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Understanding Key Therapeutic Technologies: FES, NMES, TENS, and Biofeedback for Stroke Recovery



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INTRODUCTION

For decades, the world of rehabilitation and physiotherapy has significantly benefited from technological advancements. In the pursuit of optimal therapeutic outcomes, especially for stroke victims, technologies such as Functional Electrical Stimulation (FES), Neuromuscular Electrical Stimulation (NMES), Transcutaneous Electrical Nerve Stimulation (TENS), and biofeedback have played pivotal roles. This short report aims to delve into these technologies and distinguish their specific purposes and functionalities. Importantly, it concludes that FES, coupled with biofeedback and NMES, form an unparalleled therapeutic triad, representing the ultimate Holy Grail in stroke rehabilitation.

FUNCTIONAL ELECTRICAL STIMULATION (FES)

FES is a therapeutic technique that utilizes low-energy electrical pulses to provoke muscle contractions, aiming to restore or improve the function of paralyzed or dysfunctional muscles. It plays a vital role in stroke rehabilitation by aiding mobility, enhancing muscle strength, and reducing spasticity. FES devices electrically activate nerve cells, which subsequently activate muscles or other nerves, making it a valuable tool in retraining voluntary motor functions and facilitating the restoration of impaired functions.

During stroke rehabilitation, FES is applied as a short-term therapy with the goal of restoring voluntary function rather than relying on lifelong dependence on the FES device. By directly stimulating neurons and nerves, FES can elicit muscle contractions and facilitate the rehabilitation process. This approach allows the central nervous system to relearn how to execute impaired functions effectively. FES technology's ability to stimulate both motor nerves (efferent nerves) and sensory nerves (afferent nerves) provides a comprehensive approach to stroke rehabilitation.

The application of FES in stroke rehabilitation involves applying an electrical current to the skin over a nerve or muscle, which causes the targeted muscle to contract. By engaging the mirror neuron system, FES helps the brain reestablish connections and learn new movement patterns. This targeted muscle activation assists in restoring voluntary motor control and improving functional recovery for stroke patients. FES-cycling is an exercise modality for quadriplegic and paraplegic patients to engage their paralyzed lower extremities. It improves muscle mass, blood flow, oxidative capacity, and reduces spasticity. By integrating FES into stroke rehabilitation programs, individuals can experience enhanced muscle control, improved motor recovery, and ultimately regain their independence and quality of life. Stimel-03 treatments further enhance this rehabilitation effect through the BioRhythmIQ Technology, which captures and utilizes patient-specific neuromotor signals for intended movements. This unique personalized approach of Stimel-

03 was clinically proven to increase treatment efficacy by promoting precise neural activation^{1,2,3}.

NEUROMUSCULAR ELECTRICAL STIMULATION (NMES)

NMES, like FES, uses electrical currents to stimulate muscle contractions. However, while FES targets functional movements, aiding muscle contraction for specific tasks, NMES aims to strengthen muscles. It is commonly used to prevent muscle atrophy, improve blood circulation, and enhance muscle re-education. NMES is crucial in rehabilitation therapy, especially after stroke, where it can assist in regaining muscle strength and function.

TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS)

TENS is a pain management technique that uses electrical stimulation to modulate or suppress pain signals to the brain. It operates by delivering electrical pulses across the skin's surface, thereby blocking the pain signals from reaching the central nervous system. TENS is commonly used to treat chronic and acute pain but does not typically stimulate muscle contractions or play a direct role in muscle re-education or motor control.

BIOFEEDBACK

Biofeedback is a technique that helps patients learn to control their body functions, such as heart rate or muscle tension. It involves using visual or auditory signals to provide real-time feedback about the body's physiological functions. The Stimel-03 Biofeedback feature was clinically proven to significantly improve motor functions in stroke patients by promoting patient engagement and encouraging specific muscle activity and relaxation patterns.

KEY DIFFERENCES BETWEEN FES, NMES, TENS & BIOFEEDBACK

While standard FES and NMES are essential for muscle re-education and strengthening, enhancing motor control and function, they are often limited in their customization and adaptability to individual patient needs. TENS, on the other hand, primarily targets pain management and lacks direct muscle stimulation capabilities for motor control improvements. Biofeedback provides real-time feedback, enabling patients to consciously control physiological functions, but it requires significant patient effort and cognitive engagement, which can be challenging for some patients. These technologies, while effective within their scope, do not comprehensively address the nuanced needs of every patient. Each method operates in isolation and lacks the synergistic integration that could amplify patient outcomes.

For stroke victims, the combination of FES, NMES, and biofeedback is an incredibly powerful tool for rehabilitation. FES can significantly improve motor control and reduce spasticity, while NMES effectively strengthens muscles and enhances re-education. Coupled with

¹ Daly JJ, Wolpaw JR. Brain-computer interfaces in neurological rehabilitation. *Lancet Neurol*. 2008 Nov;7(11):1032-43

² Slopsema 2018. Deep brain stimulation strategies for orientation-selective pathway activation *J Neural Eng*. 2018 October; 15(5): 056029

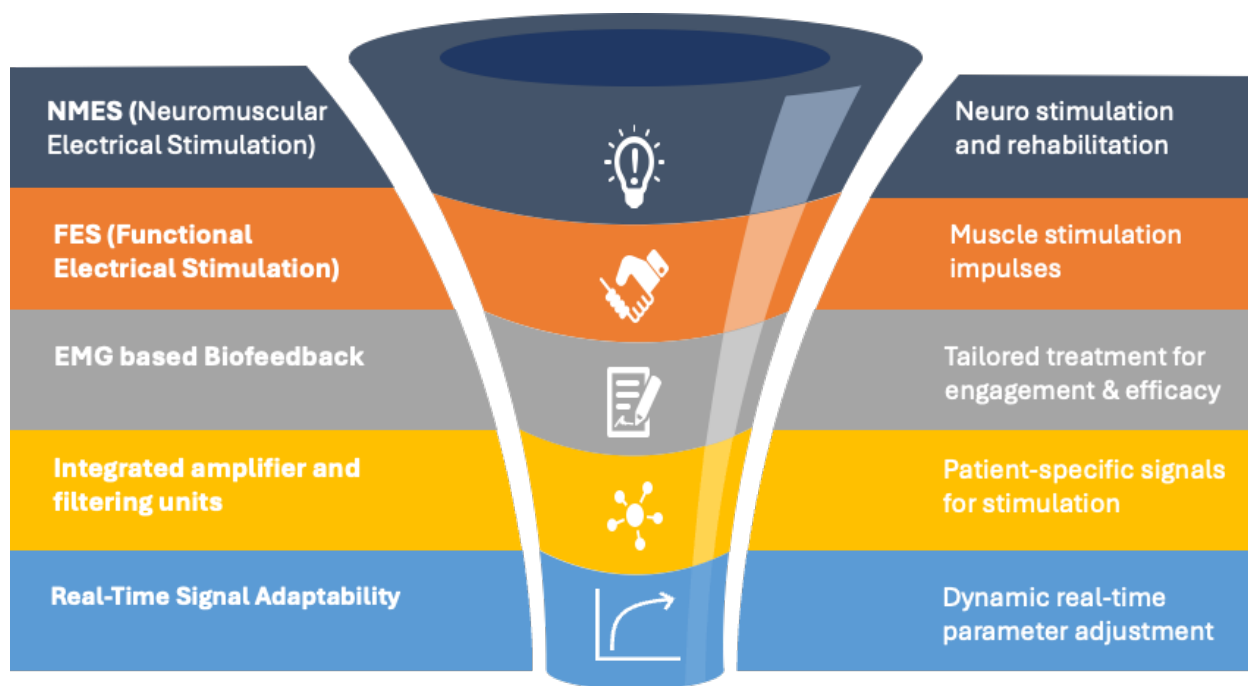
³ Merletti & Farina. *Surface electromyography: physiology, Engineering, and applications*. ISBN:978-1-118-98702-5. May 2016. Wiley-IEEE Press.

biofeedback, these interventions provide patients with a comprehensive and tailored rehabilitation plan that addresses their specific needs and goals.

Stimel-03, integrates the best attributes of FES, NMES, and biofeedback with the addition of the “secret spice” of the BioRhythmiQ technology, which harmonizes these modalities into a cohesive treatment plan tailored specifically to each patient's unique physiological rhythms. This integration not only overcomes the limitations of standalone treatments but also enhances effectiveness, ensuring more personalized therapy, faster recovery, and greater overall satisfaction in rehabilitation outcomes. Stimel-03 is not just an improvement on existing technologies; it's a complete paradigm shift in patient-centered rehabilitation, making it a superior choice for those seeking comprehensive and effective recovery solutions.

STIMEL-03 & TECHNOLOGY

The Stimel-03 represents a revolutionary approach to stroke rehabilitation. It utilizes the BioRhythmiQ, a proprietary FDA-cleared technology that uniquely combines FES, NMES, and Biofeedback. Moreover, the BioRhythmiQ utilizes smart sensors and advanced algorithm signal analysis to capture the patient-specific neuromotor "signature" and provide personalized FES-biofeedback treatment.



The integration of 3 distinct technologies creates a unique, interactive treatment platform for stroke patients, where electrical stimulation and biofeedback are linked in their operation to work together synergistically. This synergy of advanced technologies empowers stroke victims with a comprehensive and personalized solution, addressing their unique needs and optimizing their recovery journey.

The Stimel-03 taps into the remarkable mirror neuron system, which plays a crucial role in motor learning and imitation. By stimulating the mirror neurons, the device triggers the brain to send commands for natural movements, allowing stroke survivors to regain motor function as they witness the desired actions. This neural reactivation is a key mechanism for restoring lost abilities and reestablishing connections in the central nervous system.

The Stimel-03 takes rehabilitation to the next level by precisely activating targeted muscle groups, due to its unique capability to capture and utilize patient-specific neural signals. Through this electrical stimulation of intact peripheral motor nerves, the Stimel-03 triggers muscle contractions, promoting muscle strength, coordination, and overall functional capacity. This targeted approach ensures that stroke victims engage the appropriate muscles for specific movements, facilitating the retraining of the central nervous system and enhancing overall motor recovery.

Biofeedback is an integral component of the Stimel-03, providing real-time feedback on muscle activity and movement patterns. By monitoring muscle responses and visualizing them, stroke survivors can actively participate in their rehabilitation journey. This interactive feedback loop fosters a stronger mind-body connection, promoting neuroplasticity and optimizing functional recovery. With Biofeedback, individuals gain a deeper understanding of their progress and actively contribute to their own rehabilitation outcomes.

The Stimel-03's unique personalized integration of FES, NMES, and Biofeedback goes beyond conventional approaches, offering stroke victims a comprehensive and cutting-edge solution. By harnessing the power of these advanced technologies, the Stimel-03 empowers individuals to regain mobility, independence, and a higher quality of life.

The unwavering commitment of Motion Informatics to incorporate FES, NMES, and Biofeedback into the Stimel-03, by applying the unique BioRhythmIQ technology, ensures that stroke victims receive a holistic and state-of-the-art rehabilitation solution. With this advanced technology, Motion Informatics provides hope and limitless possibilities for those on their journey to recovery. By regaining control over their lives, stroke survivors can transcend the limitations of their impairments and embrace a future of renewed potential.

COMPARATIVE ANALYSIS OF FES, NMES, TENS

	FES	NMES	TENS
Primary Use	Primarily used in rehabilitation to restore or improve the functionality of paralyzed or dysfunctional muscles.	Frequently used in rehabilitation to prevent muscle atrophy, improve muscle re-education, and enhance blood circulation.	Primarily used as a simple and basic technique for pain management, offering minimal therapeutic value beyond temporary relief.
Stimulation Targets	Specifically targets motor neurons responsible for activating muscle groups involved in coordinated, functional movements. The goal is to restore or enhance these movements (e.g., grasping, walking) by stimulating the appropriate motor neurons and muscle groups in a patterned, task-specific manner.	Targets motor neurons to activate individual muscles or muscle groups for strengthening, preventing atrophy, or improving circulation, without necessarily focusing on coordinated, functional movement patterns.	Only targets nerve fibers to modulate pain signals, showing no significant contribution to muscle re-education or function.
Effect on Muscle Contraction	Directly provokes muscle contraction, contributing to improved mobility and reduced spasticity.	Stimulates muscle contraction to combat muscle atrophy and enhance muscle re-education.	Does not stimulate muscle contraction, providing no direct impact on muscle function or strength.
Patient Interaction	FES stimulates muscles to perform specific tasks, like grasping or walking. Patients interact by actively participating in these tasks, integrating the stimulation into daily activities.	NMES treatments typically don't target specific functional movements. Patients usually undergo NMES passively, without the need to perform tasks during stimulation.	Offers a passive, simplistic approach with a sole focus on pain management, not facilitating patient engagement in muscle recovery or re-education.
Regulatory Considerations	Devices should have FDA or similar regulatory clearance, indicating their efficacy and safety.	Devices should have FDA or similar regulatory clearance, emphasizing their reliability and effectiveness.	TENS units vary in quality, and many lack regulatory clearance, raising concerns about their reliability and safety. Despite this, FDA or similar regulatory clearance should always be sought.
Therapeutic Impact	Enhances motor function and promotes neuroplasticity by facilitating coordinated, functional movements, leading to improved independence and quality of life.	Increases muscle strength, prevents atrophy, and improves circulation, contributing to better muscle health and support for rehabilitation efforts.	Has a minimal therapeutic impact, restricted to basic pain relief without directly aiding in muscle function recovery or stroke rehabilitation.