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Comparative Study on Neuromuscular Electrical Stimulation and Ankle Foot Orthosis in Foot Drop

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ABSTRACT

Background: Foot drop is the first and foremost signs and symptoms of brain stroke; it is a dire need for immediate correction of it. Most of the time when foot drop has been overlooked and ignored it becomes irreversible and hinders in gait and active daily life (AD) which brings our concern for immediate interventions in correction of foot drop with neuromuscular electrical stimulation and foot drop.
Materials and Methods: A total of sixteen patients with a diagnosis of brain stroke leading to foot drop were selected for the present study. The patients were further divided into two groups. The patients of group-A received neuromuscular electrical stimulation and conventional exercise, whereas the patients of group-B received conventional exercise with ankle foot orthosis.
Results: The mean age, height, weight, and Body Mass Index (BMI) of patients treated with neuromuscular electrical stimulation was (51.50±14.75), (162.92±8.99), (65.12±9.08) and (24.54±2.91) respectively and that of ankle foot orthosis was (45.12±18.00), (168.67±6.17), (64.75±17.05) and (22.56±5.16) respectively. These observations were statistically significant with ($p < 0.001$).
Conclusions: Neuromuscular electrical stimulation is more efficient in correction of foot drop due to stroke than that of ankle foot orthosis.

Key Words: Stroke, Foot Drop, Neuromuscular Electrical Stimulation

INTRODUCTION

Stroke is a global health problem. It is the second commonest cause of death and the fourth leading cause of disability worldwide [1]. Stroke is caused by the interruption of the blood supply to the brain, usually because a blood vessel bursts or is blocked by a clot.
This cuts off the supply of oxygen and nutrients to the brain, causing damage to the brain tissue.
Currently, the stroke incidence in India is much higher than in Western industrialized countries. Large vessel intracranial atherosclerosis is the commonest cause of ischemic stroke in India. The common risk factors, that is, hypertension, diabetes, smoking, and dyslipidemia are quite prevalent and inadequately controlled, mainly because of poor public awareness and inadequate infrastructure [2].
Foot drop is a neurological deficit of stroke patients. It arises from an upper motor neuron lesion, that is, an injury to the corticospinal tracts in the brain or spinal cord. Foot drop is recognized as one of the common gait impairments associated with hemiplegia (such as unilateral weakness or paralysis) with an estimated 20% of all

stroke survivors experiencing some degree of dropped foot [3].

Neuromuscular electrical stimulation (NMES), which provides electrical stimulation on nerve fibers in healthy or denervated muscles to induce muscle contractions, is the most widely used modality in clinics and has been adopted to manage the drop foot for stroke patients, since early 1990s [4]. Applying NMES may not only improve muscle strength but decrease spasticity of agonist or antagonist muscles possibly through maximal contraction inducing relaxation or reciprocal inhibition respectively.

There is increasing evidence that NMES may benefit survivors of stroke by enhancing the recovery of lost volitional movement (referred to as a therapeutic effect) or replacing lost volitional movement (referred to as neuroprosthetic effect) [5]. Neuromuscular electrical stimulation activates the lower motor neurons and not the muscle fibers directly. Therefore, effective NMES systems can produce muscle contractions using a relatively small amount of electrical charge that does not cause discomfort.

Ankle foot orthosis (AFO's) are frequently prescribed to assist with gait impairments in post-stroke hemiparetic subjects, to control the lower extremity during each phase of the gait cycle for individuals with neuromuscular impairments that make walking difficult [6].

The solid ankle-foot orthosis, also known as a rigid AFO, is a typically fabricated from relatively thick thermoplastic and aims to hold the ankle and foot, close to biomechanically neutral position (zero degrees of ankle dorsiflexion, subtalar and calcaneal neutral, with a balanced forefoot).

The present study was underneath the objectives to compare the effectiveness of neuromuscular electrical stimulation and ankle-foot orthosis on foot drop in stroke patients.

MATERIALS AND METHODS

Subjects

The present observational study was based on randomly selected 16 stroke patients (7 male and 9 female) with foot drops aged 21 to 70 years from Ivy Hospital, Amritsar. The subjects were randomly assigned into two groups, such as Group-A - eight subjects received electrical stimulation to tibialis anterior for 9 minutes and conventional exercise for 6 weeks; and Group-B eight subjects received conventional exercise and were advised to use ankle-foot orthosis for 6 weeks. A written consent was obtained from the subjects. The Institutional Ethics Committee officially approved the study.

Anthropometric Measurements

Three anthropometric variables, such as, height, weight, and BMI were taken on each subject using the techniques provided by Lohmann et al. [7] and were measured in triplicate with the median value used as the criterion. The height was recorded during inspiration using a stadiometer (Holtain Ltd., Crymych, Dyfed, UK) to the nearest 0.1 cm. The subject was asked to stand erect on the stadiometer with barefoot. The horizontal bar of the stadiometer was placed on the vertex of the subject and the readings were recorded in centimeters. Weight was measured by digital weighing machine (Model DS-410, Seiko, Tokyo, Japan) to the nearest 0.1 kg. The subject was asked to stand erect on the digital weighing machine with minimum clothes and barefoot. The measurements were carefully monitored from the scales of the digital weighing machine in kilograms. BMI was then calculated using the formula weight (kg)/height^2 (m^2).

Fugl-Meyer Assessment Scale of Lower Extremity (FMA - LE)

Fugl-Meyer Assessment was developed by Axel Fugl Meyer [8] as a disease-specific impairment index to assess sensorimotor function, joint function, and balance abilities in stroke victims [9]. FMA scoring was divided according to domains wherein the lower extremity domain consists of a total of 34 points.

Stroke Impact Scale (SIS)

The Stroke Impact Scale was a stroke-specific, comprehensive, health status measure. The scale was developed with input from both patients and caregivers [10] and was intended to include domains from across the full impairment-participation continuum [11]. The 59 questions of the SIS were divided into eight domains, strength, hand function, mobility, activities of daily living, emotion, memory, communication, and social participation. The first four of these domains might be combined into one physical domain, but the others must be scored separately.

Functional Ambulation Category (FAC)

The Functional Ambulation Categories (FAC) was a measure developed at Massachusetts General Hospital to rate the ambulation ability of patients undergoing physical therapy. This 6- point scale assessed ambulation status by determining how much human support the patients required to walk, regardless of whether or not they used a personal assistive device [12]. To use the FAC, a physiotherapist would ask the subject various questions and would briefly observe their walking ability to provide a rating from 0 to 5 [13]].

Neuromuscular Electrical Stimulator (NMES)

In this study, neuromuscular stimulation included 9 minutes of supramaximal (25% over the intensity needed to produce maximum contraction of the muscle) muscle stimulation [14]. The stimulation current included 100 Hz pulse stimulation (pulse duration = 0.1ms, pulse interval = 0.9 ms) which was applied in surge mode (surge duration = 4 seconds and rest between = 6 seconds).

Ankle Foot Orthosis (AFO)

In this study, the post-stroke survivors were advised to wear a solid ankle-foot orthosis. The patients were asked to wear compression stockings before wearing the AFO or an elastic crepe bandage was used to reduce swelling or edema, for a snug fit of the orthosis and avoid wrinkling or irritation to the skin.

STATISTICAL ANALYSIS

Data was analyzed using SPSS (Statistical Package for Social Science) version 20.0. Independent t-test was applied for the comparisons of data among the stroke patients with foot drop treated with ankle-foot orthosis and neuromuscular electrical stimulation. Paired t-test was applied between pre and post intervention data. Pearson's correlation coefficient test was profoundly determined to observe the correlations among different dependent and independent variables. A 5% level of probability was used to indicate statistical significance.

RESULTS

Table.1 showed the descriptive statistics of eight variables in stroke patients treated with neuromuscular electrical stimulation and ankle foot orthosis. The patients treated with neuromuscular electrical stimulation had higher mean values in age (51.50 years), weight (65.12 kg), BMI (24.54 kg/m^2), FMA-LE pre (12.62), FMA-LE post (25.12), SIS (43.38), FAC (3.25) and lesser mean value in height (162.92 cm), than the patients treated with AFO (45.12 years, 64.75 kg, 22.56 kg/m^2, 5.75, 16.87, 27.36, 1.12 and 168.67 cm respectively). However, statistically significant differences ($p<0.001$) were observed in FMA-LE pre ($t = 7.322$), FMA-LE post ($t = 7.501$), SIS ($t = 4.932$) and FAC ($t = 10.319$) between them.

Table 1. Descriptive statistics of different variables studied in between Group-A and Group-B

Variables	Group-A (SPTNMES)		Group-B (SPTAFO)		t - value	p - value
	Mean	SD	Mean	SD		
Age (years)	51.50	14.75	45.12	18.00	0.775	0.451
Height (cm)	162.92	8.99	168.67	6.17	1.491	0.158
Weight (kg)	65.12	9.08	64.75	17.05	0.055	0.957
BMI (kg/m²)	24.54	2.91	22.56	5.16	0.942	0.362
FMA-LE(Pre)	12.62	0.74	5.75	2.55	7.322	< 0.001
FMA-LE(Post)	25.12	0.83	16.87	3.00	7.501	< 0.001
SIS	43.38	5.30	27.36	7.50	4.932	< 0.001
FAC	3.25	0.46	1.12	0.35	10.319	< 0.001

SPTNMES = stroke patients treated with neuromuscular electrical stimulation; SPTAFO = stroke patients treated with ankle foot orthosis

Table 2. Correlation of FMA (post) with other variables between Group-A and Group-B

Variables	Group-A (SPTNMES)		Group-B (SPTAFO)	
	r - value	p - value	r – value	p - value
FMA- LE (pre)	0.777	< 0.012	0.930	< 0.001
SIS	0.382	0.175	-0.304	0.232
FAC	0.277	0.253	0.286	0 .246

The correlation coefficients of FMA-LE post with FMA-LE pre, SIS, and FAC in patients treated with neuromuscular electrical stimulation and ankle-foot orthosis tabulated in Table 2. In patients treated with neuromuscular electrical stimulation showed significant positive correlation ($p<0.012$) with FMA-LE pre ($r = 0.777$). In patients treated with ankle-foot orthosis showed significant positive correlation ($p<0.001$) with FMA-LE pre ($r = 0.930$).

Table 3. showed the correlation coefficients of SIS with FMA-LE pre, FMA-LE post, and FAC in patients treated with neuromuscular electrical stimulation and ankle-foot orthosis. In the patients treated with neuromuscular electrical stimulation, a significant positive correlation ($p<0.001$) of SIS was observed with FAC ($r = 0.921$). In patients treated with ankle-foot orthosis, a significant positive correlation ($p < 0.038$) of SIS was observed with FMA-LE pre ($r = 0.211$).

Table 3. Correlation of SIS with other variables between Group-A and Group-B

Variables	Group-A (SPTNMES)		Group-B (SPTAFO)	
	r – value	p -value	r- value	p – value
FMA- LE (pre)	-0.088	0.418	0.211	< 0.038
FMA- LE (post)	0.382	0.175	-0.304	0.232
FAC	0.921	< 0.001	0.062	0.442

Table 4. Correlation of FAC with other variables in between Group-A and Group-B

Variables	Group-A (SPTNMES)		Group-B (SPTAFO)	
	r - value	p – value	r - value	p – value
FMA- LE (pre)	-0.104	0.403	0.357	0.193
FMA- LE (post)	0.277	0.253	0.286	0.246
SIS	0.921	< 0.001	0.062	0.442

The correlation coefficients (r) of FAC with FMA-LE pre, FMA-LE post, and SIS in patients treated with neuromuscular electrical stimulation patients and ankle-foot orthosis were shown in Table 4. In patients treated with neuromuscular electrical stimulation, significant positive correlation ($p<0.001$) of FAC was observed with SIS ($r = 0.921$).

DISCUSSION

The present study was only one of its kind in which it has been recorded that neuromuscular electrical stimulation and ankle-foot orthosis were effective and no other supporting articles had been found.

It had been found from the analysis that both the group's subjects, the group of subjects who received neuromuscular electrical stimulation and ankle-foot orthosis for six weeks had shown a statistically and clinically significant effect on improving foot drop in stroke patients. However, the greater percentage of improvement was found in the Group-A in which patients received neuromuscular electrical stimulation than that of ankle-foot orthosis.

In the NMES group, the improvement in foot drop could be because NMES produced muscle contractions which gave afferent signals to the CNS that provided motor relearning and helped in decreasing pain perception. NMES could provide severely motor-impaired individuals a significant neuroprosthetic effect for ankle dorsiflexion when their volitional effect was insufficient [5]. For chronic stroke people with inadequate ankle control, our results found that a total of 21 sessions of NMES on ankle dorsiflexion resulted in increased step length, spatial gait symmetry, and active ankle plantar flexors during push-off, together with decreased static and dynamic plantar flexors spasticity and increased dorsiflexion muscle strength [15]. Neuromuscular electrical stimulation increased sensory inputs into the central nervous system and thus accelerated motor learning by increasing neuronal plasticity [16]. The electrical stimulation application in spastic agonist muscles was to create fatigue in the spastic muscle and to decrease spasticity by increasing recurrent inhibition that developed through Renshaw cells [17]. It is widely believed that the application of NMES in a rehabilitation setting can bring about effects that are both adaptive and restorative [18]. A hypothesis addressed by Motta-Oishi [19] that plasticity effects within specific spinal cord circuitries (i.e., short-latency autogenic inhibition (Ib inhibition), recurrent inhibition from Renshaw cells, disynaptic reciprocal Ia inhibition, presynaptic inhibition of Ia terminals and post-activation depression) may be associated with the reduced spasticity induced by treatments with NMES.

The findings of the present study revealed that significant differences existed between pre and post scores of FMA-LE ($t=31.62$; $p\leq0.01$) suggesting that participants showed significant improvement in ankle dorsiflexion and overall foot function after administration of six weeks of NMES intervention.

In the group treated with ankle-foot orthosis, the improvement could be because. of an AFO for drop-foot prevention were to provide a moderate resistance during loading response to inhibit foot-slap, allowed free dorsiflexion in stance phase, and provided large resistance in swing phase to obstruct foot drop [20]. Based on the findings of Daryabor et al. [21], all types of AFO resulted in a significant improvement in ankle dorsiflexion in the early stance and swing phase by preventing foot-drop, when compared with a control group without the use of an AFO. At the skeletal muscle level, insufficient dorsiflexion during the swing phase, ankle instability, and poor lift during the last phase of walking all disturbed the normal walking pattern. AFOs may be the best orthosis for improving postural control since they compensate for the weakness of muscles around the affected foot and improve peripheral stability [22].

An AFO is thought to be the most suitable lower limb orthosis to overcome any gait deficit related to ankle instability [23] Patients wearing the AFO cleared their toes better during swing and pivoted over the stationary foot better. The corresponding changes of the ankle angles were characterized by less plantarflexion during the swing (providing better toe clearance) and a larger dorsiflexion during the stance phase [24].

In the present study, results showed that after completion of treatment i.e. after 6 weeks of AFO intervention, results revealed that significant differences existed between pre and post scores of FMA-LE ($t=8.00$; $p\leq0.01$) suggesting that participants showed significant improvement in ankle dorsiflexion and overall foot function after administration of six weeks of AFO intervention.

Some dependent variables were used like the Fugl-Meyer Assessment Scale of Lower Extremity (FMA - LE), Stroke Impact Scale, and Functional Ambulation Category (FAC). Fugl-Meyer Assessment was developed by Axel Fugl Meyer in 1975 [8] as a disease-specific impairment index to assess sensorimotor function, joint function, and balance abilities in stroke victims [9]. In the present study this scale was used in this manner where, FMA- LE -pre which was the assessment scores taken before the treatment and FMA-LE-post which was the assessment scores taken after the completion of treatment protocol.

In the present study, there was strong positive correlation of FMA-LE-post with FMA-LE-pre in both NMES intervention {FMA-LE-pre, $p<0.012$, $r=0.777$} and AFO intervention (FMA-LE-pre, $p<0.001$, $r=0.930$).

The Stroke Impact Scale is a stroke-specific, comprehensive, health status measure. The scale was developed with input from both patients and caregivers [10] and was intended to include domains from across the full impairment-participation continuum [11]. In the present study, there was a strong positive correlation of SIS with FMA-LE-pre and FAC. in AFO intervention (FMA-LE-pre, $p<0.038$, $r=0.211$} and in NMES intervention (FAC, $p<0.001$, $r=0.921$).

The Functional Ambulation Categories (FAC) was a measure developed at Massachusetts General Hospital to rate the ambulation ability of patients undergoing physical therapy [12]. In the present study, there was a strong positive correlation of FAC with SIS. In NMES intervention (SIS, $p<0.001$, $r=0.921$).

CONCLUSION

Based on the findings of the present study, both interventions appeared to have immense potential to be used as treatment options in promoting improvement in foot drop in stroke patients. However, when it came to selecting one intervention over another as a treatment choice, the results of the study showed that both are significant but the mean, as well as the t-values of Group-A with neuromuscular electrical stimulation intervention showed comparatively superior values than that of Group-B with AFO intervention. This suggested that NMES intervention was slightly more efficient in treating foot drop due to stroke than that of AFO.

Declaration by Authors

Ethical Approval: Approved

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Conflict of Interest: The authors declare no conflict of interest.

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