Functional Electrical Stimulation (FES) and Cerebral Palsy – a review of the literature

The evidence supporting the efficacy of Functional Electrical Stimulation (FES) to improve gait for children with Cerebral Palsy (CP) is growing steadily. The results of studies utilizing FES in pediatric study protocols are increasingly demonstrating improvements in gait quality, gait symmetry, and muscle strength and motor control. Given the complex nature of the gait deviations seen in children with CP, many pediatric FES studies investigate the effect of multichannel FES systems on abnormal gait. Most multichannel systems include stimulation of the anterior tibialis muscle as a treatment of for drop foot.[1-6] Two of the contributions to the FES literature involve no component of dorsiflexion, instead they address ankle plantarflexion and knee extension respectively.[7-8] An equal number of the FES studies reviewed here investigate single channel FES systems that operate as a neuroprosthetic by stimulating the Peroneal Nerve to alleviate drop foot.[9-16]

In keeping with the special concerns of a pediatric population, studies investigating the effects of FES on the gait of children with CP have addressed comfort and tolerability. Four studies addressed average wear and tolerability, finding that the children tolerated FES very well.[11-12,14-15] In the two studies that looked at longer term wear (4-6 months), the children utilized the FES system an average of 5-6 hours with the majority of children in both studies choosing to continue with FES after the treatment phase.[12,15]

Kinematic Outcomes: Much of the evidence supporting the use of FES to improve gait for children with CP demonstrates the efficacy of FES systems through changes in gait kinematics and gait symmetry.

Swing Phase: The functionality of the child's swing and placement of the foot at initial contact are important considerations as impairments here lead to instability and increased trips and falls.[15] Utilizing FES to activate the dorsiflexors during swing directly impacts the efficacy of gait, as evidenced by the decrease in both toe-drag and falls seen in one study utilizing PN FES.[14] Using motion analysis to measure dorsiflexion during swing, other studies have demonstrated a significant increase in both peak[3-6,9,13,15] and mean dorsiflexion.[13,15] FES has been shown to impact the degree of dorsiflexion at initial contact as well. Two studies demonstrated a significant increase in degree of ankle dorsiflexion at initial contact with the use of FES[4,13] with another noting an improved heel position at initial contact in some subjects both with and without FES.[5]

Stance Phase: The impact of FES on the gait of children with CP is also apparent in stance. Studies have shown that utilization of FES has improved ankle and foot posture during stance with a more symmetrical heel to toe pattern noted.[7,11] Use of PN FES to initiate dorsiflexion at terminal stance must be balanced with the child's ability to push off.[15] Studies have contributed results to the evidence that demonstrate that push-off is preserved with FES,[7,15] and also that the total work imposed on the ankle in terminal stance is improved with FES.[4,13]

The kinematic improvements in both swing and stance that are seen with the use of FES contribute to the quality of gait. Several studies demonstrated overall improvements in gait quality in the form of an increase in the symmetry of step length[1] and a decrease in overall gait deviations as compared to normative values for children with CP.[10] This improved quality can also contribute to functional mobility as evidenced in the results of several studies that demonstrate trends toward increased gait velocity and cadence.[1,3,10]

Improved muscle strength and control: Two studies looked at anatomic cross sectional area and anterior tibialis muscle thickness as measures of improved muscle function. Both of those studies showed significant increases in both cross sectional area and muscle mass in time periods ranging from 20 therapeutic sessions of FES to 3 months of FES

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wear as a neuroprosthesis.[2,9] The longer term FES study also measured cross sectional area and muscle mass at a 3 month follow-up visit to assess carry over and found that the improvements in both measures were maintained.[9] Other studies have also demonstrated improvements in muscle function with reports of significant increases in voluntary strength,[8,14] selective motor control14 and improved Gross Motor Functional Measure scores.[1] Finally, studies resulting in a decrease in lower extremity spasticity in the agonist and antagonist muscle groups have concluded that FES is beneficial to the overall balance of tone and control of the motor patterns used in gait.[8,14]

Key Points: While multichannel systems have been investigated longer, support in the evidence is clearly building for the use of Peroneal Nerve FES alone as a therapeutic and neuroprosthetic option for children with drop foot as a result of CP. Using FES in general is a rather new topic in pediatric gait research. Up to this point most studies have investigated the use of Neuromuscular Electrical Stimulation in an exercise protocol. However there has been a distinct increase in pediatric FES studies and 4 of the most recent studies have utilized the WalkAide specifically as a Neuroprosthesis.[9, 12,14-15]

The current evidence for the use of PN FES for the treatment of drop foot with children who have CP is very promising in terms of tolerability, kinematic improvements and muscle plasticity. At the 2010 International Society of Prosthetics and Orthotics meeting a group reported the results of an observational analysis utilizing the WalkAide with 124 children, 42 of which had CP. Their clinical results are very supportive of the use of FES with children. The use of FES with a pediatric population is increasingly becoming a viable and effective standard of care. The WalkAide is at the forefront of this paradigm shift and promises to be an exciting part of future therapeutic interventions.

Bibliography

1. Johnston TE, Finson RL, McCarthy JJ, Smith BT, Betz RR, Mulcahey MJ. Use of functional electrical stimulation to augment traditional orthopaedic surgery in children with Cerebral Palsy. J Pediatr Orthop. 2004;24:283–291.

2. Karabay I, Oztürk GT, Malas FU, Kara M, Tiftik T, Ersöz M, Ozçakar L. Short-Term Effects of Neuromuscular Electrical Stimulation on Muscle Architecture of the Tibialis Anterior and Gastrocnemius in Children with Cerebral Palsy: Preliminary Results of a Prospective Controlled Study. Am J Phys Med Rehabil. 2014 Nov 20. [Epub ahead of print]

3. Orlin MN, Pierce SR, Laughton Stackhouse C, Smith BT, Johnston TE, Shewokis PA, McCarthy JJ. Immediate effect of percutaneous intramuscular stimulation during gait in children with cerebral palsy: A feasibility study. Develop Med Child Neuro. 2005;47:684–690.

4. Pierce SR, Laughton CA, Smith BT, Orlin MN, Johnston TE, McCarthy JJ. Direct effect of percutaneous electric stimulation during gait in children with hemiplegic cerebral palsy: A report of 2 cases. Arch Phys Med Rehabil. 2004;85:339-43.

5. Postans NJ and Granat MH. Effect of functional electrical stimulation, applied during walking, on gait in spastic cerebral palsy. Dev Med Child Neurol. 2005;47:46-52.

6. Seifart A, Unger M, Burger M. Functional electrical stimulation to lower limb muscles after Botox in children with cerebral palsy. Pediatr Phys Ther. 2010;22:199-206.

7. Ho CL, Holt KG, Saltzman E, Wagenaar RC. Functional electrical stimulation changes dynamic resources in children with spastic cerebral palsy. Phys Ther. 2006;86:987–1000.

8. Daichman J, Johnston TE, Evans K, Tecklin JS. The effects of a neuromuscular electrical stimulation home program on impairments and functional skills of a child with spastic diplegic Cerebral Palsy: A Case report. Pediatr Phys Ther. 2003;15:153–158.

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9. Damiano DL, Prosser LA, Curatalo LA, Alter KE. Muscle plasticity and ankle control after repetitive use of a functional electrical stimulation device for foot drop in cerebral palsy. Neurorehabil Neural Repair. 2013;27(3):200-207.
10.Danino B, Khamis S, Hemo Y, Batt R, Snir E, Wientroub S, Hayek S. The efficacy of neuroprosthesis in young hemiplegic patients, measured by three different gait indices: early results. J Child Orthop. 2013;7:537–542.

11. Durham S, Eve L, Stevens C, Ewins D. Effect of Functional Electrical Stimulation on asymmetries in gait of children with hemiplegic cerebral palsy. Physiotherapy 2004;90(2):82-90.

12. Meilahn JR. Tolerability and effectiveness of a neuroprosthesis for the treatment of footdrop in pediatric patients with hemiparetic cerebral palsy. PM R 2013;5(6):503-9.

13. Pierce SR, Orlin MN, Lauer RT, Johnston TE, Smith BT, McCarthy JJ. Comparison of percutaneous and surface functional electrical stimulation during gait in a child with hemiplegic cerebral palsy. Am J Phys Med Rehabil. 2004;83:798–805.

14. Pool D, Blackmore AM, Bear N, Valentine J.Effects of short-term daily community walk aide use on children with unilateral spastic cerebral palsy. Pediatr Phys Ther. 2014;26(3):308-17.

15. Prosser LA, Curatalo LA, Alter KE, Damiano DL. Acceptability and potential effectiveness of a foot drop stimulator in children and adolescents with cerebral palsy. Dev Med Child Neurol. 2012;54(11):1044-1049.

16. van der Linden ML, Hazelwood E, Hillman SJ, Robb JE. Functional electrical stimulation to the dorsiflexors and quadriceps in children with Cerebral Palsy. Pediatr Phys Ther. 2008;20:23-29.