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Original Research Article

Effects of neuromuscular electrical stimulation and core muscle strengthening on trunk instability following stroke

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ABSTRACT

Background: Postural instability leads to balance dysfunction in stroke subjects, which always increase the risk of fall. This study aimed to compare the effect of neuromuscular electrical stimulation and core muscle strengthening on trunk balance following stroke.
Methods: Forty five stroke subjects were participated and assigned randomly into three groups; all groups received standard rehabilitation program; and core group received additional core strengthening, neuromuscular electrical stimulation (NMES) group received added electrical stimulation over paraspinal region and combination group received core muscle strengthening and NMES along with standard rehabilitation protocol. After four weeks of the interventions, primary and secondary outcome measures are evaluated. Berg Balance Scale (BBS), Postural Assessment Scale for Stroke (PASS), Trunk Impairment Scale (TIS) and Barthel Index (BI) were evaluated before and after the intervention.
Results: All the three (core MS, NMES and combination) groups showed significant improvement after the intervention (BBS 10.07, 15.54 and 18.27, PASS 6.54, 13.06 and 14.00, TIS 0.25, 0.25 and 0.51, BI 16.40, 29.93 and 36.53). The combination group (NMES and core muscle strengthening) showed better improvement than other two groups. TIS and BI total score showed positive (0.849) correlation.
Conclusions: Addition of NMES along with core muscle strengthening for stroke rehabilitation will improve trunk stability, balance and ADLs.

Keywords: Stroke, NMES, Core muscle strengthening, BBS, BI, TIS, PASS

INTRODUCTION

Currently stroke is one of the leading disabling health issue encountered in all population. Stroke survivor's shows mild to severe limitation in their activity of daily living (ADLs) depends on the age, gender, cause and type of stroke.[1] The major difficulties facing by the stroke survivors are weakness of the limb, balance dysfunction, poor postural control, deprived language and comprehension, gait abnormalities and fine motor activities.

Postural in-control or instability always adds to the risk of fall in stroke fatalities. An individual requires good postural control for performing their routine and dynamic functional and non-functional activities. The major role of postural control is by the proprioceptive feedbacks from the lower limb and trunk muscles and these are affected in hemiplegic's leading to post-stroke trunk instability in sitting and standing.[2]

Evaluation of trunk and postural instability in early phase of rehabilitation will give anticipatory feedback towards the outcome of recovery following stroke. On the other

hand, even if found the persistence of instability or poor trunk control, majority of medical or rehabilitation professionals will not address the rehabilitation of trunk muscles, instead move or more focus into rehabilitation of the weaker limbs.[3]

Literatures are available on the importance of correction of trunk instability and leading to reduction in fall risk. Balance retraining strategies, perturbations, core muscle strengthening (CMS), neuromuscular strengthening (NMES) were shown improvement in postural control.[4] In the present study, we aimed to compare the effect of NMES and CMS on trunk balance following stroke.

METHODS

Study participants and design

This randomized control trial was conducted at KENZ rehab physiotherapy centre (March 2019 to April 2021), after getting the ethical approval from the institute. After obtaining written informed consent from the caretaker of stroke patient's, study protocol was administered on acute and sub-acute stroke patients with infarction or hemorrhage. Hemiparesis with first stroke with duration less than 6 weeks, and those can't maintain static sitting balance for five minutes, mini mental status examination (MMSE) score ≥15, Berg balance scale (BBS) score ≥20 were included in the study. Stroke patients who are having bilateral weakness, severe aphasia, cognitive impairment, other neurological disorders, unilateral neglect, middle ear infection, or vestibular dysfunction other than due to stroke, and postural hypotension were excluded from the study.

All the study participants were randomly assigned into three groups using envelope method. Postural instability in group A was treated with core muscle strengthening or trunk exercises, group B was treated with NMES and group C was managed with combination of CMS and NMES. By the end of 2 years of study 45 subjects included for analysis (total 52) with 15 subjects in each group.

Sample size calculated by using the formula given.

$$n = [(Z_{\alpha/2} + 2\beta)^2 \times 2\sigma^2]/d^2$$

Where $Z_{\alpha/2}$ is 1.96, 2β is 80%, σ is 0.03 and d is 10%. Seven drop outs occurred due to medical complications, not following-up for the rehabilitation and due to death.

Interventions

All the three groups received conventional rehabilitation protocol including range of motion exercises, facilitation of muscle tone, graded strengthening, balance retraining, conventional postural exercises (sit to stand, standing, alternate shifting of body weight into paralytic lower limb) and gait training.

CMS group received additional trunk muscle strengthening in supine, prone and side lying, which includes bilateral and unilateral leg bridging, dead bug exercise, segmental rotation of trunk, plank exercises, belly blaster, bird dog exercises, side plank and side bridging exercises.[5]

NMES group received added electrical stimulation over the posterior trunk muscles. We stimulated thoracic and lumbar erector spinae muscles 5 cm lateral to T6 spinous process and 2 cm lateral to L5 spinous process on both sides with an intensity of 50-90 mA, frequency of 50 Hz, pulse duration of 250 ms, for 10 sec followed by 12 sec rest interval between the pulses. The procedure were done in independent sitting position as much they can with intensity of strong muscle contraction of NMES without producing noxious stimuli.[6]

The combination group received both CMS and NMES along with the standard rehabilitation protocol. Each additional treatment was performed five times weekly for 20 minutes per day for 4 weeks. The total rehab time was similar for all the patients in each group.

Patient evaluation

All the patients were assessed before, and after 4 weeks of physical therapy intervention by the physiotherapist. Gender (all drop out cases were females in this study), age, hemiparetic side, stroke etiology, post stroke duration, vessel involvement, MMSE score were documented in each patients. Trunk instability and associated balance dysfunction was assessed primarily by BBS (0-56), and secondary outcomes by using postural assessment scale for stroke (PASS) patients (0-36) and TIS (0-23) and for functional outcome evaluation BI (0-100) was applied.[7-10]

Statistical analysis

All the data were analyzed by using statistical package for the social sciences (SPSS) 21.0 and the significance level for this study was $p<0.05$. The baseline characters were summarized by using mean, standard deviation (SD) and frequency. Paired t test was used to find out the pre-post comparison within the group. Analysis of variance (ANOVA) was used to find out the significant changes between the group and ANOVA shows significance, Bonferroni (post-hoc) test was used to find out which group shows more improvement following the intervention. Pearson correlation test was to find out the relation between trunk stability and functional outcome.

RESULTS

Baseline characteristic features of the patients

45 male stroke survivors participated in the study which include anterior, middle and posterior cerebral artery (80% ischemic) stroke (ACA, MCA, and PCA). Out of the 45 stroke patients 57.8% have right sided 42.2% had left sided

weakness. All the stroke patient's baseline characteristics were summarized in Table 1.

Changes in variables before and after the intervention

Table 2 showed the changes in outcome following treatment in each group. All groups showed improvement in BBS, PASS, TIS and BI after the intervention which statistically significant at 0.05 level. Figure 1 showed the mean difference in each variable after the treatment.

Analysis of post-interventional effects in all three groups

For analysis of improvements after the intervention ANOVA was used and shown significant improvement in each groups (Table 3). The post-hoc (Bonferroni) test indicated that core muscle strengthening along with NMES (combination group) showed more significant improvement (Table 4) in BBS, PASS, TIS and BI compared to core muscle strengthening or NMES alone group.

Table 1: Baseline characteristics of stroke patients.

Variables	All stroke patients (N=40)	Core muscle strengthening group (CMS) (N=15)	NMES group (N=15)	Combination group (NMES and CMS) (N=15)
Age (years)	58.98±6.96	61.20±5.84	58.26±6.87	57.47±7.89
Gender	45 males	15 males	15 males	15 males
Post-stroke duration (days)	21.31±3.98	21.33±4.78	22.20±3.61	20.40±3.52
Etiology	I-36: H-9	I-11: H-4	I-13: H-2	I-12: H-3
Vessel involvement	ACA-8: MCA-32: PCA-5	ACA-3: MCA-11: PCA-1	ACA-3: MCA-10: PCA-2	ACA-2: MCA-11: PCA-2
Affected side	R-26: L-19	R-9: L-6	R-8: L-7	R-9: L-6
MMSE	24.27±2.70	22.33±3.15	24.93±1.83	25.53±1.85

Values are expressed in mean ±SD and in frequency. I-ischemic; H-hemorrhagic, R-right, L-left, ACA-anterior cerebral artery; MCA-middle cerebral artery; PCA-posterior cerebral artery

Table 2: Changes in outcome measures before and after the treatment.

Outcome measures	CMS group		NMES group		Combination group	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
BBS	25.33±2.94	35.40±4.20*	28.26±3.39	43.80±5.33*	29.13±4.41	47.40±6.38*
PASS	20.26±5.07	26.80±4.53*	16.47±4.82	29.53±2.89*	18.00±4.75	32.00±1.36*
TIS	8.53±2.69	14.46±2.59*	8.20±2.86	15.13±2.97*	8.53±2.44	18.40±2.29*
BI	30.60±8.92	47.00±8.34*	34.00±10.34	63.93±10.25*	35.07±11.01	71.60±10.17*

*P<0.05, which shows significant improvement from pre to post intervention; BBS-Berg Balance Scale, PASS-Postural Assessment Scale for Stroke; TIS-Trunk Impairment Scale, BI-Barthel Index

Table 3: ANOVA analysis between the groups.

Variable	Groups	Average improvement	SD	F value	Significance
BBS	Core MS	10.07	1.28	68.813	P<0.05
	NMES	15.54	1.96		
	Combination	18.27	2.43		
PASS	Core MS	6.54	0.74	32.316	P<0.05
	NMES	13.06	2.68		
	Combination	14.00	3.90		
TIS	Core MS	5.93	0.25	470.167	P<0.05
	NMES	6.93	0.25		
	Combination	9.87	0.51		
BI	Core MS	16.40	4.10	235.10	P<0.05
	NMES	29.93	0.25		
	Combination	36.53	1.80		

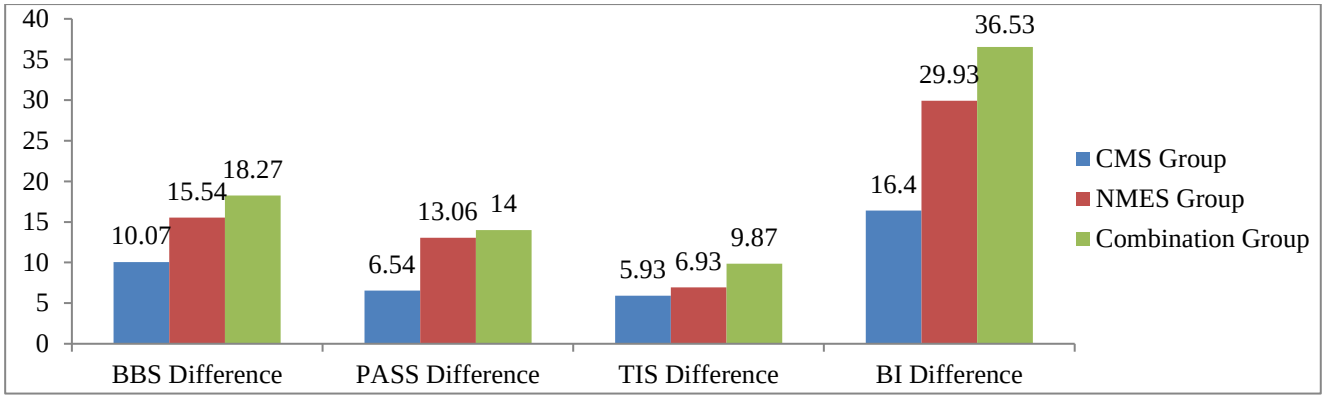

Figure 1: Pre-post difference in outcomes following the intervention.

Table 4: Bonferroni (post-hoc) analysis.

Variable	Group (i)	Group (j)	Mean Difference (i-j)	Standard error	Significance
BBS	Core MS	NMES	-5.46	0.712	P<0.05*
		Combination	-8.20	0.712	P<0.05*
	NMES	Combination	-2.73	0.712	P<0.05*
PASS	Core MS	NMES	-6.53	1.012	P<0.05*
		Combination	-7.47	1.012	P<0.05*
	NMES	Combination	-0.93	1.012	1.000
TIS	Core MS	NMES	-1.00	0.133	P<0.05*
		Combination	-3.93	0.133	P<0.05*
	NMES	Combination	-2.93	0.133	P<0.05*
BI	Core MS	NMES	-13.53	0.946	P<0.05*
		Combination	-20.13	0.946	P<0.05*
	NMES	Combination	-6.60	0.946	P<0.05*

*The mean difference is significant at the 0.05 level.

Correlations between trunk stability and functional outcome

Table 5 shows the relationship between trunk instability scale and ADL. Result showed positive correlation between the total score of TIS and BI.

Table 5: Pearson correlation between TIS and BI.

Variable	BI	Significance
TIS	0.849	P<0.05*

*Correlation is significant at the 0.05 level.

DISCUSSION

This randomized study indicates that trunk instability significantly reduced after the introduction of NMES and core muscle strengthening in stroke survivors supported by the trunk balance scales. In addition, this study also proves that more statistically significant improvement in trunk balance observed in the group three by the combination core strengthening and NMES.

The changes of BI in the combination group was higher when comparing with CMS and NMES alone groups. BBS, PASS and TIS are recognized criteria that can be used to assess trunk balance. The existing result indicated significant improvements in BBS and TIS when core muscle strengthening is added with NMES. This study also indicates the importance of incorporating coordination exercises to get higher scores in coordination subscales. We are agreeing with previous studies, which state the importance of trunk exercises on improving trunk instability and postural control.[11] Riyas et al showed that improvement of postural control and balance following unstable surface task oriented training and visual deprived balance training in stroke patients. Improvement of BI, which represents the functional outcome showed an association with improvement in total score with TIS.[12] As a result, enhanced trunk constancy may possibly result in healthier functional outcomes following stroke. As the combination group illustrated better progression in trunk performances than the NMES or CMS alone groups, greater improvement in BI was also experienced in the combination group.

Balance is a composite development that necessitates interactions among visual, proprioception, vestibular, musculoskeletal and cognitive systems. For the automatic postural control both the trunk and limb muscles are having equal roles in coordinating and regulating balance and that can be improved by activation of theses muscles

either through strengthening protocol or by means of any modalities like NMES.[13] The muscles in and around the pelvis, abdomen, lumbar and thoracic extensors helps in maintaining the stable platform for all the lower and upper extremity activities; this leads to the importance of core muscle strengthening protocol in rehabilitating stroke patients for improving balance.

In our study NMES applied over paraspinal muscle of thoracic and lumbar region to improve or to assist multifidus muscle to maintain proper curvature of the spine during the pelvic or limb activities. Somato-sensory stimulation by means of neuromuscular stimulators over stroke subjects shown enhanced cortical excitability and is well documented in literatures. Neuro-plasticity due to the repititive contractions on muscles by NMES brings the alteration in postural control as this concerned in the initiation of new motor learning.[14] Trunk muscle weakness following stroke are explained by many researchers, and are stating reasons as motor cortex of both hemispheres supply nerves to the trunk and lesion in these structure cause bilateral weakness of the trunk, compensatory or accessory movements leading to excessive energy expenditure, and by disuse/not retraining of trunk muscles.

The present study provide better results in trunk stability by the combination of NMES and core muscle strengthening in early days of stroke. We also recommend all the rehabilitation professionals to incorporate trunk exercise in early phases of rehabilitation to improve trunk stability, balance and postural control which sequentially improves the functional outcomes and can perform activities of daily living in optimum level.

Limitations

Long term follow-up assessment not performed, for generalization of the result required enrolment of patients from multiple geographical locations and need to consider chronic stroke patients too.

CONCLUSION

NMES along with core muscle strengthening shows enhanced trunk stability and balance leading to improvement in functional outcomes following stroke.

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