Original article:

Effects of Task Oriented Exercises with Altered Sensory Input on Balance and Functional Mobility in Chronic Stroke: A Pilot Randomized Controlled Trial

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Abstract

Background: Stroke subjects presented with greater postural instability which lead to challenge their balance control in sensory conflict conditions. Studies have shown that deficits of sensorimotor integration and an inability to select the appropriate sensory input are associated with balance measures following stroke.However, limited studies have been focused to sensorimotor integration in balance rehabilitation. ***Objective:*** Our study aimed to evaluate the Task Oriented Training (TOT) with sensory manipulation to enhance balance and functional mobility in chronic stroke subjects. ***Design:*** Randomized controlled pilot study. ***Setting:*** Department of Physiotherapy in a Tertiary care Hospital. ***Subjects:*** A convenience sample consisting of 26 hemi paretic subjects at least 6 months post stroke duration with Brunnstrom's recovery stage ≥5 for the lower limb and Berg Balance Score of 40 or above were randomly assigned control group (n=13) and in experimental group (n=13). ***Interventions:*** Control group received the conventional physical therapy and in the Experimental group received TOT with manipulations of sensory inputs and provision of sensory conflict for the trunk and lower limb focusing on balance and mobility were implemented for 15 sessions, 5 days a week for 3 weeks with each session of 45-60 mints duration. ***Outcome measures:*** Dynamic Gait Index (DGI), Timed Up and Go Test (TUGT) and Fall Efficacy Scale (FES) were analyzed before and after the training. ***Results:*** Post training there was a significant improvement in all the outcome measurements for both the groups. However components 3, 4 and 5 of DGI, TUGT and FES of experimental group had a highly significant statistical difference between-group analysis with $p<.05$. ***Conclusion:***Task oriented exercises with altered sensory input was found to be effective in improving functional mobility in terms of dynamic balance and reduction in their fear of fall levels after a 3 week training program.

Keywords: Stroke; Mobility; Balance; Task Oriented Training; Sensory Integration

Bangladesh Journal of Medical Science Vol. 16 No. 02 April'17. Page : 307-313

Introduction

Stroke is the leading cause of high levels of morbidity and long-term functional disability in adults.[1]When balance impairment is affected early after stroke, performance of simple as well as complex tasks become difficult which results in their functional mobility.[2] Impaired balance has also been identified as the strongest predictor of falling, which in turn is related with fear of falling, limited activity and quality of life. Thus, this vicious cycle of balance disability is continued, resulting in delaying the recovery process of stroke rehabilitation.[3,4]Balance

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skills are the complexinteractions between multiple sensorimotor processes, environmental and functional contexts.[5]

Visual, Vestibular and Proprioception are the three main sensory modalities involved in postural control and they can be modulated dynamically and modified by changes in environmental conditions.[6]In a healthy adult, to control balance in orthostatic position the central nervous system gives priority to one system over another which depends on the functional and environmental contexts.[7]This ability to choose and rely on appropriate sensory input is called sensory re-weighting and it is a continuous process.[8,9] Balance control also involves a general neural process in central nervous system to resolve the sensory conflicts from different sensory modalities and also synthesizing information from disparate sensory inputs and combiningefferent and afferent information for sensorimotor integration to avoid fall.[10-13]

Following stroke, the ability to analyze, compare, and to select the appropriate sensory information are impaired resulting in problems with sensory reweighting and integration. The decreased ability to maintain static and dynamic balance in stroke has also been related to the inability in selecting reliable visual, vestibular and somatosensory information in order to produce proper motor action necessary to maintain postural stability and balance.Post stroke patients are known to exhibit excessive reliance on visual input for balance and walking and are unable to use somatosensory and vestibular input correctly.[14-16] Hence to address this deficits of sensorimotor integration adaptation of regular physical therapy exercises with the use of vision and surface input manipulations along with sensory conflict conditions to challenge balance has shown to have positive effects on balance recovery. [17]

Recent studies have shown that exercise interventions in the form of task oriented exercises which are intended to reinforce the relationship between training and functional performance, such as exercises in sitting, standing, walking and stair climbing as a strategy to improve balance and functional mobility in stroke patients.[18-20]Bayouk et al, in their study, found that task oriented balance training with altered sensory input shows significant improvement in standing balance in chronic stroke patients.[14] However, there is very limited evidence on using task-oriented exercises with sensory manipulations in enhancing functional mobility and dynamic balance in stroke patients.

Materials and Methods

Sample size estimation

The estimated power of the study is 80% with 95% confidence interval. The sample size was calculated based on the mean and standard deviation derived from the previous findings.[19]Thus $N = 2 (Z_\alpha + Z_\beta)^2 \sigma^2 / \delta^2$ Where, $Z_\alpha = 1.96$, $Z_\beta = .84$, σ (Standard error) = 2.2 and δ (difference in the mean)= 2.33.The sample size was estimated to be 26 (13 in each group).

Procedure

This study was approved by the scientific committee and the Time bound research ethical committee, Kasturba Medical College, Mangalore,Manipal University,Karnataka,India.The study was conducted in tertiary care hospitals Mangalore from March 2011-April 2012. The diagnosis of a stroke was made by a neurologist in all patients and confirmed on computed tomography scan or magnetic resonance imaging of the brain.The purpose of the study was explained to the stroke subjects and on their approval, a written informed consent was obtained from them. Subjects where then screened for study criteria. The inclusion criteria are 1) first episode of unilateral supratentorial stroke2) Brunnstrom's recovery stage of 5 or above for the lower limb 3) Subjects who are able to stand for 5 mints without support 4) Mini Mental State Examination score of 23 or more 5) Berg Balance Score of 40 or above. The exclusion criteria are 1) Any severe limitation that would limit the subject's participation in the exercise program or interfere with functional assessments performed in this study 2) Presence of vestibular disorders, vertigo or somatosensory deficits 3) Presence of visual problems like homonymous hemianopsia 4) Presence of severe orthopaedic conditions involving the lower limbs. Demographic data of the subjects included were taken following which, an independent blinded observer, who was blinded to the treatment allocation assessed the stroke subjects for the baseline scores of all the three outcome measures Dynamic Gait Index (DGI)[21,22],Timed Up and Go Test(TUGT)[23,24] ,Fall Efficacy Scale(FES)[25,26]

The patients were allotted into control group and experimental group following simple randomization and the total intervention period was 15 sessions, 5 days a week for 3 weeks. Subjects in the control group received conventional physiotherapy programe[Appendix 1]. The subjects of the experimental group received task-oriented training with manipulations of sensory inputs and provision of sensory conflict for the trunk and lower limb[Appendix 2].The materials used in TOT training were a Chair,Stopwatch,SwissBall, Exercise Stepper,Cardboard for obstacles, Foams (50cm x 62cm x 8cm),Blindfold Panel made by Cardboard and Visual Conflict Dome.[14-16] The total approximate duration of training for both control and experimental groups was approximately 45 - 60 minutes. Adequate rest periods were provided for the participants during the session. The blinded observer re-evaluated the patient's performance by using the same outcome measures used for baseline assessment at the end of the intervention program following 3 weeks.

Data analysis

The software used was SPSS version 16.0 for Windows. Kolmogorov-Smirnov test was used to test the normality of the data.The results were statistically analyzed using the Student's unpaired t-test, Student's paired t-test and Chi Square test. Student's unpaired t-test was used to analyze and compare between the scores of control group with that of the experimental group. Student's paired t-Test was used to analyze and compare the difference in scores before and after the intervention of the same person (i.e. pre-intervention scores and post-intervention scores).Chi square test was used for descriptive statistics. A p value of 0.05 was considered to be statistically significant.

Results

There were 26 subjects included in the study, out of which 13 underwent conventional rehabilitation in the clinic while the remaining 13 were included in the experimental group, wherein they underwent task oriented approach with sensory manipulation. Table 1 shows the group means and standard deviations for age, duration since the onset of stroke and the Berg Balance Scores. It also shows the frequency counts for gender, type of lesion and Brunnstrom stage of recovery. Both the groups were matched for all the above-mentioned criteria, as there were no statistically significant differences found between the two groups. [Table 1]

There has been a significant improvement in all the outcome measures in both the groups as evident by table 2($p < 0.0001$). Although the difference between groups in DGI scores lacks statistical significance ($p = 0.206$) the TUGT and FESS scores, a highly significant difference has been observed in between the groups ($p < 0.05$). [Table 2]

A significant difference within-group total score of DGI suggests a greater improvement in the experimental group. In Table 3 when the individual components of DGI were analyzed a highly significant statistical difference was obtained in the between-group analysis of components 3, 4 & 5 with *p* values of 0.0001, 0.0001 & 0.008 respectively. [Table 3]

Discussion

The aim of the current study was to compare the effectiveness of task oriented exercises with altered sensory input and conventional rehabilitation in improving the functional mobility in stroke patients. The subjects included in the study were in Brunnstrom recovery stages 5 & 6, thus ensuring that excessive spasticity and lower limb basic synergy patterns were not causing balance impairments.[27] The BBS scores of the subjects were above 43 ensuring a higher level of static balance.[28] Since the included subjects were chronic stroke patients, spontaneous recovery was fairly ruled out.[14] The baseline characteristics of all the subjects also showed no significant statistical difference and hence, did not influence the results of the study.

Task oriented training, known to be very effective in rehabilitation of stroke patients, when incorporated with altered sensory input are challenging in nature and progressively induce the patients to use lower limb somatosensory inputs to maintain balance.[18.19] Challenging various sensory systems in the exercises also forces the stroke patients to improve the process of sensory reweighting.[5] Earlier studies done on stroke patients have established the effectiveness of strategies like vision deprivation, sensory conflict conditions and various sensory manipulations on postural adjustments and static balance.[14-17] Thus, the exercises planned for the experimental group was based on these studies on multisensory training on stroke patients.

The present study showed a significant improvement in functional mobility (DGI scores) in the experimental group subjects as well as the control group subjects. Although the between-group analysis showed no significant difference, the improvement in the experimental group had a clinical significance based on the minimal clinically important difference (MCID) of 4 established for DGI.[29] Subjects in the experimental group, post-training, showed improvement, particularly in three components of the DGI comprising of walking with horizontal and vertical head turns and pivot turning. Studies show that although head motions produce little displacement in the body center of mass, the complex information channeled from vestibular, visual and neck proprioceptive afferents must be processed by the central nervous system in relation to motor commands for smooth and rapid execution of head movements while maintaining balance. The altered postural adjustments to head motions observed in stroke patients suggest an underlying impairment in sensorimotor integration.[30] Studies have also found that stroke alters the coordination behavior of head and pelvic rotations, which may contribute to balance dysfunctions during locomotion. Thus specific improvement in the above-mentioned components could be the result of sensory-specific task oriented training that emphasizes on all the sensory systems contributing to an improved functional balance.[31, 32]The improvement in the control group could be a result of a comprehensive impairment based protocol that they underwent and there was no particular trend of improvement seen in the individual components of DGI.

The current study showed that there was a highly significant difference in the between-group scores of TUG. This result is in agreement with studies done previously showing improvement in gait mechanics post a sensory-based rehabilitation program.Itemphasized that sensory input integration is very important for maintaining equilibrium during walking and found that sensory conflict training improves postural adjustment mechanisms, which directly influences walking speed.[33]

The present study also showed that there was a moderately significant difference in the between-group scores of FES. The baseline fear of falling levels of the subjects was low as the patients had achieved independence in mobility, fairly good static balance, higher recovery stage and no history of falls. The subjects in the experimental group underwent a highly challenging task oriented training program, thereby improving their ability to perform relatively simpler functional tasks listed in the scale.[18,19] The control group training was also found to be simple and impairment-specific, and hence was not reflected in the fear of falling levels.

Limitations: The study intervention was given only for a period of 15 sessions and hence, only the short term effects was focused upon. The patients could not be followed up in order to ascertain, whether the intervention had long lasting effects. A larger sample size would allow better stratification of the obtained results in terms of age ranges, stages of recovery, balance scores to allow better applicability of the intervention. The current study found the effect of the sensory-based intervention on functional mobility, but if a sensory specific outcome measure like sensory organization test with posturography is used, then the effects of the intervention directly on the sensory system could be evaluated.

Conclusion:

Following 3 weeks of Task oriented training with altered sensory input it was found effective in improving functional mobility in terms of associated head movements and pivot turns. These exercises also positively influenced the patient'sdynamic balance and walking speed. The patients also experienced a reduction in their fear of fall levels after the intervention. Therefore, sensory manipulations can be imbibed in the routine rehabilitation of chronic stroke patients to enhance their functional mobility and independency in ADLs.

Table 1: Demographics of the Study Participants

Variables	Control Group (n=13)	Experimental Group(n=13)	p value
Age(Mean±SD) in years	60.07±7.56	58.82±9.12	0.38(t)
Gender			
Male (%)	9(69%)	9(69%)	0.66(F)
Female (%)	4(31%)	4(31%)	
Type of Lesion			0.12(F)
Ischemic (%)	5(38%)	9(69%)	
Hemorrhagic (%)	8(62%)	4(31%)	
Duration Since Stroke (Mean±SD) in Months	10.9±3.7	11.2±4.2	0.72(t)
Brunnstrom Lower Extermity Recovery Stage Stage V Stage VI	9(69%) 4(31%)	8(61%) 5(38%)	0.54(M)
Berg Balance Score Mean±SD	46.92±3.25	47±4	0.96(t)

NOTE. Values are mean ±SD or as otherwise indicated.Statistics:t,independent t test; F,Fisher exact test; M,Mann-Whitney U test.

Table 2:Mean and Standard Deviations of DGI, TUGT, FESS (pre and post) scores and the change scores with their *p* value in the Control as well as the Experimental Group

Outcome measures	Control Group			Experimental Group			*p* value for between groups scores
	Pre	Post	Change scores with *p* value	Pre	Post	Change scores with *p* value	
DGI	12.5 ± 1.7	15.5 ± 0.9	3.08 ± 1.61 (*p* **<0.05***)	13.2 ± 2.8	17.2 ± 2.4	3.95 ± 1.41 **(*p*<0.05*)**	0.20 (NS)
TUGT in Seconds	15.5 ± 3.1	13.2 ± 2.4	2.46 ± 1.4 (*p*<**0.05***)	16.6 ± 2.5	12.6 ± 2.4	4 ± 1.41 (*p*<**0.05*)**	**0.01***
FESS	64.8 ± 6.7	58.3 ± 6.9	6.23 ± 2.8 (*p*<**0.05***)	67.2 ± 6.9	58.3 ± 6.3	8.92 ± 3.93 (*p*<**0.05***)	**0.05***

* *p*values which show statistically significant difference NS-Non Significant

Table 3:*p* values of between group analyses of individual components of DGI

DGI Components	Control Vs Experimental Group (*p* value <.05)
1.Walkning on level Surface	0.09(NS)
2.Gait Speed	0.29(NS)
3.Walking with Horizontal Head Turns	<.001*
4.Walking with Vertical Head Turns	<.001*
5.Walking and Pivot turn	<.008*
6.Walking over Obstacles	0.17(NS)
7.Walking around Obstacles	0.17(NS)
8.Steps	0.70(NS)

* *p*values which show statistically significant difference NS-Non Significant

Appendixces

The intervention in both the Groups lasted for a period of 3 weeks i.e. 15 sessions with 5 sessions per week. The duration for the exercises was approximately 45 – 60 mints. All the below exercises were done strictly under the supervision of a tester to ensure safety of the subjects. The subjects were allowed to rest for 2 mints in between every new exercise or as and when hewished.

Appendix 1 Conventional Rehabilitation

1. Facilitatory techniques like quick icing, quick stretching, muscle belly tapping, joint approximation for paretic muscles and Inhibitory techniques like prolonged icing, sustained stretching for spastic muscles.
2. Strengthening for weak muscles.
3. Bed mobility exercises with emphasis on transitions.
4. Balance training in Single limb Stance, Reaching.
5. Gait training.
6. Functional training involving activities of daily living.

Appendix 2 -Task Oriented Exercise With Sensory Manipulation

1. Sitting on a swiss ball and reaching out for objects (10 repetitions)
2. Sit-to-stand from a stool (10 repetitions)
3. Performing double legged stance for 10 counts (normal base of support) and then with decreased base of support for 10 counts
4. Performing tandem stance for 10 counts (If the

patients finds tandem stance difficult, then he can maintain the same by increasing the step length)

5. Performing unilateral stance for 10 counts with or without minimal support
6. Reciprocal leg flexion and extension in standing i.e. marching with or without minimal support
7. Stepping forward, backward and sideways on a stepper
8. Stepping over boards of various heights (6 inches, 8 inches, 10 inches)
9. Standing up from a chair, walking four steps, performing a bilateral stool touch and walking back to the chair
10. Forward and backward walking in tandem walking pattern

Session 1 All the above exercises were performed with the patient's eyes open and on a normal, hard surface so that the patient could learn the exercises.

Session 2 The chest panel was used for all exercises (except 8 & 9), in order to occlude the sight of the patient's feet.

Sessions 3, 4 The patient was blindfolded for all exercises except 8 & 9* to cause vision deprivation, thereby challenging the vestibular and the somatosensory system.

Sessions 5, 6

The patient was asked to perform all exercises except 1, 2 & 8*, on the foam by manipulating his somatosensory input.

Sessions 7, 8 The patient performed all exercises except 1, 2 & 8*, on the foam with the chest panel to occlude the sight of his feet.

Sessions 9, 10 The patient was blindfolded and was asked to perform all exercises except 1, 2, 8 & 9* on the foam.

Sessions 11, 12 The patient was asked to do exercises no. 2, 3, 4, 5, 6, 7 & 10* on the floor with the visual conflict dome to provide a visual conflict condition.

Sessions 13, 14

The patient was made to do the exercises 2, 3, 4, 5, 6, 7 & 10* with the visual conflict dome on the foam.

*As each balance system was challenged, a few exercises were modified or passed over. This was done as these exercises would be very difficult to perform in the absence of that particular sensory input.

References:

1. Wolfe CDA. The impact of stroke. *Br Med Bull* 2000; **56**:275–286. https://doi.org/10.1258/0007142001903120
2. Sturm JW, Dewey HM, Donnan GA, Macdonel RAL, McNeil JJ, Thrift AG. Handicap after stroke: How does it relate to disability, perception of recovery and stroke subtype? The North East Melbourne Stroke Incidence Study (NEMESIS). *Stroke* 2002; **33:**762-8. https://doi.org/10.1161/hs0302.103815
3. Lamb SE, Ferrucci L, Volapto S, Fried LP, Guralnik JM, Gustafson Y. Risk factors for falling in home-dwelling older women with stroke: the women's health and aging study. *Stroke* 2003; **34**:494–501. https://doi.org/10.1161/01.STR.0000053444.00582.B7
4. Belgen B, Beninato M, Sullivan PE, Narielwalla K. The association of balance capacity and falls self-efficacy with history of falling in community- dwelling people with chronic stroke. *Arch Phys Med Rehabil* 2006; **87**:554–61. https://doi.org/10.1016/j.apmr.2005.12.027
5. Oliveira CB, Medeiros IRT, Frota NAF, Greters ME, Conforto AB. Balance control in hemiparetic stroke patients: Main tools for evaluation. J *Rehabil Res Dev* 2008; **45**:1215-26.

https://doi.org/10.1682/JRRD.2007.09.0150

6. Peterka JR. Sensorimotor integration in human postural control. *J Neurophysiol* 2002; **88**(3):1097–1118.
7. Forssberg H, Nashner LM. Ontogenetic development of postural control in man: Adaptation to altered support and visual conditions during stance. *J Neurosci* 1982; **2**(5): 545–52
8. Shumway-Cook A, Woollacott MH. Motor control: Theory and practical applications. 2nd ed. Philadelphia (PA): *Lippincott, Williams & Wilkins*. 2001;**18.**
9. Horak FB. Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? *Age Ageing* .2006; **35** Suppl 2:ii7–ii11. https://doi.org/10.1093/ageing/afl077
10. Merfeld DM, Zupan L, Peterka RJ. Human use internal models to estimate gravity and linear acceleration. *Nature* 1999; **398**:615−8. https://doi.org/10.1038/19303
11. Connor NP, Abbs JH. Sensorimotor contributions of the basal ganglia: recent advances. *Phys The*r 1990; **70**:864−872.
12. Kohl RL. Sensory conflict theory of space motion sickness: an anatomical location for the neuroconflict. *Aviat Space Environ Med* 1983; **54**:464−465.
13. Parsons LM, Bower JM, Gao JH et al.Lateral cerebellar hemispheres actively support sensory acquisition and discrimination rather than motor control. *Learn Mem* 1997**;** **4**:49−62. https://doi.org/10.1101/lm.4.1.49
14. Bayouk JF, Boucher JP, Leroux A. Balance training following stroke: effects of task oriented exercises with and without altered sensory input. *Int J Rehab Res* 2006; **29**:51-59. https://doi.org/10.1097/01.mrr.0000192100.67425.84
15. Bonan IV, Colle FM, Guichard JP et al. Reliance on visual information after stroke. Part I: Balance on dynamic posturography.*Arch Phys Med Rehabil* 2004; **85**:268−273. https://doi.org/10.1016/j.apmr.2003.06.017
16. Bonan IV, Yelnik AP, Colle FM et al. Reliance on visual information after stroke. Part II: Effectiveness of a balance rehabilitation program with visual cue deprivation after stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2004; **85**:274−278. https://doi.org/10.1016/j.apmr.2003.06.016
17. Yelnik AP, Breton FL, Colle FM, Bonan IV, Hugeron C, Egal V et al. Rehabilitation of balance after stroke with multisensorial training: a single-blind randomized controlled trial. *Neurorehabil Neuro Repair* .2008; **22**:468-76. https://doi.org/10.1177/1545968308315996
18. Dean CM, Richards CL, Malouin F. Task-related circuit training improves performance of locomotor tasks in chronic stroke: a randomized, controlled pilot trial. *Arch Phys Med Rehabil*. 2000; **81:**409-17. https://doi.org/10.1053/mr.2000.3839
19. Salbach NM, Mayo NE, Wood-Dauphinee S, Hanley JA, Richards CL, Cote R. A task-oriented intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. *ClinRehabil* 2004; **18**:509-19. https://doi.org/10.1191/0269215504cr763oa
20. Rensink M, Schuurmans M, Lindeman E, Hafsteinsdottir. Task-oriented training in rehabilitation after stroke: systematic review. *J AdvNurs* 2009; **65**:737-54. https://doi.org/10.1111/j.1365-2648.2008.04925.x
21. Jonsdottir J, Cattaneo D. Reliability and validity of the dynamic gait index in persons with chronic stroke. *Arch Phys Med Rehabil* 2007; **88**:1410-15. https://doi.org/10.1016/j.apmr.2007.08.109
22. Lin J, Hsu M, Hsu H, Wu H, Hsieh C. Psychometric comparisons of 3 functional ambulation measures for patients with stroke. *Stroke* 2010; **41**:2021-25. https://doi.org/10.1161/STROKEAHA.110.589739
23. Ng SS, Hui-Chan CW. The Timed Up & Go Test: its reliability and association with lower limb impairments and locomotor capacities in people with chronic stroke. *Arch Phys Med Rehabil* 2005; **86**:1641-47. https://doi.org/10.1016/j.apmr.2005.01.011
24. Thrane G, Joakimsen RM, Thornquist E. The association between timed up and go test and history of falls: The Tromso study. *BMC Geriatrics* 2007**;** **7**:1. https://doi.org/10.1186/1471-2318-7-1
25. Bosscher RJ, Raymakers ER, Trompe EA, Smith JH. Fear of falling: psychometric aspects of Tinnetti"s Fall Efficacy Scale. *TijdschrGerontolGeriat*r 2005; **36**:5-10. https://doi.org/10.1007/BF03074686
26. Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validation of the Falls Efficacy Scale-International.*AgeAging* 2005;**34**:614-619. https://doi.org/10.1093/ageing/afi196
27. Duncan PW. Stroke disability. *Phys Ther* 1994; **74:**399-407.
28. Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: A systematic review. Phys Ther 2008; 88:559-566. https://doi.org/10.2522/ptj.20070205
29. Lin J, Hsu M, Hsu H, Wu H, Hsieh C. Psychometric comparisons of 3 functional ambulation measures for patients with stroke. *Stroke* 2010; **41**:2021-25. https://doi.org/10.1161/STROKEAHA.110.589739
30. Lamontagne A, Paquet N, Fung J. Postural adjustments to voluntary head motions during standing are modified following stroke. *ClinBiomech* 2003; **18**:832-42. https://doi.org/10.1016/s0268-0033(03)00141-4
31. Lamontague A, De serres SJ, Fung J, Paquet N. Stroke affects the coordination and stabilization of head, thorax and pelvis during voluntary horizontal head motions performed in walking. *ClinNeurophysiol* .2005; **116:**101-11. https://doi.org/10.1016/j.clinph.2004.07.027
32. Lamontagne A, Fung J. Gaze and postural reorientation in the control of locomotor steering after stroke. *Neurorehabil Neural Repair*. 2009; **23**(3):256-66.
33. Smania N, Picelli A, Gandolfi M, Fiaschi A, Tinazzi M. Rehabilitation of sensorimotor integration deficits in balance impairment of patients with stroke hemiparesis: a before/after pilot study. *NeurolSci* .2008; **29:**313-19. https://doi.org/10.1007/s10072-008-0988-0