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Effectiveness of Functional Electrical Stimulation (FES) on Gluteus Muscle to Improve Gait in Patient with Spastic Diplegic Cerebral Palsy - A Single Case Study

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Abstract: ***Background: Cerebral palsy (CP) is a neurodevelopmental disorder characterized by abnormalities of muscle tone, movement, and motor skills, and is attributed to injury to the developing brain. Factors that contribute to early brain damage include premature birth, infections, and lack of oxygen in the brain. To make the patients more independent, rehabilitative interventions such as repetitive locomotor training followed by muscle activation and strengthening exercises of the lower limb. Gait training and other weight-bearing exercise improve joint perception, which allows individuals to focus on improving their ability and minimizing the chances of falling and making them more independent. Functional electrical stimulation (FES) involved in gait training on the gluteus muscle addresses these challenges and improves muscle function and movement in cerebral palsy patients. Aim: To determine the most effective intervention for gluteal muscle activation in children with CP. Method: This was a case study of an adult with CP with (Gross Motor Function Classification System [GMFCS] levels III, age 26 years). Over the course of three weeks of FES use, gait evaluations were conducted with FES and non-FES regimes and the results were noted. Results: Intense gait training along with conventional therapy was given for 5 hours per day for 6 days per week for 3 weeks. For the evaluation of walking ability, pre and post-intervention measures were found to be statistically significant using spatio-temporal variables. Improvement in gait speed was observed and documented. Conclusion: FES-based Gait training leads to gluteus muscle activation and improves strength with an increase in the walking speed in patients with Cerebral Palsy.***

Keywords: Cerebral Palsy, FES, GAIT, 10 MWT, Gluteus muscle

1. Introduction

‘‘Cerebral palsy is a persisting qualitative motor disorder due to non-progressive interference with the development of the brain occurring before the growth of the central nervous system is complete’’(1) The term "cerebral palsy" is said to have been coined in 1889 by an English physician, Sir William Osler(2). Recent population-based studies worldwide report an estimated prevalence of CP ranging from 1 to almost 4 per 1,000 births or children (3) (4). Risk factors are commonly categorized by the timing of their proposed occurrence: prenatal, perinatal, and postnatal. The leading prenatal and perinatal risk factors for CP are birth weight and gestational age. Other risk factors include neonatal encephalopathy, multiple pregnancy, infection and inflammation, and a variety of genetic factors (5).

Symptoms of cerebral palsy can vary widely but may include difficulty with movement, muscle stiffness or weakness, abnormal reflexes, and difficulty with balance and coordination. However, it affects every individual differently depending on their type and clinical presentation (6). Cerebral Palsy is classified into (1) spastic (hemiplegic, double hemiplegic, and diplegic); (2) dystonic; (3) choreoathetoid; (4) mixed; (5) ataxic; and (6) atonic CP (7). Among them, spastic diplegic cerebral palsy is the most common type which occurs due to damage in the motor cortex area of the brain that primarily affects motor control in the legs. The etiology of hip related movement compensations is multifactorial. Delay developmental milestones, weakness, impaired motor control, spasticity, and altered joint and bony morphology are common features in CP (8)

The main goal of treatment for CP is to develop a plan to help the patient to reach his or her full potential. Common interventions include medicines; surgery; braces; physical; occupational and speech therapy. (9) Many studies have shown the use of Functional Electrical Stimulation, a device administered through electrodes placed over the skin to activate muscle for its physiological response is proven to be effective when applied with physical intervention. In particular, strengthening exercises with FES targeting the gluteal musculature are prescribed in attempting to address compensatory movement patterns, and in doing so, maximize walking function and promote independence and participation.

2. Literature Survey

Finite rehabilitative interventions using FES for Cerebral Palsy have been studied and implemented. To broaden the horizon the aim of this literature is to provide optimal treatment emphasizing gait training with FES and documenting our clinical experience and reiterating the publications about Cerebral Palsy rehabilitation.

3. Case Presentation

This is a fictional case study involving an adult having Spastic Diplegic Cerebral Palsy (CP) classified as GMFCS (Gross Motor Function Classification System) level 3 (Walks with an assistive mobility device indoors and outdoors on level surfaces). For the purpose of the case study, we have outlined the presentation of a 26-year-old female who attends outpatient physiotherapy with musculoskeletal and neurological symptoms leading to difficulty in independent walking, climbing stairs, and performing ADLs.

Diagnosis and History
Investigation: Brain MRI shows PVL due to hypoxic ischemic insult

Diagnosis: Spastic diplegic cerebral palsy

Present History: As per her orthopedic assessment,
1) Difficulty in balancing and walking
2) Bilateral squinting of patella
3) Bilateral hip Fixed Flexion Deformity of 20-30 degrees
4) Bilateral equino valgus deformity and slight midfoot break
5) Bilateral increased femoral anteversion
6) Bilateral external tibial torsion 30 degrees

Perinatal History: Spontaneous vaginal delivery, one of twins, premature (8 months), birth cry present

Post-Natal History: Kept in an incubator for about 1 and a half weeks because of neonatal jaundice and seizures, global development delay presented.

Surgical History: The patient underwent traditional lengthening of both hamstring muscles at the age of 10 years.

Rehabilitation history: The patient was diagnosed with CP at the age of 5 years and started physiotherapy, which was then discontinued for approximately 10 years. Presently, the Patient ambulates using standard walker and ankle foot orthosis.

Objective Assessment: The patient uses a walker and braces as walking aids. Dominating pattern of weakness in the bilateral lower limb with enhanced extensor tone in the antigravity muscles while standing and walking.

Examination Motor Function
Tone: Increased (bilateral lower limb)
Spasticity: Present (Antigravity Muscles)
Reflexes: Exaggerated
MMT: Weakness (left>Right lower limb)

GAIT Analysis
Type of GAIT: Crouch gait

Use of Assistive Devices: Standard Walker, AFO Braces

Phases of GAIT: The pelvis drops to the contralateral side while standing and walking. Bilaterally reduced hip and knee flexion during initiation of swing phase along with inadequate locking of the knee joint during stance phase. Moreover, a bilateral absence of heel strike observed. Compensatory strategies - side flexes on the right during left swing phase.

Clinical Procedure
The patient diagnosed with CP was referred to us for physical rehabilitation. After assessing and evaluating her condition, a treatment regime focusing on intense gait training, and balance and strength training was implemented. The gait training was conducted daily for 2 hours with the application of FES over the Gluteus Musculature bilaterally using AFO and walker as assistive devices. Pre and Post therapy, outcome measures were taken.

4. Method/ Approach

Patient received assisted over-ground walking, with the use of FES over Gluteus muscle bilaterally along with AFO and assistive devices. Locomotor training was done through continuous walking for 2 hrs.

Treatment parameters were indicated below:
Treatment Session: 18
Intensity: Gait Training: 2 hours (1 hour forward walk and 1 hour backward walk)
Conventional Training: 3 hours (Balance and strengthening exercises)
Total treatment period: 5 hours/ session
Total number of sessions: Single session /day
Frequency: 6 days/week
Duration: 3 weeks

Figure 1: Tools used in the study

Figure 2: Ankle Foot Orthosis

Set-Up

The criteria used to make this assessment primarily focused on safety by examining the stability of the pelvis during static and dynamic activities, amount of hip and knee movements, heel strike, toe off, and foot clearance of both lower limbs. On the basis of the assessment, FES was applied over both Gluteal Musculature.

Stimulation Muscles: Stimulation to the Gluteus during the stance phase of gait.

Electrode Placement: Active electrode over the Gluteus Medius muscle and Indifferent electrode over the Gluteus maximus muscle.

Footswitch: First metatarsal

Stimulation Parameters: 2 channel FES

Table 1: 2 channel FES stimulation parameters for gait training

Parameters	Channel 1	Channel 2
Walking set up		
Output Amplitude	40 mA	40 mA
Pulse Width	180 µs	180µs
Rising Ramp	500ms	500ms
Extension Time	1000ms	100/0ms
Falling Ramp	500ms	500ms
Time Out	No Time Out	No Time Out
Delay	2000ms	2000ms
Waveform	Asymmetrical	Asymmetrical
Frequency	40Hz	40Hz
Timing	Adaptive	Adaptive
Foot Switch	Heel Rise	Heel Rise
Total Walk Time	2 hours	2 hours

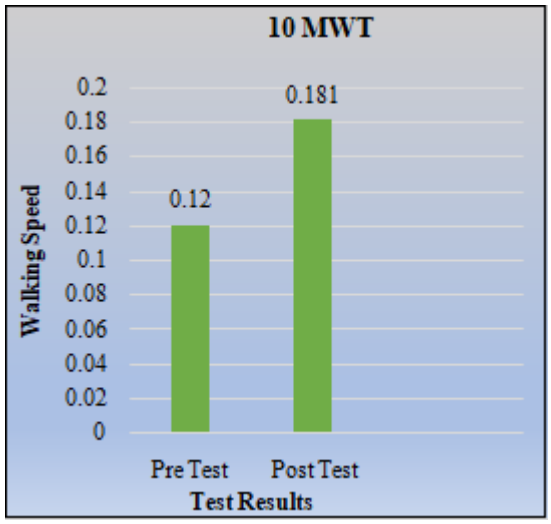
Ankle Foot Orthosis: Bilaterally AFO is applied as an adjunct to maintain the ankle in a neutral position so that the heels strike the floor at initial contact, control the plantarflexion moment at heel strike, and maintain the ankle in dorsiflexion during mid swing and late swing.

Treatment Progression Using FES:

FES assisted gait training with standard walker during the three weeks of research study.

Outcome Measures:

(a) 10-meter walk test (10MWT) – see bar graph (a) and
(b) Spatial temporal measures – see table 2



Bar Graph (a): 10-meter walk test (10MWT)

Spatial-temporal Measures

Table 2: Spatial-temporal measures

Parameters	**Pre-Test**		**Post Test**	
	Right	Left	Right	Left
Step Length	20 cm		22 cm	
Stride Length	60.5 cm	60.7 cm	50.3 cm	50.8 cm
Total Time	83 seconds		55 seconds	
Speed	0.120 m/sec		0.181 m/sec	
Cadence	0.60		0.82	

5. Discussion

In the CP population, this study demonstrates that the gluteal muscles can be effectively activated using FES during strengthening activities such as walking. The outcomes of this study will serve to guide practitioner a new approach on the

efficacy of hip muscle strengthening regimens in CP population.

Impaired lumbopelvic postural control, insufficiencies in hip extensors, abductors and quadriceps muscle function are common features, contributing to altered patterns of movement about the lumbar spine, pelvic, hip, and knee regions including excessive trunk lean and pelvic movement (11) (12) (13). Such patterns lead to alterations in force attenuation, particularly in reducing the hip extension and abduction moment resulting in the development of a different gait which may find walking difficult (14) (15) (16) (17). The study represents that by activating the gluteus muscle in close kinematic, patient will be able to utilize the muscle energy for better ground reaction forces with aligned Centre Of Pressure (COP).

In individuals with Cerebral palsy, Gluteus muscles are affected which causes difficulty with movements that involve the hip and thigh, such as walking or standing up from a sitting position. Functional Electrical Stimulation is one of the re-education techniques when used in conjunction with physical therapy helps to improve muscle strength, endurance, and control resulting in better function and mobility.The 10 MWT showedan increase in gait speed from 0.10 m/s to 0.18m/s post-intervention in a CP patient as a result of FES-assisted gait training. Moreover, spatial-temporal variables show improvement in cadence from 0.52 to 0.82 post-intervention. Hence, the clinical use of Functional Electrical Stimulation on muscles leads to faster progress in all the measured parameters, demonstrating its effectiveness in enhancing the results of walking

Similar results were found in the study done on the effect of surface EMG on gluteal muscles in which the strength of the muscles is significantly increased. (10)

2-channel Functional Electrical Stimulation over the gluteus muscle assists in walking by promoting hip extension and lateral stability to the pelvis and thus providing significant effect on improving the quality of gait increasing the walking speed with quality improvement in gait pattern.As stimulation parameters vary over individuals, further evaluation is encouraged in correspondence to the betterment of selection criteria and maximize utilization of stimulation.Moreover, the use of Functional Electrical Stimulation (FES) improves patients' confidence and ability to perform exercises that target specific functional goals. This case study aims to encourage new and simplified approaches to therapy that are more accessible for patients to understand and less complex to perform.

6. Conclusion

Functional Electrical Stimulation based Gait training leads to muscle activation and improves strength with an increase in the walking speed in patients with Cerebral Palsy. Use of FES during walking assists the patient in providing stability and mobility as it assistsglobal stabilizers and stimulates prime movers hence, achieving two goals by doing functional-oriented tasks.

Author's Note

In a challenging case like CP, patients find it difficult in ambulation due to weakness of certain muscles such as gluteus, quadriceps or calf which disturb kinematic chain. By using two channel FES for gluteal muscles, we were able to contract gluteal muscles during stance phase and allow easy swing phase by stabilizing the pelvis. Our present single case study focus on two channel FES which assist the person to achieve stability at proximal muscles thus improvement in walking by correcting kinematic chain. This simplified approach will not only improve biomechanics but also will increase the confidence of patients, making them step towards independent life. This study aims to encourage patients as well as researchers to evaluate further to improvement in quality of life of an individual with CP with use of two channel FES or multiple channel FES.

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