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Effectiveness of semi-immersive virtual reality therapy along with conventional physiotherapy on improving standing balance and upright mobility function in individuals with chronic incomplete spinal cord injury: A pilot study

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Abstract
Background: Spinal cord injury occurs when there is any damage to the spinal cord that blocks communication between the brain and the body. Spinal cord injury is a kind of high disabling injury; it not only can lead to damage or loss of sensation and motor function, but also may lead to multiple organ dysfunction. Symptoms differ for each person according to the level of injury. Some of the symptoms include loss of motor abilities and sensation, weakness or inability to walk, difficulty with balance and coordination and loss of bowel and bladder control.
Objectives: The study's primary objective was to find out the effectiveness of combined virtual reality and conventional physiotherapy on improving standing balance and upright mobility in subjects with chronic incomplete spinal cord injury.
Subjects and Methods: This study is a pilot study. 10 subjects were recruited by using the selection criteria They received virtual reality therapy along with conventional physiotherapy for 6 weeks. Pre-test and post-test evaluation score for balance and upright mobility was taken using Limit of stability, Berg balance scale, timed up and go test, Activity specific balance scale and Walking index for spinal cord injury-II the values were recorded for statistical analysis.
Result: The statistical analysis showed that the calculated 't' value using the paired 't' test for balance on limit of stability of overall, forward, backward, more affected, less affected were 42.39, 6.324, 9.005, 31.46, 28.92 respectively and for berg balance scale was 17.1 which was greater than the table value of 2.262 with $p<0.05$.
The statistical analysis showed that the calculated 't' value using the paired 't' test for upright mobility on time up and go test, activities specific balance scale, walking index for spinal cord injury-II were 13.70, 6.4, 9.78 respectively which was greater than the table value of 2.262 with $p<0.05$. Thus, the resultant of the study shows that there was significantly improvement in standing balance and upright mobility among chronic incomplete spinal cord injury subjects.
Conclusion: The study concluded that semi-immersive virtual reality therapy along with conventional therapy was found to be effective in improving standing balance and upright mobility among chronic incomplete spinal cord injury subjects.
Clinical implications: The semi-immersive virtual reality therapy along with conventional therapy improves standing balance and upright mobility. Increasing standing balance and upright mobility improves symptoms in chronic incomplete spinal cord injury subjects.

Keywords: ISCI, virtual reality, conventional PT, balance, mobility, BBS, ABC scale, TUG test, LOS etc.

Introduction

Spinal cord injury occurs when there is any damage to the spinal cord that blocks communication between the brain and the body [1]. SCI is a kind of high disabling injury; it not only can lead to damage or loss of sensation and motor function, but also may lead to multiple organ dysfunction [2].
Spinal cord injury has an annual incidence between 40 and 80 cases per million people. Most of them are male (82% in the United States, 72.2% in India), and the mean age is 33 years, with a tendency to rise [3]. In India, approximately 1.5 million people live with SCI. In India fall from height rates highest among the etiological factor [4]. In Tamil Nādu, a total number of 245 cases of spinal cord injury were studied.

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Among them 88% of the patients were males and 12% were females.

The spinal cord comprises a bundle of neurons and has its place in the spinal canal that protects it. In humans, it has a cylindrical form, with 8-10mm of medium diameter, starts at the base of the skull to the level of 1st lumbar vertebrae. The spinal cord gives rise to 31 pairs of spinal nerves. the weight of spinal cord is 30g. it is surrounded by three meningeal layers [dura mater – arachnoid mater – pia mater]. Spinal cord is composed of two different types of tissue; the inner part appears greyish and is called gray matter; the outer instead is white and is called white mater [3].

The causes of spinal cord injury are of two types 1. Traumatic they include (motor vehicle accidents, falls, violence, football, gymnastics, diving into shallow water). The other type of cause is 2. Non traumatic causes they include (cancer, multiple sclerosis, arthritis, osteoporosis, inflammation of the spinal cord).

There are two types of spinal cord injury one is complete spinal cord injury in this there will be no motor or sensory functions below the level of lesion caused by complete transection, severe compression or extensive vascular impairment to the spinal cord. The other is incomplete spinal cord injury in this some amount of motor functions below the level; of lesion indicating that some viable neural tissue is crossing the area of injury to more distal segments. Incomplete lesion is further divided into: (Anterior spinal cord injury, Posterior spinal cord injury, Cauda equina syndrome, Brown Sequard syndrome, central cord syndrome).

The spinal cord injury can be further divided based on their level of injury. They can be classified as: Cervical level injury (were the person is said to have tetraplegia or quadriplegia), Thoracic level injury (were the person is said to have paraplegia), Lumbar level injury (there will be loss of function of hips and legs with little or no control of bladder or bowel but can manage with special equipment), Sacral level injury (there will be loss of function of the hip and legs little or no voluntary control of the bowel and the bladder control but can manage on their own with special equipment).

Management in physiotherapy includes: Respiratory management (Breathing exercise), Bedsore management (positioning, pressure relieving mattress), Spasticity management (roods approach, passive stretching), Bowel and Bladder management (abdominal massage, Valsalva maneuvers), Bed mobility training (mat activities), Transfer techniques, Gait training (orthosis), ADL activity training.

Methodology
Study design: A pre-test, post-test pilot study design was used with interventions to assess the effectiveness of semi-immersive virtual reality therapy along with conventional physiotherapy on standing balance and upright mobility function in individuals with chronic incomplete spinal cord injury.
Subjects: Those subjects with medical history of chronic incomplete spinal cord injury >1year post injury. 10 subjects with incomplete spinal cord injury were selected for this study. Subjects were selected using convenience sampling. This study was conducted at Ashwin multi-speciality hospital and Outpatient Department of PPG College of physiotherapy. The period of study was for 6

month. The treatment duration was for 6 weeks. The inclusion criteria for this study is: Age of 20 to 40. Both males and females. Lumbar L4-L5 level injury was taken. American spinal injury association impairment scale score of D. Ability to walk independently with or without assistive device for > 10m according to WISCI II. Ability to tolerate standing for at least 5min without external support. The exclusion criteria are Lower limb orthopaedic impairment or pain. Use of spinal stabilization braces that may limit mobility. Inability to recognize an object presented on display due to visual impairment. Inability to follow intervention program.

Methods: After getting approval, the study was planned to be conducted at Ashwin multi-speciality hospital and outpatient department of PPG College of Physiotherapy.

Treatment procedure was clearly explained to the patient and the inform consent form was received from the patient prior to the study. 10 subjects were used in a sample of convenience. They received virtual reality therapy and strengthening exercise for 6 weeks. Pre-test and post-test evaluation score for balance, upright mobility was taken using limit of stability, berg balance scale, timed up and go test, activities balance confidence scale and walking index spinal cord injury II and the values were recorded for statistical analysis.

Description of experimental intervention
Virtual reality
The use of virtual reality (VR) in the field of medicine is steadily expanding. As developing technologies to view three-dimensional (3D) objects, such as 3D printing, are being implemented to overcome limitations of observing data in two dimensions (2D), VR is an interactive tool wherein humans can experience a virtual 3D world.

The implementation of VR in medicine has shown positive results in treating peripheral vestibular disorders, reducing pain and anxiety, improving balance in patients with stroke, and increasing patient engagement. VR has the advantage of providing real time performance and graduated stimulus as well as augmenting patients attention and motivation.

Level of immersion
The VR apparatus used depends on the level of immersion, which can be classified into non immersive, semi-immersive and immersive. A Semi-immersive VR system overlays virtual images onto real images (not avatar) to increase the information content. Semi-immersive VR allows individualized programs to be provided to individual patients, and immersion is higher than non-immersive VR in that real images are used in the virtual environment. Semi-immersive VR therapy has already proven to be an effective intervention method for balance and walking function in various subjects, such as community living older adults, those with brain tumours or traumatic brain injuries, and patient's post- stroke. Nevertheless, to date, there have been few studies on the effect of semi-immersive VR therapy on functional ability in patients with chronic ISCI. Wall *et al*. – recently reported that VR therapy improves balance and walking ability in patients with chronic ISCI.

Before starting the treatment session extra-ocular eye exercises was given as warm up session for extra ocular muscle. They are;
1. Blinking eyes for 10 seconds.
2. Eye movement (up and down), (right and left) 3 times.

3. Move the eye in figure of 8 for 30 seconds.
4. Focusing the finger few inches away from eyes and then focusing on other objects alternatively.

Each subject underwent semi-immersive VR therapy 30 minutes per day, 3 times a week for 5 weeks followed by 1 week of treatment in the normal environment. An Interactive Rehabilitation Exercise (IREX) system was used for the VR therapy. The IREX system consists of a television screen, camera, red gloves, and a green screen and mat as a background.

Of the 20 programs available on the IREX, five were included: "soccer," "conveyor," "volleyball," "formula racer," and "snowboard." Each program was performed for 5 minutes with a 1-minute break between programs.

Strengthening exercise
Muscle-strengthening exercise, sometimes referred to as strength/weight/resistance training or exercise, is a voluntary activity that includes the use of weight machines, exercise bands, hand-held weights, or own body weight (example push-ups or sit-ups). When performed regularly, clinical exercise studies show that muscle-strengthening exercise increases skeletal muscle strength, power, endurance and mass. This exercise-related behaviour is usually performed during a person's leisure time, commonly within community (fitness centres/gyms) or home settings. An individual may engage in muscle-strengthening exercise for numerous purposes, including for strength-related sports (e.g., weight/power lifting), aesthetic purposes (e.g., body-building/sculpting); physical therapy (e.g., rehabilitation from injury); conditioning for sports performance and for general fitness and health.

Four exercises were selected for 30min with 5 min rest period given with 3 to 5 sets of 8 to 15 repetitions. The exercises are given in the format of: Straight leg raise, Bridging, Side lying straight leg raise, Heel raise.

Statistical analysis
The result was analysed for pre and post-test values using paired 't' test favoured for alternate hypothesis. The statistical tools used in the study are paired t-test. The paired 't' test was used for within group analysis. Pre-test and post-test values were calculated using paired 't' test at significant level of $p< 0.05$ at 9 degrees of freedom with t value of 2.262

Results
The demographical presentation of subjects is shown in table 1. The group consists of 7 males and 3 females. The age range of the group is 20-40 years. The calculated 't' value for balance on limit of stability of overall, forward, backward, more affected, less affected were 42.39, 6.324, 9.005, 31.46, 28.92 respectively and for berg balance scale was 17.1 which was greater than the table value of 2.262 with $p<0.05$. and the calculated 't' value for upright mobility on time up and go test, activities specific balance scale, walking index for spinal cord injury-II were 13.70, 6.4, 9.78 respectively which was greater than the table value of 2.262 with $p<0.05$. Thus, the resultant of the study shows that there was significantly improvement and difference between pre-test and post-test values.

Table 1: Demographic characteristics of subjects

Age	20 – 40 20 – 23 = 2 members 1 male, 1 female 24 – 27 = 2 members 2 males 28 – 35 = 5 members 3 males, 2 females 36 – 40 = 1 member 1 male
Gender	Male – 7 Female - 3
Duration	6 weeks

Table 2: within group analysis for balance (limit of stability and berg balance scale) with spinal cord injury during preintervention and post-intervention phase.

Outcome parameters	Group	Mean	SD	T Value
Limit of stability- overall	Pre-test	31.9	2.1	42.39
	Post-test	46.3	1.5	
Limit of stability- forward	Pre-test	32.3	2.5	6.32
	Post-test	36.3	2.6	
Limit of stability- backward	Pre-test	30.8	1.9	9.0
	Post-test	33.5	1.6	
Limit of stability- more affected	Pre-test	28.3	1.7	31.46
	Post-test	42.9	1.5	
Limit of stability- less affected	Pre-test	33.2	1.9	28.92
	Post-test	47.6	1.2	
Berg balance scale	Pre-test	34.0	0.91	17.1
	Post-test	39.7	0.72	

Table 3: within group analysis for Upright mobility (TUG test, ABC scale, WISCI-II) in individuals with chronic incomplete spinal cord injury during preintervention and post-intervention phase.

Outcome parameters	Group	Mean	SD	T-value
TUG Test	Pre-test	18.7	1.14	13.70
	Post-test	15.1	1.18	
ABC Scale	Pre-test	66.2	1.82	6.4
	Post-test	75.2	2.06	
WISCI-II	Pre-test	15.1	2.11	9.78
	Post-test	17.7	2.07	

The table 2 analysis showed that the calculated 't' value using the paired 't' test for balance on limit of stability of overall, forward, backward, more affected, less affected were 42.39, 6.324, 9.005, 31.46, 28.92 respectively and for berg balance scale was 17.1 which was greater than the table value of 2.262. Hence, the statistical reports states that there was significant improvement of balance in individuals with chronic incomplete spinal cord injury.

The table 3 analysis showed that the calculated 't' value using the paired 't' test for upright mobility on TUG Test were13.70, ABC Scale were 6.4 and WISCI-II were 9.78 which was greater than the table value of 2.262. Hence, the statistical reports states that there was significant improvement of upright mobility in individuals with chronic incomplete spinal cord injury.

Discussion
Spinal cord injury occurs when there is any damage to the spinal cord that blocks communication between the brain and the body. SCI is a kind of high disabling injury; it not only can lead to damage or loss of sensation and motor function, but also may lead to multiple organ dysfunction. After a spinal cord injury, a person's sensory, motor and reflex messages are affected and may not be able to get past the damage in the spinal cord.

Regaining walking function and maintaining a steady standing posture are listed as top priorities for individuals with incomplete spinal cord injury

Virtual reality is a computer-generated environment with scenes and objects that appear to be real, making the user feel they are immersed in their surroundings.

The previous studies demonstrated the effectiveness of virtual reality and conventional therapy for chronic incomplete spinal cord injury.

In 2018, Young-Hyun Park, *et al*., conducted a study to investigate the effects of semi-immersive VR therapy on standing balance and upright mobility function in individuals with chronic ISCI. After semi-immersive VR therapy, LOS and BBS scores were significantly increased. In addition, the TUG test results increased significantly over time, while ABC scale scores and WSCI-II levels improved significantly. This study is the first to assess the effects of semi-immersive VR therapy for patients with chronic ISCI and limited functional abilities. These results indicated that semi-immersive VR therapy has a positive effect and is a useful intervention for standing balance and upright mobility function in patients with chronic ISCI.

In 2017 Jamal Ali Moiz, et.al, conducted a study on Activities-specific balance confidence scale for predicting future falls in Indian older adults. Activities-specific balance confidence (ABC) scale is a subjective measure of confidence in performing various ambulatory activities without falling or experiencing a sense of unsteadiness. The mean ABC-H scale score of the faller group was significantly lower than that of the non-faller group (52.6±8.1 vs 73.1±12.2; *P*<0.001). The optimal cutoff value for distinguishing faller and non-faller adults was ≤58.13. The ABC-H scores were significantly and independently related with future falls in the community-dwelling Indian older adults. The ability of the ABC-H scale to predict future falls was adequate with high sensitivity and specificity values.

In 2010 Federica Tamburella, et.,al, conducted the study walking index for spinal cord injury version 2 (WISCI-

II)with reliability of the 10- mm walk time on regional spinal cord injury center of the Delaware valley Toronto Canada, in this 76 chronic spinal cord injury patients were selected and 10 minutes walking test were calculated and convergent validity were assessed by correlating WISCI-II levels to LEMS (lower extremity motor scores)and walking speed the result concluded that WISCI-II should be a useful outcome for finding changes in walking function of an individual following spinal cord injury.

The present study demonstrates the effect of semi-immersive virtual reality on standing balance and upright mobility function along with conventional physiotherapy in patients with chronic incomplete spinal cord injury. The study concluded that the semi-immersive virtual reality therapy along with conventional therapy was found to be effective in improving standing balance and upright mobility among chronic incomplete spinal cord injury subjects. The data analysis showed that obtained results was greater than the observed values. Statistical analysis is also evidence for significant reduction and improvement. Eventually, alternative hypothesis is accepted. This resultant of the study is might be due to the following mentioned mechanism of VR: VR-induced neuroplasticity promotes motor relearning and this technology has been widely used in neurological rehabilitation. In VR training, as the body's centre of gravity moves beyond the base of support, proprioceptive sensations at the joints increase, therefore, participants are trained to adjust the balance perturbations. Unlike the conventional training, the difficulty levels can be graded and fine-tuned by manipulating the angulation and speed of the stimulus. Hence, participants learn postural control, functional stretching of extremities and weight shifting, which are all useful in real-life situations.

Limitations
1. This study is of small sample size.
2. This study was a short-term study.
3. The study was conducted with few months.
4. This study did not include a control group.
5. No follow up measures were taken after the intervention.

Further directions of the study
1. A similar study may be extended with large sample size.
2. A similar study with longer duration can be performed for more effectiveness.
3. Future study can be compared with various techniques.
4. Having a control group is desirable.

Conclusion
There is a significant improvement in standing balance and upright mobility function following the application of 6 weeks of semi-immersive virtual reality therapy along with conventional physiotherapy in chronic incomplete spinal cord subjects.

The present study adds value to the literature that applying semi-immersive virtual reality along with conventional physiotherapy improves balance and upright mobility function in patients with chronic incomplete spinal cord individual.

Authors contribution

I understand my agreement to participation in this study and I am not waiving any of my legal rights. I confirm that Mr. Pranesh Sam.G / Dr. C. Sivakumar MPT (ORTHO)., PhD have explained me the purpose of study, the study procedure and possible risk that I may experience. I have read and I have understood this concern to participate as a subject in this study.

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