Critically Appraised Topic Template

Title:
Functional Electrical Stimulation plus Repetitive Task Practice Improved Upper Extremity Movement and Functional Task Performance in Less Time Compared to Other Therapy Alone for Chronic Stroke

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CLINICAL SCENARIO

Clinical Problem

A cerebrovascular accident (CVA), also known as a stroke, is caused by a lack of oxygen to the brain. The different types of strokes can be classified as ischemic, hemorrhagic, or mini strokes. The most common type is an ischemic stroke, which is the blockage of cerebral vasculature caused by a build-up of plaque within an artery or an embolus/blood clot. A hemorrhagic stroke is caused by an aneurysm that has ruptured or a blood vessel leakage (Gillen, 2011). A mini stroke, also known as a transient ischemic attack (TIA), is caused by a blood clot temporarily blocking the cerebral vasculature, and usually these clots dissolve. However, a TIA is a serious medical condition that may lead to future strokes (American Stroke Association, 2016). Blockage of a blood vessel or bleeding into the brain deprives the brain cells of oxygen and nutrients which causes tissue damage. Depending on the location and severity of brain tissue damage, motor and sensory functions may be affected on the contralateral side of the body in relation to the damaged primary motor and sensory cortices of the brain (Gillen, 2014). A diagnosis of stroke can be confirmed by images from computerized tomography (CT) and/or magnetic resonance imaging (MRI), and they will indicate the extent and location of vascular blockage and/or brain tissue damage (Pendelton & Schultz-Krohn, 2014). A stroke is typically classified as acute, sub-acute, or chronic depending on time frame since the stroke occurred, but time frames and definitions of the types of stroke are variable in the literature. Acute stroke is usually defined as less than five to six months, sub-acute stroke has been defined as within three to six months, and chronic stroke has been defined as 5 months or longer (American Heart & Stroke Association, 2016).

Residual Problems

Some of the common problems caused by stroke include: hemiplegia or hemiparesis displayed as weakness on one side of the body; dysphagia, exhibited as swallowing and speech difficulty; ataxia, exhibited by problems with posture, walking, balance and fine motor skills; hemianesthesia or decreased ability to feel pain, touch, temperature or position; astereognosis, the inability to recognize what is in your hand by touching it; paresthesias, which is pain, numbness, tingling or pricking sensations in the affected limb; incontinence, due to the inability to sense the need to urinate or control bladder function; chronic pain, due to nerve damage or mechanical problems from damage caused by the stroke; receptive and/or expressive aphasias with global aphasia being the most severe; memory, learning and awareness difficulty; neglect, which is the lack of awareness on impaired side or inability to feel sensory stimuli; ataxia, the inability to plan and carryout a movement; anosognosia, the lack of acknowledgement of the physical impairment; depression, fear, sadness and grief are also common emotions experienced after a stroke (NINDS, 2016).

Incidence/Prevalence

According to the Centers for Disease Control and Prevention (2015), every year more than 795,000 people have a stroke and about 130,000 people die of stroke every year. About 610,000 of these occur for people who have had a stroke in the past or they are strokes people had for the first time. Ischemic stroke is more common than hemorrhagic stroke, and ischemic strokes occur 87% of the time. Stroke is a leading cause of long-term disability, and it is estimated that the costs associated with stroke per year in the United States, including treatment, healthcare services, and missed work-related expenses, total $34 billion every year. According to a 2002 World Health Report from the World Health Organization (2016), it has been reported that about 15 million people per year worldwide have a stroke, with 5 million of them dying, and 5 million are permanently disabled.

Effects on Occupational Performance

Upper extremity (UE) dysfunction affects approximately 60% of people post-stroke. Shoulder, wrist, elbow, and hand motor control impairments are common, and these impairments limit full participation in functional activities (Gharib et al., 2014). A limited ability to perform motor skills such as reaching, grasping, holding, and manipulating objects will affect activities of daily living (ADLs) such as brushing teeth, coming hair, bathing, and dressing because each task requires motor control and motor skills to perform the tasks effectively. In addition, instrumental activities of daily living (IADLs) such as meal preparation and clean up, home establishment and management, caring for others, and driving and community mobility require UE motor control and skills (Gillen, 2011). Moreover, many ADLs and IADLs are more challenging to complete without bilateral mobility of upper and lower extremities due to hemiplegia, such as dressing, transferring, and toileting. Physical dysfunction causing mobility barriers may prevent someone from participating in those occupations as he/she once did before the stroke. Many occupations are closely related to environment or have habitual behaviors that would require the ability to freely move about (Brown, Stoffel & Munoz, 2011). Some examples would be going to the laundromat, shopping at the farmer's market and swimming at the beach.

Dysphagia is loss of speech due to inability to control facial muscles caused by neuron damage following stroke. Aphasia is inability to express or comprehend speech due to damage of neurons in the left hemisphere following stroke. This will negatively impact both verbal communication (inability to properly form words) and nonverbal communication (inability to create appropriate facial expressions). This can affect relationships; areas of work, job performance, and leisure participation that require a social component or speech fluency (American Stroke Association, 2015).

Psychosocial and Cognitive Implications

Depression, fear, sadness and grief are also common emotions experienced after a stroke (NINDS, 2016). In one study by Dunlop, et.al, 2005, the likeliness of a depressed adult to have an ADL disability is 4.3 more likely than a non-depressed adult. ADL disability was defined as "the inability to independently perform at least one ADL task (dress, toilet, bathe, etc.) for a time period of at least 3 months." In one study by McCall & Dunn, 2003, impaired cognition was closely linked with IADL's in severely depressed adults. Severity of depression is more closely related to ADLs than IADL's. This is due to lack of engagement in self-care stemming from lack of volition, interest, or drive despite having knowledge and ability to perform the occupation. IADLS with social components such as community mobility of riding a bus or shopping may be challenging to someone with anxiety. Decreased cognition may reduce attentiveness that could result in safety issues (forgetting to turn off the burner when cooking) or reduce the ability to follow sequences (follow directions when driving), and reduce memory (i.e. cannot remember Dr. Appointments when/if bills are paid, what bus to take, etc.) (Brown, Stoffel & Munoz, 2011).

Intervention

Intervention included the use of functional electrical stimulation (FES), and electrodes were attached to the affected UE target muscles in the forearm and hand. FES devices delivered electrical current pulses ranging from 0.1 to 300 milliseconds at a frequency of 20 to 40 Hertz for a total treatment time of 30 to 120 minutes. All participants had a stroke that affected their UE, and they varied from having no active extension of the affected wrist or fingers to having trace muscle contraction to 10 degrees of wrist extension.

Intervention included repetitive task practice (RTP) or motor learning (ML) of functional tasks and occupations that are performed every day. RTP/ML was used in combination with FES to perform tasks of everyday living. In conjunction with ML principles, the RTP/ML included feedback about performance and tasks were progressively challenging as performance improved. Time, planes of motion, and/or distance changes were all ways to progressively challenge the participant. RTP/ML with the affected UE ranged from 30 to 300 minutes, which occurred during or immediately following FES. Functional tasks and activities were either chosen by participants or they were assigned by the researchers. Examples of assigned functional activities included stirring food in a bowl, writing with a pen/pencil, and/or other tasks such as reaching, grasping, and releasing various sized objects.

Occupational Therapy Theoretical Basis

A systems model of motor behavior is addressed with FES combined with ML/RTP intervention during stroke rehabilitation. Following stroke, rehabilitation involves many systems working together and influencing each other. Not only do multiple body systems within the person affect the performance patterns and skills involved, but also the task and the environment including the context and activity demands affect a person's overall occupational performance (Gillen, 2011).

Neuroplasticity is a theory directed at the nervous system and its ability to repair and adapt at the tissue, cellular, and molecular level according to the context and conditions it experiences (Dimyan & Cohen, 2011). Following stroke, occupational therapy interventions may target the repair and remediation of the neuromuscular systems in order to perform occupations of interest. ML theory emphasizes that practice, repetition, feedback, goal-setting, and motivation are required to promote neuroplastic changes. Therefore, occupational therapy intervention involving FES and ML/RTP combined will theoretically promote neuroplastic changes allowing the person to perform an activity that they could not do before.

Hypothesis: If a person performs functional tasks and activities based on ML principles using FES and RTP/ML with the appropriate context and conditions, then neuroplastic changes will occur, including improved motor performances such as reaching, grasping, holding, and manipulating objects that enable the person to participate in specific activities and occupations.

Science Behind the Intervention

Electrical stimulation is an intervention that uses electrical current to stimulate the peripheral nervous system (PNS) that depolarizes peripheral nerves and motor end plates causing a muscle contraction (i.e. movement). Depending on the level of impairment, the movement a person experiences may be variable. For example, a person with little to no impairment may experience a visible muscle contraction through the full range of motion (ROM). However, a person with a high level of impairment may experience visible muscle contraction, but not through the joint's entire ROM. Electrical stimulation of the PNS can influence the central nervous system through afferent pathways leading to the anterior horn of the spinal cord by means of antidromic, or backfiring, impulses the electrical stimulation creates. It has been hypothesized that electrical stimulation simultaneously combined with voluntary effort to move a limb, which activates the corticospinal tract pathway, can restore the motor pathway between the brain, spinal cord, and peripheral nerves that activate muscles (Rushton, 2003).

Increasing the cognitive attention to a specific task during a specific activity has been shown to activate parts of the brain and pathways of the nervous system that are not normally activated if cognitive attention is not occurring. In addition, performing tasks/activities that are motivating and they provide interest to the person enhances cognitive attention. Therefore, providing electrical stimulation during functional activities that are meaningful (FES combined with RTP/ML) results in greater activation of the neural pathways required to perform certain activities or occupations (Lazar, & Nicolás Cuenca, 2008).

Based on the ideas of neuroplasticity and several studies, individuals in the chronic stroke time frame experience cortical reorganization through the use of FES combined with RTP/ML. Studies have examined the cortical changes through functional magnetic resonance imaging (fMRI) following a protocol that uses FES combined with RTP/ML, and results of these studies indicate that increased cortical activation results in improved motor performances with the affected extremity. Motor performance changes included increased joint ROM, muscle strength, coordination movement patterns, and improved voluntary motor control to perform skilled tasks such as reaching, grasping, holding, and manipulating objects (Page et al., 2010).

Appropriate Occupational Therapy Intervention

Functional Electrical Stimulation is a preparatory method (specifically preparatory task) designed to target specific client factors such as body structures and functions. Primary body structures involved are the neuromusculoskeletal systems, and the primary body functions involved are control of voluntary movement, muscle power/tone/endurance, and joint ROM (Occupational Therapy Practice Framework: Domain and Process, 2014). Individuals with UE impairments can use FES to facilitate movement of the affected body structures/functions to participate in functional movement patterns. FES is used to produce muscle contractions that prepare muscles for RTP/ML activities (Seale, 2015). FES could be classified as a preparatory method/task because it prepares an individual for occupational performance. However, RTP/ML intervention would be considered activities and/or occupations. RTP/ML would be classified as an activity if the actions were designed to target performance skills and performance patterns in order to support occupational participation, and it could be classified as an occupation if they were everyday activities chosen by the client in order to support occupational performance goals (Occupational Therapy Practice Framework: Domain and Process, 2014).

FOCUSED CLINICAL QUESTION:

In adults with chronic stroke, is functional electrical stimulation combined with other treatment more effective than other treatment alone for improving upper extremity movement and functional task performance?

SEARCH SUMMARY

A literature review was conducted through five different databases that investigated functional electrical stimulation and its effects on upper extremity movement and functional task performance in individuals with chronic stroke. Ten studies were located that included relevant information related to the focused clinical question, and three randomized control trials were selected and critiqued. Selection of articles was based on the strength and rigor of study and specific inclusion/exclusion criteria such as outcome measures, population, intervention, and comparison intervention. All three selected studies were 1b (moderate) level of evidence.

Search Terms	Inclusion and Exclusion Criteria
stroke + functional electrical stimulation stroke + FES + occupational therapy stroke + occupational therapy stroke + hemiplegia stroke + upper extremity stroke + FES + hemiplegia stroke + FES + upper extremity chronic stroke +FES chronic stroke + FES + occupational therapy chronic stroke + FES + upper extremity FES + hemiplegia CVA + FES CVA + FES + upper extremity CVA + FES + occupational therapy	Inclusion: Publishes in 2006 or after Exclusion: Published prior to 2006, lower extremity, acute and sub-acute

CLINICAL BOTTOM LINE:
Based on these three articles, there is strong evidence that supports functional electrical stimulation combined with repetitive task practice is an effective intervention for improving upper extremity movement and functional task performance for adults with chronic stroke ages 21-81 years old.

Limitation of this CAT: This critically appraised or topic has been reviewed by occupational therapy graduate students and the course instructor.

TABLE 1: SEARCH STRATEGY

TABLE 2: SUMMARY OF STUDY DESIGNS OF ARTICLES RETRIEVED

Level	Study Design/ Methodology of Articles Retrieved	Total Number Located	Citation (Name, Year)
1a	Systematic Reviews or Meta-analysis of Randomized Control Trials	2	Howlett, 2015 Handy, 2004
1b	Individualized Randomized Control Trials	6	McCabe, 2015 Gharib, 2014 Page, 2012 Chan, 2009 Barker, 2008 Thrasher, 2008
2a	Systematic reviews of cohort studies	1	Hara, 2008
2b	Individualized cohort studies and low quality RCT's (PEDro ≤4)		
3a	Systematic review of case-control studies	1	Panel, 2006
3b	Case-control studies and non-randomized controlled trials (quasi experimental or clinical trials)		
4	Case-series and poor quality cohort and case-control studies		
5	Expert Opinion		

STUDIES INCLUDED

	Study 1	Study 2	Study 3
Design	Randomized Control Trial	Randomized Control Trial	Randomized controlled trial
Level of Evidence	1b (Moderate)	1b (Moderate)	1b (Moderate)
Rigor Score	9/11	7/11	8/11
Population	N: 40 stroke patients of both sexes (45-65 y/o, mean 54.42±6.25 years; 6-18-month post 1st stroke ever; wrist/finger flexor spasticity=grade 1 or 2 on MAS; AROM >60* shoulder flexion/ >10*	N: 32 (15 men, 17 women) Age: 38-75, mean: 57.6 Mean time since stroke onset: 53.8 months, range: 7-324 months. No active extension in wrist or fingers History of 1 stroke No excessive pain or spasticity	N: 35 Age: 21-81 years old, Post-stroke: 1st stroke >1 yr. with trace wrist extensor contraction, able to follow 2-step commands
Intervention Investigated	Functional electrical stimulation (FES) for 30 minutes immediately followed by 45 minutes of repetitive task specific practice (RTP); 3 days/week for 8 weeks	Functional Electrical Stimulation (FES) using a electrical stimulation neuroprosthesis (ESN) with repetitive task-specific practice (RTP) using participant valued activities for 30,60,120 min., 5 days a week for 8 weeks	Functional electrical stimulation (FES) + Motor Learning (ML) **(FES+ML)** Dosage: 3.5 hr./day ML and 1.5 hr./day of FES, 5 days/week for 12 weeks
Comparison Intervention	30 minutes of sham FES immediately followed by 45 minutes of RTP every day, 3 days/week for 8 weeks	Home exercise program for 30 min./day, 5 days/week, for 8 weeks	**ML only**: 5 hr./day partial & whole-task practice of complex functional tasks **ML+ Robotics**: 3.5 hr./day ML & 1.5 hr./day shoulder/elbow robotics training
Dependent Variables	1)Hand motor skills 2) Motor function of the hand in everyday tasks 3) Thumb, middle, index, ring fingers measured for ROM PIP joints; Extension ROM of MCP joints; Abduction ROM	1) Upper extremity movement, strength and coordination of the shoulder, elbow, wrist and hand. 2) Measure of upper extremity movement performance, quality and time performing functional activities. 3) Upper extremity function of grasp, grip, pinch and gross movement with everyday objects and activities. 4) Hand gross grasp and speed of movement	1) Upper extremity (UE) limb joint movement/range of motion, strength, and coordination 2) Functional task performance of everyday living (i.e. pick up comb and comb hair, pick up mug and drink)

Outcome Measures	1) Motor Assessment Scale (MAS) scores; 2) Jebsen-Taylor Hand Function Test (JTHFT) time 3) ROM of Thumb, middle, index, ring fingers: Extension of PIP joints; Extension of MCP joints; Abduction	1) Fugl-Meyer (FM) upper extremity section 2)Arm Motor Ability Test (AMAT) 3) Action Research Arm Test (ARAT) 4) Box and Blocks Test (BBT)	1) Fugl-Myer (FM) UE motor coordination scale 2) Arm Motor Ability Test (AMAT)
Results	P < 0.05. There was statistically significant difference between mean values of baseline and post treatment of MAS scores, mean time of JTHFT (in experimental group only), extension ROM of metacarpophalangeal and proximal interphalangeal joints for index, middle and ring fingers and abduction ROM of thumb, index, middle, and ring fingers.	No between groups test. 120 min group: FM: P=.0007, AMAT: functional ability P=.02, quality of movement P=.002 ARAT: P=.02, 60 min group: P=.04	Between groups, no significant differences, AMAT: (P >.584) & FM: (P>.590). Within groups, all 3 groups showed clinically and statistically significant improvements, AMAT & FM: (P<.009)
Effect Size	<u>Within Group FES+RTP</u> MAS: d=1.793 JTHFT: d=1.709 Digital ROM: d=1.457- 4.67 <u>Within Group Sham FES+RTP</u> MAS: d=1.197 JTHFT: d=0.015 Digital ROM: d=0.451- 3.536	<u>Within Group FES + RTP (120 minute)</u> FM: d=.500 ARAT: d=.279 AMAT (Functional Ability): d=.229 AMAT (Movement Quality): d=.312 <u>Within Group FES + RTP (60 minute)</u> ARAT: d=.095	<u>Within-groups</u> <u>FES + ML intervention</u>: AMAT: d=0.94 FM: d=1.22 <u>ML only:</u> AMAT: d=0.67 FM: d=1.38
Conclusion	By incorporating FES with repetitive task practice, statistically, significant improvement of hand motor function can be achieved. FES and repetitive task practice or repetitive task practice alone can statistically, significantly, improve PIP and MCP extension ROM and	Statistically significant results were achieved for improvement in upper extremity motor and functional tasks for the 120 minute group with FES + RTP of chronic stroke patients. Statistically significant improvement of functional task performance for the 60 minute group with FES + RTP	Statistically significant improvements are achievable for UE coordination and complex functional task performance through intensive and long-duration intervention with ML alone, ML plus FES, or ML plus robotics training.

	Abduction ROM of thumb, index, middle, and ring fingers and improve motor control of the UE	of chronic stroke patients resulted.	

SYNTHESIS SECTION

PICO Question:
In adults with chronic stroke, is functional electrical stimulation combined with other treatment more effective than other treatment alone for improving upper extremity movement and functional task performance?

Overall Conclusions:

Variables
Upper Extremity Movement Variables

- Upper extremity (UE) client factor variables that were measured included quality of limb movements, joint ROM, muscle strength, and UE coordination.

Functional Task Performance Variables

- Performance skill variables that were measured including bilateral UE coordination, reaching, grasping, holding, and manipulating everyday objects in order to complete ADL activities. For example, functional tasks performed included stirring food in a bowl, sweeping with a broom, typing at a computer, etc.

Results
Functional Task Performance

- Participants that received FES combined with Repetitive Task Practice (RTP) achieved statistically significant improvements in functional task performance with a minimum total treatment time of 2,400 minutes, that included 60 minute/day, 5 days/week for 8 weeks. These effect sizes were small to large ranging from .02 to 1.71.
- The only control group that achieved statistically significance improvements in functional task performance were participants that received only RTP for a total of 18,000 minutes that included 5 hours/day, 5 days/week for 12 weeks. These effects sizes for the other treatment control groups were small to medium ranging from .02 to .67.

UE Movement

- Participants that received FES combined with Repetitive Task Practice (RTP) achieve statistically significant improvements in UE movement with a minimum total treatment time of 1,800 minutes that included 75 minutes/day, 3 days/week for 8 weeks. These effects sizes were medium to very large ranging from 0.5 to 4.67.
- Control groups that received other treatment alone showed statistically significant improvements in UE movement with a minimum total treatment time of 1,080 minutes that included treatment for 45 minutes/day, 3 days/week for 8 weeks. These effects sizes were small to large ranging from 0.12 to 3.11.

Results: Similarities

Outcome measures in all studies measured UE movement and functional task performance as dependent variables. All studies had the experimental group use FES combined with RTP, and all studies had control groups that performed RTP or similar performance tasks that included reaching, grasping, and releasing. In all three studies, experimental groups achieved statistically significant improvements in the UE movement and functional task performance variables.

Results: Differences

All three studies differed with respect to treatment dosage, schedule, setting, and protocols. For all experimental groups (RTP plus FES), the studies varied in the total treatment time ranging from a minimum of 1,800 minutes over 8 weeks to a maximum of 18,000 minutes over 12 weeks. For all control groups, the total treatment time ranged from a minimum of 1,200 minutes over 8 weeks to a maximum of 18,000 minutes over 12 weeks. Control groups varied with respect to treatment: Page et al., (2012) used only a home exercise program, Gharib et al., (2015) used sham electrical stimulation plus RTP, and McCabe et al., (2015) used only RTP. However, McCabe et al., (2015) was the only study that used a 1:3 group paradigm with one therapist treating three participants for both the experimental and control groups.

Boundaries:

There was a total of 107 participants, 62 males and 45 females, ages 21-81 years old. All participants had experienced only one stroke (greater than 6 months prior to the study) that affected the upper extremity. Participants varied from having no active extension of the affected wrist or fingers to 10 degrees of wrist extension. In addition, all participants had a limited amount of spasticity, a score of two or less on the Modified Ashworth Scale. Participants did not have additional neurological conditions, and were all able to follow instructions during the studies. Voluntary movement of the upper extremity was not reported.

Implications for Practice:

- These studies demonstrated that FES combined with RTP results in statistically significant improvement in UE movement with 1,800-18,000 minutes of total treatment time (minimum of 30 minutes/day of FES combined with 45 minutes/day of RTP, 3 days/week for 8 weeks).

- These studies demonstrated that FES combined with RTP results in statistically significant improvement in UE movement and functional task performance with 4,800-18,000 minutes of total treatment time (minimum of 120 minutes/day of FES combined with RTP, 5 days/week for 8 weeks).

- Two of the studies demonstrated statistically significant improvement in UE movement with RTP alone with a minimum of 1,080 minutes of total treatment time (45 minutes/day, 3 days/week for 8 weeks). However, significant improvements in functional task performance only occurred with long-duration treatment with 18,000 minutes of total treatment time (5 hours/day, 5 days/week for 12 weeks).

- Long-duration and high-intensity RTP treatment protocols may significantly improve UE movement and functional abilities. However, FES combined with RTP may decrease the time that is required to achieve significant improvements.

- Individuals with chronic stroke (>6 months) having mild to no active extension of the wrist and fingers (severe to moderate impairment) may benefit from FES combined with RTP to significantly improve UE movements and functional abilities.

REFERENCES

Critiqued Articles

Gharib, N. M., Aboumousa, A. M., Elowishy, A. A., Rezk-Allah, S. S., & Yousef, F. S. (2014). Efficacy of electrical stimulation as an adjunct to repetitive task practice therapy on skilled hand performance in hemiparetic stroke patients: a randomized controlled trial. *Clinical rehabilitation*, 0269215514544131.

McCabe, J., Monkiewicz, M., Holcomb, J., Pundik, S., & Daly, J. J. (2015). Comparison of robotics, functional electrical stimulation, and motor learning methods for treatment of persistent upper extremity dysfunction after stroke: a randomized controlled trial. *Archives of physical medicine and rehabilitation,* 96(6), 981-990.

Page, S. J., Levin, L., Hermann, V., Dunning, K., & Levine, P. (2012). Longer versus shorter daily durations of electrical stimulation during task-specific practice in moderately impaired stroke. *Archives of physical medicine and rehabilitation*, 93(2), 200-206.

Related Articles (Not Individually Appraised)

Birenbaum, D., Bancroft, L. W., & Felsberg, G. J. (2011). Imaging in Acute Stroke. *Western Journal of Emergency Medicine*, 12(1), 67–76.

Dimyan, M. A., & Cohen, L. G. (2011). Neuroplasticity in the context of motor rehabilitation after stroke. *Nature Reviews Neurology*, 7(2), 76-85.

Kleim, J. A., Barbay, S., Cooper, N. R., Hogg, T. M., Reidel, C. N., Remple, M. S., & Nudo, R. J. (2002). Motor learning-dependent synaptogenesis is localized to functionally reorganized motor cortex*. Neurobiology of learning and memory*, 77(1), 63-77.

Lazar, E., & Nicolás Cuenca, J. (2008). *Functional electrical simulation in stroke*. Retrieved from http://www.veritymedical.hk/upload/documents/Cuenca_Lazar_FES-STROKE.pdf

Page, S. J., Harnish, S. M., Lamy, M., Eliassen, J. C., & Szaflarski, J. P. (2010). Affected arm use and cortical change in stroke patients exhibiting minimal hand movement. *Neurorehabilitation and neural repair*, 24(2), 195-203.

Page, S. J., Levin, L., Hermann, V., Dunning, K., & Levine, P. (2012). Longer versus shorter daily durations of electrical stimulation during task-specific practice in moderately impaired stroke. *Archives of physical medicine and rehabilitation*, 93(2), 200-206.

Rushton, D. N. (2003). Functional electrical stimulation and rehabilitation—an hypothesis. *Medical engineering & physics*, 25(1), 75-78.

Seale, J. (2015). *Functional Electrical Stimulation in Neurorehabilitation*. PhysicalTherapy.com, Article 2512. Retrieved from: http://www.physicaltherapy.com

Other Related Information

American Heart & Stroke Association. (2016). *An updated definition of stroke for the 21st century*. Retrieved from: http://stroke.ahajournals.org/content/44/7/2064

American Stroke Association. (2015). *Types of aphasia*. Retrieved September 29, 2016, from http://www.strokeassociation.org/STROKEORG/LifeAfterStroke/RegainingIndependence/CommunicationChallenges/Types-of-Aphasia_UCM_310096_Article.jsp#.V-2Bq4WcE2 w

American Stroke Association. (2016). *Types of stroke*. Retrieved from http://www.strokeassociation.org/STROKEORG/AboutStroke/TypesofStroke/Types-of-Stroke_UCM_308531_SubHomePage.jsp

Brown, C., Stoffel, V., & Munoz, J. P. (2011). Occupational therapy in mental health: A vision for participation. Philadelphia: F.A. Davis.

Centers for Disease Control and Prevention. (2015). *Stroke injury*. Retrieved from http://www.cdc.gov/stroke/facts.htm

Gillen, G. (2011). Stroke rehabilitation: a function-based approach. Elsevier Health Sciences.

National Institute of Neurological Disorders and Stroke (NINDS). (2016). *NINDS stroke information page.* Retrieved from http://www.ninds.nih.gov/disorders/stroke/stroke.htm

Occupational Therapy Practice Framework: Domain and Process, 3rd Edition. (2014). American Journal of Occupational Therapy. Vol. 68, S1-S48.

Pendleton, H. M. & Schultz-Krohn, W. (2012). Pedretti's occupational therapy: Practice skills for physical dysfunction (7th ed.). St. Louis, MO: Elsevier Mosby.

Radomski, M., & Trombly, C. (2014). Occupational Therapy for Physical Dysfunction (7th ed.). Baltimore, MD: Lippincott Williams & Wilkins.

United States Department of Health and Human Services. (2014). *Post Stroke Rehab*. Retrieved from http://www.ninds.nih.gov/disorders/stroke/post-stroke_rehab_brochure_508comp.pdf

World Health Organization. (2016). *World health report for 2002*. Retrieved from http://www.who.int/whr/2002/en/