EFFECTIVENESS OF FUNCTIONAL ELECTRICAL STIMULATION ON SPASTICITY AMONG SPASTIC HEMIPLEGIC STROKE SURVIVORS IN UNIVERSITY OF BENIN TEACHING HOSPITAL, BENIN CITY

BY

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CERTIFICATION

This dissertation by **NWABUISI CHINENYE DORCAS** is accepted in present form as satisfying the dissertation requirement of the degree of Bachelor of Physiotherapy, School of Basic Medical Sciences, and College of Medical Sciences of the University of Benin.

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DEDICATION

I dedicate this work to God Almighty, who blessed me with the knowledge, grace and perseverance to complete this work. I am absolutely nothing without him. Glory to God!

ABSTRACT

Background: Stroke is a major cause of motor impairment, death and disability globally. It often results in spastic hemiplegia due to upper motor neuron lesions, hindering activities of daily living. Clinical evidence shows that functional electrical stimulation facilitates neuromuscular re-education through electrical impulses, thus, enhancing motor recovery, improving muscle strength and promoting functional independence post-stroke.

Aim: The aim of this study is to determine the effectiveness of functional electrical stimulation on spasticity among spastic hemiplegic stroke survivors in UBTH.

Methods: Simple random sampling technique was used to select 2 groups of participants; experimental and control group. A sample size of 40 participants was recruited for this study, and the FES device, MAS, MRS, FIM and demographic questionnaire was used to obtain data. Descriptive statistics of frequency and percentage distribution and inferential statistics of one way anova was used to summarize the data. Alpha level was 0.05.

Results: The study demonstrated a significant reduction in upper limb spasticity following Functional Electrical Stimulation, with participants in the experimental group showing better spasticity reduction and improves activities of daily living than those receiving conventional therapy alone. Thus, confirming the clinical effectiveness of FES in modulating abnormal muscle tone among post-stroke survivors.

Conclusion: The integration of FES into physiotherapy practice enhanced ADL and upper limb spasticity. Hence, is a reliable tool in post stroke rehabilitation, fostering neuro plasticity recovery and improved quality of life.

Key words: Functional electrical stimulation, spasticity, stroke.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Stroke is an injury to the brain with rapidly developing signs of focal or global disturbance to cerebral function, lasting 24 hours or longer leading to death with no apparent cause other than vascular origin and includes cerebral infarction, intercerebral hemorrhage, and subarachnoid hemorrhage (WHO, 1970). Furthermore, it was proposed recently by the American Stroke association that stroke encompasses any evidence of persistent brain damage, spinal cord or retinal cell loss due to vascular cause based on pathological or imaging evidence with or without the presence of clinical symptoms (Sacco et al., 2013). As the third leading cause of mortality and long-term disability, Stroke poses a great challenge globally affecting millions annually, with a disproportionate burden in low- and middle-income countries (LMICs) like Nigeria (Owolabi et al., 2021). According to the Global Burden of Disease Study, stroke accounted for 6.5 million deaths and 143 million disability-adjusted life years (DALYs) in 2020, with LMICs bearing over 80% of this burden (Feigin et al., 2022). The condition predominantly affects working-age adults, exacerbating socioeconomic challenges. Ischemic stroke, caused by arterial occlusion, constitutes the higher number of stroke affectation, with approximately 85% of cases in Nigeria, while hemorrhagic stroke, linked to hypertension, accounts for the remainder (Akinyemi et al., 2021).

Spasticity is a condition characterized by an abnormal increase in muscle tone or stiffness, resulting from damage to the brain or spinal cord, which can impede movement and coordination. Spasticity is one of the most frequent and disabling clinical manifestations of patients with stroke (Laura et al 2021). This condition affects approximately 30–50% of stroke survivors within the first six months, with spastic hemiplegia—unilateral muscle weakness and increased tone—being particularly common (Thibaut et al., 2013). Spasticity manifests as muscle stiffness, involuntary contractions, and restricted joint mobility, significantly limiting activities of daily living (ADLs) such as dressing, walking, and self-care. This further elaborates the presentation to be an upper motor neuron dysfunction visibly seen in stroke, spinal cord injury, multiple sclerosis, cerebral palsy and traumatic brain injury. While spasticity can aid function in cases such as weight bearing in weak limbs; its severe form can cause pain, contractures and reduce QOL. Stroke survivors will most definitely be affected by "Plegia' depending on the severity of affectation and region of affectation of the brain. These plegia's may be monoplegia, hemiplegia, paraplegia or quadriplegia; with hemiplegia being the most dominant feature of stroke. In the context of hemiplegia, spasticity predominantly affects the upper and lower limbs, leading to flexed postures, pain, and an elevated risk of contractures (Stephen et al., 2022).

Hemiplegia is a neurological condition characterized by paralysis or significant weakness of one side of the body, typically affecting the arm, leg and sometimes the face on same side. It results from damage to the CNS, also seen in cerebral palsy and other neurological disorders. The affected side is contra lateral to the brain lesion.The management of stroke and its associated complications has undergone a profound transformation over the past few decades, evolving from predominantly pharmacological and passive interventions to a more comprehensive, multidisciplinary approach grounded in evidence-based rehabilitation strategies. Historically, rehabilitation practices such as the Bobath approach, which emphasized the normalization of muscle tone through specific handling techniques, were widely utilized. However, Bobath therapy did not clearly reduce lower limb activities more than combined interventions; therefore it is not superior to other interventions with exception to PNF (Scrivener et al., 2020). Contemporary rehabilitation protocols have shifted focus towards active, task-specific training modalities that are designed to enhance neuroplasticity—the brain's ability to reorganize itself by forming new neural connections. This shift is exemplified by the implementation of Constraint-Induced Movement Therapy (CIMT), which has been shown to significantly improve upper limb function in individuals with hemiplegia following a stroke. Meta-analyses indicate standardized effect sizes for CIMT ranging from 0.4 to 0.8, underscoring its effectiveness in promoting functional recovery (Kwakkel et al., 2021). Furthermore, treadmill-based gait training, often augmented with body-weight support, has demonstrated efficacy in improving walking speed and endurance among chronic stroke survivors, thereby enhancing their overall mobility and quality of life (Mehrholz et al., 2020). In the context of spasticity management, Neuromuscular Electrical Stimulation (NMES) and Transcutaneous Electrical Nerve Stimulation (TENS) have emerged as prominent therapeutic modalities. NMES, in particular, has been shown to yield moderate effects on muscle tone reduction when applied consistently for a minimum of 30 minutes daily (Thibaut et al., 2020).

FES represents an advanced rehabilitation technique that delivers controlled electrical impulses to stimulate paralyzed or weakened muscles, thereby facilitating movement and reducing spasticity. It is also designed to produce functional movements such as grasping a key, standing, holding a toothbrush and walking (Marquez-Chin et al., 2020). Recent studies has revealed that FES systems have emerged as promising upper limb rehabilitation tools, offering innovation neuromuscular reeducation approaches (Muhammad et al., 2023). Additionally, FES has been shown to promote neuroplasticity by facilitating cortical reorganization and increasing motor function, thereby serving as a valuable tool for post-stroke squeal (Aline et al., 2023).

1.2 Statement of the problem

Stroke remains a leading cause of long term disability globally, with its burden rising significantly in low and middle income countries like Nigeria (Fang et al., 2023). Spastic hemiplegia is a common consequence of stroke, particularly debilitating, leading to increased muscle tone, impaired motor function, poor balance and reduced independence in daily living activities (Purohit et al., 2024). In Nigeria, access to structured neuro-rehabilitation service is often inadequate, particularly in public hospitals where stroke survivor faces persistent functional impairment and low quality of life due to limited access to advanced therapeutic interventions (Ogunlana et al., 2019). FES has been widely studied as a rehabilitative approach to promote motor recovery, reduce spasticity and improve functional performance in post-stroke patients. Recent systematic reviews and clinical trial has shown that FES significantly enhances upper and lower limb function with improvement in manual muscles testing scores, gait performance and reactive balance in individual with hemi paresis (Khan et al., 2023).

Although numerous studies have been conducted internationally on the impact of spasticity in individuals with spastic hemiplegic stroke, there remains a paucity of research within the Nigerian context, and to the best of current knowledge, no documented studies have specifically focused on Edo State. Understanding and addressing these contextual gaps is imperative for the development of targeted and effective interventions, particularly within healthcare institutions such as UBTH, where variations in resource availability and patient demographics may influence clinical outcomes and rehabilitation strategies. This study seeks to investigate the effectiveness of FES on spastic hemiplegic limbs among stroke survivors in UBTH, with the ultimate aim of guiding more holistic and evidence based practice.

1.3 Research questions

This study therefore aims to answer the following questions;

i. What is the effect of functional electrical stimulation on upper limb spasticity among hemiplegic stroke survivors in UBTH?
ii. What is the effect of functional electrical stimulation on lower limb spasticity among spastic hemiplegic stroke survivors in UBTH?
iii. What is the effect of functional electrical stimulation on upper limb muscular strength among spastic hemiplegic stroke survivors in UBTH?
iv. What is the effect of functional electrical stimulation on activities of daily living among spastic hemiplegic stroke survivors in UBTH?

1.4 Aim of the study

This study aims to establish the effectiveness of functional electrical stimulation on spasticity among spastic hemiplegic stroke survivors in UBTH.

1.5 Specific Objectives

The specific objectives of the study are:

i. To determine the effect of functional electrical stimulation on upper limbs spasticity among spastic hemiplegic stroke survivors in UBTH?

ii. To determine the effect of functional electrical stimulation on lower limbs spasticity in spastic hemiplegic stroke survivors in UBTH?

iii. To determine the effect of functional electrical stimulation on upper limb muscular strength in UBTH?

iv. To determine the effect of functional electrical stimulation on activities of daily living in spastic hemiplegic stroke survivors in UBTH?

1.6 Hypothesis

1.6.1 Main Hypothesis

There is no significant effect of FES on spasticity among spastic hemiplegic stroke survivors in UBTH.

1.6.2 Sub Hypothesis

i. There is no significant effect of FES on upper limbs spasticity among spastic hemiplegic stroke survivors in UBTH.

ii. There is no significant effect on FES on lower limbs spasticity among spastic hemiplegic stroke survivors in UBTH.

iii. There is no significant effect of FES on upper limb muscular strength among spastic hemiplegic stroke survivors in UBTH.

iv. There is no significant effect of FES on ADL performance among spastic hemiplegic stroke survivors in UBTH.

1.7 Significance of the study

This study will provide important evidence on FES can help reduce spasticity, improve motor recovery, and increase independence in daily activities for people with post-stroke hemiplegia. It will help stroke survivors by identifying treatments that could improve their movement and daily functioning. It will assist researchers by adding to the current knowledge about FES and its effects, guiding future studies in this area. Policymakers and health institutions will also benefit, as the findings can inform decisions about rehabilitation programs and the allocation of resources for stroke care, ensuring that effective and affordable treatments are made available.

Furthermore, because there is limited research on neuro rehabilitation technologies in Nigeria, this study will help fill that gap. It will encourage more local research and development of rehabilitation methods that are practical and suitable for the Nigerian healthcare setting, ultimately improving the quality of care for stroke survivors in the country.

1.8 Scope of study and delimitation

This study is delimited to Spastic hemiplegic stroke survivors receiving physiotherapy care at the outpatient clinic in UBTH. The research will focus on assessing the impact of FES on the motor and functional outcomes of spastic hemiplegic stroke survivors in UBTH**.**

1.9 Limitations of the study

i. The duration for this study was a period of 8 weeks, and excellent rate of improvement in spasticity may not have occurred within this short period of time.

1.10 Definition of terms

Stroke: Stroke is a clinical syndrome characterized by the sudden onset of neurological deficits resulting from a disturbance in cerebral blood flow due to either an obstruction or a rupture of a blood vessel.

Spasticity: A motor disorder characterized by a velocity-dependent increase in muscles tone resulting from hyper excitability of the stretch reflex, commonly observed in patients with upper motor neuron lesion such as stroke.

Spastic Hemiplegia: A motor disorder characterized by increased muscle tone and weakness affecting one side of the body, typically resulting from a stroke or other central nervous system injury.

Functional Electrical Stimulation (FES): A rehabilitative techniques involving the application of electrical currents to evoke muscle contractions in individuals with neurological impairments, aiming to restore or improve motor function.

Muscular strength: Defined as the maximum force a muscle or group of muscles can produce in a single effort, muscular strength is essential for daily activities, posture, and joint stability, relying on both muscle size and neural control.

Stroke survivors: Stroke survivors are individuals who have suffered a stroke resulting in lasting neurological impairments and who may require ongoing care and rehabilitation to regain function and independence.

1.11 Abbreviations

ADL: Activity of Daily living

FES: Functional Electrical Stimulation

LMICs: Low and middle income countries

NMES: Neuromuscular electrical Stimulation

TENS: Transcutaneous Electrical Nerve Stimulation

UBTH: University of Benin Teaching Hospital

WHO: World Health Organization

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical Framework

This study is grounded in the neuroplasticity theory, which provides a foundational understanding of the brain's capacity to adapt and reorganize in response to injury such as stroke. Stroke remains one of the leading causes of adult disability globally, primarily due to its impact on the central nervous system and the disruption of voluntary motor control. A major consequence of stroke is spastic hemiplegia, where one side of the body experiences increased muscle tone and exaggerated reflexes resulting from the loss of supraspinal inhibition over spinal reflexes. This condition is tightly linked to damage within the corticospinal tract, affecting the transmission of motor commands from the brain to the periphery. However, the human brain possesses a remarkable capacity known as neuroplasticity. Neuroplasticity involves the formation of new neural connections and the strengthening of existing pathways, which are critical for recovery of motor function following brain injury (Reddy, 2025).

Neuroplasticity, the brain's intrinsic ability to reorganize and adapt after injury, is central to functional recovery following stroke. When a stroke occurs, particularly in the motor cortex or corticospinal tract, neural circuits responsible for voluntary movement are damaged. This disruption often leads to hemiplegia and spasticity, particularly on the side of the body contra lateral to the lesion. However, the nervous system compensates for such losses through neuroplastic mechanisms, including the remodeling of dendrites and dendritic spines, axonal sprouting, myelin regeneration, synapse shaping and neurogenesis. These processes allow surviving regions of the brain to take over lost functions and facilitate partial or complete recovery whilst microglia-targeted rehabilitative intervention that influences spasticity is incorporated (Qiao et al., 2023). Rewiring of the brain following stroke is highly dependent on structured activity i.e.; exercise especially in ischemic stroke. It is considered an effective and feasible rehabilitation strategy for improving cognitive and motor recovery through the facilitation of neuroplasticity. This adaptive rewiring is influenced by therapeutic stimuli, task repetition, and experience, all of which guide recovery (Xing et al., 2020). This further underscores the impact of physiotherapy intervention using a mix of component from different approaches, with health education inclusive which is more effective in attaining functional independence following stroke (Adebisi et al.,2024). Without sufficient engagement, there is a risk of maladaptive plasticity, where compensatory movements or learned non-use dominate, further impairing function.

FES has emerged as a highly effective neuro rehabilitative technique that complements neuroplasticity. It involves the application of low-level electrical currents to stimulate peripheral nerves, generating muscle contractions that mimic voluntary movement. FES delivers low-frequency electrical impulses to peripheral nerves, inducing muscle contractions that simulate voluntary movement. When these stimulations are combined with the patient’s active intention to move, they produce synchronized activation of afferent sensory and efferent motor pathways, creating ideal conditions for Hebbian plasticity—the principle that “neurons that fire together wire together” (Rong et al., 2022). This synchronization strengthens sensorimotor pathways, improves voluntary control, and helps normalize cortical excitability. Use of FES to enhance neuroplasticity leads to improved functional motor outcomes. FES also normalizes muscle tone and reduces spastic hyperactivity, thus facilitating improved voluntary movement in individuals with spastic hemiplegia. A randomized controlled trial study showed that FES improved upper limb motor scores and decreased spasticity, and functional outcomes in hemiplegic wrist flexor spasticity (Guldal et al.,2017). These findings support the notion that FES promotes adaptive neuroplastic changes, which are critical for functional restoration. Importantly, the timing of intervention plays a critical role, early post-stroke period particularly within the first three to six months is recognized as a critical window of heightened neural plastic potential, during which the brain demonstrates increased responsiveness to external stimuli and rehabilitative input. This phase allows for maximal reorganization of cortical and sub cortical structures in response to damage, making early, targeted interventions highly effective (Yi et al., 2022). Study showed that intervention duration ranged from 3-5 times per week indicating the intensity typically required to see functional gains and improved balance (Hanbit et al., 2020).

Thus, neuroplasticity provides the biological foundation for stroke recovery, while interventions like FES act as practical tools to channel and augment this intrinsic capability. By harnessing experience-dependent plasticity, reducing maladaptive reflex patterns, and encouraging the re-establishment of functional corticomotor connections, the integration of FES into post-stroke rehabilitation offers a robust and scientifically grounded pathway toward improved motor outcomes and reduced spasticity. The International Classification of Functioning, Disability and Health (ICF) framework (WHO, 2020) complements neuroplasticity theory by framing stroke rehabilitation outcomes across multiple domains: body functions and structures (e.g., muscle spasticity), activity limitations (e.g., motor control), and participation restrictions (e.g., activities of daily living). This comprehensive approach enables a holistic evaluation of FES's therapeutic effects beyond clinical impairment, emphasizing functional independence and societal reintegration, which aligns closely with the aims of this study.

2.2 Overview of Stroke

Stroke remains the second leading cause of death and disability worldwide, with a growing burden in LMICs due to rising non-communicable disease prevalence and limited healthcare infrastructure (Feigin et al., 2022). In, Africa stroke is a major public health concern, with data published within the past decade shows that stroke has an annual incidence rate of up to 316 per 1000,00, a prevalence of up to 1,460 per 100,000 and a 3-year fatality rate greater than 80% (Akinyemi et al., 2021). Hypertension is preeminent among the vascular risk of stroke occurrence, with up to 70% of stroke in Africa, 35% due to undiagnosed hypertension and 36% due to treated but uncontrolled hypertension (Owolabi et al., 2024). The complications of stroke encompasses pain, paralysis, language or swallowing difficulties, and sensory deficits that profoundly affect patients daily experience (Wenqiang et al., 2023). These impairments lead to long-term disability, reduced work force participation, and significant economic costs, especially where rehabilitation services are often inadequate. Stroke rehabilitation has undergone significant advancements, moving from passive, therapist-driven techniques to active, patient-centered interventions. Modern protocols of stroke rehabilitation often emphasize neuroplasticity-driven interventions in the treatment of hemi paresis, including CIMT, which encourages use of the affected limb by constraining the unaffected one, yielding improvements in activities of daily living and social participation (Joyce et al., 2022). Robotic-assisted therapy and virtual reality-based training have shown promise in high-income settings, due to its support for neuroplasticity through repetitive, controlled movements' .Overall, robot-assisted therapy may be a promising approach to improve motor recovery and independence in post-stroke patients**,** enhancing both quality of life and functional independence in daily living (Fatih et al., 2024).

2.3 Epidemiology

According to the most recent estimates of the global burden of disease (GBD) 2019 stroke burden, continues to be the second most common cause of death plus disability, accounting for approximately 5.5 million deaths annually, with 44 million disabilities adjusted life years lost. Projections indicate that in the absence of efficacious therapies, over 23 million individuals will have suffered their first stroke by 2030, translating into an estimated 7.8 million fatalities (Mukherjee et al 2011). 12.2million (95% UI 11.0-13.6) incident cases of stroke,101 million (93.2-111) prevalent cases,143 million(133-153) stroke related DALYs, and 6.55 million(6.00-7.02) stroke related deaths were reported in 2019 (Feigin et al.,2021). Globally, 70% of strokes and 87% of both stroke related deaths and disability-adjusted life years occur in low and middle income countries. Stroke incidence in low and middle income countries have doubled in the past four decades. During these decades, stroke incidence has declined by 42% in high income countries between the early 2002s (Linxin et al., 2020). Stroke is more common in older age, above 65years. Over one-third of deaths from cardiovascular illnesses occur in people under the age of 70, and stroke accounts for more than four out of every five deaths from these conditions (WHO, 2019).

Research on epidemiology of stroke in Africa demonstrated that Sub-Saharan Africa is the continent with the highest rate of hypertension, the strongest and most prevalent modifiable risk factor for stroke (Owolabi et al., 2018). Stroke has the greatest fatality rate among cardiovascular diseases and is regarded as the second most prevalent cause of death in Africa. A research conducted by Adeloye et al., (2019), demonstrated that the pooled crude incidence of stroke in Nigeria was 26.0/100,000 person-years, with this higher among men at 34.1/100,000 compared to women at 21.2/100,000. The pooled crude prevalence of stroke survivors in Nigeria was

6.7/1000 population, with this also higher among men at 6.4/1000, compared to women at 4.4/1000. Additionally (Adeloye et al., 2019) pointed out regional differences showing that the south-south region had the highest prevalence of stroke survivors (13.4/100,000) and rural residents (10.8/100,000).

2.4 Risk Factors

2.4.1 Modifiable Risk Factors

i. Hypertension: The most common stroke risk factor is hypertension. It plays a crucial role in both hemorrhagic and ischemic stroke (Wajngarten & Silva., 2019). Hypertension is defined by the American Heart Association as systolic blood pressure readings higher than 140 mm Hg or diastolic blood pressure readings higher than 90 mm Hg. Having a family of hypertension, cigarette smoking, physical inactivity, alcohol consumption, and heart disease were determinants of stroke (Muluken et al., 2025).

ii. Diabetes: Stroke disease is common in people with diabetes. A persistently elevated glucose level is a clinical disease known as diabetes. It can go undetected in people who don’t have any symptoms, but it still increases the chance of having a stroke. People with stroke have a 1.5-2 times higher risks of stroke compared with people without diabetes, with risk increasing with diabetes duration (Ofri et al., 2023). Uncontrolled diabetes puts subjects at risk for both ischemic and hemorrhagic strokes. In both ischemic and hemorrhagic strokes, hyperglycemia during the acute ischemic stroke phase is associated with a higher risk of hemorrhagic transformation and poor functional outcome, with evidence in favor of early intervention to limit and manage severe hyperglycemia (Sacco et al., 2024).

iii. Obesity: Body mass index (BMI), which is weight in kilograms divided by height in meters squared, is used to identify obesity. A BMI of 30 kg/m or more is used to classify individuals as obese.

iv. Sedentary lifestyle: Its prevalence has dramatically increased in recent decades, making it a major global public health concern. There is a clear link between obesity and heart conditions like stroke. A sedentary lifestyle has been linked to an increase in obesity and has been linked positively to stroke, whereas physical activity has been associated negatively with stroke (Long et al., 2024).

v. Smoking: Reliability to smoking remains a significant risk factor for cardiovascular disease (CVD) and the primary preventable cause of death globally (Kondo *et al*., 2019). In patients who are already at risk, smoking has been linked to an increased risk of ischemic stroke (Sakinah & Nugroho., 2022).

vi. Alcohol intake: The association between alcohol consumption and stroke is not apparent; distinct forms of stroke are linked to moderate and heavy drinking. A mendelian randomized study performed by Larsson *et al*., (2020), showed that genetically predicted alcohol consumption was consistently associated with stroke and peripheral artery disease across the different analyses. Hemorrhagic stroke has been directly linked to alcohol use. Excessive alcohol use may increase the risk of stroke by raising blood pressure (Ohira, 2009). Cutting back on alcohol is one of the most important ways to reduce the risk of having a stroke for the first time. Reducing alcohol intake has a substantial impact on lowering the chance of stroke.

vii. Hyperlipidemia: A well-known risk factor for stroke is hyperlipidemia, which is defined by high blood levels of triglycerides and cholesterol. A systematic review performed by Sakinah & Nugroho (2022) showed that most studies confirmed that hyperlipidemia is a risk factor for stroke and correlated in patients with CVD.

viii. Physical inactivity and sedentary lifestyle: Higher levels of physical activity are associated with lower stroke risk. Several studies indicate that leisure time physical activity protects against vascular diseases and can be beneficial for stroke prevention. (Federico et al., 2024). Any impact of physical activity can reduce the conventional risk factors for stroke.

2.4.2 Non-Modifiable Risk Factors

i. Race/ethnicity: According to statistics, African Americans are far more likely than Caucasians to die from a stroke than any other racial group. Racial disparities are even eider among women than men (Molly & Charles., 2023).

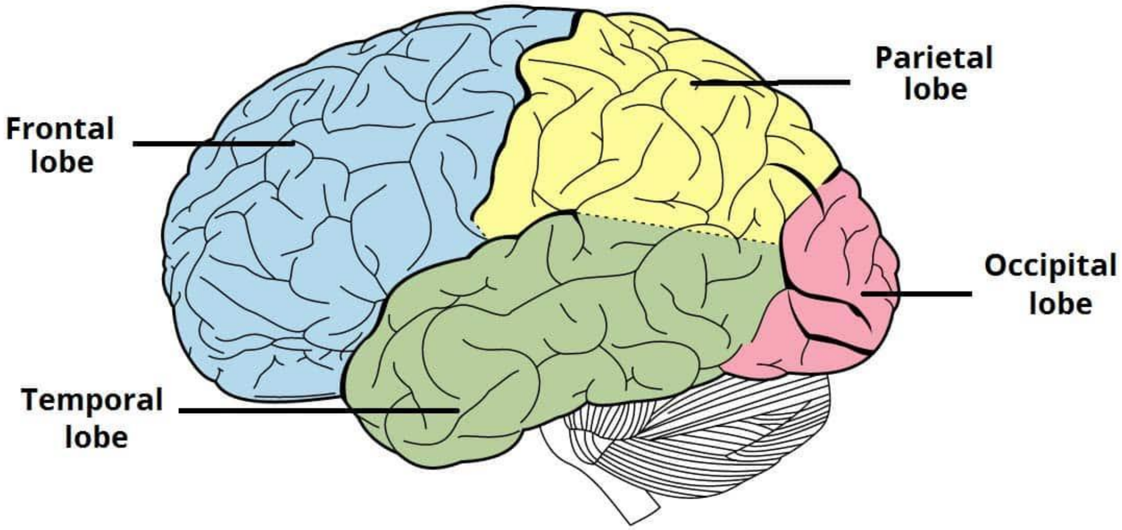
ii. Gender: Different studies have opined various thoughts on stroke affectation among men and women. A recent study by Fatemeh et al., 2023 indicated that the prevalence of stroke is high in both male and female and its rate increase with age. Recognition of age-sex variations in stroke incidence can help guide intervention efforts and reduce stroke incidence among men and women, as women have a lower hazard of stroke than men (Vyas et al., 2021).

iii. Age: The overall age-standardized stroke incidence rate among adults aged 45 years and older is projected to increase from 2020 to 2030, with an estimated annual percentage change of 1.29. Men will bear a greater burden than women (Weinv et al., 2024).

iv. Hereditary: People who have a family history of stroke are more vulnerable. This heritability estimates up to 39% for ischemic stroke and 29% for intercerebral hemorrhage (Nicola et al., 2025). Thus, genetic predisposition is a crucial determinant of stoke susceptibility.

2.5 Relevant Anatomy

2.5.1 The Brain



The lobes of the cerebral cortex

https://teachmeanatomy.info/neuroanatomy/structures/cerebrum/

The brain controls nearly all of the body's physiological and mental processes. Its complex mechanism propels humans above all other animals by controlling and integrating a myriad of physiological functions. The brain, which is shielded by the strong skull, is a sensitive organ that can be harmed by deep cuts, compression from tumors, or lack of oxygen because of a cerebral artery rupture or blockage. This complex organ is vital to the development of human potential and experiences since it not only controls physiological processes but also permits the development of higher cognitive capacities.

2.5.2 Parts of the Brain

The human brain, the most complex organ in the body, orchestrates a vast array of physiological and cognitive functions essential to human survival and behavior. Structurally and functionally, it is conventionally divided into three major parts: the cerebrum, cerebellum, and brainstem. Each plays an indispensable role in sensory processing, motor coordination, autonomic regulation, and lifelong learning process (Kandel 2023).

The brain is divided into three basic parts, which include the cerebrum, cerebellum and brainstem.

i. Cerebrum: The cerebrum is the largest and most evolutionarily advanced section of the brain, comprising approximately 85% of total brain mass. It is anatomically split into two hemispheres connected by the corpus callosum, a dense bundle of nerve fibers that enables communication between the two sides (Maldonado & Alsayouri, 2023). Each hemisphere is further divided into four lobes: frontal, parietal, temporal, and occipital, each with specialized functions. The frontal lobe governs voluntary motor activity, complex problem-solving, planning, and social behavior, while the parietal lobe integrates sensory information from the body to construct spatial awareness and somatosensory perception (Muhammad & Adonis, 2024). The temporal lobe is pivotal for auditory processing, memory consolidation, and language comprehension, and the occipital lobe is primarily responsible for visual processing (Kandel et al., 2021). Beneath the cortical gray matter lies the white matter composed of myelinated axons, facilitating rapid inter- and intra-hemispheric communication essential for integrative brain functions. Deep within the cerebrum lie sub cortical structures such as the basal ganglia and limbic system, which modulate motor control, reward processing, emotion, and memory formation. The cerebrum thus represents a critical hub for both the execution and modulation of complex behaviors and conscious thought.

ii. Cerebellum: The cerebellum is often described as the “little brain” due to its distinctive shape and extensive neuronal density, housing over 50% of all brain neurons despite its smaller volume (Manto et al., 2020). Traditionally regarded as primarily responsible for balance, posture, and fine motor coordination, the cerebellum operates by comparing intended motor commands with sensory feedback to fine-tune movements and ensure precision and smooth execution (Singh, 2021). The cerebellum has historically been linked to movement tasks; emerging evidence has expanded the cerebellum’s functional beyond motor control to include roles in cognitive processing, language, emotion, and learning (Schmahmann, 2019). The cerebellum receives input from multiple sources, including the cerebral cortex and spinal cord, and outputs signals that modulate motor and cognitive functions via the deep cerebella nuclei and thalamus, indicating its integral role in brain-wide networks (Buckner, 2019). Damage to the cerebellum can result in ataxia, impaired motor learning, and even cognitive-affective syndromes, underscoring its broad functional importance.

iii. Brainstem: The brainstem is the oldest and most primitive brain structure, forming the critical connection between the cerebrum, cerebellum, and spinal cord. It is composed of the midbrain, Pons, and medulla oblongata, each housing vital nuclei and fiber tracts that regulate essential autonomic functions such as respiration, cardiovascular control, and arousal states (Sciacca et al., 2019). The midbrain contains centers that mediate auditory and visual reflexes and is a conduit for ascending sensory and descending motor pathways. The Pons serves as a relay station linking the cerebellum with the cerebrum and contains nuclei involved in sleep regulation, respiration, and facial movements. The medulla oblongata controls vital reflexes such as heartbeat, breathing rhythm, swallowing, and vomiting, highlighting its multiple functional centers (Radostina & Anil., 2023). The brainstem also hosts nuclei of cranial nerves III to XII, which govern functions ranging from eye movement to taste and hearing. Due to its compact structure and critical functions, lesions in the brainstem often have catastrophic consequences, including coma and death (Aparna et al., 2024). These three brain regions, while anatomically distinct, are interconnected components of a highly integrated neural network. Sensory information ascends through the brainstem to the thalamus and cerebral cortex, while motor commands are processed and refined through basal ganglia and cerebella circuits before descending via brainstem tracts to spinal motor neurons .This dynamic interplay between brain regions enables humans to perform complex sensorimotor tasks, adapt behavior based on experience, and engage in sophisticated cognitive functions such as planning, reasoning, and emotional regulation (Kandel et al., 2021).

2.5.3 Arterial Blood Supply to the Brain

The human brain is an essential organ that depends on an intricate system of arteries to provide it with a steady and sufficient blood flow, which is necessary for optimal brain function. The cerebral arterial circle, also referred to as the Circle of Willis, is formed by the union of the internal carotid arteries and the vertebral arteries, two major paired arteries that supply the brain with arterial blood.

i. **Internal Carotid Arteries**: The internal carotid arteries (ICAs) are among the primary conduits of arterial blood to the brain, responsible for arterial supply to the brain into the anterior circulation (Dylan et al., 2022). The anterior cerebral artery supplies the medial surfaces of the frontal and parietal lobes, regions associated with motor planning and somatosensory integration, middle cerebral artery, being the largest branch of the ICA, supplies the lateral cerebral cortex, including areas vital for speech, motor control, and sensory processing, while posterior communicating artery serves as a critical link between the anterior and posterior circulations of the brain, enabling collateral flow in cases of arterial obstruction. Disruption to ICA blood flow, whether from atherosclerosis, stenosis, or embolic stroke, can lead to profound neurological deficits, particularly affecting cognition, speech, and voluntary motor control (Ruijun& Jing 2022). In ischemic stroke, for example, ICA occlusion is a common culprit due to its direct role in per fusing large, functionally critical brain territories.

ii. **Vertebral Arteries:** The vertebral arteries arise as major branches from the subclavian arteries bilaterally and are critical components of the brain's posterior circulation. Each vertebral artery ascends through the transverse foramina of the cervical vertebrae (typically C6 to C1), providing a protected bony canal before entering the cranial cavity through the foramen magnum at the base of the skull (Troupis et al., 2023). Inside the cranial cavity, the two vertebral arteries converge at the pontomedullary junction to form the basilar artery, a central vessel that supplies blood to several vital structures including the brainstem, cerebellum, and posterior cerebral hemisphere. The vertebrobasilar system also gives off smaller but crucial branches such as the pontine arteries, which perfuse the Pons and midbrain, and the superior cerebella arteries and anterior inferior cerebella arteries (AICA) that supply different parts of the cerebellum. These branches ensure the functionality of motor coordination, balance, and autonomic control centers. Impairment or occlusion of the vertebral or basilar arteries can result in posterior circulation strokes, manifesting with symptoms like dizziness, ataxia, visual disturbances, and even life-threatening brainstem dysfunction (Tiago et al., 2023).

2.6 Types of Stroke

Stroke is broadly categorized into two major types based on underlying pathology: ischemic and hemorrhagic strokes. Ischemic strokes is caused by an obstruction in blood vessels supplying the brain and also account for approximately 87% of all strokes according to the 2020 American Heart Association's Heart Disease and Stroke Statistics report (Virani et al., 2020). Hemorrhagic strokes, characterized by bleeding into or around the brain tissue, represent about 15% of all stroke cases. These are further subdivided into primary hemorrhagic strokes, which occur spontaneously due to vessel rupture (most commonly from hypertension or aneurysms), and secondary hemorrhagic strokes, which arise as complications after ischemic infarction or trauma (David & Stephen., 2023). Primary hemorrhages comprise the majority, while secondary hemorrhages make up an estimated 10-25% of hemorrhagic stroke cases (Kuriakose & Xiao, 2020). Clinically, hemorrhagic strokes carry a significantly higher fatality rate compared to ischemic strokes, largely due to the rapid increase in intracranial pressure and extensive brain tissue damage caused by bleeding.

2.6.1 Ischemic Stroke

Ischemic stroke is the most common type of stroke, accounting for approximately 87% of all stroke cases globally (Virani et al., 2021). It occurs when cerebral blood flow is obstructed, leading to decreased oxygen and nutrient supply to brain tissues. This lack of perfusion initially results in a temporary disruption of function, which if not promptly reversed progresses to irreversible infarction and cell death (Feske, 2021).Ischemic strokes are caused by either the local formation of a thrombus or the embolic migration of a clot from another part of the body. Both mechanisms result in occlusion of cerebral arteries and focal neurological deficits, such as hemiplegia, aphasia, or visual loss (Sacco et al., 2013).There are two subtypes of ischemic stroke:

i. **Embolic Stroke:** The term “embolic” was introduced by Rudolf Virchow in 1854 to describe clot formation originating from the heart and lodging in cerebral arteries. Evidence indicates that a substantial proportion of ischemic strokes are embolic in nature (Ntaios & Hart, 2017). Embolic strokes result from thrombi or other emboli formed in extra cranial sites most commonly the heart traveling to and obstructing intracranial vessels. Atria fibrillation, myocardial infarction, valvular heart disease, and left ventricular thrombus are common cardiac sources of emboli (Yuyi et al., 2024). When the embolus occludes a cerebral artery, it impairs blood supply and causes infarction in the downstream tissue.

ii. **Thrombotic Stroke:** Thrombotic strokes result primarily from atherosclerosis within cerebral arteries, leading to local thrombus formation and vessel occlusion. The progression of atherosclerotic plaques narrows arterial lumens, impairing cerebral perfusion. Rupture of unstable plaques triggers platelet aggregation and thrombosis, causing ischemia in downstream brain regions (Brian et al., 2021).

2.6.2 Hemorrhagic Stroke

Hemorrhagic stroke occurs when a cerebral blood vessel ruptures, causing bleeding directly into or around the brain tissue. This intracranial hemorrhage leads to increased intracranial pressure and direct damage to brain structures, often resulting in more severe neurological deficits compared to ischemic strokes (Feigin et al., 2021). Hemorrhagic strokes manifested a notable increase compared to ischemic stroke globally, and carry disproportionately high rates of mortality and morbidity (Daniela et al., 2024). There are two main subtypes of hemorrhagic stroke:

i. **Intracerebral Hemorrhage (ICH):** ICH is characterized by a sudden onset of neurological symptoms caused by bleeding within the brain parenchyma or ventricular system without preceding trauma. It accounts for about 10%-20% of all strokes and is frequently associated with chronic hypertension, cerebral micro bleed and chronic kidney disease, which induces degenerative changes in small penetrating arteries, leading to vessel rupture (Tsaong, 2025). Other most spontaneous causes include cerebral amyloidal angiopathy, anticoagulant use, and deep perforator arteriopathy (Cesar et al., 2022).

ii. **Subarachnoid Hemorrhage (SAH):** Represents both young and geriatrics population with majority of stroke cases resulting from rupture of an arterial vessel within the brain, usually non-traumatic. It also involves intracranial bleeding into the cerebrospinal filled space beneath the arachnoids membrane that covers the brain, usually traumatic (Henry et al.,2023). Patients typically present with a sudden, severe headache, nausea, vomiting, neck stiffness, and altered consciousness in emergency phone calls (Asger et al., 2021). SAH carries a high risk of complications such as cerebral vasospasm and hydrocephalus, contributing to significant morbidity and mortality.

2.7 Radiological Investigations

Prompt and accurate diagnosis of stroke is critical in determining appropriate management, minimizing neurological damage, and improving outcomes. Radiological imaging plays a pivotal role in distinguishing between ischemic and hemorrhagic stroke, guiding therapeutic decisions. Computed Tomography (CT) remains the first-line imaging modality in the acute assessment of stroke. A non-contrast CT scan is widely used due to its rapid acquisition, broad availability, and high sensitivity in detecting intracranial hemorrhage. It is particularly effective in identifying intracerebral bleeding, subarachnoid hemorrhage, and mass effect, helping clinicians immediately rule out hemorrhagic stroke (Muir, 2020). However, in the early hours of ischemic stroke, CT may appear normal or show subtle signs like loss of gray-white matter differentiation.

Magnetic Resonance Imaging (MRI), particularly Diffusion-Weighted Imaging (DWI), is more sensitive than CT in detecting acute ischemic lesions, often identifying infarcts within minutes of symptom onset. MRI is especially valuable in posterior circulation strokes and in cases where CT results are inconclusive. Additionally, sequences such as Fluid-Attenuated Inversion Recovery (FLAIR) and Susceptibility-Weighted Imaging (SWI) assist in differentiating stroke subtypes and identifying micro bleeds or underlying vascular abnormalities (Haacke & Jurgen., 2014).

Advanced vascular imaging techniques, including CT Angiography (CTA) and Magnetic Resonance Angiography (MRA), allow for detailed visualization of cerebral arteries, identifying vascular occlusions, stenosis, and aneurysms. These tools are vital for evaluating candidates for mechanical thrombectomy and assessing the risk of rebleeding in hemorrhagic strokes (Fiebach et al., 2018). Emerging modalities such as CT Perfusion (CTP) and MR Perfusion imaging information about cerebral blood flow and perfusion deficits provide functional benefits.

2.8 Spasticity

Spasticity is defined as a “motor disorder characterized by a velocity dependent increase in tonic stretch reflex(muscle tone) with exaggerated tendon jerks, resulting from hyper excitability of the stretch reflex, as one component of the upper motor neuron syndrome” (Lance et al., 1980). This definition has been recently confirmed and updated by a European consensus, stating that “spasticity refers to velocity dependent stretch hyper reflexia as part of hyper-resistance (Noort et al., 2017). The velocity-dependent nature of spasticity distinguishes it from rigidity; as the speed of passive movement increases, so does the resistance to stretch (Burridge et al., 2018). It manifests clinically as increased resistance to passive stretch, involuntary muscle contractions, and exaggerated tendon reflexes. This hypertonia commonly affects flexors in the upper limb and extensors in the lower limb, producing abnormal posturing and impairing voluntary movement. It is a hallmark feature of upper motor neuron (UMN) syndrome and frequently arises following cerebrovascular accidents such as stroke. The manifestation of spasticity is often delayed, affecting approximately 25% of individuals within two weeks of a stroke and increases to 44% in patients who have had a second stroke (Emanuel et al., 2024). It can significantly impact voluntary motor control, leading to stiffness, involuntary muscle spasms, and functional disability. The condition typically arises from lesions involving the corticospinal tract or other descending supraspinal tracts, reduction in inhibitory activity within spinal cord circuits, and adaptive changes within motor neurons (Jonathan et al.,2023). The severity and distribution of spasticity vary depending on the lesion site, stroke type, and degree of neuronal damage. Additionally, lesions in the following regions can contribute to the development of spasticity; superior corona radiata, posterior limb of the internal capsule, posterior corona radiata, thalamus and insula were associated with the development of upper limb spasticity. Additionally, lesions of the superior corona radiate, posterior limb of the internal capsule, caudate nucleus, posterior corona radiate and external capsules are responsible for lower limbs spasticity (Lim et al., 2019).

2.8.1 Spastic Hemiplegia

Spastic hemiplegia describes unilateral paralysis accompanied by spasticity, typically affecting arm and leg on the same side. It is predominantly caused by lesions to the corticospinal tract (CST) or cortical motor areas, leading to weakness combined with increased muscle tone and reflexes (Urban et al., 2021). It is most commonly observed in patients who have suffered a stroke. The motor deficits typically affect the upper and lower limbs on the contra lateral side of the cerebral lesion. Common clinical signs include a flexed arm, clenched fist, and extended leg posture, often leading to a circumductive gait (Takashi 2023). In post-stroke populations, spasticity can develop within days to months. Epidemiological studies indicate that approximately 40% of stroke survivors develop spasticity, plantar flexor muscles are often affected, with severe functional impairment (Marco et al., 2024). Damage to the upper motor neurons, especially within the motor cortex, internal capsule, corona radiata, or corticospinal tract, is central to the development of spastic hemiplegia. The corticospinal tract, in particular, plays a pivotal role as it conveys descending motor commands from the primary motor cortex to the anterior horn cells of the spinal cord, thereby controlling fine voluntary movements, especially of the distal limbs (Adriana et al., 2023). Lesions in the posterior limb of the internal capsule often lead to dense contralateral hemiplegia. The high concentration of motor fibers in this region makes it highly vulnerable to ischemic or hemorrhagic stroke, even when the lesion size is small (Li et al., 2020). Neuroimaging studies have shown that cortical and sub cortical strokes involving the basal ganglia, thalamus, and periventricular white matter are frequently associated with motor impairments and spasticity (Klein et al., 2022). The basal ganglia, though traditionally associated with extra pyramidal function, have been shown to modulate motor output via complex feedback loops with the cortex, and lesions here can indirectly disrupt cortical motor control and contribute to muscle over activity (Codex, 2023). Additionally, injury to the corona radiata can disrupt motor signal transmission as it serves as a conduit between the cortex and lower brain structures. White matter integrity in this region is a significant predictor of long-term motor recovery (Wang et al., 2022). Brainstem involvement, particularly within the Pons and medulla, can result in more extensive and bilateral motor deficits if both the corticospinal and corticobulbar tracts are affected. These tracts govern voluntary control of limb and cranial musculature, respectively. A stroke in these areas may lead to locked-in syndrome, pseudo bulbar palsy, or spastic quadriplegia depending on the extent of damage (Zelik et al., 2025). Spastic hemiplegia significantly impacts ADL, mobility, and quality of life. The altered tone and weakness in the affected limbs impair functional independence, often necessitating assistive devices and caregiver support. In the upper limb, contractures and reduced dexterity limit self-care activities, while in the lower limb, extensor spasticity may interfere with gait and balance (Jinyao et al., 2025).

A particularly notable neuromotor manifestation in spastic hemiplegia is motor overshooting, a phenomenon where voluntary movements overshoot their intended target due to impaired sensorimotor integration and loss of inhibitory control from damaged corticospinal and cerebella pathways. Overshooting reflects a breakdown in proprioceptive feedback and feed forward motor control loops. This contributes to clumsy, exaggerated, and poorly graded movements, particularly during reaching tasks or directional changes. The affected individual may reach beyond a cup when attempting to grasp it or knock over objects unintentionally, increasing dependency and risk of injury.

2.8.2 Functional Electrical stimulation in Post-Stroke Spasticity Management

FES is a promising intervention that offers both therapeutic and functional benefits in the management of post-stroke spasticity. FES involves the application of electrical currents to peripheral nerves to induce muscle contractions in a controlled and purposeful manner. This stimulation not only augments voluntary motor activity but also plays a neuromodulatory role by promoting reciprocal inhibition and reducing excessive muscle tone (Quandt & Hummel, 2020). Through repetitive use and individualized approaches, FES integrates neuroplasticity in stroke recovery, highlighting instances where neuroplasticity contributes to motor and cognitive recovery. The role of individualized approaches is underscored as pivotal in maximizing the potential of neuroplasticity and ensuring meaningful, sustainable recovery aligned with each patient’s unique needs and aspirations (Wenbin et al., 2023). FES also enhances cortical excitability, promoting long-term motor recovery through neuroplasticity (Quandt et al., 2020). FES in stroke rehabilitation improves the ability to perform activities, especially where conventional training is insufficient (Howlett et al., 2015). Similarly, a systematic review by Kim et al. (2023) concluded that FES, when combined with conventional therapy, yielded superior outcomes in reducing spasticity and improving gait parameters compared to physiotherapy alone. These findings are particularly relevant for chronic stroke populations, where pharmacological management of spasticity (e.g., with Baclofen or Botulinum toxin) may not always be feasible due to cost and availability constraints in LMICs. Nigerian research on stroke rehabilitation has highlighted the challenges of managing spasticity and improving QOL. FES induces as asynchronous muscle contractions, which helps reduce fatigue and improve neuromuscular coordination (Sharif et al., 2017). Study found that stroke survivors in Ibadan experienced significant motor recovery within 6 months, but spasticity persisted in 45% of cases, limiting functional gains (Olaleye et al 2021). Community-based rehabilitation, involving home exercises and caregiver support, has shown promise in rural areas, but urban centers like Lagos and Benin City face challenges in scaling such programs (Akinyemi et al., 2021). NMES has been explored in Nigeria, with a 2020 reporting improved wrist flexor tone in 55% of participants after 4 weeks of therapy (Ekechukwu et al., 2021).

Edo State’s stroke rehabilitation landscape is characterized by limited research and resource constraints, despite UBTH’s role as a leading tertiary center. Study by reported that 60% of stroke survivors in Edo State experienced severe disability, with spasticity contributing to reduced mobility and QOL (Ojagbemi et al., 2020). Current physiotherapy practices in UBTH rely on manual therapy and task-oriented exercises, with minimal use of electrical stimulation due to equipment shortages and lack of trained personnel (Ekechukwu et al., 2020). No studies have investigated FES in Edo State, highlighting a significant research gap. This study aims to provide foundational evidence on FES's efficacy, potentially catalyzing its integration into local practice.

2.9 Empirical Review

AUTHOR/ YEAR/ COUNTRY	TITLE	SAMPLE SIZE	AIM OF STUDY	STUDY TYPE	OUTCOME MEASURE	FINDING
Ada et al.,2010, Australia	FES and muscles activation in hemiparesis	45 participant				Significant improvement in gait speed and spasticity.
El-sayed et al., 2019, Eygpt Yang et al., 2021,Australia	FES and Balance in Chronic Stroke FES combined with gait training in stroke rehabilitation	40 stroke patients 60 hemiparetic stroke survivors	To evaluate the role of FES in gait and balance To assess effect of FES assisted gait training	Quasi-experimental Randomized Control Trial	Berg Balance Scale, 6 MWT Gait speed, 10MWT, MAS	FES enhanced balance and endurance during gait.
Greene et al., 2023 USA Ekechukwu et al., 2020,	Early FES intervention in Acute stroke	38 40 stroke patients	To explore FES prevention of spasticity when started early	MAS, NIH stroke scale Quasi-Experimental	Experimental study MAS, Goniometry	Initating FES early within 2 weeks post stroke significantly reduced later spasticity and improved

Nigeria	patients with risks of developing spasticity Effect of NMES on wrist flexor tone in post-stroke patients		post stroke To evaluate NMES effects on wrist flexor tone in stroke patients	study		motor outcomes at 3months follow up 55% showed improved wrist flexor tone after 4 weeks of NMES therapy
Howlett et al., 2015, Australia	FES improves activity after stroke: A systematic Review with Meta-Analysis	485 participants	To investigate the effects of FES on improving activity after stroke To investigate whether FES is more effective than training alone	Systematic Review and Randomized Controlled Trials	Motor Assessment Scale Upper Extremity Function Test	FES led to a greater improvement in about 70% of the included trial. Positive effects were observed after 3-4 weeks of therapy

Mahmood et al., 2022, Pakistan	Effects of FES on upper limb spasticity in stroke patients	60 stroke survivors	To evaluate the effect of FES on spasticity levels in upper limbs post-stroke	Randomized Controlled Trial (RCT)	Modified Ashworth Scale (MAS)	FES led to a 1.2- point reduction in MAS Score after 8 weeks of therapy, indicating decreased spasticity
Sharif et al., 2017, Pakistan	Effectiveness of FES versus EMS in gait rehabilitation of patients with stroke	38 participants (19 in FES group, 19 in EMS group_	To compare the effectiveness of FES versus EMS in gait rehabilitation of stroke patients	Randomized Controlled Trial(RCT)	Modified Ashworth Scale, Fugl-Meyer Assessment, Berg Balance Scale	FES group showed significantly greater improvement in motor gait performance, balance and spasticity reduction compared to EMS

2.10 Summary

From the reviews stated above, many studies conducted on FES have established its effectiveness in reducing spasticity which has posed a major problem. Other conflicting reviews exists which is minimal, thereby driving the researcher into conducting this research to add to knowledge, especially in a clime as UBTH. This summary emphasizes findings from various literatures, recording stroke recovery outcomes in both acute and chronic phases of stroke. Ekechukwu et al., 2020 c0nducted a study and evaluated the effect of NMES on wrist flexor tone in post stroke patients. Using a sample of 40 stroke patients and a quasi experimental study, the work also concluded that 55% of participants showed improved wrist flexors tone after 4 weeks of NMES therapy.

Greene et al., 2023 investigated into early FES intervention in acute stroke patients and its risk of developing spasticity. A total of 38 patients was used, and findings to this study recorded that early FES (within two weeks post stroke) significantly reduced later spasticity and improved motor outcomes. Furthermore, a study conducted by Howlett et al.,2015 on the systematic review and meta analysis of FES impact on post stroke activity , using a sample size of 485 patients reveals a greater benefit after 3-4 weeks of therapy, maintained through a 3 month follow up. Another reviewed literature from Mahmood et al., 2022 critically examines th effect of FES on upper limb spasticity in stroke survivors, using 60patients. It was observed that FES caused a 1.2 point reduction in spasticity scores, indicating substantial improvement in muscle tone.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Participant

This study was conducted among spastic hemiplegic stroke patients at the Department of Physiotherapy, UBTH.

3.1.2 Selection Criteria

3.1.2.1 1nclusion Criteria

i. Participants must be 18-65years
ii. Participants must be able to provide informed consent; ensuring ethical participation.
iii. Patients with diagnosis of stroke, 3 months post onset to confirm chronicity.

3.1.2.2 Exclusion Criteria

i. Stroke survivors with severe cognitive impairment which may affect compliance.
ii. Stroke survivors who have contraindications to FES , such as pacemakers or skin lesions at stimulation sites

3.1.3 List of Instruments

i. Demographic information form

ii. FES machine

iii. Modified Ashworth Scale

iv. Functional independent measure

v. Medical Research Council Scale

3.1.4 Description of Instruments

i. Demographic Information Form: A self structured questionnaire was used to assess and garner fundamental demographic details, including age, gender, marital status, educational background, religion, and occupation. Marital status was categorized as single, married, or, divorced. Religion was categorized as Christian, Muslim, traditional or other.

ii. FES Machine: This device comes in different shapes and sizes, and is beneficial for individuals with neurological deficit like stroke, and has weakened or paralyzed muscles. It works by sending electrical impulse to specific muscles or nerves via electrodes placed on the skin, which causes contraction, mimicking the natural process of muscle movement. The main muscles that are stimulated for hemiplegic stroke survivors include; hamstrings, gluteus and calf muscles.

Validity

FES has been extensively proven to be valid, and an extensive modality in rehabilitation, particularly in patients with neuromuscular impairments. Content validity has been themed to identify its appropriateness, comprehensibility, and comprehensiveness, thus the tool is a valid resource in neurorehabilitation (Samantha et al., 2022).

Reliability

The reliability of FES is widely supported and backed up by research, especially in areas pertaining to operational consistency, user adherence, physiological response reproducibility and safety. This reliability forms a strong foundation for their integration into both clinical and community-based rehabilitation programs (Gad Alon 2018).

iii. Modified Ashworth Scale (MAS): A reliable tool for assessing spasticity, scoring resistance to passive movement .The test is performed by extending the patients limbs first from a position of maximal possible flexion to maximal possible extension ;afterwards the MAS is assessed while moving from extension to flexion.

SCORE	DESCRIPTION
0	Slight increase in tone giving a catch when the limb is moving in flexion or extension
1	Slight increase in muscle tone, indicated by a catch followed by minimal resistance throughout the range of motion (ROM).
2	More marked increase in muscle tone through most of the range of motion, but the limb easily flexed.
3	Considerable increase in tone, passive movement difficult
4	Limb rigid in flexion and extension

Validity: The modified ashworth scale remains a useful, rapid clinical adjunct, but it does not measure velocity-dependent spasticity, rather it measures composite muscle resistance. Its scores should be interpreted cautiously and, supported with more specific tools. Criterion validity varies by muscle group with upper limbs being more specific (Anand et al., 2003).

Reliability

The modified ash worth scale exhibits moderate to good reliability, particularly for upper limb muscles and when assessments are standardized, yet its consistency varies across muscle groups. In a 2011 study involving 23 post stroke patients assessing hip adductors, knee extensors, and ankle plantar flexors, intra rater reliability for hip adductors was K=0.45 (moderate),while for knee extensors, it weighed K=0.62. The intrarater reliability of the MAS for lower limb spasticity was very good, and it can be used as a measure of spasticity over time (Nastaran et al., 2011).

iv. Functional Independent Measure: This measures an individual’s ability to perform activities of daily living, assessing 18 common ADL involving 13 motor and 5 cognitive skills. Some of these ADL include Feeding, bathing, bladder control, toileting, chair transfer, grooming, and dressing, mobility on level surface, bowels and stair climbing.

SCORING

Scoring range: 1 to 7

SCORE	LEVEL OF INDEPENDENCE	DESCRIPTION
7	Complete independence	Performs task without aid.
6	Modified independence	Performs task independently but uses
		an assistive device.
5	Supervision	Requires supervision or cues
4	Minimal Assistance	Needs slight physical help
3	Moderate Assistance	Performs 50-74% of tasks
2	Maximal Assistance	Performs 25-49% of the task
1	Total Dependence	Needs more than 1 person’s help

Functional Independent Measure has 2 major subscales; motor and cognitive, with different categories embedded in both. Motor subscale include self care (6 items), Sphincter control (2 items), Transfers (3 items), Locomotion (2 items). Cognitive subscale includes communication (2 items) and social cognition (3 items). For a consistent grading of participants with this measure, we can classify their ADL into the following; 18-36 represents total dependence,37-54 represents maximal to moderate assistance, 55-90 represents minimal assistance and 91-126 represents modified to complete independence.

Validity: The functional independent measure is a validated measure for assessing basic daily functions. While its structure may vary by context, its clinical utility is strong. Construct validity is strong when compared against barthel index, when the two disability scores was compared using subjective and objective assessment the agreement between them was comparable, although neither was high. (Kidd et al., 1995)

Reliability: The functional independence measure demonstrates a good level of reliability to changes in ADL ability. It has been found that the modified functional independence measure is equally reliable in the assessment of disability (Kidd et al., 1995).

v. **Medical Research Council Scale**: This is a system for grading muscle strength and the ability of muscles to contract and move a joint against resistance. It is a numerical scale that ranges from 0 to 5.

MRS MUSCLE POWER SCALE

SCORE	**DESCRIPTION**
0	No contraction
1	Flicker or trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and resistance
5	Normal power.

Validity

The MRC scale is a clinically valid and reliable tool for manual muscle strength testing, validated by both subjective grading and objective measures, especially in neuromuscular and spinal cord conditions. However, its precision is limited by broad ordinal categories and context specific restrictions. To maximize its validity, clinicians must standardize scoring procedures (Usker et al., 2025).

Reliability

The Medical Research council scale demonstrates high reliability, especially when used with standardized protocols. Intra rater reliability is consistently strong, with intra class correlation coefficients ranging from 0.84 to 0.96. Inter rater reliability is also substantial to excellent, with weighted kappa values between 0.70 and 0.96 in neuromuscular disease and spinal cord injury populations. Reliability is highest when testing major muscle groups and among trained clinicians (Janine et al., 2000).

3.2 METHODS

3.2.1 Research Design

A pretest-posttest experimental design was used for this study. Participants were randomly assigned to either an experimental group or a control group. This experimental group was given FES in addition to the usual treatment while control group was given only conventional physiotherapy treatment. The pre-test, post-test control group experimental design used in this study was adopted because it was appropriate for comparing the difference in upper and lower extremities spasticity, muscle strength and activities of daily living of stroke survivors prior to, and following an 8-weeks intervention using FES. The design provided avenue through which difference were checked. The design is illustrated as follows:

R O_1 O_2

R O_1 X_1 O_2

Where:

R =Randomization

O_1 =Pretest

O_2 =Post test

X_1 = FES

3.3.2 Sampling Technique

This study was conducted in the Physiotherapy Department, UBTH. The participants were selected via a simple random sampling technique. This technique gave each patient equal chances of being recruited into the experimental or control group, by picking a piece of shuffled paper from a bag. A numerical list of all patients was written and each patient was assigned a unique number, and selected randomly.

3.2.3 Sample size

A sample population was drawn from the medical records of the specified number of stroke patients attending the out- patient clinic at UBTH. Sample size calculation using Taro Yamane's formula considering a confidence level of 95% and a margin error of 5% . Taro yamane's formula is:

n =N/(1+N(e) 2) (Yamane,1967)

Where; n= sample size

N= population size =44

e= level of precision or sampling error which is +5%

therefore n= 110/ (1+44(0.05) 2) =40

3.2.4 Ethical Considerations

Ethical approval for this study was obtained from the Medical advisory committee in charge of ethics, monitoring and evaluation in the University of Benin Teaching Hospital .Afterward, informed consent will be obtained from the participants, ensuring that their privacy and confidentiality is protected.

3.3 Procedure for Data Collection

The participants who met the inclusion criteria were given the informed consents to sign. They will afterward receive a detailed explanation of the study's objectives and methodology which would encourage maximum participation .The socio-demographic and health profile characteristics such as age, gender, marital status, occupation, baseline data was obtained from the participants case files, prior to the first treatment and all information was recorded.

3.3.1 Procedure for usage (FES)

The surface electrode to which the wires attach was placed on the skin with sticky pads, and they fully embered into the skin or area surrounding the targeted muscles. The functional electrical stimulation device used was a MH6000 COMBO, edition: V2.O, produced by Medihightec Medical Co., Ltd. The voltage, frequency and stimulation needed were determined by the therapist depending on the severity of affectation. Some parameters used during the procedure include; intensity (typically ranges from 120MA to 300MA), Pulse duration (200 to 350microseconds), frequency (30Hz to 50Hz for a 15mins session).

3.3.2 Procedure for Usage of Functional Independent Measure

The researcher started by assessing and recording activities the patients can perform and those they have difficulty in performing. The patient was allowed to complete functional skills with much independence as possible and less assistance from the examiner. It should be noted that assistive device can be used, and scored as independent, except in cases where they require supervision for safety.

Participants underwent an 8 weeks intervention featuring:

i. Experimental group: Consent was obtained from each participants and screening done for contraindications to FES. Vitals, muscle strength, spasticity grade was measured and recorded before and after the treatment. FES was applied to the wrist extensors and elbow flexors combined with conventional physiotherapy. Muscles targeted for upper limbs are; Triceps brachia, extensor carpi radialis, extensor digitorium, posterior deltoid, latissimus dorsi. Lower limb muscles include gluteus maximus tibialis anterior, hamstrings. The conventional physiotherapy treatment includes: Joint mobilization to the affected side, Soft tissue mobilization to the paretic regions, stretching and strengthening exercises, thermotherapy, reciprocal pulley exercises, gym protocol plus FES therapy which was administered by the researcher and trained research assistant. Typical parameters used in stroke rehabilitation are waveform (pulsed current), pulsed width (200-400us), frequency (30-50Hz), intensity adjusted to achieve visible muscle contraction without discomfort, on/off times (10-15sec on, and 30-60sec), Duration (30-45mins), frequency (3 times per week for a period of 8 weeks). Surface electrodes will be placed on muscle bellies and motor point for effective contraction. During stimulation, patients were instructed to attempt active movement in coordination with FES (e.g. wrist extension, foot lift) and results were recorded.

ii. Control group: Conventional physiotherapy treatment which includes stretching and strengthening exercises, range of motion (ROM) , Joint mobilization, thermotherapy, STM, Proprioceptive neuromuscular facilitation, reciprocal pulley exercises. These treatments are used on target muscles such as wrist extensors, hamstrings, biceps, calf muscles and elbow flexors. All these interventions are tailored to improved joint mobility and prevent contractures.

3.4 Data Analysis

The data obtained was analyzed using descriptive statistics of mean, frequency, and standard deviation and inferential statistics. Inferential statistics included one-way ANOVAs to compare pre-test and post-test scores within each group, and also to compare the differences between the experimental and control groups. A significance level of $p< 0.05$ was set for all statistical analysis. The frequency and constituents' ratio (%) were used to describe the categorical data. The measurement data used the Shapiro-wilk normality test. The mean + standard deviation was used to describe the data that conforms to a normal distribution. One-way ANOVA was used to analyze the effect of FES on spasticity among hemiplegic stroke survivors. Moreover, $p < 0.05$ indicated a statistical significance. Data was analyzed using Statistical Package for the Social Sciences (SPSS) version 27.

CHAPTER FOUR

RESULTS

4.1. Preamble

The main purpose of this study was to evaluate the effectiveness of FES on spasticity among spastic hemiplegic stroke survivors in UBTH. A total of 40 participants, with 20 per group were recruited from the Physiotherapy outpatients department in UBTH. Participants were randomly distributed into 2 groups of experimental and control.

4.1.1 Sociodemographic Characteristics of the Participants

The age of the participants ranged between 30 and 60 with a mean age of 47.As Shown in table 1. Male and female genders were represented among the participants, with 19 males (47.5%) and 21 females (52.5%). There was more affectation of ischemic stroke with value 29 (72.4%) than hemorrhagic stroke with value 11(27.6%) among the participants.

Table 1**: Descriptive statistics showing the demographic parameters of participants**

Variable	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
Gender				
Male	19	47.5		
Female	21	52.5		
Age			47	7.867
Types of Stroke				
Ischaemic	29	72.4		
Hemorrhagic	11	27.6		

4.1.2 Presentation of results

Hypothesis 1

There is no significant effect of FES on upper limb spasticity among stroke survivors in UBTH.

Table 2: **One way anova showing the main and interaction effects of functional electrical stimulation on spastic upper limbs of participants**.

Variables	categories	Sum of Squares	df	Mean Square	F	Sig.
Shoulder Flexion	Between Groups	9.634	3	3.211	3.937	.011
	Within Groups	61.988	76	.816		
	Total	71.622	79			
Shoulder Extension	Between Groups	14.334	3	4.778	5.901	.001
	Within Groups	61.538	76	.810		
	Total	75.872	79			
Elbow Extensor	Between Groups	4.413	3	1.471	2.921	.039
	Within Groups	38.275	76	.504		
	Total	42.688	79			
Wrist Extensors	Between Groups	4.525	3	1.508	2.380	.076
	Within Groups	48.175	76	.634		
	Total	52.700	79			

From Table 2, the ANOVA test showed that there was a statistically significant ($p<0.05$) difference in spasticity level of the participants exposed to FES. An exception lies in the wrist extensors, where spasticity did not improve for these participants. Due to this significant difference, hypothesis 1 is rejected. This however necessitated probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on upper limb spasticity of the participants. The results of the interaction are summarized in Table 3.

Table 3: Post-Hoc table showing upper limb spasticity

Dependent Variable	(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Shoulder Flexion	Pre-test experimental	post-test experimental	.7750*	.2856	.040
		pre-test control	-.1000	.2856	.985
		post-test control	.0500	.2856	.998
	post-test experimental	Pre-test experimental	-.7750*	.2856	.040
		pre-test control	-.8750*	.2856	.016
		post-test control	-.7250	.2856	.062
	pre-test control	Pre-test experimental	.1000	.2856	.985
		post-test experimental	.8750*	.2856	.016
		post-test control	.1500	.2856	.953
	post-test control	Pre-test experimental	-.0500	.2856	.998
		post-test experimental	.7250	.2856	.062
		pre-test control	-.1500	.2856	.953
Shoulder Extension	Pre-test experimental	post-test experimental	.1750	.2846	.927
		pre-test control	-.7500*	.2846	.049
		post-test control	-.7500*	.2846	.049
	post-test experimental	Pre-test experimental	-.1750	.2846	.927
		pre-test control	-.9250*	.2846	.009
		post-test control	-.9250*	.2846	.009
	pre-test control	Pre-test experimental	.7500*	.2846	.049

		post-test experimental	.9250*	.2846	.009
		post-test control	.0000	.2846	1.000
	post-test control	Pre-test experimental	.7500*	.2846	.049
		post-test experimental	.9250*	.2846	.009
		pre-test control	.0000	.2846	1.000
Elbow Extension	Pre-test experimental	post-test experimental	.5750	.2244	.059
		pre-test control	.4000	.2244	.290
		post-test control	.5750	.2244	.059
	post-test experimental	Pre-test experimental	-.5750	.2244	.059
		pre-test control	-.1750	.2244	.863
		post-test control	.0000	.2244	1.000
	pre-test control	Pre-test experimental	-.4000	.2244	.290
		post-test experimental	.1750	.2244	.863
		post-test control	.1750	.2244	.863
	post-test control	Pre-test experimental	-.5750	.2244	.059
		post-test experimental	.0000	.2244	1.000
		pre-test control	-.1750	.2244	.863
Wrist Extensors	Pre-test experimental	post-test experimental	.3750	.2518	.449
		pre-test control	.4750	.2518	.242
		post-test control	.6500	.2518	.056

	post-test experimental	Pre-test experimental	-.3750	.2518	.449
		pre-test control	.1000	.2518	.979
		post-test control	.2750	.2518	.695
	pre-test control	Pre-test experimental	-.4750	.2518	.242
		post-test experimental	-.1000	.2518	.979
		post-test control	.1750	.2518	.899
	post-test control	Pre-test experimental	-.6500	.2518	.056
		post-test experimental	-.2750	.2518	.695
		pre-test control	-.1750	.2518	.899

SFSp= Shoulder flexion spasticity, PReE= pre-test experimental, PReC= Pretest control, SESp=Shoulder extension spasticity, PostE= Post-test experimental.

Anova post-Hoc test was carried out to determine the interaction effect of the independent intervention groups on spasticity of the upper limbs of the participants. For the upper limbs, all the pair wise of mean difference was found to be statistically insignificant (p>0.05) except PreE SFSp verses post SFSp (.7750*), PostE SFSp verses preE SFSp (-7750*), postE SFSp verses preC SFSp (-8.750), preC SFSp verses postE SFSp (.8750*), preE SESp verses preC SESp (-7500*), preE SESp verses postC SESp (-7500*), postE SESp verses preC SESp (-9250), postE SESp verses postC SESp (-9250*), preC SESp verses preE SESp (.7500*), preC SESp verses postE SESp (.9250),postC SESp verses preE SESp (7500*) and postC SFSp verses postC SFSp (9250*) are shown in Table 3. This implies that the entire mean pair had variation. Therefore, FES had no effect on wrist extensors. However, FES had substantial effect on spasticity among spastic hemiplegic stroke survivors in UBTH.

Hypothesis 2

There is significant effect of FES on lower limb spasticity among spastic hemiplegic stroke survivors in UBTH.

TABLE 4: One-way ANOVA table showing Lower limb spasticity

Variables	Category	Sum of Squares	df	Mean Square	F	Sig.
Hip Extensors	Between Groups	1.138	3	.379	1.690	.176
	Within Groups	17.050	76	.224		
	Total	18.188	79			
Knee Flexors	Between Groups	5.259	3	1.753	8.673	.000
	Within Groups	15.363	76	.202		
	Total	20.622	79			
Ankle Dorsiflexors	Between Groups	.309	3	.103	.266	.849
	Within Groups	29.413	76	.387		
	Total	29.722	79			

Table 4 shows the result of anova test. A statistically insignificant (p>0.05) difference in the spastic hemiplegic lower limbs of the participants exposed to FES, with the exception of the knee flexors Due to this insignificant difference, hypothesis 2 is not rejected. This implies that FES had no substantial effect on lower limb spasticity of the participants.

Hypothesis 3

There is no significant effect of FES on upper limb muscular strength among spastic hemiplegic stroke survivors in UBTH.

TABLE 5: One way ANOVA table showing the muscle strength of participants

Variables	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.600	3	.200	.472	.703
Within Groups	32.200	76	.424		
Total	32.800	79			

From Table 5, the anova test performed shows an insignificant ($p>0.05$) difference in the muscle strength of upper limbs of the participants. Due to this insignificant difference, hypothesis 3 is not rejected. This implies that FES had no substantial effect on the upper limb muscle strength of participants recruited for this study.

Hypothesis 4

There is no significant effect of FES on ADL among spastic stroke survivors in UBTH.

TABLE 6: **One way ANOVA table showing the ADL**

Variables	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	2576.137	3	858.712	4.349	.007
Within Groups	15006.850	76	197.459		
Total	17582.987	79			

Table 6 shows the result of anova test depicting a statistically significant ($p<0.05$) difference in the activities of daily living of participants who underwent FES for their spastic hemiplegic upper and lower limbs. Due to this significant difference, hypothesis is rejected, necessitating for a probing into the post-hoc analysis to investigate the interaction effect of the independent intervention group on the effect of FES on ADL. The results of these interactions are summarized in Table 7 below.

Table 7: Post-hoc table showing ADL

(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Pre-test experimental	post-test experimental	.000	4.444	1.000
	pre-test control	-13.350*	4.444	.019
	post-test control	-8.100	4.444	.271
Post-test experimental	Pre-test experimental	.000	4.444	1.000
	pre-test control	-13.350*	4.444	.019
	post-test control	-8.100	4.444	.271
Pre-test control	Pre-test experimental	13.350*	4.444	.019
	post-test experimental	13.350*	4.444	.019
	post-test control	5.250	4.444	.640
Post-test control	Pre-test experimental	8.100	4.444	.271
	post-test experimental	8.100	4.444	.271
	pre-test control	-5.250	4.444	.640

PreE= pretest experimental, PreC=pretest control, PostE=post test experimental, PostC=post-test control.

Anova Post-Hoc test was carried out to determine the interaction effects of FES on ADL. For upper and lower limbs, all the pair wise of mean difference was found to be statistically insignificant ($p>0.05$) except preE verses preC(-13.350*), preE verses preC(-13.350*),preC verses preE(13.350*) and preC verses preE(13.350*) as shown in Table 9. This implies that the entire pair wise mean had variation.

4.2 Hypothesis Testing

Hypothesis 1: There is no significant effect of FES on upper limb spasticity.

Alpha level: 0.05

Test Statistics: One way ANOVA

Observed: $p < 0.05$

Since the observed p value was less than 0.05 Alpha level. The hypothesis was therefore REJECTED.

Hypothesis 2: There is no significant effect of FES on lower limb spasticity.

Alpha level: 0.05

Test Statistics: One way ANOVA

Observed: $p> 0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore NOT REJECTED.

Hypothesis 3: There is no significant effect of FES on upper limb muscle strength.

Alpha level: 0.05

Test Statistics: One way ANOVA

Observed p: > 0.05

Since the observed p value was greater than 0.05 Alpha level, the hypothesis was therefore NOT REJECTED.

Hypothesis 4: There is no significant effect of FES on ADL.

Alpha level: 0.05

Test Statistics: One way ANOVA

Observed p: <0.05

Since the observed p value was less than 0.05, the hypothesis was therefore REJECTED.

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This study evaluated the effectiveness of FES on spasticity among spastic hemiplegic stroke survivors in UBTH. The results of the upper limb spasticity showed a significant difference ($p < 0.05$) alongside the results of activities of daily living. But there was no significant difference from the lower limbs and muscle strength results, thus offering important insights into post-stroke rehabilitation, aligning with and extending previous empirical evidence.

The observed reduction in upper limb spasticity ($p< 0.05$) corroborates with the findings of Mahmood et al, (2022) and Shariff et al. (2017), who reported that FES significantly decreased upper limb spasticity and improved voluntary control among stroke survivors. This supports the neuroplasticity theory, which posits that electrical stimulation promotes cortical reorganization by enhancing motor unit recruitment and afferent feedback. The result affirms that FES facilitates improved neuromuscular coordination and reduced hyper tonicity, which are essential for motor recovery. Conversely, the insignificant improvement ($p >0.05$) noticed in the lower limbs and muscle strength of the stroke survivors contrasts with the findings of El-Sayed et al.,(2019) and Yang et al.(2021), who found that FES when combined with gait or balance training , improved lower limb spasticity, coordination and endurance. This discrepancy may be attributed to differences in stimulation parameters, duration of treatment and participant's chronicity. Moreover, the lower limbs being larger and more weight-bearing, may require longer treatment duration or higher intensities for observable improvements.

Similarly, the lack of significant change in upper limb muscle strength ($p< 0.05$) among participants suggests that while FES can modulate tone, it may not directly translate to increased muscle power within short intervention windows, agreeing with Howlett et al. (2015). Notably, meaningful muscle strength gain often requires task-oriented practice or longer therapy durations to consolidate neuroplastic changes into functional strength. It is worthy of note that this study found a significant improvement in ADL performance ($p < 0.05$) among participants who received FES, hence aligning with Ekechukwu et al.(2020) and Green et al. (2023). Their findings indicated that early or consistent rehabilitation using FES enhances functional independence by integrating motor gains in everyday's task. Movement control gains from upper limb spasticity translate to improved activity of daily living. Combined together, these results reinforce the relevance of FES in upper limb recovery and overall functional independence. However, the non-significant lower limb and strength findings suggests that treatment intensity, duration and early initiation post-stroke are critical for maximizing benefits which is consistent with the assertion of Green et al.,(2023) and Adebisi et al.,(2024) regarding early multidisciplinary rehabilitation.

5.2 Conclusion

This study established that FES is effective in reducing upper limb spasticity and improving upper limb spasticity and improving activities of daily living among spastic hemiplegic stroke survivors. It demonstrated clear clinical benefits in enhancing functional performance and independence. These findings confirm that FES, when integrated into conventional physiotherapy, facilitates neuroplastic recovery and promotes better functional outcomes post-stroke. Conclusively, FES remains a safe, effective, and evidence-based intervention for managing post-stroke spasticity, especially in chronic stages where muscle tone and daily activities are markedly impaired.

5.3 Recommendation

The researcher highly recommends that FES be incorporated into standard neurorehabilitation protocols for stroke survivors, particularly those with upper limb spasticity. It should also be implemented early in the management of these patients in order to harness the brains optimal window of neuroplasticity and prevent chronicity in spasticity. Furthermore, Nigeria’s stroke rehabilitation centers should be better equipped and armed with the pre-requisite knowledge for clinicians and patient’s maximum benefits. Policy makers should prioritize the procurement of FES devices and allocate funding for maintenance and accessibility, especially in public hospitals. Extended treatment duration would ideally sustain motor recovery and measureable gain, and as such should be established. Finally, an effective rehabilitation of stroke survivors is possible with a multidisciplinary practice, and is recommended that FES therapy, occupational therapy and functional task practice is harnessed in order to transfer gains to real life activities.

5.4 Implications for further study

The findings of this study highlights important directions for future inquiry; Extended longitudinal trials are required to determine the long term effects of FES on muscle strength, tone and functional mobility in both upper and lower limbs. The relative effects between FES and the interventions; TENS, NMES, and CIMT can be clarified from comparative studies. Also, conducting multi-site studies across various Nigerian tertiary hospitals will enhance generalizability and create standardized rehabilitation guidelines for stroke survivors. Future work should incorporate electromyography (EMG) and neuroimaging to objectively assess cortical reorganization from FES therapy. The psychological impact and implication on quality of life effects on FES, including self efficacy and participation in community reintegration, will broaden understanding of its holistic benefits.

REFERENCES

Adebisi, A., Yusuf, A., & Olaniyan, S. (2024). Integrating multidisciplinary approaches for stroke rehabilitation: Effectiveness of combined physiotherapy and health education. Journal of Rehabilitation Science, 19(1), 45–53.

Adeloye, D., Ezejimofor, M., Auta, A., & Rex, G.M.(2019). Estimating morbidity due to stroke in Nigeria: A systematic review and meta-analysis. Journal of the neurological sciences 402, 136-144, 2019 .https://doi.org/10.1016/j.jns.2019.05.020

Adriana L, N., Vamsi R., & Bruno B. Neuroanatomy, corticospinal cord tract. StatPearls [internet], 2023

Aline ,C. B., Ana, P. B., Andersom R.,& Marcia Rosangela B. Peripheral electrical stimulation on neuroplasticityand motor function in stroke patients: a systematic review and meta-analysis. Neurological research 45(12),1111-1126,2023

Akinyemi, R. O., et al. (2021). Stroke in Nigeria: Current status and burden. Stroke Research and Treatment, 2021, 1–12. https://doi.org/10.1155/2021/6653408

Akinyemi, R. O., Bruce O., Olaleye A. A., Fred S. S., &Foad A. Stroke in Africa: profile, progress,prospects and priorities. Nature Reviews Neurology 17(10), 634-656, 2021

Anand D., Christopher P., Michael P., & Garth R. A biomechanical investigation into the validity of the modified Ashworth scale as a measure of elbow spasticity. Clinical rehabilitation 17(3), 290-294, 2003

Aparna M Prabhu MD MRCP, Paulina Henriquez Rojas MD. Coma due to primary brainstem and diencephalic lesions. In: Roos RP, Editor-in-Chief. MedLink Neurology. San Diego: MedLink, LLC. Available at www.medlink.com. Updated: October 5, 2024.

Asger S., Sarita E., Laurits E., &Niklas B. Symptoms presented during emergency telephone calls for oatients with spontaneous subarachnoid haemorrhage. Scandinavian journal of trauma, resuscitation and emergency medicine 29, 1-10, 2021.

Benjamin, E. J., Muntner, P., Alonso, A., Bittencourt, M. S., Callaway, C. W., Carson, A. P., … Virani, S. S. (2019). Heart disease and stroke statistics—2019 update: A report from the American Heart Association. Circulation, 139(10), e56–e528. https://doi.org/10.1161/CIR.0000000000000659

Bourke, G., Knight, M. M., & McDonnell, M. N. (2020). Spasticity after stroke: Mechanisms, assessment, and treatment. Clinical Rehabilitation, 34(3), 313–319. https://doi.org/10.1177/0269215519885306

Brian M,G., Nasir F., &Shadi Y. Thrombotic Strokes. Cerebrovascular Disorders, 243-260, 2021.

Buckner L, R., Lauren M,D. The brains default network: updated anatomy , physiology and evolving insights.. Nature reviews neuroscience 20 (10), 593-608, 2019

Cesar-Alejandro G., Eduardo F., Ricardo C., & Ernesto R. Essential topics about the imaging diagnosis and treatment of hemorrhagic stroke: a comprehensive review of the 2022 AHA guidelines. Current problems in cardiology 47 (11), 101328, 2022

Chen, N. H., Tang, S. F., & Hui-Chan, C. W. Y. (2021). Spastic hemiplegia in poststroke patients: A clinical review. Journal of Physical Therapy Science, 33(5), 395–402. https://doi.org/10.1589/jpts.33.39.

Chen, R., Ovbiagele, B., & Feng, W. (2016). Diabetes and stroke: Epidemiology, pathophysiology, pharmaceuticals and outcomes. The American Journal of the Medical Sciences, 351(4), 380–386.

Codex Y.The impact of basal ganglia ischemic damage localization on clinical outcomes following endovascular recanalization for acute ischemic stroke involving lenticulostriate arteries: A comprehensive review. Yubestu codex medicine & physiology. https://codex.yubestu.com/article/3020ad011c76431993ce7f18ed416d

Daniela R., Juliana N, A., Audrey C., & Kevin N, S. Burden of ischemic and hemorrhagic stroke across the US from 1990 to 2019. JAMA neurology 81 (4), 394-404, 2024.

David J, W., & Stephen J, M. Stroke: causes and clinical features. Medicine 51 (9), 602-607, 2023.

Dylan N, W., Adrienne M, M., & Jeremy J, H. Anatomy of the intracranial arteries: the internal carotid artery. Neuroimaging Clinics 32 (30, 603-615, 2022

El-Sayed, D.A.F.,& Ramadan, B.M.(2019) Assessment of the risk factors and functional outcomes after stroke . Eygptian Journal of Neurology, Psychiatry and Neurosurgery,55(6) Article 17

Emanuel A, P., Teodora P., Bogdan-Emilian I., & Cristina G. 713 Poststroke Spasticity: PAthophysiology and Management an accurate evaluation of spasticity. Balneo and PRM Research Journal 15(2), 2024.

Fatemah R., Mojgan R., Roumina R., & Mohsen K. Prevalence of stroke in the elderly: a systematic review and meta-analysis. Interdisciplinary Neurosurgery 32,101746, 2023

Fatih T., Umut S., &Ummuhan M. The effects of Robot- Assisted therapy on Upper Extremity functions and functional independence in Geriatric individuals with Chronic stroke: A Randomized Controlled Study. Perpetual and motor skills, oo315125251347790, 2024.

Federico de S., Michele R., Matteo F., & Francesco D, S. Risk of stroke with different levels of leisure time physical activity: a systematic review and meta-analysis of prospective cohort studies. Journal of Neurology, Neurosurgery & Psychiatry 95 (6), 504-514, 2024.

Feigin, V. L., Benjamin A. S., Catherine O.W., & Gregory A.R. (2021). Global, regional and national burden of stroke and its risk factors , 1990-2019: a systematic analysis for the Global Burden of Disease Study . The Lancet Neurology 20(10) , 795-820, 2021.

Feigin, V. L., Michael B., Bo N., & Sheila M. World Stroke Organization (WHO): global stroke fact sheet 2022. International Journal of Stroke 17(1), 18-29,2022.

Feigin V, L.,& Rita V, K. Global burden of stroke. Stroke: Pathophysiology, Diagnosis, and Management, 7th ed.; Grotta, J., Albers, G., Broderick, Kasner, S., Lo, E., Sacco, R., Wong, L., Day, A., Eds, 163-178, 2021.

Feske K, S. Ischemic stroke. The American jurnal of medicine 134 (12), 1457-1464, 2021.

Fiebach J, B., Gotz T., Claus Z. S.,Florent B., &Grethe A. MRI- guide thrombolysis for stroke with unknown time of onset. New England Journal of Medicine 379 (7), 611-622, 2018.

Gadd Alon. Functional Electrical Stimulation(FES): Clinical successes and failures to date. J Nov Physiotherapy Rehabiltation **2** (3), 080-6, 2018.yv

Guldal, F, N., Burcu, K, D., &Nese, O. A randomized controlled study: Effectiveness of Functional Electrical Stimulation on Wrist and Finger Flexors Spasticity in Hemiplegia. Journal of Stroke and cerebrovascular Diseases 26(7),1467-1471,2017.

Haacke M, E & Jurgen r, r. Susceptibility weighted imaging in MRI: basic concepts and clinical applications. John wiley&sons , 2014.

Hanbit K, Howook K, Yeongwook K, & Min K. Dose-response effect of Daily rehabilitation time on Functional gain in Stroke patients. Annals of Rehabilitation Medicine 44(2), 101-108, 2020

Henry W, S., Caleb E,S., Patrick L., & Kevin Y. Pathophysiology, management, and therapeutics in subarachnoid hemorrhage and delayed cerebral ischemia: an overview. Pathophysiology 30 (3), 420-442, 2023.

Janine M., Michael J., Peter A., & Tudor L. Reliability of measurementsof muscle tone and muscke power in stroke patients. Age and ageing 29(3), 223-228, 2000.

Jinyao X., Jermy W., Elisabeth P., & Li G. Stroke-related factors associated with gait symmetry in ambulatory stroke survivors : A systematic review and meta-analysis. Gait & Posture, 2025.

Jonathan M., Valerie S., & Louise J. Treatment of spasticity. Handbook of Clinical Neurology 196, 497-521, 2023

Joyce A, A., Felipe D, S., ValquiraM,S., & Kelly R. Effects of Constraint –induced movement on activity and participation after a stroke: Systematic review and meta-analysis. Frontiers in human neuroscience 16, 987061, 2022.

Kandel Deepak (2023). Principles of Neural Science (6th ed.)

Kidd D., Stewart G., Baldry J., & Rossiter D. The functional indeoendence measure: a comparative validity and reliability study. Disability and rehabilitation 17(1), 10-14, 1995.

Kondo T., Yoshihisa N., Shiro A., 7 Toyoaki M. Effects of tobacco smoking on cardiovascular disease. Circulation Journal 83(10), 1980-1985, 2019.

Kuriakose D., & Xiao Z. Pathophysiology and treatment of stroke: present status and future perspectives. International journal of molecular sciences 21 (20), 7609, 2020.

Lance JW. Symposium synopsis. In Feldman RG, Young RR, Koella WP, editors. Spasticity: disordered motor control. Yearbook Medical, Chicago; 1980, pp. 485-494.

Larsson S,C., Stephen B., Amy M & Karl M. Alcohol consumption and cardiovascular disease: a Mendelian randomization study. Circulation: Genomic and Precision Medicine 13(3), e002814, 2020.

Laura Gomez- Cuaresma, David Lucena-Anton, Gloria Gonzalez-Medina (2021).Effectiveness of Stretching in Post-Stroke Spasticity and Range of motion.. Pers. Med. 2021, 11(11), 1074; https://doi.org/10.3390/jpm11111074

Lim S, H., Kyoung N, L., Bo Y, H., & Sung K. Which brain lesions produce spasticity ? An observational study on 45 stroke patients. PLoS One 14 (1), e0210038, 2019.

Linxin L., Catherine A.S., & Peter M.R. Trends in stroke incidence in high-income countries in the 21st Century: Population based study and systematic review. Stroke, 2020. Volume 51, Number 5. https://doi.org/10.1161/STROKEAHA.119.028484

Long B., Zongliang W., X uebingY.,&Shenqin W. Association of physical activity , sedentary behavior and stroke in older adults. Frontiers in public health 12, 1484765, 2024.

Maldonado A, K., Alysayouri K. Physiology, brain. StatPearls, 2023

Manto, M., Frank V, O., Zaira C., Maria L. Consensus paper: cerebellum and social cognition. The cerebellum 19, 833-868, 2020

Marco B., Margherita B, B., Stefano C., & Alessio B. Post- stroke spasticity: follow-up and functional implications of chronic long-term treatment with botulinum toxin. European Journal of physical and rehabilitation medicine 60 (4), 581, 2024.

Marquez-Chin, C., Popovic ,M.R. Functional electrical stimulation for restoration of motor function after spinal cord injury and stroke: a review. BioMed EngOnLine 19,34(2020).https://doi.org/10.1186/s12938-020-00773-4

McDonnell, M. N., et al. (2013). Physical activity frequency and stroke risk: A systematic review and meta-analysis. Stroke, 44(5), 1321–1329.

Mehrholz, J., Thomas, S., & Elsner, B. (2020). Treadmill training with partial body-weight support after stroke. Cochrane Database of Systematic Reviews, 10, CD002840. https://doi.org/10.1002/14651858.CD002840.pub4

Molly M ,J., Charles E. Stroke in women between 2006 and 2018: Demographic, socioeconomic, and age disparities. Women's health 19, 17455057231199061, 2023

Muhammad A., & Adonis S. Anatomy and Physiology of Brain. Australasian MEDICAL jiournal(online) 17 (9), 1-6, 2024

Muhammad A K, Hoda F, Hemant G & Iris C. A Systematic review on functional electrical stimulation based rehabilitation systems for upper limbs post stroke recovery. Frontiers in Neurology 14, 1272992, 2023

Muir K, W. Prognostic value of acute CT in stroke thrombolysis. Journal of Neurology, Neurosurgery & Psychiatry 91 (12), 1254-1254, 2020.

Mukherjee, D., & Chirag G,P., Epidemiology and the Global burden of stroke. World neurosurgery 7696), S85- S90, 2011.

Muluken D., MollaK,Y., Abebe B. J.,& Yohannes K., Determinanats of stroke among adult hypertension patients in dessie comprehensive specialized hospital and kombolcha general hospital, Amhara, Ethiopia: A case-control study. PloS one 20(4), E0319016, 2025.

Nastaran G., Noureddin N., Soofia N., & Scott H. Measurement of lower limb muscle spasticity: intrarater reliability of Modified Ashworth Scale. Journal of rehabilitation Research & Development 48(1), 2011

Nicola L.B., Lanyue Z., Murad O., &Marios K, G. Genetic Risk Scores in stroke Research and Care. Stroke. 2025. https:// doi.org/10.1161/STROKEAHA.125.050961

Noort JCVD, Bar-on L, Aertbelien E., &Harlaar J. European consensus on the concept and measurement of the pathophysiological neuromuscular responses to passive muscle strtch. Eur J Neurol. 2017. https://doi.org/10.1111/ene.13322

Nudo, R. J. (2013). Recovery after brain injury: Mechanisms and principles. Frontiers in Human Neuroscience, 7, 887.

Ntaios G., & Robert G, H. Embolic stroke. Circulation 136(25), 2403-2405, 2017

Ofri M., Alice Y. C., Alejandro A,B., Simona S.Diabetes and atroke; what are the connections? Journal of stroke 25(10, 26-28, 2023

Ohira, T., Takeshi T., MinakoT.,& Hironori I. Effects of habitual alcohol intake on ambulatory blood pressure, heart rate, and its variability among Japanese men. Hypertension 53(1), 13-19, 2009.

Owolabi M., Fred S. S., OsahonJ,A., &Onoja M,A. Stroke occurene by hypertension treatment status in Ghana and Nigeria : A case Study. Journal of the Neurological Sciences 459, 122968, 2024

Owolabi M.O., Fred S., Rufus A., &Mylugeta G. Dominaant modifiable risk factors for stroke in Ghana and Nigeria (SIREN): a case-control study. The LncetGlobal Health 6940, e436-e446, 2018.

Pandyan, A. D., Gregoric, M., Barnes, M. P., Wood, D., Van Wijck, F., Burridge, J., … Johnson, G. R. (2015). Spasticity: Clinical perceptions, neurological realities and meaningful measurement. Disability and Rehabilitation, 27(1–2), 2–6. https://doi.org/10.1080/09638280400003907

Peters, S. A. E., et al. (2013). Stroke risk in African Americans: A systematic review and meta-analysis. International Journal of Stroke, 8(7), 500–506.

Popović, M. R., Schwirtlich, L., &Popović, D. (2019). Definition and fundamentals of functional electrical stimulation for motor recovery: A review. Acta Physiologica, 226(3), e13224. https://doi.org/10.1111/apha.13224

Purohit, A., Sharma, N., & Patel, V. (2024). Efficacy of functional electrical stimulation on spastic hemiplegia in stroke survivors: A systematic review. NeuroRehabilitation, 54(1), 101–115.

Qiao, C ;Lui, Z; Qie, S. The Implication of Microglial Regulation in Neuroplasticity-Dependent Stroke Recovery. Biomolecules 2023,13,571. https//doi.org/10.3390/biom13030571

Radostina L., & Anil K, R. 2023. Neuroanatomy, Medulla Oblongata

Reddy, K. J. (2025). Neuroplasticity and Technology. In: Innovations in Neurocognitive Rehabilitation . Springer, Cham. https://doi.org/10.1007/978-3-031-88117-6_8

Rong, X., Guang, Y. Z., Jun, Z., & Yong, W (2022)Usinghebbian type stimulation to rescue arm function after stroke: study protocol for a randomized clinical trial . Frontiers in neural circuit 15, 789095, 2022

RuijunL.,& Jing S. Reseaechprogress on risk factors related to intracranial artery, carotid artery, and coronary artery stenosis. Frontiers in cardiovascular medicine 9, 970476, 2022

Sacco, R., Tanya N, T., Scott E, K., & Harry V, V. (2013). An updated definition of stroke for the 21st century: A statement for healthcare professionals from the American Stroke Association. Stroke, 44(7), 2064–2089. https://doi.org/10.1161/STR.0b013e318297b396

Samantha, C., Nathalie A., Rebecca F., & Chris T. Evaluating the validity of a functional electrical stimulation clinical decision making tool: a qualitative study. Frontiers in Neurology 13, 1001123, 2022.

Sakinah, S., & Nugroho, D.S., Relationship between smoking and ischaemic stroke: meta analysis. Journal of epidemiology and public health 791), 120-129, 2022.

Sciacca S., Lynch L., Indran D., & Robert B. Midbrain, pons and medulla:,anatomy and syndromes. Radiographics 39(4), 1110-1125, 2019.

Schmahmann, J. D. (2019). The cerebellum and cognition. Neuroscience Letters, 688, 62–75

Scrivener K, Dorsch S, McCluskey A, Schurr K, Graham PL, Cao Z, Shepherd R, Tyson SB. Bobath therapy is inferior to task-specific training and not superior to other interventions in improving lower limb activities after stroke: a systematic review. Journal of Physiotherapy. 2020 Oct; 66(4): 225–235. doi:10.1016/j.jphys.2020.09.008

Simona S., Matteo F., Raffaele O., & Federico D, S. Prevention and treatment of ischaemic and haemorrhagic stroke in people with diabetes :a focus on glucose and comorbidities. Diabetelogia 67(7), 1192-1205, 2024

Singh M., & Sunil S.Cerebellum: Silent Area of Brain. Clinical schizophrenia & Related Psychoses 15, 2021.

Stephen A., Jorge Jacinto., Lynne Turner-Stokes.(2025).Meta- Analysis of Goal Setting and Physical Treatment Categorisation for Focal Spasticity Following Stroke or Other Acquired Brain Injury. Advances in Rehabilitation Sciences and Practice. RPO 25-0007.R2,1-25

Takashi S. Step to Step Lateral Balance Control in Asymmetric Gait and A poyential Therapeutic Modality. University of Nebraska at Omaha, 2023.

Tiago V., Valter D., Laura B., &Gorete J. From dizziness and hearing loss to coma: a case of basilar artery occlusion. Cureus 15 (8), 2023

Thibaut, A., et al. (2020). Non-invasive stimulation therapies for stroke rehabilitation: A review of current evidence. Nature Reviews Neurology, 16(8), 483–495.

Thibaut, A., Simis, M., Battistella, L. R., Fregni, F., &Donati, A. (2020). Spasticity after stroke: Physiology, assessment and treatment incompatibility. Frontiers in Neurology, 10, 558.

Troupis T., Tsantili AR., SamolisA.,&Chrysikos D. Anatomical variations of human vertebral and basilar arteries: a current review of the literature. Morphologie 107 (357), 169-175, 2023

Tsong-Hai Lee. Intracerebral hemorrhage. Cerebrovascular Diseases Extra 15 91), 1-8, 2025.

Virani S, S., Alonso A., Emelia J, B., & Marcio S, B. Heart disease and stroke statistics- 2020 update: a report from the American Heart Association. Circulation 141 (9), e139-e596, 2020

Vyas V,M., Frank L,S., Peter C,A., & Amy Y,Y. Stroke incidence by sex across the lifespan. Stroke 52(2), 447-451, 2021.

Usker N., Konstantinos M., & Andrew L. Muscle strength grading. StatPearls [internet], 2025.

Wang Y., Xueling B., Chen Y., &Yifan Y. The association between the severity and distribution of white matter lesions and hemorrhagic transformation after ischaemic stroke: a systematic review and meta-analysis. Frontiers in Aging Neuroscience 14, 1053149, 2022

Wajngarten M., & Silva, G,S. Hypertension and Stroke: update on treatment. European Cardiology Review 14(2), 111, 2019.

Weinv F., Qinghua M., Qiongfeng G., & Feng W. Forcasting the world wide impact of stroke for individuals aged 45 and above. Neuroepidemiology, 1-13, 2024.

Wenbin D, Jiamin S, & Tong S, Neuroplasticity in stroke rehabilitation : Harnessing brains adaptive capacities for enhanced recovery. Journal of Innovation in Medical Research 2(11), 50-58, 2023.

Wenqiang C., Yinong H., Cheong-Meng C.,&Haiqing Z. Post –stroke complications: mechanisms, diagnosis and therapies. Frontiers in Neurology 14, 1292562, 2023.

World Health Organization. (2020). International Classification of Functioning, Disability and Health (ICF). Geneva: WHO.

Xing, Y., Bai, Y. A Review of Exercise- Induced Neuroplasticity in Ischaemic Stroke: Pathology and Mechanisms. Mol Neurobiol 57, 4218-4231 (2020). https://doi.org/10.1007/s12035-020-02021-1

Yamane, Taro. 1967. Statistics, An Introductory Analysis, 2nd Ed, New York: Harper and Row.

Yi L, Jui-Haw Y, Jiunn-Tay L &Giia-Sheun P. Early rehabilitation after acute stroke : the golden recovery period. Acta Neurol Taiwan 32, 1-8,2022

Yuji K., Kenta T., Shintaro N., & Takeshi H. Cardioembolic Stroke: past advancement, current challenges, and future directions. International Journal of Molecular Science 25 (11), 5777, 2024.

Zelik U., Wojciech F., Joanna S., & Sabina A. Locked-in Syndrome: Insights into Etiology, Diagnosis, Management, and Quality of Life. Quality in Sport 37, 57097-57097, 2025.

APPENDICES

APPENDIX 1

INFORMED CONSENT FORM

My name is **NWABUISI CHINENYE DORCAS,** a final year student of the Department of Physiotherapy, College of Basic Medical Sciences, University of Benin, Benin City, Edo State. I'm carrying out a research titled: "**EFFECTIVENESS OF FUNCTIONAL ELECTRICAL STIMULATION ON SPASITICTY AMONG SPASTIC HEMIPLEGIC STROKE SURVIVORS IN A TERTIARY INSTITUTION IN BENIN CITY"**. This research study will be conducted as part of the requirement for the award of Bachelor of Physiotherapy (B.PT). Your participant is voluntary and you are free to ask questions about the study and you are also free to withdraw at any time you desire. Your response will be strictly confidential and will be used solely for the purpose of this research. Please kindly include your signature and date if you are willing to participate.

PARTICIPANT'S SIGNATURE	**RESEARCHER'S SIGNATURE**
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