ACP® Outcomes Accelerated

# Cerebrovascular Accident

## Functional Electrical Stimulation

A large and consistently increasing amount of evidence supports the utilization of functional electrical stimulation (FES) to improve gait for individuals who have experienced a cerebrovascular accident (CVA). Much of that support is specific to the use of peroneal nerve FES to alleviate drop foot. The improvements shown in these and other studies demonstrate that utilization of FES can significantly impact gait speed, quality and symmetry as well as energy costs, spasticity, neuroplasticity and quality of life.

Benefits of FES found in the published research for individuals with CVA include:

### Gait Speed

- Statistically significant improvement in gait speed[1,3,5,7-10,12-21,29,33-36,40]
- Significant changes in gait speed with FES short term (2 to 5 months)[3,5,12-14,20]
- Significant changes in gait speed with FES long term (6 to 12 months)[7-10,15-19,29]
- Significant therapeutic effect (improvement in gait speed even with FES device turned off)[15,17,19-20,29]

### Energy Cost

- Reduced effort required to ambulate[1,12,14,17-20,22]
- Decreased physiological cost index (PCI); energy cost considering heart and respiratory rates[1,12,14,17-20,22]
- Decreased total work; energy cost of walking both when the FES was turned on and off [22]
- Subjective reports that walking with FES was more comfortable,[37-38] less fatiguing[37] and felt more normal[38]

### Gait Symmetry

- Improved Gait Asymmetry Index[13]; marker of inter limb coordination/balance status and fall risk[13,15,24]
- Decreased gait swing and stride time variability increased gait stability (correlates with fall reduction) [13,15,24]
- Improved hip and knee flexion angles and symmetry of hip and knee motion during gait[23]
- Improved push off at terminal stance; demonstrated restoration of gait symmetry to near normal[23]
- Improved ankle dorsiflexion and symmetry of swing[23]
- Improved entire lower extremity flexor pattern[23]
- Improved Rivermead Visual Gait Analysis (RVGA); trunk, pelvis, hip, knee and ankle symmetry[5]

### Spasticity

- Decreased spasticity of the antagonist gastroc-soleus/plantar flexor muscles[2,28,39]
- Improved Composite Spasticity Score (CSS)[2]

### Neuroplasticity

- Improved Motor Evoked Potentials (MEP)[18,29]
- Increased voluntary anterior tibialis muscle activity and maximum voluntary contractions (MVC)[2,6,18,29]
- A “training or therapeutic effect” with improvements in gait speed when FES is turned off [40]

### Quality of Life (QOL), Patient Preference and Rehabilitation Efficiency

- Preferred FES to an AFO[7-8,25]
- Felt safer when using FES[7,13,32, 38]
- Objective improvements in obstacle avoidance[37]
- Decreased fear of falling[27]
- Reported fewer falls[13]
- More stability of gait with FES, which helped walking over uneven terrain or on inclines[41]
- Positive impact on disability post CVA and overall QOL[26]
- Improved functional independence in the activities of daily living, motor recovery and gait performance[43]
- Positive effects associated with FES use via the Psychosocial Impact of Assistive Devices Scale (PIADS)[5]
- Improved balance abilities; Overall Stability Index and Overall Directional Control Index[36]
- Improved Berg Balance Scale,[9]
- Improved 6-Minute Walk Test[9]
- Improved Modified Emory Functional Ambulation Profile tasks[9,10]
- Cost effective, decreased time to complete rehabilitation, improved rehabilitation outcomes, increased number of patients discharged to home[2,30,31]
- Improved functional mobility and QOL[4]

These studies support that FES is at least an equivalent alternative to bracing and may perform better than an AFO on some measures of function and balance.[42] Gait speed is an important indicator of overall functional mobility and has been shown to be a good, discriminate measure of physiological and functional recovery for patients post CVA.[11] The support in the literature for changes in gait speed with the utilization of FES is robust. The literature also shows that FES improves gait speed at no additional energy cost. Reported decreases in PCI, which indicate that individuals using FES walk faster and farther with less effort, have significant and positive implications and improve the prognosis for functional mobility. The positive neuroplastic outcomes of cortical activation and motor control represent true CNS recovery, even in patients many years post CVA,[7,18] making the neuroprosthetic application of FES a viable option for any patient suffering from decreased mobility after CVA.

## Bibliography


1. Burridge, J., Taylor, P., Hagan, S., Wood, D. & Swain, I. (1997). The Effects of Common Peroneal Nerve Stimulation on the Effort and Speed of Walking: A Randomized Controlled Clinical Trial with Chronic Hemiplegic Patients. *Clin Rehab, 11*:201-210.
2. Yan, T. B., Hui-Chan, C. W., & Li, L. S. (2006). Effects of Functional Electrical Stimulation on the Improvement of Motor Function of Patients with Acute Stroke: A Randomized Controlled Trial. *Zhonghua Yi Xue Za Zhi, 86*(37), 2627-2631.
3. Morone, G., Fusco, A., Di Capua, P., Coiro, P., & Pratesi, L. (2012). Walking Training with Foot Drop Stimulator Controlled by a Tilt Sensor to Improve Walking Outcomes: A Randomized Controlled Pilot Study in Patients with Stroke in Subacute Phase. *Stroke Res Treat, 2012,* 523564. doi: 10.1155/2012/523564
4. Sheffler, L. R., Taylor, P. N., Gunzler, D. D., Burke, J. H., Ijzerman, M. J., & Chae, J. (2013). Randomized Controlled Trial of Surface Peroneal Nerve Stimulation for Motor Relearning in Lower Limb Hemiparesis. *Arch Phys Med Rehabil, 94,*1007-1014.
5. Wilkinson, I. A., Burridge, J., Strike, P., & Taylor P. (2014). A Randomised Controlled Trial of Integrated Electrical Stimulation and Physiotherapy to Improve Mobility for People Less than 6 Months Post Stroke. *Disabil Rehabil Assist Technol, 14,*1-7. [Epub ahead of print]
6. Kottink, A. I., Hermens, H. J., Nene, A. V., & Tenningo, M. J., Groothuis-Oudshoorn, C. G., & Ijzerman, M J. (2008). Therapeutic Effects of an Implantable Peroneal Nerve Stimulator in Subjects with Chronic Stroke and Footdrop: A Randomized Clinical Trial. *Phys Ther, 88*(4), 437-448.
7. Everaert, D. G., Stein, R. B., Abrams, G. M., Dromerick, A. W., Francisco, G.E., Hafner, B. J., Huskey, T. N., Munin, M. C., Nolan, K. J., & Cufta, C. V. (2013). Effect of a Foot-Drop Stimulator and Ankle-foot Orthosis on Walking Performance After Stroke: A Multicenter Randomized Controlled Trial. *Neurorehabil Neural Repair, 27,* 579-591.
8. Kluding, P.M., Dunning, K., O'Dell, M.W., Wu, S. S., Ginosian, J., Feld, J., & McBride, KI. (2014). Foot Drop Stimulation Versus Ankle Foot Orthosis after Stroke: 30-Week Outcomes. *Stroke, 44,*1660-1669.
9. Bethoux, F., Rogers, H. L., Nolan, K. J., Abrams, G. M., Annaswamy, T. M., Brandstater, M., Browne, B., Burnfield J. M., Feng, W., Freed, M. J., Geis, C., Greenberg, J., Gudesblatt, M., Ikramuddin, F., Jayaraman, A., Kautz, S. A., Lutsep, H. L., Madhavan, S., Meilahn, J., Pease, W. S., Rao, N., Seetharama, S., Sethi, P., Turk, M. A., Wallis, R. A., & Kufta, C. (2014). The Effects of Peroneal Nerve Functional Electrical Stimulation Versus Ankle-Foot Orthosis in Patients with Chronic Stroke: A Randomized Controlled Trial. *Neurorehabil Neural Repair, 28*(7), 688-697.
10. Bethoux, F., Rogers, H. L., Nolan, K. J., Abrams, G. M., Annaswamy, T. M., Brandstater, M., Browne, B., Burnfield J. M., Feng, W., Freed, M. J., Geis, C., Greenberg, J., Gudesblatt, M., Ikramuddin, F., Jayaraman, A., Kautz, S. A., Lutsep, H. L., Madhavan, S., Meilahn, J., Pease, W. S., Rao, N., Seetharama, S., Sethi, P., Turk, M. A., Wallis, R. A., & Kufta, C. (2015). Long-Term Follow-Up to a Randomized Controlled Trial Comparing Peroneal Nerve Functional Electrical Stimulation to an Ankle-Foot Orthosis for Patients with Chronic Stroke. *Neurorehabil Neural Repair, 29*(10), 911-22. doi: 10.1177 /1545968315570325
11. Harris, J. E., Eng, J. J., Marigold, D. S., Tukuno, C. D., & Louis, C. L. (2005). Relationship of Balance and Mobility to Fall Incidence in People with Chronic Stroke. *Phys Ther, 85,*150–158.
12. Burridge, J. H., Elessi, K., Pickering, R.M., & Taylor, P. N. (2007). Walking on an Uneven Surface: The Effect of Common Peroneal Stimulation on Gait Parameters and Relationship Between Perceived and Measured Benefits in a Sample of Participants with a Drop-Foot. *Neuromodulation, 10*(1), 59-67.
13. Hausdorff, J. M., & Ring, H. (2008). Effects of a New Radio Frequency-Controlled Neuroprosthesis on Gait Symmetry and Rhythmicity in Patients with Chronic Hemiparesis. *Am J Phys Med Rehabil, 87*(1), 4-13.
14. Johnson, C. A., Burridge, J. H., Strike, P. W., Wood, D. E., & Swain, I. D. (2004). The Effect of Combined Use of Botulinum Toxin Type A and Functional Electrical Stimulation in the Treatment of Spastic Drop Foot after Stroke: A Preliminary Investigation. *Arch Phys Med Rehabil, 85*(6), 902-909.
15. Laufer, Y., Ring, H., Sprecher, E., & Hausdorff, J. M. (2009). Gait in Individuals with Chronic Hemiparesis: One-Year Follow-up of the Effects of a Neuroprosthesis that Ameliorates Foot Drop. *J of Neuro PT, 33,* 104-110.
16. Laufer, Y., Hausdorf, J. M., & Ring, H. (2009). Effects of a Foot Drop Neuroprosthesis on Functional Abilities, Social Participation, and Gait Velocity. *Am J Phys Med Rehabil, 88,* 14-20.
17. Stein, R. B., Chong, S. L., Everaert, D. G., Rolf, R., Thompson, A. K., Whittaker, M., Robertson, J., Fung, J., Preuss, R., Momose, K., & Ihashi, K. (2006). A Muliticenter Trial of a Footdrop Stimulator Controlled by a Tilt Sensor. *Neurorehabil Neural Repair; 20*(3), 371-379.
18. Stein, R. B., Everaert, D., Chong, S. L., & Thompson, A. K. (2007). Using FES for Foot Drop Strengthens Cortioco-Spinal Connections. 12th Conference of the International FES Society, 2007.
19. Stein, R. B., Everaert, D. G., Thompson, A. K., Chong, S. L., Whittaker, M., Robertson, J., & Kuether, G. Long Term Therapeutic and Orthotic Effects of a Foot Drop Stimulator on Walking Performance in Progressive and Nonprogressive Neurological Disorders. *Neurorehabil Neural Repair, 24*(2), 152-167.

20. Taylor, P. N., Burridge, J. H., Dunkerley, A. L., Wood, D. E., Norton, J. A., Singleton, C., & Swain, I. D. (1999). Clinical Use of the Odstock Dropped Foot Stimulator: Its Effect on the Speed and Effort of Walking. *Arch Phys Med Rehab, 80,* 1577-1583.
21. Wieler, M., Stein, R. B., Ladouceur, M., Whittaker, M., Smith, A. W., Naaman, S., Barbeau, H., Bugaresti, J., & Aimone, E. (1999). Multicenter Evaluation of Electrical Stimulation Systems for Walking. *Arch Phys Med Rehab, 80,* 495-500.
22. Voigt, M., & Sinkjaer, T. (2000). Kinematic and Kinetic Analysis of the Walking Pattern in Hemiplegic Patients with Foot-Drop Using a Peroneal Nerve Stimulator. *Clin Biomech, 15*(5), 340-51.
23. van Swigchem, R., Weerdesteyn, V., van Duijnhoven, H. J., den Boer, J., Beems, T., & Geurts, A. C. (2011). Near-Normal Gait Pattern with Peroneal Electrical Stimulation as a Neuroprosthesis in the Chronic Phase of Stroke: A Case Report. *Phys Med Rehabil, 92,* 320-24.
24. Ring, H., Treger, I., Gruendlinger, L., & Hausdorf, J. M. (2009). Neuroprosthesis for Footdrop Compared with Ankle-Foot Orthosis: Effects on Postural Control During Walking. *J Stroke Cerebrovasc Dis, 18*(1), 41-47.
25. Sheffler, L. R., Hennessey, M. T., Naples, G. G., & Chae, J. (2006). Peroneal Nerve Stimulation Versus an Ankle Foot Orthosis for Correction of Footdrop in Stroke: Impact on Functional Ambulation. *Neurorehabil Neural Repair, 20*(3), 355-360.
26. Wilkie, K. M., Shiels, J. E., Bulley, C., & Salisbury, L. G. (2012). "Functional Electrical Stimulation (FES) Impacted on Important Aspects of My Life": A Qualitative Exploration of Chronic Stroke Patients' and Carers' Perceptions of FES in the Management of Dropped Foot. *Physiother Theory Pract, 28*(1), 1-9.
27. Robertson, J. A., Eng, J. J., & Hung, C. (2010). The Effect of Functional Electrical Stimulation on Balance Function and Balance Confidence in Community-Dwelling Individuals with Stroke. *Physiother Can, 62,* 114–19.
28. Burridge, J. H., & McLellan, D. L. (2000). Relation between Abnormal patterns of Muscle Activation and Response to Common Peroneal Nerve Stimulation in Hemiplegia. *J Neurol Neurosurg Psychiatry, 69,* 353-361.
29. Everaert, D. G., Thompson, A. K., Chong, S. L., & Stein, R. B. (2010). Does Functional Electrical Stimulation for Foot Drop Strengthen Corticospinal Connections? *Neurorehabil Neural Repair, 24*(2), 168-177.
30. Taylor, P., Humphreys, L., & Swain, I. (2013). The Long-Term Cost-Effectiveness of the Use of Functional Electrical Stimulation for the Correction of Dropped Foot Due to Upper Motor Neuron Lesion. *J Rehabil Med, 45*(2), 154-160.
31. Tanovic, E. (2009). Effects of Functional Electrical Stimulation in Rehabilitation with Hemiparesis Patients. *Bosn J Basic Med Sci, 9*(1), 49-53.
32. Taylor, P. N., Burridge, J. H., Dunkerley, A. L., Lamb, A., Wood, D. E., Norton, J. A., & Swain, I. D. (1999). Patients' Perceptions of the Odstock Dropped Foot Stimulator (ODFS). *Clin Rehabil, 13*(5), 439-46.
33. Perera, S., Mody, S.H., Woodman, R.C., & Studenski, S. A. (2006). Meaningful Change and Responsiveness in Common Physical Performance Measures in Older Adults. *J Am Geriatr Soc, 54,* 743-749.
34. Tilson, J. K., Sullivan, K. J., Cen, S. Y., Rose, D. K., Koradia, C. H., Azen, S. P., & Duncan, P. W. (2010). Locomotor Experience Applied Post Stroke (LEAPS) Investigative Team. Meaningful Gait Speed Improvement During the First 60 Days Poststroke: Minimal Clinically Important Difference. *Phys Ther, 90,* 196-208.
35. Shiels, J., Wilkie, K., Bulley, C., Smith, S.,& Salisbury, L. (2011). A Mixed Methods Service Evaluation of a Pilot Functional Electrical Stimulation Clinic for the Correction of Dropped Foot in Patients with Chronic Stroke. *Primary Health Care Research & Development, 12,* 187–199
36. El-Sodany, A., El-Kafy, E., & El-Fiky, A.. (2016). Effectiveness of Functional Electrical Stimulation for Foot Drop on Walking Abilities and Balance Performance in Saudi Individuals with Chronic Stroke. *Jokull.*
37. Van Swigchem, R., Vioothuis, J., den Boer, J., Weerdesteyn, V., & Geurts, A.C. (2010). Is Transcutaneous Peroneal Stimulation Beneficial to Patients with Chronic Stroke Using an Ankle-Foot Orthosis? A Within Subjects Study of Patients' Satisfaction, Walking Speed and Physical Activity Level. *J Rehabil Med, 42,* 117-121.
38. Bulley, C., Shiels, J., Wilkie, K., & Salisbury, L. (2011). User Experiences, Preferences and Choices Relating to Functional Electrical Stimulation and Ankle Foot Orthoses for Foot-Drop after Stroke. *Physiotherapy, 97*(3), 226-33.
39. Ghedira, M., Albertsen, I., Mardale, V., Gracies, J., Bayle, N., & Hutin, E. (2017). Wireless, Accelerometry-Triggered Peroneal Nerve Stimulation in Spastic Paraparesis: A Randomized, Controlled Pilot. *Official Journal of RESNA, 29*(2), 99-105.
40. Street, T., Swain, I., & Taylor, P. (2017). Training and Orthotic Effects Related to Functional Electrical Stimulation of the Peroneal Nerve in Stroke. *J Rehabil Med, 49*(2),113-119. doi: 10.2340/16501977-2181
41. Van Swigchem, R., van Duijnhoven, H. J., den Boer, J., Geurts, A. C., & Weerdesteyn, V. (2012). Effect of Peroneal Electrical Stimulation Versus an Ankle-Foot Orthosis on Obstacle Avoidance Ability in People with Stroke- Related Foot Drop. *Phys Ther, 3*(92), 398-406.
42. Prenton, S., Hollands, K., & Kenney, L. (2016). Functional Electrical Stimulation Versus Ankle Foot Orthoses for Foot-Drop: A Meta-Analysis of Orthotic Effects. *J Rehabil Med, 48,* 646-656
43. Dujovic, S., Malesevic, J., Malesevic, N., Vidakovik, A. S., Bijelic, G., Keller, T., & Konstantinovic, L. (2017). Novel Multi-pad Functional Electrical Stimulation in Stroke Patients: A Single-Double Blind Randomized Study. *NeuroRehabilitation, 41*(4), 791-800.


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