literature they present significant results after the application of virtual therapy. The game used in this study was not rated as adequate to improve the postural control and, therefore, other games could have their efficacy evaluated.

REFERENCES

1. Velasques BB, Ribeiro P. Reabilitação motora no acidente vascular encefálico: uma abordagem das neurociências. 2 ed. São Paulo: Rubio; 2013.
2. Pollock AS, Durward BR, Rowe PJ, Paul JP. What is balance? Clin Rehabil. 2000;14(4):402-6.
3. An S, Lee Y, Lee G. Validity of the performance-oriented mobility assessment in predicting fall of stroke survivors: a retrospective cohort study. Tohoku J Exp Med. 2014;233(2):79-87. DOI: http://dx.doi.org/10.1620/tjem.233.79
4. Almeida S. Análise epidemiológica do acidente vascular cerebral no Brasil. Rev Neurocienc. 2012;20(4):481-2.
5. Shumway-Cook A, Woollacott MH. Controle motor: teoria e aplicações práticas. Barueri: Manole; 2003.
6. Oliveira CB, Medeiros IR, Frota NA, Greters ME, Conforto AB. Balance control in hemiparetic stroke patients: main tools for evaluation. J Rehabil Res Dev. 2008;45(8):1215-26. DOI: http://dx.doi.org/10.1682/JRRD.2007.09.0150
7. Barbosa AF, Costa TDA, Oliveira MFP, Castro PCG, Moreira MCS, Goroso DG, et al. Quantificação do equilíbrio pelo vídeo game: estudo piloto. Acta Fisiatr.2014;21(1):21-5.
8. Gil-Gómez JA, Lloréns R, Alcañiz M, Colomer C. Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: a pilot randomized clinical trial in patients with acquired brain injury. J Neuroeng Rehabil. 2011;8:30. DOI: http://dx.doi.org/10.1186/1743-0003-8-30
9. Lohse KR, Hilderman CG, Cheung KL, Tatla S, Van der Loos HF. Virtual reality therapy for adults post-stroke: a systematic review and meta-analysis exploring virtual environments and commercial games in therapy. PLoS One. 2014;9(3):e93318. DOI: http://dx.doi.org/10.1371/journal.pone.0093318
10. Cho KH, Lee KJ, Song CH. Virtual-reality balance training with a video-game system improves dynamic balance in chronic stroke patients. Tohoku J Exp Med. 2012;228(1):69-74. DOI: http://dx.doi.org/10.1620/tjem.228.69
11. Barcala L, Colella F, Araujo MC, Salgado ASI, Oliveira CS. Balance analysis in hemiparetics patients after training with Wii Fit program. Fisioter Mov. 2011;24(2):337-43. DOI: http://dx.doi.org/10.1590/S0103-51502011000200015
12. Morone G, Tramontano M, Iosa M, Shofany J, Iemma A, Musicco M, et al. The efficacy of balance training with video game-based therapy in subacute stroke patients: a randomized controlled trial. Biomed Res Int. 2014;2014:580861. DOI: http://dx.doi.org/10.1155/2014/580861
13. Valerio Netto A, Machado LS, Oliveira MCF. Realidade virtual: definições, dispositivos e aplicações. REIC. 2002:1-33.
14. Saposnik G, Teasell R, Mamdani M, Hall J, McIlroy W, Cheung D, et al. Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. Stroke. 2010;41(7):1477-84. DOI: http://dx.doi.org/10.1161/STROKEAHA.110.584979
15. Souza LB, Paim CRP, Imamura M, Alfieri FM. Uso de um ambiente de realidade virtual para reabilitação de acidente vascular encefálico. Acta Fisiatr. 2011;18(4):217-21. DOI: http://dx.doi.org/10.5935/0104-7795.20110010
16. Halton, J. Virtual rehabilitation with video games: A new frontier for occupational therapy. Occup Ther Now. 2008;9(6):12-4.
17. Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. Phys Ther. 2008;88(10):1196-207. DOI: http://dx.doi.org/10.2522/ptj.20080062
18. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther. 1987;67(2):206-7.
19. Meldrum D, Glennon A, Herdman S, Murray D, McConn-Walsh R. Virtual reality rehabilitation of balance: assessment of the usability of the Nintendo Wii® Fit Plus. Disabil Rehabil Assist Technol. 2012;7(3):205-10. DOI: http://dx.doi.org/10.3109/17483107.2011.616922
20. Goble DJ, Cone BL, Fling BW. Using the Wii Fit as a tool for balance assessment and neurorehabilitation: the first half decade of "Wii-search". J Neuroeng Rehabil. 2014;11:12. DOI: http://dx.doi.org/10.1186/1743-0003-11-12