ORIGINAL ARTICLE

The Effect of Virtual Rehabilitation and Constraint Induced Movement Therapy (CIMT) on Improving Upper Extremity Motor Activity Post-Stroke

Aiman Farogh Anjum, Humaira Fayyaz, Arif Siddiqui

ABSTRACT

Objective: This study aimed to assess the effect of Constraint Induced Movement Therapy (CIMT) augmented by Virtual Rehabilitation in improving upper extremity activity capacity and ability to perform Activities of Daily Living (ADL).

Study Design: Pre/Post Quasi Experimental Study.

Place and Duration of Study: It was carried out at the Physiotherapy department at Holy Family Hospital, Rawalpindi in collaboration with Islamic International Medical College, Riphah International University, Islamabad, Pakistan from March 2015 to March 2016.

Materials and Methods: The study included 20 stroke patients who were subjected to Constraint Induced Movement Therapy augmented by Virtual Rehabilitation using Nintendo WiiTM four times a week for four weeks. Upper extremity activity capacity and Activities of daily living (ADL) were measured pre- and post-intervention using Action Research Arm Test (ARAT) and Barthel Index respectively.

Results: The ARAT improved from a pre-intervention mean score of 16.20+3.942 to 48.30+5.768 post-intervention ($p<0.001$). Barthel index showed improvement from the pre-intervention mean score of 9.05+2.544 to a post-intervention mean score of 16.80+1.609 ($p<0.001$).

Conclusion: Virtual rehabilitation using Nintendo WiiTM has a positive impact on upper extremity motor recovery and subsequently the ability to carry out Activities of Daily Living, if used as an adjunct to Constraint Induced Movement Therapy (CIMT).

Key Words: *Constraint Induced Movement Therapy (CIMT), Nintendo WiiTM, Stroke, Upper Extremity Motor Capacity, Virtual Rehabilitation.*

Introduction

Stroke is the most common cause of disability worldwide[1] with 350,000 new cases per annum and a prevalence of 4.8% in Pakistan.[2] Thromboembolism of cerebral arteries and hemodynamic disturbances are the two main mechanisms involved in the pathophysiology of stroke. Ischemic stroke accounts for 87% of the total burden of stroke while hemorrhagic strokes (spontaneous intracerebral and subarachnoid hemorrhage) comprise of the remainder of all cases.[3]

Survivors of stroke suffer debilitating sequelae like impairment of motor function of the upper and/or lower limbs, speech difficulties, sensory deficits, impairment of genitourinary or bowel functions etcetera, that hinder activities of daily life and lower the chances of leading a normal, productive and fulfilling existence.[4] Upper limb motor function impairment after stroke (the primary focus of this study) is one such complication that neuro-physicians and physiotherapy specialists strive to improve as it allows the patients to, not only carry out daily life tasks with more ease and comfort but it has been shown to have a positive impact on the psychological well-being of stroke survivors as well.[5]

Regaining upper limb motor function post stroke by means of physical therapy has a corresponding positive impact on the ability to carry out routine tasks like bathing, dressing, toilet use, feeding and climbing up and down the stairs (collectively termed as Activities of Daily Living (ADL)).[6] Constraint-induced movement therapy (CIMT) is based on forced use of the affected limb by restraining the uncompromised limb for 90% of the waking hours and "shaping", a form of behavioral conditioning in which certain task specific exercises are aimed at

Department of Physiology
Islamic International Medical College
Riphah International University, Islamabad

Correspondence:
Dr. Aiman Farogh Anjum
Department of Physiology
Islamic International Medical College
Riphah International University, Islamabad
E-mail: aiman.anjum@hotmail.com

Funding Source: NIL; Conflict of Interest: NIL
Received: Apr 22, 2016; Revised: Nov 05, 2016
Accepted: Jan 10, 2017

achieving a specific goal (such as movement of the impaired arm). The intensity of these tasks is increased in a step-ladder pattern according to the patient's improvement.[7]

Virtual Rehabilitation is a novel technology that relies on the mirror-neuron system to bring about restructuring of the neuronal network in regions of the brain concerned with memory, learning and motor function.[8] In this aspect, Nintendo WiiTM is an innovative, cost-effective and ubiquitous technology which makes use of an on-screen "avatar" in order to incite "mirror-neurons" through "audio-visual" input to bring about neuronal re-organization and subsequent motor improvement. It has an added benefit of modifiable skill and speed which can be tailored according to the user's needs.[9]

Numerous studies have been conducted to shed some light on the effectiveness of Virtual Rehabilitation on motor improvement in stroke survivors but they have mainly focused on regaining lower limb function. Furthermore, combination of VR with CIMT for the purpose of improving the motor function profile in stroke survivors is an area that has not been explored at length as yet.[10] As far as the role of CIMT augmented by motion capture consoles like Nintendo WiiTM in improving upper extremity motor function is concerned, a dearth of bonafide research still remains.[11]

Application of virtual reality based video games, Nintendo Wii in particular, for objectives other than stroke rehabilitation have shed some light on the effect of this console on improving hand-eye coordination. A study conducted at Arizona State University by Kullman, 2008, evaluating the efficacy of Nintendo Wii as a tool for improving hand-eye coordination in surgeons found that the use of Nintendo Wii among surgeons "improves hand-to-eye coordination, strength and dexterity as the motion-sensitive controller allows some games to require very precise hand movements, similar to those executed during surgery".[12] This effect might similarly manifest, albeit to a lesser extent, in the stroke survivor population undergoing "Wii-habilitation"[13] allowing them to regain some level of coordinated hand and arm motion as well as a greater degree of strength and skill.

Data pertaining to upper extremity rehabilitation employing Constraint Induced Movement Therapy based on exergaming technology is scarce. This study aimed to assess the effect of Constraint Induced Movement Therapy (CIMT) augmented by Virtual Rehabilitation in improving upper extremity activity capacity and ability to perform Activities of Daily Living (ADL).

Materials and Methods

This was a Pre/Post Quasi Experimental study with one year duration from March 2015 to March 2016. The study was conducted at Medical Unit I and II and the Physiotherapy department of Holy Family Hospital Rawalpindi in collaboration with Islamic International Medical College Rawalpindi after the approval of Ethical Review Committees at both institutions.

The inclusion criteria were; first event of stroke, age ranging from 30 to 60 years, impairment of motor function in one arm, 1-4 months since the event of stroke, an understanding of computer/video game technology and clinically defined stroke by CT-scan or MRI. Patients of stroke with other neurological diseases, cognitive deficits, diagnosed dementia or epilepsy, language difficulty that would affect the capacity to receive information about the training procedure, visual impairment, orthopedic injuries that could impair locomotion, and inability to carry out voluntary arm movement were not included in the study. A total of 20 stroke patients were recruited in the study by purposive sampling.

Written informed consent was taken from all the subjects. The subjects were asked to report at Physiotherapy Department at Holy Family Hospital Rawalpindi in the morning. Age, gender, blood pressure, hemisphere, type of stroke, and handedness of the subjects were recorded. "Activities of Daily Living (ADL)" were measured using the "10-item Modified Barthel Index" which has a score of 0-20. Upper extremity "activity capacity" was assessed using the "Action Research Arm Test (ARAT)", scored from 0 to 57.

The subjects were then subjected to Constraint Induced Movement Therapy/CIMT for the upper extremity (a physiotherapy regimen where the use of the un-affected limb is limited by putting a weighted mitt over it for majority of the waking hours) using interactive video gaming technology (Nintendo WiiTM) for four sessions a week for four weeks (total 16 sessions) of 20 minute duration. The subjects were made to wear a weighted mitt on the unaffected arm during the course of the session. The speed and difficulty of each game was set according to each subject's level of comfort and the dexterity and mobility of the affected arm. The tasks each of the games demanded to be performed are listed in Table I.

Table I: Tasks/Movements Demanded by each of the Nintendo WiiTM Games Employed in the Study

Nintendo Wii™ Games	Tasks Performed by the affected upper limb
Wii Bowling	Gripping the Wiimote Swinging of the arm Wrist movement Supination and pronation of the forearm Flexion and extension of the wrist Flexion and extension of the elbow joints Flexion, extension, abduction and adduction of the shoulder joint
Cooking Mama for Nintendo Wii™	Gripping the Wiimote Slicing movements, Grasping, pinching, rolling of fingers

The gameplay was displayed on a projector screen. Since the intervention pertained to the upper extremity only, the patients performed the tasks demanded by the games while sitting upright on a stool. The researcher herself carried out the intervention sessions, providing guidance to the subjects throughout the duration of the gameplay as well as assisting the subjects in case they encountered instability in maintaining sitting position (a rare occurrence). The gameplay sessions were scheduled for four days a week. Ten minutes were designated to each of the two games mentioned. Patients initially found it difficult to grasp the Wii-mote optimally and were thus assisted by the Velcro strap provided along with the Wii-mote to cater for such difficulties.

Each subject's progress in terms of gameplay, speed and dexterity was charted along the course of the intervention phase. The level of difficulty of each game was progressively increased after the subjects showed improvement in performing the tasks demanded by the previous level of the videogames. The subjects were also asked to limit the use of the unaffected arm for the rest of the day and note the time for which they complied with this undertaking. They reported the time for which the unaffected was not used during the previous days before every session.

"Activities of Daily Living" and upper extremity "activity capacity" were assessed using the "Barthel index" and "ARAT" respectively.

Statistical Analysis was done using SPSS 21. Results were documented as mean + SD. Statistical significance was set at $p < 0.05$. Paired-samples t-test was used to check difference in pre- and post-intervention scores of ARAT and Barthel index.

Results

The demographic variables of the 20 subjects included in the study are given in Table II. Highly significant ($p<0.001$) improvement was seen between the pre- and post-intervention scores of ARAT. All four subtests of ARAT i.e, grasp, grip, pinch and gross movement also showed highly significant improvement between the pre- and post-intervention scores, given in Table III. The pre-intervention mean Barthel index score was 9.05 +2.544. Post-intervention Barthel index scores improved to a mean value of 16.80 +1.609. The difference was highly significant ($p<0.001$), given in Table IV. Figures I, II, III and IV depict the comparisons of the items pertaining mainly to upper extremity function, namely "grooming, toilet use, feeding and dressing" in the Barthel index, between the pre- and post-intervention scores of the subjects. The differences between the pre- and post-intervention scores in the "grooming" item was significant ($p<0.05$) while it was highly significant in the "feeding", "toilet use" and "dressing" ($p<0.001$).

Table II: Demographic Variables of the 20 Stroke Patients in terms of Mean ± SD of Age (years), Gender, Type of Stroke, Stroke Hemisphere, Handedness and Mean ± SD Time since Stroke (months)

Parameter	Values
Age (years)	51.85 + 6.107
Gender	Male = 14 Female = 6
Stroke type	Ischemic = 11 Hemorrhagic = 9
Stroke Hemisphere	Right = 11 Left = 9
Handedness	Right = 20 Left = nil
Time since stroke (months)	2.70 ±1.174

Table III: Comparison Between the Mean ± SD Total Scores of ARAT, Grasp, Grip, Pinch and Gross Movement, Pre and Post Intervention

Parameter	Pre-intervention	Post-intervention
Total ARAT score (0-57)	16.20+3.942	48.30+5.768**
Grasp (0-18)	4.20+2.567	14.65+2.300**
Grip (0-12)	4.05+ 1.395	10.25+1.293**
Pinch (0-18)	6.40+1.569	15.40+1.930**
Grosmt (0-9)	1.90+2.292	8.00+1.214**

Action Research Arm Test (ARAT), Gross movement (Grosmt) * = P<0.05 (pre-intervention vs post-intervention)
** = P<0.001 (pre-intervention vs post-intervention)

Table IV: Comparison Between the Mean ± SD Barthel Index Scores Between the Pre- and Post-Intervention Assessment

Parameter	Pre-intervention	Post-intervention
BI (0-20)	9.05+2.544	16.80+1.609**

Barthel Index (BI)
* = P<0.05 (pre-intervention vs post-intervention)
** = P<0.001 (pre-intervention vs post-intervention)

Discussion

The results showed that CIMT augmented with Virtual Rehabilitation has a positive effect on improving upper extremity activity capacity which lends credibility to similar results seen in the single subject design trial by Slijper et al. 2014, testing the effectiveness of computer game based upper extremity function showed marked improvement in ARAT scores in 11 of its 12 subjects after a five week intervention phase.[14] Other similar trials have also shown improvements in ARAT scores following interventions based on computer, video game consoles as well as virtual rehabilitation. A pilot study aimed at evaluating the safety and effectiveness of Nintendo WiiTM as a rehabilitative tool for stroke survivors (Christie et al., 2010) showed that although there was an overall improvement in ARAT scores in 6 out of the 9 total subjects after an intervention phase of 6 weeks, only the Grip subscale showed significant improvement (p<0.05) in the affected arm. The finger Pinch subscale also showed marked improvement but was not found to be statistically significant.[15] The improvement in ARAT scores in the current study could be attributed to two things. Firstly, the current study employed not only Nintendo WiiTM but also subjected the patients to a detailed regimen of CIMT while Christie et al., used Nintendo WiiTM as the sole tool for improving motor function. Secondly, the improved motor status of the upper extremity, is believed to be a consequence of long-term potentiation, as observed by Saposnik et al. 2010 in the EVREST trial, which results in the motor cortex retrieving old, and securing new patterns of motor function as a result of task repetition (one of the hallmarks of virtual rehabilitation).[16]

It has been observed that the scores of ARAT, although consistently improved, are not statistically increased in majority of the trials that employ Nintendo WiiTM as the sole vehicle for upper extremity rehabilitation. However, studies that have used Virtual rehabilitative tools as adjuncts to either conventional therapy or to CIMT[17] have shown significant improvements in ARAT scores post-intervention; findings supported by the current study's results.

The highly significant improvement seen in the study group Barthel index scores lend strength to a number of similar studies that employed virtual rehabilitation to achieve motor function improvement for the upper extremity. One such study was the 12 week trial by Cameirão et al. aimed at "using a multi-task adaptive VR system for upper limb rehabilitation in the acute phase of stroke" which showed significant improvement in Barthel index, Motricity and Fugl-Meyer scales for the upper extremity in the study group which underwent rehab therapy using a "Rehabilitation Gaming System (RGS)".[18] Trials conducted by Kyoung-Hee Lee 2015, Kwon JS et al. 2012 and Yoon J et al. 2015 were based on comparing the effectiveness of Virtual Rehabilitation as an adjunct to conventional therapy versus conventional therapy alone for upper extremity rehabilitation. All three trials exhibited significant improvement in the respective forms of Barthel indices used in each study in the study groups.[19-21] Evidence based on such data suggests a positive impact of Virtual rehabilitation on the improvement in upper limb function and subsequently on the quality of everyday life. The possible explanation for the overwhelming improvement in the ADL scale scores of the study groups in each of the trials mentioned as well as those of the current study could be the self-driven effort of the subjects in each study to adhere strictly to the therapy regimen, improvement in hand-eye coordination and overall increased therapy time (CIMT plus time spent playing the virtual rehab games) in addition to the long term potentiation induced by repetitive tasks required to be performed during the gaming sessions.

The role of CIMT in bringing about significant improvement in motor function, as reflected by results of ARAT and Barthel index in the current study cannot be ignored. According to Langhorne et al., 2009 and van Peppen et al., 2004, CIMT has "a significant effect on increasing upper extremity (arm) function" and a "moderate effect on increasing performance of the activities of daily living immediately following treatment (Sirtori et al., 2009)."[22-25]

Conclusion

Virtual rehabilitation has a positive impact on upper extremity motor recovery if used as an adjunct to more robust models of therapy like Constraint Induced Movement Therapy (CIMT). It is an effective and safe means of engaging stroke survivors in rehabilitative practices by increasing self-directed therapy time and improving motor function. However, there is a need for trials to be carried out on a larger scale, involving a greater population of stroke patients.

REFERENCES

1. Feigin VL. Stroke epidemiology in the developing world. The Lancet. 2005; 365: 2160-1.
2. Khealani BA, Wasay M. The burden of stroke in Pakistan. International Journal of Stroke. 2008; 3: 293-6.
3. Sierra C, Coca A, Schiffrin EL. Vascular mechanisms in the pathogenesis of stroke. Current hypertension reports. 2011; 13: 200-7.
4. Whitall J, Waller SM, Silver KH, Macko RF. Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. Stroke. 2000; 31: 2390-5.
5. Raghavan P. Upper Limb Motor Impairment Post Stroke. Physical medicine and rehabilitation clinics of North America. 2015; 26: 599-610.
6. Sehatzadeh S. Effect of Increased Intensity of Physiotherapy on Patient Outcomes After Stroke: An Evidence-Based Analysis. Ontario Health Technology Assessment Series. 2015; 15: 1-42.
7. Covinsky KE, Palmer RM, Fortinsky RH, Counsell SR, Stewart AL, Kresevic D, et al. Loss of independence in activities of daily living in older adults hospitalized with medical illnesses: increased vulnerability with age. Journal of the American Geriatrics Society. 2003; 51: 451-8.
8. Persson HC. Upper extremity functioning during the first year after stroke. Goteborg Universitetsbibliotek. 2015; 15: 178-86.
9. Grotta JC, Noser EA, Ro T, Boake C, Levin H, Aronowski J, et al. Constraint-induced movement therapy. Stroke. 2004; 35: 2699-701.
10. Lambercy O, Dovat L, Yun H, Wee SK, Kuah CW, Chua KS, et al. Effects of a robot-assisted training of grasp and pronation/supination in chronic stroke: a pilot study. Journal of neuroengineering and rehabilitation. 2011; 8: 1-3.
11. Sgandurra G, Ferrari A, Cossu G, Guzzetta A, Biagi L, Tosetti M, et al. Upper limb children action-observation training (UP-CAT): a randomised controlled trial in Hemiplegic Cerebral Palsy. BMC neurology. 2011; 11: 80.
12. Mao Y, Chen P, Li L, Huang D. Virtual reality training improves balance function. Neural Regeneration Research. 2014; 9: 1628-34.
13. Zhu N, Diethe T, Camplani M, Tao L, Burrows A, Twomey N, et al. "Bridging e-health and the internet of things: The sphere project." IEEE Intelligent Systems. 2015; 4: 39-46.
14. Kullman J. Wii" bit of technology aids medical education. Retrieved June. 2008; 9: 5-6.
15. Winkels DG, Kottink AI, Temmink RA, Nijlant JM, Buurke JH. Wii™-habilitation of upper extremity function in children with cerebral palsy. An explorative study. Developmental neurorehabilitation. 2013; 16: 44-51.
16. Slijper A, Svensson KE, Backlund P, Engström H, Sunnerhagen KS. Computer game-based upper extremity training in the home environment in stroke persons: a single subject design. Journal of neuroengineering and rehabilitation. 2014; 11: 1-4.
17. Christie L, Kennedy S, Brennan K, Ellis G, Barber M. Does stroke Wii HAB work? Use of the Nintendo Wii for upper limb rehabilitation following stroke. Cerebrovasc Dis. 2010; 29: 254-5.
18. 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: 1477-84.
19. Gordon AM, Okita SY. Augmenting pediatric constraint-induced movement therapy and bimanual training with video gaming technology. Technology and Disability. 2010; 22: 179-91.
20. Cameirão MS, Oller ED, Verschure PF, editors. Using a multi-task adaptive VR system for upper limb rehabilitation in the acute phase of stroke. Virtual Rehabilitation, 2008; 2008: IEEE.
21. Park HJ, Kim TU, Hyun JK, Kim JY. Family History and Functional Outcome in Korean Stroke Patients: A Preliminary Study. Annals of Rehabilitation Medicine. 2015; 39: 980-5.
22. Kwon JS, Park MJ, Yoon IJ, Park SH. Effects of virtual reality on upper extremity function and activities of daily living performance in acute stroke: a double-blind randomized clinical trial. NeuroRehabilitation. 2012; 31: 379-85.
23. Chen CC, Chen YL, Chen SC. Application of RFID technology—upper extremity rehabilitation training. Journal of Physical Therapy Science. 2016; 28: 519-24.

24. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. The Lancet Neurology. 2009; 8: 741-54.

25. Sirtori V, Corbetta D, Moja L, Gatti R. Constraint-induced movement therapy for upper extremities in stroke patients. Cochrane Database Syst Rev. 2009; 4: 4-6.

....