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Original Research Article

Electrophysiological Study to Evaluate Cross Education in Lower Extremity Using Mirror Movements in Stroke

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ABSTRACT

Aim: To evaluate cross education effect in paretic and non-paretic lower limb while performing movements with and without mirror in chronic stroke patients.

Background: Cerebrovascular stroke causes impairments of motor function in lower extremity leading to restrictions in functional mobility. There is paucity of literature on cross education in stroke patients. Present study was designed explore effects of cross education effects in lower extremity, and also to evaluate if visual feedback with mirror augments recruitment.

Methodology: Study commenced after an ethical approval from MGM Institutional Ethical Review Committee. 30 stroke subjects fulfilling inclusion criteria participated in study. Written informed consent was obtained from each subject. Each participant performed 3 trials of 2 functional concentric movements (Knee extension, Heel slide). Surface electromyography (sEMG) was recorded for vastus medialis and vastus lateralis for knee extension, hamstrings and quadriceps for heel slide on both paretic and non-paretic lower limb. Spasticity was assessed by Modified Ashworth Scale, cognition by Mini-Mental Scale and motor function by Fugl Meyer scale.

Results: Muscle activity was noted in paretic extremity during performance of concentric functional movement. There was low to moderate non-significant correlation of muscle activity of non-paretic limb to paretic limb during concentric movement ($p>0.05$). Results indicate trend towards improvement in level of muscle recruitment in agonist muscle with visual feedback when compared to activity without mirror ($p>0.05$).

Conclusion: Present study indicates a preliminary evidence of cross education effect with concentric functional movements in stroke and indicates that visual feedback augments cross education.

Keywords: Cross Education, Stroke, Mirror movements, Visual feedback.

INTRODUCTION

STROKE is one of leading cause of serious long-term disability in adults. Incidence and prevalence of stroke in developing countries in comparison to developed countries is much high. Incidence of stroke ranges from 105 to 152/100,000 persons per year, and prevalence of stroke ranges from 44.29 to 559/100,000 persons during past decade in India. [1] Motor function is impaired in lower extremity due to stroke resulting in abnormal motor control and altered muscle timing which ultimately results in restricted functional mobility. [2] Impairments of lower limb function is correlated more closely with activities of daily living than impairments of upper limb function. [3] Neurological deficits of lower extremity results in poor balance, risk of fall and increased energy expenditure during activity of lower limb. [2] Hemiparesis produces typical asymmetry resulting in more affected and less affected side. [4] 35% of patients who presented lower limb hemiparesis continue to suffer from reduced function post six months up to a year. [5] Physical therapy of hemi paretic patients in weeks post stroke consists of exercise therapy based on muscle re-education, practice of task oriented training for lower extremity such as transfer activities, weight shifts, components of gait training using restorative or compensatory approaches.

Application of rehabilitation strategies to non-paretic side for improving recruitment of paretic side can prove to be of immense help during early stages. Cross-education is defined as increase in strength or functional performance of untrained contralateral limb after unilateral training of opposite homologous limb. [6-7] Neurological basis for cross education is attributed to interneurons and anatomical connection of corpus callosum and anterior commissure between two hemispheres. [8] Spinal cord may facilitate cross education by altering descending commands. [9]

Findings of a systematic review suggest that mirror visual feedback is beneficial in enhancing motor network. [10] Mirror therapy is designed to trick brain into experiencing movement of paretic limb. This involves placing mirror in patient's mid sagittal plane and then asking patient to perform specific movements of unaffected limb while watching its reflection superimposed over unseen impaired limb. Mirror visual therapy activates broad network in brain using attention and observation to task.[10]Action observation, mental imagery, and action execution activate mirror neurons in frontal lobe facilitating functional recovery. [11] Mirror therapy for lower extremity enhances motor recovery in acute and sub-acute stage post stroke. [12-13]

Numerous studies recommend application of cross-education in rehabilitation; however, a large gap remains in literature with respect to applying cross-education to clinical settings. In a recent study, patients with post stroke weakness performed high-intensity maximal isometric dorsiflexion resistance training. Strength gains were noted in both lower extremities. [14] Recent systematic review suggests paucity of literature in stroke with respect to cross education, stating that cross education is a relatively new concept in neuro rehabilitation There is dearth of well-controlled studies that have applied cross-education to clinical rehabilitation in neurology. [15] Previous studies on cross education effect have applied maximal voluntary isometric contraction to non-paretic side. To our knowledge, effect of concentric functional movements of non-paretic side on cross education of paretic side has not been studied. Post stroke we emphasise on training activities of daily living, most of which involve functional concentric movements.

In present study, we explored cross education effect in functional concentric movements of lower extremity using surface electromyography in patients with stroke. This study also evaluates if visual feedback changed level of muscle recruitment of paretic side when non-paretic side was performed concentric functional movements.

MATERIALS AND METHODS

Study commenced after Ethical approval by Institutional Ethical Review Committee of MGM University of Health Sciences, Navi Mumbai. 30 stroke subjects (20 males and 10 females) were selected by convenience sampling participated in study. Subjects with deficits in language and attention, presence of peripheral neuropathies, acute stroke, and cognitive impairment were excluded. Subjects fulfilling inclusion criteria and willingly participate were explained about procedure in language best understood by them. Written informed consent was taken from each participant.

Participants:

Demographic details including name, age, gender and past history was documented. Assessment of spasticity was done using Modified Ashworth Scale, motor function by Fugl - Meyer Scale (lower extremity component) and cognition by Mini Mental Scale Examination (MMSE).

Material: Materials used for data collection included Biograph Infinity Electromyography equipment with software, laptop, plinth, mirror, ultrasonic gel, velcro straps.

Methods: General instructions were given prior to beginning study procedure. They were asked to be relaxed and comfortable during surface Electromyography recording. Also to report any discomfort during entire process. Prior to placing surface electrodes, skin was shaved and cleaned with spirit to get best signal. For both concentric movements, activity was recorded from agonist and synergist muscle from paretic and non-paretic lower extremity. Biograph Infinity equipment attached to a laptop (installed with Biograph Infiniti Software) via a USB cable was used. Instruction was given to "Start" "& "stop". 3 trials were recorded. Post each trial, rest pause of 30 seconds was given to ensure return to baseline. Biograph Infinity Software recorded the parameters from both affected and unaffected lower limb.

Concentric knee extension movement was demonstrated. Participant was positioned in sitting at edge of plinth without back support. Lower extremity was kept unsupported. Subjects were then instructed to perform concentric knee extension movement from non-paretic side. Tri-polar surface electrodes were placed along muscle fibres of vastus lateralis & vastus medialis and secured firmly with velcro straps. Muscle activity was recorded from paretic and non-paretic side lower limb muscles. Mirror was placed in mid sagittal plane in between thigh such that affect extremity was not seen.

Heel slide from knee extended position to flexed position was demonstrated. Participant was then positioned in long sitting with back support. Surface electrodes were placed along muscle fibres on quadriceps and hamstring muscles for recording muscle activity during heel slide from both unaffected and affected side. Participant then performed demonstrated movement. Muscle activity was recorded from paretic and non-paretic side lower limb muscles. Mirror was placed in mid sagittal plane in between both legs such that affect extremity was not seen by patient. Amplitude from both affected and unaffected limbs using surface Electromyography was recorded.

Statistical Analysis:

SPSS (version 16) software was used for statistical analysis. Linear Regression equation was used to study influence on muscle activity of paretic extremity when non-paretic extremity performed concentric movements. As data was not normally distributed, non-parametric Wilcoxon signed rank test was used to compare muscle activity performed with mirror and without mirror for all lower limb activities. Level of significance was set at $p<0.05$ for all inferential statistics.

RESULTS

Study was an experimental design to explore cross education effect in lower extremity of chronic stroke patients with following two objectives: (a) to correlate muscle recruitment in paretic lower limb when non-paretic extremity performed concentric knee extension and heel slides (b) To compare level of recruitment of paretic extremity with and without mirror. Following table demonstrates baseline characteristics of study participants.

Table 1 Characteristics of stroke subjects

Characteristics	Mean ± SD
Age	57 ± 10
Male :Female	20:10
Duration post stroke (years)	5.46 ± 2.84
MMSE	27.66 ± 2.04
Fugl Meyr Scale (Lower limb)	31.6±2.9

Results towards objective (a) Linear Regression and Correlation of amplitude between paretic and non-paretic lower limb:

Table 2 Results of correlation and linear regression between muscle recruitment of paretic side when non- paretic side performed knee extension in both testing conditions.

Correlation of Amplitude Unaffected vastus medialis to affected vastus medialis					
	R value	**R square**	**Standard error**	**F value**	**P value**
Without mirror	0.27	0.07	14.12	2.12	0.16
With mirror	0.12	0.06	8.07	0.42	0.52
Correlation of Amplitude Unaffected vastus lateralis to affected vastus lateralis					
Without mirror	0.01	0.00	4.08	0.00	0.98
With mirror	0.19	0.04	5.76	1.05	0.32
Correlation of Amplitude Unaffected vastus medialis to affected vastus lateralis					
Without mirror	0.16	0.07	4.02	0.75	0.39
With mirror	0.11	0.01	5.83	0.36	0.55

Table 3 Results of correlation and linear regression between muscle recruitment of paretic side when non-paretic side performed heel slides with and without mirror.

Correlation of Amplitude Unaffected hamstring to affected hamstring					
	R value	**R square**	**Standard error**	**F value**	**p value**
Without mirror	0.02	0.00	09.58	0.01	0.93
With mirror	0.13	0.02	31.82	0.46	0.50
Correlation of Amplitude Unaffected quadriceps to affected quadriceps					
Without mirror	0.15	0.02	1.93	0.68	0.42
With mirror	0.28	0.00	7.19	0.02	0.88
Correlation of Amplitude Unaffected hamstring to affected quadriceps					
Without mirror	0.34	0.12	1.84	3.67	0.65
With mirror	0.12	0.01	7.14	0.38	0.54

Results towards objective (b) Comparison of muscle recruitment with and without mirror within experimental group using Wilcoxon sign rank test.

Table 4: Comparison of muscle activity with mirror and without mirror during Heel slide and Knee extension

Heel slide						
	Without mirror		**With mirror**		**Z value**	**P value**
Muscle activity	**Mean (SD)**	**Median**	**Mean(SD)**	**Median**		
Affected hamstrings	13.9 (9.4)	12.1	20.3 (31.5)	10.8	-0.2	0.8
Affected quadriceps	0.9 (1.9)	0.5	1.8 (7.1)	0.1	-1.5	0.1
Knee extension						
	Without mirror		**With mirror**		**Z value**	**P value**
Muscle activity	**Mean (SD)**	**Median**	**Mean(SD)**	**Median**		
Affected vastus medialis	6.6 (14.3)	2.1	5.5 (7.9)	1.9	-0.6	0.5
Affected vastus lateralis	1.0 (4.01)	-0.4	1.3 (5.7)	-0.5	-0.1	0.9

Thus it can be concluded that there was low-moderate non-significant correlation ($p > 0.05$) between muscle recruitment of paretic muscle when non-paretic extremity performed concentric movement. Results indicate a non-significant trend towards improvement in level of muscle recruitment in agonist muscle with visual feedback in comparison to without mirror condition.

DISCUSSION

The purpose of this study was to evaluate muscle activity in paretic and non-paretic lower limb while performing lower limb movement by non-paretic lower extremity in patients with chronic stroke. Our results demonstrate low to moderate positive correlation between muscle activity between paretic and non-paretic lower extremity. Also in comparison to without mirror condition, muscle recruitment improved with use of mirror in agonist muscles. However, results are not statistically significant.

Findings of current study indicate that in chronic stroke patients motor overflow may not be as evident as in acute and sub-acute phase. Participants in our study were in chronic phase post stroke. Adaptive changes including muscle fibre shift, metabolic changes and sarcopenia have influence on force production; [16]

which may contribute to low motor overflow effect.

All patients did not use similar movement strategy and few patients did not complete entire range of movement which can be attributed to non-significant findings. Cross education depends on type of contraction, speed, intensity, dominance and novelty of task. [7,17-18] In our study we explored effects of cross training using concentric movements which were task specific. These concentric movements were not similar to maximal isometric contractions which produce maximal intensity leading to irradiation to paretic side. [6]

Results demonstrate that recruitment of agonist muscle improved with visual feedback using mirror. However, it was not significantly. Mirror movements engage mirror neuron system and give a constant feedback which can be attributed to improvement in muscle recruitment. [12] Mirror therapy is a form of visually guided motor imagery. This form of therapy requires undivided attention to task in order to activate cortical networks. Lack of attention towards mirror while performing functional task could have confounded outcome, thus affecting level of recruitment. [19]

In case of lower extremity it is difficult to completely obstruct view of paretic extremity in long sitting position. This could have also caused similar results in both conditions. All participants did not use similar motor strategy during movement even after standardised instructions which may have also contributed to non-significant change.

CONCLUSION

Present study was one of few studies that explored cross education in concentric functional movements. However, present study included stroke patients in chronic phase and with a limited sample. Therefore, only a limited interpretation of present results is possible. Further studies must be performed with large sample and training for longer period.

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