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Effect of Transcranial Direct Current Stimulation (tDCS) on Plantar Flexor Spasticity by using H reflex

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ABSTRACT

Background: *A spastic ankle reduces walking velocity and mobility resulting in impaired gait and difficulty in ambulation. Increased plantar flexor spasticity has a devasting effect on dorsiflexion range and also contribute to increased energy consumption during gait. H amplitude as objective measurement is more accurate in assessing spasticity by using H reflex.* ***Objective:*** *To determine the effect of various types of tDCS on plantar flexor spasticity by using H reflex and also to know which type of tDCS is more efficient in reduction of plantar flexor spasticity* ***Methods:*** *A total of 30 participants were included in study with plantar flexor spasticity. patients were randomized into 4 groups using chit method. All Patients were evaluated for spasticity grade by using modified Ashworth scale (MAS). H reflex was assessed for all patients followed by application of Cathodal tDCS for group 1 (n=8), Anodal tDCS for group 2 (n=7), Bi-hemispheric tDCS for group 3 (n=7) and sham tDCS for group 4 (n=8) for about 20 minutes. Post tDCS intervention all patients were reassessed for plantar flexor spasticity by H reflex and MAS scale* ***Results:*** *All the groups have shown significant reduction of spasticity post cathodal tDCS. The mean improvement of cathodal tDCS was found to be -0.9275 anodal tDCS was found to be -0.5229, bi-hemispheric tDCS was found to be -0.3357 and sham tDCS was found to be -0.4988.* ***Conclusion:*** *cathodal tDCS application has shown reduction of spasticity after tDCS application in plantar flexor spasticity patients. This study concludes that cathodal tDCS over ipsilesional hemisphere as a treatment modality.*

Keywords— *Cathodal tDCS, Anodal tDCS, Bi-hemispheric tDCS and Sham tDCS, Spasticity, H reflex.*

1. INTRODUCTION

Spasticity is defined as the velocity dependent increase in tonic stretch reflex with exaggerated tendon reflexes[1]. About 12 million people in the world are affected with spasticity[2]. 39.5 % of stroke survivors have spasticity; about 9.4% are depicting severe spasticity and the overall prevalence of spasticity in post stroke patients is about 0.2%[3]. It was reported that about 50% of multiple sclerosis patients has minimal to mild spasticity and 17 % shows moderate spasticity and 16.8% shows severe spasticity in multiple sclerosis[4]. Almost 62% of patients with spinal cord injury experience spasticity[5]

With UMN lesion, there will be appearance of spasticity, clonus, co-contraction, and spastic dystonia. Spasticity is most evidently seen in upper limb flexors i.e., finger flexors, wrist flexors, and elbow flexors whereas extensor muscles such as knee extensors, and ankle extensors in lower limbs[6].

There are diverse approaches for measurement of spasticity. These comprise clinical scales, biomechanical methods and neurophysiological methods, but all of these have their own limitations and are inappropriate as they can be controlled or influenced by examiner i.e., they are subjective methods. Therefore, there is a need for accurate and objective method of assessment for spasticity because of increased availability of advanced treatment techniques, approaches and equipment's for spasticity treatment[7]. Piper showed H reflex for the first time in 1912. Later Hoffmann has described it more detail in 1918[7].The neural pathway of H reflex can be elicited by percutaneous electrical nerve stimulation along the course of the nerve. Large diameter 1a afferents are activated by the percutaneous electrical stimulation of mixed nerve. The volley of impulses transmitted to the spinal cord via dorsal root, there the synaptic afferents synapse with alpha motor neurons which belong to the same muscle. These motor neurons situated

in the ventral horn synapse with the synaptic afferents[8.] Modified Ashworth scale is the simplest tool for evaluating the muscle spasticity. It is largely used in clinical practice and in literature because of its simple application. The scale works on the principle of resistance felt to the passive movement of the joint[9].

Transcranial Direct current stimulation (tDCS) is an attractive tool as it is invasive method, reusable, relatively inexpensive, delivers painless stimulation, provides reversible change in the specific areas of the brain. tDCS is a good equipment for treating in various domains like cognitive, motor, social, and affective domains. All these above characteristics of tDCS makes it easy administration even at home[10]

Depending on the electrode placed over the cerebral cortex, tDCS can be categorized into two types as cathodal tDCS and anodal tDCS. Application of anodal tDCS over cerebral cortex increases the cortical excitability whereas application of cathodal tDCS application over cerebral cortex decreases the cortical excitability[11].Bihemispheric tDCS is bilateral unbalanced montage where both electrodes are placed over C3 and C4 of motor cortex with cathodal electrode over contralesional side and anodal over ipsilesional side[12]

Within few minutes after application of tDCS, neuronal cortical activity alters in the cerebral cortex and these effects lasts even post application for more than several minutes to hours[11].

Electrode placement is generally done by using 10 -20 EEG system[13]. Other techniques used for localization of specific effect are using TMS on the specific point to induce motor evoked potentials, or by using MRI, or by use of Neuro Navigation Software as this provides more precise location for accurate electrode placement[10].

Dongyu Wu has conducted a study about effect of tDCS on upper limb in post stroke patients. In this study the patients receive cathodal tDCS over the primary sensory motor cortex on the side of lesion along with conventional physiotherapy. This study concludes that there was reduced muscle tone post application of cathodal tDCS. Also, they added they found increased motor function and improved Barthel Index score[14].

Till date, there is little research in the literature which compare the effect of cathodal, anodal, biphasic and sham tDCS on changes of motor neuron excitability by using H reflex.

2. METHODOLOGY

- **Study Design:** Quasi Randomized Single Group Before and After study Design
- **Study Setting:** Dr. Dy. Patil College of Physiotherapy, Dr. Dy. Patil Vidyapeeth, Pimpri, Pune.
- **Target Population:** Patients with plantar flexor spasticity
- **Sample Population:** Patients with plantar flexor spasticity avail in Dr. Dy. Patil college of physiotherapy OPD and Dr. Dy. Patil medical hospital and Research center.
- **Sample Size:** 30 [Assuming the effect size of 0.25 with an alpha error of 0.05 power of 0.8 sample size works out 28, Sample size will be 30.]

2.1 Inclusion criteria

- Subjects with plantar flexor Spasticity.
- **Gender**: Both Males and Females
- Subjects who able to follow simple verbal directions

2.2 Exclusion criteria

- Patients with history of any recent musculoskeletal injuries like fractures, dislocation, joint Instability or any soft tissue Injuries.
- Patients with deformities in lower limbs.
- Hemodynamically Unstable Patients.
- Uncooperative patients or patient who is not willing to participate
- Altered Sensation of skin
- Preceding Epilepsy
- Patients who went surgical procedures to the lower extremities in the preceding 12 months.
- Serious Cardiac or Orthopedic Problems
- Subjects who are having metallic Implants Within the skull
- Who are taking any pharmacological agents at the time of the study and had no previous surgical procedures for the purpose of reducing spasticity.

2.3 Methodology

In this study ,30 subjects were taken who fulfilled inclusion criteria with plantar flexor spasticity. Subjects were allocated into 4 groups by chit method of randomization. All subjects were positioned in prone lying. H reflex was elicited from soleus muscle by percutaneous stimulation of the posterior tibial nerve delivered by a stimulator. The active surface electrode was placed at the distal edge of calf muscle and anodal electrode was placed on Achilles' tendon. Ground electrode was placed proximal to the cathode electrode. The site which provides maximum amplitude of evoked potential was first obtained by a hand-held cathode electrode stimulator and was considered as stimulation site. Electromyographic (EMG) signals were amplified with a rate of occurrence ranging from 2 HZ to 5KHZ with a sweep speed of 10ms/Division and stored for analysis with commercially available Octopus Software.

Careful preparation of skin (cleaning with alcohol) was done to attain less impedance. To obtain the maximum amplitude of EMG response, the soleus site was determined by pilot testing the tibial nerve. About 15 H reflex responses were recorded. H latency, M latency, H amplitude were recorded.

After a rest period of 5 minutes, group 1 was given cathodal tDCS, group2 were received anodal tDCS, group 3 were taken biphasic tDCS and group 4 were received sham tDCS. tDCS is employed using two rubber (Non – Metallic) electrodes with electrode gel applied over it. For cathodal tDCS, the cathodal electrode was placed over the primary motor cortex of M1 region contralateral to the lower limb with plantar flexor spasticity or on the affected motor cortex. For anodal tDCS, anodal electrode was applied over the ipsilesional C3 region and cathodal electrode over contralateral supraorbital region. For Bi-hemispheric tDCS, both placed over C3 and C4 of motor cortex with cathodal electrode over contralesional side and anodal over ipsilesional side. Anodal electrode is placed over ipsilesional side and cathodal over contralesional side. For Sham tDCS, the cathodal electrode was placed over the primary motor cortex of M1 region contralateral to the lower limb with plantar flexor spasticity or on the affected motor cortex with zero intensity. All groups receive tDCS for about 20 minutes and patient was monitored continuously to know any discomfort.; following the 10-20 International Electroencephalogram System and the anodal electrode was positioned on the contralateral supraorbital fossa. In the first 30 seconds the stimulation was gradually increased until it reaches 1.5mA and gradually diminished in the last 1 minute of the treatment.

After completion of tDCS application, all subjects were again taken into prone lying. After secure placement of electrodes i.e., active surface electrode was placed on the distal edge of the calf muscle and anode electrode was placed on the Achilles tendon. Ground electrode was placed proximal to cathode electrode. Stimulation site was obtained by pilot testing for the maximum H amplitude response. About 15 H reflex responses were recorded. H latency, M latency, H amplitude were recorded.

3. DATA ANALYSIS AND RESULTS

The data collected were analyzed using Epi Info, Primer and Winpepi software. Normality of the data was analyzed using Shapiro francis test using winpepi software and was determined as a normal distribution if the p >0.05. If the data was normally distributed, the pre and post tDCS comparison was done using Paired t test. If the data was not normally distributed Wilcoxon signed rank test was used for comparison of pre and post tDCS. Kruskal wallis test were used to compare between groups if data is not normally distributed and ANOVA were used to compare between groups if data is normally distributed.

TABLE 1: PRE AND POST MAS SCORE OF CATHODAL tDCS SHOWING MEAN, SD, MEDIAN & IQR

CATHODAL tDCS	MEAN	SD	MEDAN	IQR	W VALUE	P VALUE
PRE-MAS SCORE	**1.375**	**0.231**	**1.5**	**1 to 1.5**	**36.0**	**P< 0.024**
POST MAS SCORE	**0.125**	**0.35**	**0**	**0 to 1**		

Table 1 shows pre and post MAS score of cathodal tDCS, representing w value of 36.0. Table 1 also shows mean of 1.375, SD of 0.231s, median of 1.5 and IQR of 1 to 1.5 of pre-MAS score, along with mean of 0.125, SD of 0.35, median of 0 and IQR of 0 to 1 of post MAS score. Table 1 shows a decrease in mean, SD and median value indicating decrease in MAS Score after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 2: PRE AND POST MAS SCORE OF ANODAL tDCS SHOWING MEAN, SD

ANODAL tDCS	MEAN	SD	t VALUE	P VALUE
PRE-MAS SCORE	**1.214**	**0.267**	**7.12**	**P< 0.001**
POST MAS SCORE	**0.286**	**0.488**	**Df: 6**	**P=0.000**

Table 2 shows pre and post MAS score of anodal tDCS, representing t value of 7.12 and P value less than 0.001. Table 2 also shows mean of 1.214, SD of 0.267, along with mean of 0.286, SD of 0.488 of post anodal tDCS MAS score. Table 2 shows a decrease in mean, SD and median value indicating decrease in MAS Score after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 3: PRE AND POST MAS SCORE OF BIPHASIC tDCS SHOWING MEAN,

BIPHASIC tDCS	MEAN	SD	t VALUE	P VALUE
PRE-MAS SCORE	**1.143**	**0.244**	**9.17**	**P< 0.001**
POST MAS SCORE	**0.143**	**0.378**	**Df: 6**	**P=0.000**

SD: Table 3 shows pre and post MAS score of Biphasic tDCS, representing t value of 9.17 and P value less than 0.001. Table 2 also shows mean of 1.143, SD of 0.244, along with mean of 0.143, SD of 0.378 of post Biphasic tDCS MAS score. Table 3 shows a decrease in mean, SD and median value indicating decrease in MAS Score after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 4: PRE AND POST MAS SCORE OF SHAM tDCS SHOWING MEAN, SD, MEDIAN & IQR

SHAM tDCS	MEAN	SD	MEDAN	IQR	W VALUE	P VALUE
PRE-MAS SCORE	**1.1875**	**0.2588**	**1**	**1 to 1.5**	**36.0**	**P< 0.024**
POST MAS SCORE	**0.25**	**0.462**	**0**	**0 to 1**		

Table 4 shows pre and post MAS score of sham tDCS, representing w value of 36.0. Table 4 also shows mean of 1.1875, SD of 0.2588, median of 1 and IQR of 1 to 1.5 of pre-MAS score, along with mean of 0.25, SD of 0.462, median of 0 and IQR of 0 to 1 of post MAS score. Table 4 shows a decrease in mean, SD and median value indicating decrease in MAS Score after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 5: PRE AND POST CATHODAL tDCS H AMPLITUDE SHOWING MEAN, SD, MEDIAN & IQR

H AMPLITUDE	MEAN	SD	MEDAN	IQR	W VALUE	P VALUE
PRE-CATHODAL Tdcs	**1.5713**	**1.0**	**1.225**	**0.815 to 1.955**	**36.0**	P< 0.024
POST CATHODAL tDCS	**0.6438**	**0.4**	**0.465**	**0.355 to 0.905**		

Table 5 shows pre and post cathodal tDCS H amplitude, showing W value of 36.0. Table 2 also represents mean, SD, median and IQR score of pre cathodal tDCS H amplitude of 1.571,1.0 ,1.225 and 0.8 to 1.9 respectively, along with mean.SD. median and IQR score of post cathodal tDCS H amplitude of 0.6438 ,0.4,0.465 and 0.3 to 0.9 respectively. Table 5 shows a decrease in mean, SD and median value indicating decrease in H amplitude after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 6: PRE AND POST ANODAL tDCS H AMPLITUDE SHOWING MEAN, SD

H AMPLITUDE	MEAN	SD	P VALUE	t VALUE
PRE-ANODAL Tdcs	**1.0971**	**0.4879**	**0.062**	**2.29**
POST ANODAL Tdcs	**0.5743**	**0.1765**		**DF:6**

Table 6 shows pre and post anodal tDCS H amplitude, showing t value of 2.29 and P value of 0.062 which is statistically significant. Table 6 also represents mean and SD score of pre tDCS H amplitude of 1.0971 and 0.4879 respectively, along with mean and SD score of post tDCS H amplitude of 0.5743 and 0.1765 respectively. Table 6 shows a decrease in mean and SD value indicating decrease in H amplitude after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 7: PRE AND POST BIPHASIC tDCS H AMPLITUDE SHOWING MEAN, SD

H AMPLITUDE	MEAN	SD	P VALUE	t VALUE
PRE-BIPHASIC tDCS	**0.7871**	**0.2462**	**0.020**	**3.14**
POST BIPHASIC tDCS	**0.4514**	**0.2234**		**DF:6**

Table 7 shows pre and post Biphasic tDCS H amplitude, showing t value of 3.14 and P value of 0.020 which is statistically significant. Table 7 also represents mean and SD score of pre tDCS H amplitude of 0.7871 and 0.2462 respectively, along with mean and SD score of post Biphasic tDCS H amplitude of 0.4514 and 0.2234 respectively. Table 7 shows a decrease in mean and SD value indicating decrease in H amplitude after tDCS application, which indicates there was reduction in plantar flexor spasticity.

TABLE 8: PRE AND POST SHAM tDCS H AMPLITUDE SHOWING MEAN, SD

H AMPLITUDE	MEAN	SD	P VALUE	t VALUE
PRE-SHAM tDCS	**1.2350**	**1.0465**	**0.055**	**2.30**
POST SHAM tDCS	**0.7362**	**0.8342**		**DF:7**

Table 8 shows pre and post sham tDCS H amplitude, showing t value of 2.30 and P value of 0.055 which is statistically significant. Table 8 also represents mean and SD score of pre tDCS H amplitude of 1.2350 and 1.0465 respectively, along with mean and SD score of post tDCS H amplitude of 0.7362 and 0.2234 respectively. Table 8 shows a decrease in mean and SD value indicating decrease in H amplitude after tDCS application, which indicates there was reduction in plantar flexor spasticity.

Table 9: COMPARISON OF CATHODAL, ANODAL, BIPHASIC, AND SHAM tDCS

TYPE	MEAN	SD	MEDIAN	IQR	H VALUE	P VALUE
CATHODAL tDCS	**-0.9275**	**1.0851**	**-0.49**	**-1.05 to -0.395**	**2.337 With 3 df**	**0.69**
ANODAL tDCS	**-0.5229**	**0.6046**	**-0.42**	**-0.76 to -0.21**		
BIPHASIC tDCS	**-0.3357**	**0.2825**	**-0.27**	**-0.46 to -0.1**		
SHAM tDCS	**-0.4988**	**-06132**	**-0.4750**	**-0.7050 to -0.1050**		

Table 9 represents the comparison of H amplitude between cathodal, anodal, biphasic and sham tDCS along with mean, SD and median values. Cathodal tDCS has shown a mean value of -0.9275, SD of 1.0851 and median of -0.49. Anodal tDCS has shown a mean value of -0.5229, SD of 0.6046 and median of -0.42. Biphasic tDCS has shown a mean value of -0.3357, SD of 0.2825 and median of -0.27. Sham tDCS has shown a mean value of -0.498 SD of 0.6132 and median of -0.4750. Table 27 shows that cathodal tDCS has highest effect in reduction of plantar flexor spasticity followed by anodal tDCS, sham tDCS and least affect has shown on biphasic tDCS but the difference of comparison of effect is not statistically significant.

Table 10: COMPARISON OF MAS SCORE DIFFERENCES OF PRE AND POST CATHODAL, ANODAL, BIPHASIC, AND SHAM tDCS

INTERVENTION	MEAN	SD	P VALUE	F VALUE
CATHODAL tDCS	**1.25**	**0.378**	**P=0.219**	**F=1.58**
ANODAL tDCS	**0.9286**	**0.345**		
BIPHASIC Tdcs	**1**	**0.2887**		
SHAM Tdcs	**0.9375**	**0.3204**		

Table 10 represents the comparison of MAS score between cathodal, anodal, biphasic and sham tDCS along with mean, SD and median values. Cathodal tDCS has shown a mean value of 1.25, SD of 0.378. Anodal tDCS has shown a mean value of 0.9286, SD of 0.345. Biphasic tDCS has shown a mean value of 1, SD of 0.2887. Sham tDCS has shown a mean value of 0.9375, SD of 0.3204. Table 10 also depicts f value of 1.58 and P value of 0.129. Table 10 shows that cathodal tDCS has highest effect in reduction of plantar flexor spasticity followed by biphasic tDCS, sham tDCS and least affect has shown on anodal tDCS but the difference of comparison of effect is not statistically significant.

TABLE 11: ANOVA FOR DIFFERENCES OF SCORES OF MAS

Source of variation	Sum of squares (ss)	Degrees of Freedom (df)	MS (Variance)	F value
Between Groups	0.5336	3	0.1779	F=1.518
Within Groups	2.933	26	0.1128	
Total	3.467	29		

Table 11 shows comparison of between groups and within groups of differences of MAS Score for cathodal, anodal, bi-hemispheric tDCS application. It was found that sum of squares (ss) between groups is 0.5336 with 3 degrees of freedom (df) and variance of 0.1779 and sum of squares (ss) within groups is 2.933 with 26 degrees of freedom (df) and variance of 0.1128. The total value of ss was found to be 3.467 with 29 df.

4. DISCUSSION

The aim of the study was to compare the effect of various types of tDCS which is portable, safe, and have very few side effects on plantar flexor spasticity. The findings from the present study indicate that motor neuron excitability is decreased after application of tDCS in plantar flexor muscles. Patient were assessed for plantar flexor spasticity using MAS scale. patients were made to be in prone lying and has taken H reflex and about 10 -15 H waves were recorded.

Following a 5minutes of rest, cathodal tDCS was given for group 1, anodal tDCS to group 2, biphasic tDCS to group 3 and sham tDCS to group 4. For cathodal tDCS, cathodal electrode was placed over the primary motor cortex of M1 region contralateral to the lower limb with plantar flexor spasticity or on the affected motor cortex. For anodal tDCS, anodal electrode was applied over the ipsilesional C3 region and cathodal electrode over contralateral supraorbital region. For Bihemispheric tDCS, both electrodes were placed over C3 and C4 of motor cortex, Anodal electrode is placed over ipsilesional side and cathodal over contralesional side. For Sham tDCS, the cathodal electrode was placed over the primary motor cortex of M1 region contralateral to the lower limb with plantar flexor spasticity or on the affected motor cortex with zero intensity.All groups receive tDCS for about 20 minutes and patient was monitored continuously to know any discomfort. After administration of tDCS patient was again instructed to be in prone lying and H reflex was assessed. About 15 H reflex waves were recorded and assessed for H amplitude. No adverse effects have been reported during or after the study in any patient.

AuroreThibaut, AndreaDarulli has assess the effect of bilateral cathodal application at M1 region on arm, wrist and plantar flexor muscles spasticity in chronic patients with disorder of consciousness. The P value for MAS score for arm flexors is 0.180 with Z value of -1.341. The finger flexors have shown statistically significant improvement in spasticity with P value of 0.019and z value of -2.341. The study reported that 4 individuals with disorder of consciousness has shown a significant improvement in decreasing muscle tone with cathodal tDCS application over M1region[15].

This present study also assesses the MAS score after application of biphasic tDCS on plantar flexor spasticity muscle. P value was found using paired t test for pre and post MAS score calculation using Winpepi software. The t value was found to be t=3.14 and p value of 0.020with decrease of mean and SD values post application of tDCS, indicating the reduction of spasticity after post tDCS application.

Parade Auvichayapat, Benchapam Aree-uea has assessed the effect of anodal tDCS in left hand basal ganglia and ipsilesional motor cortex M1region in children with spastic cerebral palsyThe study include10 subjects and were assessed pre and immediate post tDCS. The study has shown p value of 0.030 increase in the ration of N-acetyl aspartate/creatine (NAA/Cr), choline/creatine ratio was increased showing a p value of 0.008. There was an improvement in extent of spasticity and hand function with p value of 0.028 with anodal tDCS although it is excitatory[16].

Gonacolo V Mendonca, pedropezoral correia has compared the excitability of motor neurons through H reflex and V wave between men and women. participants were assessed for H reflex after performing Isometric plantar flexor muscle contractions. The study reported a greater P value of H max/M max ratio in men than women with F=4.6 and $p<0.05$. The study also found the greater level of co-activation of tibialis anterior in women than in men with F=30.5 and $p<0.0001$. The peak -peak amplitude of M wave during maximum voluntary contraction was similar in both genders whereas amplitude of V wave was found to be greater in men with F=4.2 and $p<0.05$. The study reported that women have shown lower H reflex excitability than men[17].

The present study has included 7 females and 23 males. Frequency distribution was done using Medcalc software. About 23%of females and 77% of men were included in the study. Hence the study shows that cathodal tDCS application has shown reduction of spasticity after tDCS application in plantar flexor spasticity patients. This study concludes that cathodal tDCS over ipsilesional hemisphere as a treatment modality has shown significant reduction in plantar flexor spasticity compared to anodal, biphasic and sham tDCS application.

5.CONCLUSION

This study concludes that cathodal, anodal, bi-hemispheric and sham tDCS over as a treatment modality has shown significant reduction in plantar flexor spasticity. Cathodal tDCS has shown greater improvement in reduction compared to anodal, biphasic and sham tDCS application although the difference is not statistically significant.

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