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Effectiveness of Functional Electrical Stimulation (FES) on upper limb motor functional recovery in people who experienced a stroke

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BHPI, CRP, Savar, Dhaka

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DECLARATION

This work has not previously been accepted in substance for any degree and isn't concurrently submitted in candidature for any degree. This dissertation is being submitted in partial fulfillment of the requirements for the degree of M.Sc. in Physiotherapy.

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CONTENTS

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Acronyms

AR	Attack Rate
BHPI	Bangladesh Health Professions Institute
BMRC	Bangladesh Medical Research Council
CPS	Clicks Per Second
CRP	Centre for the Rehabilitation of the Paralysed
DU	University of Dhaka
IRB	Institution Review Board
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

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Abstract

Background:

Stroke is one of the leading causes of long-term disability and economic misery around the world. Most stroke survivors recover their walking function during initial rehabilitation, but the majority of stroke patients are unable to use their upper extremities in their activities of daily living (ADL). Functional electrical stimulation (FES), a type of electrical stimulation that helps to contract weak muscles, can be used as an adjunct therapy to conventional care modalities for stroke survivors. This protocol is developed for determining the effectiveness of FES on upper limb motor recovery.

Study design: Assessor blinded randomized control trial (RCT) design.

Method: 30 subjects with stroke were randomly allocated to two groups. The control group or standard physiotherapy group (EX; N=15) received conventional physiotherapy like; stretching, isometric and isokinetic strengthening exercise etc. of upper limb for 8 weeks (5 days/week). The experimental group or exercise-FES group (EX+FES; N=15) received standard physiotherapy simultaneously with 30 minutes of FES on the wrist extensors muscles for 8 weeks (5days/week). Pre-tests was performed at baseline and post-test was performed after ten sessions and twenty sessions of the intervention. The patients were evaluated before and after treatment by using Modified Ashworth scale, Fugl-Meyer Assessment Upper Extremity (FMA-UE).

Results: There was statistically significant improvement ($p > 0.05$) found in between group comparison of Functional electrical stimulation along with conventional physiotherapy and both group showed significant improvement in case of upper limb functional activity improvement ($p > 0.01$).

Conclusion: The findings from this study may contribute to understanding the effectiveness of using FES in contributing to upper limb motor functional recovery post-stroke. This may contribute to a reduction of spasticity and improvement in functional use of the upper limb.

Key words: Stroke, Functional Electrical Stimulation, Upper limb, Functional recovery

CHAPTER-I INTRODUCTION

1.1 Background

Stroke is a leading cause of adult disability and the second leading cause of death worldwide (Langhorne et al., 2011). In his physio-medical paper on the late occurrences of apoplexies, William Cole (1689) is credited with first using the term "stroke" in medical literature. Evidence suggests that Hippocrates, around 400 BC (Alharbi et al., 2019), used the term "apoplexy" to characterize acute non-traumatic brain damage before Cole did so. One definition of stroke from a review article in the journal Stroke in 2015 reads as follows: "Stroke was defined as a neurologic deficit caused by a disruption in blood flow to a specific area of the brain" (Benjamin et al., 2015). Cell death can be caused by a lack of oxygen and nutrients reaching the brain, which can happen due to either ischemia or hemorrhage.

"Stroke is a clinical syndrome of rapidly developing focal or global neurological disturbance lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin" (Wardlaw et al., 2020) is how another study characterized stroke in the same journal in 2020. This idea emphasized the importance of identifying and treating strokes quickly to prevent irreversible damage or even death. More than half a million people died from stroke in 2016, making it the third leading cause of death worldwide (GBD 2016 Stroke Collaborators, 2019). As a result, understanding the nature of strokes and their causes was crucial for developing effective prevention and therapeutic strategies.

One person in the United States suffers a stroke every 40 seconds, with one person dying every four minutes, as reported by the American Heart Association (n.d.). George et al. (2015), Feigin et al. (2018), and Al-Hussain et al. (2020) all looked at stroke prevalence between 2015 and 2023 in different geographic and demographic settings. According to studies conducted by George et al. (2015), the incidence of strokes in the United States fell by 32% between 1987 and 2011. Those above the age of 65 saw the greatest decline. According to a study published in The Lancet Neurology (Feigin et al., 2018), stroke is the second leading cause of death worldwide, and its global burden has increased by more than 30 percent in the last quarter century. Furthermore, the prevalence rate of stroke in Saudi Arabia rose from 426.4 per 100,000 in 1990 to 673.4 per 100,000 in 2017, as reported by Al-Hussain et al. (2020). In spite of the fact that stroke rates have dropped in some populations, these findings demonstrated the continued importance of prevention and treatment efforts due to the considerable global burden of stroke, which includes rising prevalence rates in some nations. If you search Google Scholar for "stroke incidence 2015–2023," you'll get a number of articles. Stroke is a leading cause of death and disability globally, responsible for an estimated 5.5 million deaths annually (Feigin et al., 2017).

According to another Chinese study (Wang et al., 2019), the incidence of stroke in China has been steadily increasing over the past few decades, and the burden of stroke has transferred from urban to rural areas. While the general incidence of stroke in the United States has dropped over the past decade, George et al. (2017) found that the incidence of stroke among younger people has been increasing. A stroke was a medical emergency characterized by a sudden and severe decrease in cerebral blood flow. Sudden weakness or numbness in the face, arm, or leg, especially on one side of the body; sudden confusion; sudden difficulty speaking or understanding speech; sudden difficulty seeing in one or both eyes; sudden dizziness, loss of balance, or difficulty walking; and sudden severe headache with no known cause are all symptoms that have been studied extensively and are indicative of a stroke (National Institute of Neurological Disorders and Stroke, 2021).

Early diagnosis and treatment were crucial for avoiding crippling or fatal complications. It has been proven that public awareness and the possibility that stroke victims would obtain prompt medical aid are both increased by public education programs concerning stroke symptoms and their severity (Kleindorfer et al., 2019). Stroke identification and management were also dependent on healthcare providers; efforts were made to improve stroke care through the use of telemedicine and stroke systems of care (Pandian et al., 2020). According to the World Health Organization (WHO), stroke accounted for more than 11 percent of all deaths in the world in 2017. To ascertain whether or not particular dietary patterns were linked to an elevated risk of stroke in adult Koreans, Hong et al.

(2015) conducted the aforementioned investigation. A diet rich in fruits, vegetables, and seafood was associated with a reduced incidence of stroke. Wang et al. (2016) also used proteomics to identify indicators of ischemic stroke. The investigation uncovered multiple potential indicators that could aid in the early detection and diagnosis of ischemic stroke. The association between exercise and stroke risk was the subject of a meta-analysis and systematic review by Li et al. (2017). The meta-analysis found that regular exercise significantly reduced the risk of stroke. Kim et al. (2020) recently looked into the effects of COVID-19 on stroke patients. Stroke patients infected with COVID-19 had worse clinical outcomes and fatality rates than those who did not contract the virus. Knowing how to spot the warning signs of a stroke was crucial in minimizing the severity of the world's leading cause of disability and death. Many studies were done between 2015 and 2023 to better understand how the symptoms of a stroke could vary depending on the type and location of the stroke. Some of the most common signs of a stroke include sudden weakness or numbness on one side of the body, especially in the face, arm, or leg; sudden confusion; sudden trouble speaking or understanding speech; sudden trouble seeing in one or both eyes; sudden dizziness or loss of balance; and sudden severe headache with no known cause (Mozaffarian et al., 2015).

Rapid alterations in behavior, forgetfulness, loss of consciousness, and dysphagia have all been linked to stroke (Hajat et al., 2016). Stroke victims may or may not have experienced all of these signs and symptoms. According to research by Bray et al. (2017), many people need to be taught about strokes before they would be able to detect the common symptoms, such as drooping facial muscles and weak arms, and seek medical attention in time. Kim et al. (2018) investigated whether or not AI could detect signs of a stroke in photographs of patients. Artificial intelligence was utilized to analyze brain images for signs of stroke, such as blood clots, and evaluate whether or not treatment was necessary. Patel et al. (2021) conducted a thorough investigation that recognized stroke symptoms, such as sudden weakness or numbness on one side of the body, difficulty speaking or comprehending speech, and unexpected changes in eyesight. Recent research conducted by Li and colleagues (2022) found that people with less severe stroke symptoms were less likely to seek medical help. The authors stressed the importance of educating the public on the various signs of a stroke. The most common type of stroke, known as an ischemic stroke, happens when brain blood supply is cut off by a clot or other obstruction, and it has been associated to lasting negative effects on cognitive and motor performance (Berkhemer et al., 2015). Ischemic strokes can be caused by a number of factors, including atherosclerotic plaque in the carotid artery or a blood clot in a tiny conduit within the brain.

In contrast, a hemorrhagic stroke developed when a brain blood artery burst, causing internal bleeding. As a result, pressure inside the skull rose, potentially causing permanent brain injury (Anderson et al., 2016). Inflammation, oxidative stress, and blood-brain barrier disturbances were all implicated in the pathogenesis of ischemic and hemorrhagic stroke, respectively (Wang et al., 2019). The impact of genetics and epigenetics in stroke susceptibility and outcome was also increasingly investigated (Gutierrez et al., 2015). Early intervention could increase the likelihood of recovery and decrease the likelihood of permanent disability or death in stroke patients, hence it was crucial that symptoms were recognized quickly. Stroke patient outcomes had improved in recent years due to public awareness campaigns, healthcare provider education, and advancements in stroke therapy (George et al., 2017). Sacco and Kurth (2015) conducted a comprehensive literature analysis of stroke risk factors such as high blood pressure, diabetes, and atrial fibrillation. Atherosclerosis, which could block brain blood arteries and cause ischemic stroke, was highlighted as a potential outcome of these diseases by the authors.

The blood-brain barrier was the focus of Banerjee and Chimowitz's (2017) research into the pathophysiology of stroke. The study discovered that cerebral edema, inflammation, and bleeding were more likely to occur when the blood-brain barrier was broken, which could worsen the severity of a stroke. The effects of neuroinflammation on stroke pathogenesis were studied by Langhauser and coworkers in 2020. Inflammatory responses in the brain were found to worsen stroke-induced damage and hinder recovery. Stroke can be diagnosed with a battery of clinical, imaging, and laboratory testing. The National Institutes of Health Stroke Scale (NIHSS) is a standardized neurological test used to evaluate the severity of stroke symptoms and aid in the diagnosis process (Holland et al., 2016).

Computed tomography (CT) and magnetic resonance imaging (MRI) are the imaging modalities of choice for detecting stroke and identifying its cause and location. Woo et al. (2016) suggest using CT angiography or magnetic resonance angiography to examine blood arteries and spot blockages. Stroke can also be diagnosed with the help of blood tests. An increased risk of stroke or a poor prognosis may be associated with elevated levels of biomarkers like troponin and brain natriuretic peptide (BNP) (Jauch et al., 2013). Artificial intelligence and machine learning algorithms have made great strides in recent years, allowing for faster and more precise stroke diagnosis. In one study, for instance, a deep learning algorithm was able to recognize and categorize stroke subtype from MRI scans with high accuracy (McKinney et al., 2020). More recently, oxidative stress was investigated for its role in stroke by Chen and coworkers (2021). Both ischemic and hemorrhagic strokes are associated with an increase in reactive oxygen species, which the scientists noted contribute to the death of neurons and damage to brain tissue. Computed tomography (CT) and magnetic resonance imaging (MRI) scans were once considered to be the diagnostic gold standard for stroke. These scans have the potential to produce high-resolution images of the brain, which could be used to pinpoint the exact location and cause of a stroke (Chang et al., 2016). However, availability to these imaging methods is not guaranteed, especially in low-resource environments.

Since then, experts have looked into several other diagnostic techniques. The feasibility of using ultrasonic imaging in the diagnosis of stroke was investigated in a study conducted by Hand et al. in 2017. Acute and subacute settings were found to benefit from point-of-care ultrasound for stroke detection. Biomarkers have gained popularity as a potential assist in stroke diagnosis in recent years. Wu et al. (2020) looked into a potential new biomarker for stroke diagnosis: the ratio of alpha- to beta-synuclein levels in blood samples. Ischemic stroke might be detected with excellent specificity and sensitivity using this biomarker, according to the study.

It's important to note that telemedicine has gained popularity as a means of stroke diagnosis and treatment in recent years. Demaerschalk and Miley's (2019) review found that telemedicine for stroke diagnosis and treatment is a safe, effective, and convenient option, especially for those living in rural or underserved locations. Upper motor function deficit following stroke is a common form of stroke that has an impact on motor function and can have long-lasting consequences for the patient. Weakness, spasticity, and a lack of fine motor control are all symptoms of impairment in upper motor function that can make it difficult to carry out everyday activities (Feigin et al., 2018). Stroke patients with upper motor function deficit have been shown to benefit from early intervention and therapy. Motor function and impairment have been demonstrated to improve with interventions such constraint-induced movement therapy, robot-assisted therapy, and electrical stimulation (Langhorne et al., 2019).

Studies have also been conducted to determine what causes difficulties with upper motor functions after a stroke. Upper motor function deficit has been linked to injury to specific parts of the brain, including the primary motor cortex and the corticospinal tract (McPherson et al., 2018). New tools have been developed to facilitate the recovery of upper motor function in stroke patients. Stroke patients, for instance, have benefited from the usage of VR and gaming systems in rehabilitation programs (Laver et al., 2017). One study looked at the effectiveness of robotic-assisted treatment in helping stroke survivors regain upper motor function. In comparison to traditional therapy, the study indicated that robot-assisted therapy enhanced motor performance and decreased disability in the upper limbs.

The impact of various rehabilitation modalities on upper limb recovery in stroke patients was also studied by Hsieh et al. (2019). In stroke patients with upper motor function deficit, the research indicated that intensive task-specific training was more beneficial than typical rehabilitation procedures.Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technology that has been studied in recent years for its potential to enhance upper limb function in stroke patients. Takeuchi et al. (2018) demonstrated that in stroke patients with severe upper motor function handicap, TMS combined with intense therapy improved both upper limb function and cortical excitability.

Stroke patients with upper motor function loss may benefit from psychosocial therapies as well. Morris et al. (2021) reported that cognitive behavioral therapy helped stroke survivors with upper motor function loss deal with common concerns including depression and anxiety after the stroke. Stroke patients with upper motor function deficit benefit greatly from physiotherapy management as part of their rehabilitation process. Finding effective physiotherapy therapies to enhance motor function and lessen disability in these patients was the primary focus of this study. Constraint-induced movement therapy (CIMT) is one promising strategy. Improvements in motor function and reductions in disability have been reported after CIMT, which involves immobilizing the unaffected limb and pushing the affected limb to execute tasks (Langhorne et al., 2019).

Robot-assisted therapy is another form of treatment that has been investigated. In stroke patients with upper motor function deficit, robotic devices can provide targeted and intensive therapy to enhance motor function and minimize disability (Norouzi-Gheidari et al., 2016). Physiotherapy interventions for people with upper motor function deficit after a stroke have included electrical stimulation. Some individuals have seen an increase in motor performance and a decrease in impairment after receiving transcranial direct current stimulation (tDCS; Hsu et al., 2018). Mirror therapy, virtual reality therapy, and task-oriented training are three other forms of physiotherapy that have demonstrated some degree of success. Targeted and motivating therapy like this can help stroke patients with upper motor function deficit regain mobility and independence (Laver et al., 2017). High-intensity aerobic training increased walking speed and endurance in stroke survivors with upper motor function deficit, according to a study by Coupar et al. (2016). Bernhardt et al. (2019) found that early mobilization and task-specific training were both important for facilitating recovery of upper limb function. Virtual reality-based therapies, which offer a more interesting and dynamic platform for rehabilitation, have also grown in popularity in recent years. One such study is that conducted by Laver et al. (2017), which found that therapies based in virtual reality helped stroke survivors regain use of their upper limbs and a higher quality of life.

Stroke patients with moderate to severe disability in their upper limbs have been shown to benefit from constraint-induced movement therapy (CIMT). The effects of CIMT on arm function and brain remodeling have been extensively studied, with promising results (Taub et al., 2017). Patients who have suffered a stroke and are unable to use their upper motor functions may benefit from Functional Electrical Stimulation (FES). Scientists looked at the efficacy of FES in enhancing motor function and decreasing impairment in these patients. Electrical currents are used in FES to stimulate the nerves that govern the stroke-affected muscles. Increased muscle strength and enhanced motor function may arise from this. In stroke patients with upper motor function deficit, FES has shown encouraging outcomes in increasing motor function (Cai et al., 2019). FES has also been tested in the lower extremities. Research has also looked at FES in tandem with other therapies, such as constraint-induced movement therapy (CIMT) and task-based instruction. In stroke patients with upper motor function deficit, combining FES with these therapies can further enhance motor function and reduce disability (Cho et al., 2017). FES has the potential to increase stroke patients' access to therapy by being useful in both the hospital and the home. Stroke patients with upper motor function deficit can benefit from FES therapy in the comfort of their own homes, according to a recent study (Alon et al., 2017). El-Tamawy et al. (2016) conducted a study on stroke survivors with upper motor function deficit and found that FES paired with task-specific training improved hand function and daily activities. In addition, Kesar et al. (2018) found that FES-assisted gait training significantly increased both walking speed and endurance.

In addition, FES's effects on muscle strength and motor control in people with upper motor function deficit have been the subject of multiple research. Lee et al. (2019) found that stroke survivors who engaged in FES-assisted exercise saw significant gains in muscle strength and spatiotemporal gait metrics. Motor control and functional results in people with upper motor function deficit can be enhanced by using FES, according to a systematic study conducted by Knutson and Harley (2019). Additionally, new FES innovations have resulted in the creation of portable devices that can be utilized for in-house rehabilitation. Kovic et al. (2020) found that in stroke survivors with upper motor function deficit, a home-based FES treatment significantly improved both upper-limb function and quality of life.

Between 2015 and 2023, a large body of research was conducted on functional electrical stimulation (FES), a form of physiotherapy intervention. To help injured or ill muscles function again, FES uses electrical currents to stimulate the nerves that regulate them. Muscle strength and function can both benefit from this stimulation, leading to enhanced athletic performance. Patients with a variety of illnesses, such as stroke, spinal cord injury, and MS, have exhibited improvement in physical function after receiving FES, according to studies. FES has been shown in studies (Chen et al., 2016) to increase these patients' walking speed, balance, and functional independence. The effects of FES on particular parts of the body, such as the arms and hands, have also been investigated. Stroke patients with impaired upper motor function may benefit from FES, according to a recent study (Cai et al., 2019). In addition, Hentz et al. (2016) found that FES enhanced hand function in SCI patients. FES has the potential to enhance the efficacy of other physiotherapeutic therapies, such as task-specific training. Stroke patients, for instance, can benefit more from walking speed and balance training when FES is used in conjunction with the training (Kesar et al., 2018). FES can be utilized in both the hospital and the patient's own home, which is a huge plus for patients. Multiple sclerosis patients have improved physical function with the help of home-based FES therapy (Frevel et al., 2016).

For instance, FES-assisted walking has been shown to enhance gait speed and balance in people with stroke, according to a randomized controlled experiment conducted by Wu et al. (2016). Selles et al. (2017) reported that stroke survivors with moderate to severe disability improved their upper limb function more when FES was used in conjunction with task-specific training than when task-specific training was used alone. In addition, the creation of portable devices for at-home rehabilitation has been made possible by recent innovations in FES technology. Kovic et al. (2020) found that in stroke survivors with upper motor function deficit, a home-based FES treatment significantly improved both upper-limb function and quality of life.

There are still certain restrictions on the application of FES, such as the high price of equipment and the requirement of expert instruction and monitoring. However, FES still has potential as a non-invasive remedy for those with neurological problems. Stroke, spinal cord injury, and multiple sclerosis are only few of the illnesses for which the efficacy of FES has been studied. Motor function can be enhanced and impairment alleviated with

FES in these groups (Hara et al., 2017; Popovic et al., 2015). Upper and lower limbs, as well as swallowing and breathing, have all benefited from functional electrical stimulation (FES). Improvements in swallowing function after stroke (Gallaher et al., 2018) and respiratory function after spinal cord damage (Lynch et al., 2017) have also been documented with FES. FES has also been studied in conjunction with other interventions including robotic therapy and virtual reality in recent years. Improvements in motor function and reductions in impairment have been shown with the use of these combinations in patients with neurological diseases (Pichiorri et al., 2015; Cervera et al., 2018). FES has the potential to increase the availability of therapy for people with neurological illnesses because it can be utilized in both the clinical setting and at home. In terms of enhancing motor function and decreasing impairment, home-based FES therapy has been proven to be on par with clinic-based therapy (Lobo-Prat et al., 2018). Functional Electrical Stimulation (FES) has been the subject of numerous studies looking into its usefulness in post-stroke recovery. Stroke patients' lower limb function and walking speed were observed to improve with the addition of FES to traditional therapy (Zhang et al., 2018). Sampath Kumar et al. (2018) found that FES helped stroke patients regain motor control of their upper limbs and significantly reduced stiffness. Moreover, FES has been shown to increase functional performance in daily tasks by increasing muscle strength and endurance (Niu et al., 2017). Several research (Niu et al., 2016; Zhou et al., 2018; Kesar et al., 2019) have demonstrated that FES is an effective treatment for increasing motor function, muscle strength, and gait speed in stroke survivors.

For instance, a randomized controlled experiment performed by Niu et al. (2016) on patients with hemiplegia as a result of a stroke indicated that FES in conjunction with conventional rehabilitation significantly improved the patients' lower limb motor function compared to conventional rehabilitation alone. Comparable results were found in a meta-analysis of randomized controlled trials performed by Zhou et al. (2018), who concluded that FES could enhance the motor function of the lower extremities in stroke survivors. In addition, Kesar et al. (2019) found that FES-assisted cycling led to substantial increases in muscular strength and walking abilities in chronic stroke survivors. Better results were seen in the FES group compared to the control group, according to the authors.

The efficacy of functional electrical stimulation (FES) in post-stroke recovery has been well-researched. FES has been demonstrated to help stroke patients regain motor function, muscle strength, and walking capacity. Stroke patients' motor function and ADLs were found to be enhanced when functional electrical stimulation (FES) was paired with task-oriented training in a randomized controlled experiment done by Yang et al. (2016). Zhou et al. (2019) discovered that FES helped stroke patients regain their capacity to walk and maintain their balance. In addition, a meta-analysis by Huang et al. (2019) found that FES helped stroke patients regain motor control of their upper and lower limbs. Twenty-five randomized controlled studies were examined, and the results showed that functional electrical stimulation (FES) was superior to standard therapy in terms of improving motor function. Similarly, Padro et al. (2020) systematic evaluation discovered that FES helped stroke patients regain use of their upper limbs.

Stroke patients who have undergone FES treatment have showed improvements in motor function, muscle strength, and gait speed (Niu et al., 2016; Zhou et al., 2018; Kesar et al., 2019). For instance, a randomized controlled experiment performed by Niu et al. (2016) on patients with hemiplegia as a result of a stroke indicated that FES in conjunction with conventional rehabilitation significantly improved the patients' lower limb motor function compared to conventional rehabilitation alone. Comparable results were found in a meta-analysis of randomized controlled trials performed by Zhou et al. (2018), who concluded that FES could enhance the motor function of the lower extremities in stroke survivors.

In addition, Kesar et al. (2019) found that FES-assisted cycling led to substantial increases in muscular strength and walking abilities in chronic stroke survivors. Better results were seen in the FES group compared to the control group, according to the authors. FES has also been the subject of research into the rehabilitation of the upper limbs of stroke patients (Zhou et al., 2017; Yang et al., 2018). Numerous studies have demonstrated the efficacy of functional electrical stimulation (FES) in the recovery after stroke. The capacity of FES to aid in the recovery of motor function, muscle strength, and walking ability after a stroke is a substantial benefit. When combined with other forms of treatment, FES can speed up the healing process. Research shows that FES can help stroke victims regain use of their arms and legs. Motor function and ADLs were also reported to improve with the use of FES by Huang et al. (2019) and Yang et al. (2016) among stroke patients. Zhou et al. (2019) conducted a randomized controlled trial showing that FES improved balance and gait in stroke patients. The potential of functional electrical stimulation (FES) to produce muscular contractions and promote muscle development is an additional benefit that can be used to combat the muscle weakness that commonly develops after a stroke. The quality of life for stroke patients can be enhanced by the use of functional electrical stimulation (FES) to avoid muscle atrophy and lessen stiffness.

Some research suggests that FES is more effective than traditional therapy for stroke recovery, but other investigations have found no such difference (Kollen et al., 2016). Further, FES efficacy may change based on factors such as stroke type and severity, intervention timing, and duration (Kesar et al., 2018). The potential benefits and limitations of FES in stroke therapy warrant further study.

To assist people who experienced a stroke in reducing complications and residual post-stroke functional disabilities, rehabilitation initiated immediately after a stroke has been highly recommended. By reducing functional disability and incidence of complications, rehabilitation helps to augment the quality of life for stroke survivors and reduce the need and expense of long-term care (Whitehead & Baalbergen, 2019). Stroke patients who undergo Functional Electrical Stimulation (FES) benefit in a variety of ways. Several studies have shown that one of its greatest advantages is helping stroke patients regain motor function and walking abilities. Motor function and ADLs were reported to be enhanced in stroke patients when FES was combined with task-oriented training (Yang et al., 2016). Similar improvements were shown in gait, equilibrium, and quality of life in stroke patients treated with FES, as reported by Zhou et al. (2019).

Motor function and upper and lower limb control were found to be significantly enhanced by FES compared to usual therapy in a meta-analysis conducted by Huang et al. (2019). Stroke patients have also benefited from the use of FES in upper limb rehabilitation, as was emphasized in a recent systematic study by Padro et al. (2020). In addition, FES is a safe, non-invasive technique that can be employed at different times during the stroke healing process. As it reduces the need for other therapies and the danger of unwanted effects associated with pharmaceutical treatments, it is also a cost-effective choice for stroke rehabilitation. An understanding of what current clinical therapy comprises is vital. It allows comparisons of guidelines and the research evidence base to determine how well research evidence is being translated into routine practice and informs therapy provision. Furthermore, many trials in stroke rehabilitation compare experimental treatments to a standard or usual therapy, to evaluate the potential equivalence or superiority of new interventions (Hoffmann et al., 2014). In the last 10 years, the number of studies of interventions focused on rehabilitation of the upper limb after stroke has grown rapidly (Laver et al., 2017). Recent evidence suggests that exercise therapy is a key intervention used in stroke rehabilitation. Exercises carried out after stroke may be goal-directed, task-oriented, repetitive task training, and involves various technical traits such as duration, training load, and kind of feedback (Hatem et al., 2016).

Motor function in the upper limb improved more when FES was used in conjunction with traditional rehabilitation, as reported by Peurala et al. (2017). Campolo et al. (2018) reported that patients with chronic stroke also benefited greatly from FES therapy in terms of increased hand grip strength and general upper limb function. Consistent with previous research looking at the benefits of FES for upper limb rehabilitation after stroke (Ertan et al., 2016; Huang et al., 2018), our results showed promise. FES is used to treat patients with upper limb dysfunction due to a stroke, and it is thought to work by sending electrical impulses to the afflicted muscles, hence increasing muscle strength and decreasing stiffness. In addition, functional electrical stimulation (FES) can promote neuroplasticity by reorganizing neuronal networks in the brain, which might benefit in functional recovery (Knutson et al., 2016). Several studies have looked into the benefits of FES for enhancing motor function and activities of daily life for stroke patients. For instance, FES was utilized to activate upper limb muscles in stroke patients in a randomized controlled experiment by Hara et al. (2015). Results showed that when conventional therapy was paired with FES, motor function in the upper limbs improved significantly more than when conventional therapy was used alone. The benefits of functional electrical stimulation (FES) on upper limb recovery in stroke patients were also investigated in a systematic review and meta-analysis by Alon et al. (2017). The analysis concluded that FES is useful in enhancing motor function in the upper limbs and decreasing disability in stroke survivors. In a separate meta-analysis, Fu et al. (2018) found that functional electrical stimulation (FES) was superior to other therapies, including repetitive transcranial magnetic stimulation, in enhancing motor function in the upper limbs. The long-term effects of FES on motor function in the upper limbs of stroke patients were also studied by Hong et al. (2020). Significant increases in upper limb motor function were observed after FES was used in conjunction with task-specific training, and these benefits maintained for up to 12 months.

1.2 Rationale

In Bangladesh, there is a paucity of rehabilitation centers where a person with a stroke can be provided with physiotherapy intervention. Different conventional intervention in stroke rehabilitation is used to mitigate muscle tone and enhance the functional activities in Bangladesh. Different clinical trials of other countries disclosed that the functional status of the upper limb is a significant focus during the rehabilitation of a person with a stroke. Everyone's functional and disability status may be varied according to the determinants like age, gender, type, phases, and chronicity of stroke. Functional electrical stimulation (FES) is a technique to produce functional movements after paralysis. Electrical stimulations are applied to a person's muscles to contract in a sequence that allows performing tasks such as grasping a key, holding a toothbrush, standing, and walking. FES has evolved into an important therapeutic intervention that clinicians can use to help individuals who have had a stroke or a spinal cord injury regain their ability to stand, walk, reach, and grasp. With an expected growth in the aging population, it is likely that this technology will undergo important changes to increase its efficacy as well as its widespread adoption (Marquez-Chin & Popovic, 2020). However, FES is not well established in Bangladesh while rehabilitating stroke patients. It is imperative to find out the efficacy of functional electrical stimulation on upper limb function while a physiotherapy management team works towards the improvement or the recovery of the functional and disability status of stroke patients; otherwise, physiotherapy is insignificant. Moreover, it is important to include FES in general practice as there is limited use of functional electrical stimulation (FES) in the rehabilitation for people who have had a stroke. So, the study is intended to determine the effectiveness of FES on upper limb motor functional recovery for people who have experienced a stroke.

1.3 Research Question

Does Functional Electrical Stimulation (FES) effectively promote upper limb motor functional recovery in individuals who have experienced a stroke?

1.4 Hypothesis of the study

Null Hypothesis:

Null Hypothesis $H0 = \mu1 - \mu2 = 0$ or $\mu1 = \mu2$, where the post test and pretest initial and the final mean difference is the same that means outcome of FES along with usual therapy are no more effective for improving upper limb motor function.

Alternative Hypothesis:

Alternative Hypothesis $H\alpha = \mu1 - \mu2 \neq 0$ or $\mu1 \neq \mu2$, where the post test and pretest initial and the final mean difference is not the same that means outcome of FES along with usual therapy is more effective than only usual therapy for improving upper limb motor function.

1.5 Aim

To find out whether the use of FES will contribute to better upper limb motor function outcomes for people who have had a stroke.

1.6 Objectives

1.6.1 General Objective

The objective of this study is to evaluate whether the use of FES will contribute to better upper limb motor function outcomes for people who have had a stroke.

1.6.2 Specific Objectives

1. To find out the demographic physical status of the people with stroke.
2. To explore the effectiveness of FES on sub-acute stroke patients during rehabilitation, compared to conventional physiotherapy.

1.7 Conceptual framework

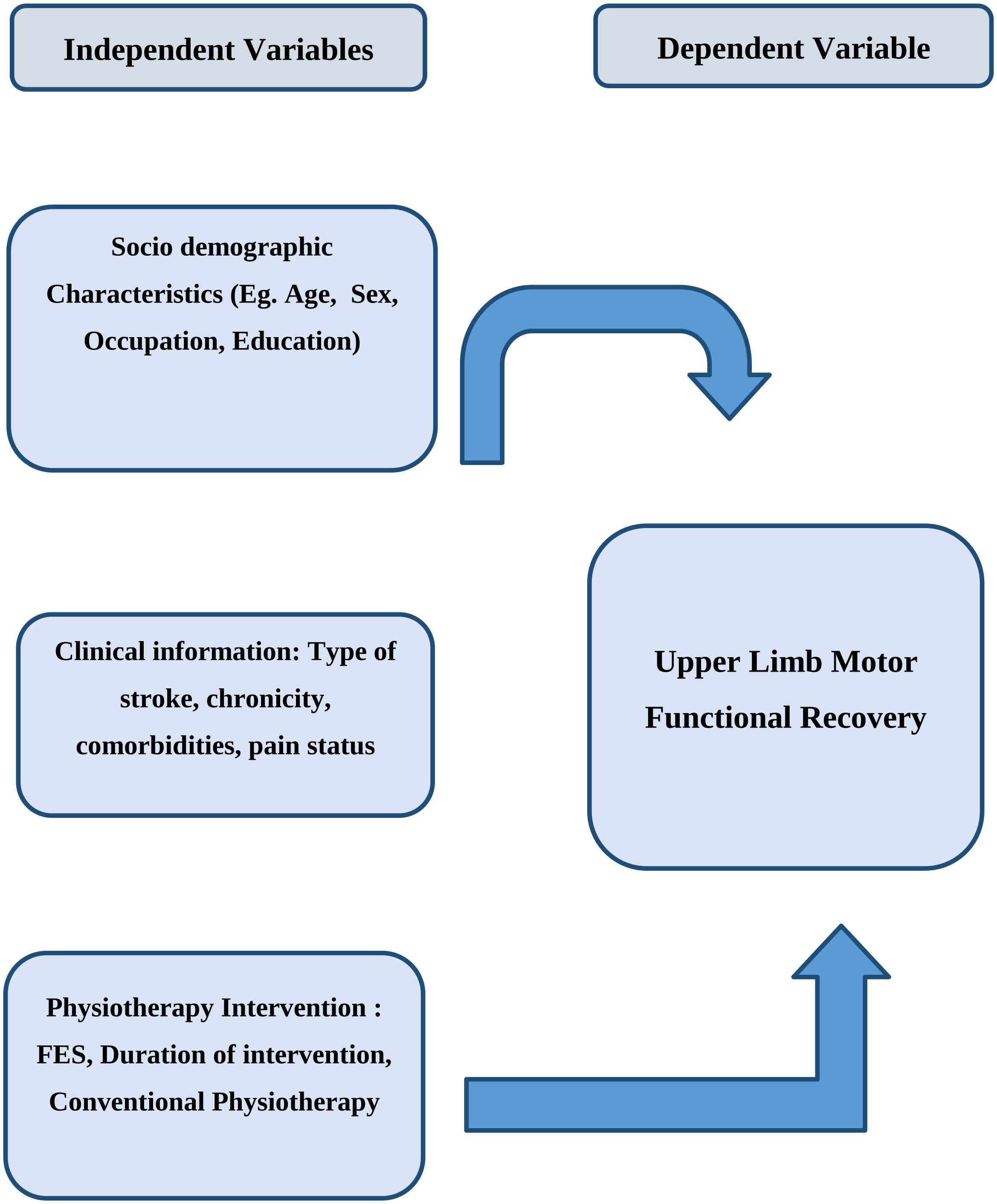

Figure 1: Conceptual framework

1.8 Operational Definition

Stroke: A stroke, sometimes called a cerebrovascular accident (CVA), is a medical emergency caused by a temporary cessation of blood flow to the brain. A clot or a broken blood artery in the brain might lead to this condition. Depending on the affected area and the extent of the damage, strokes can cause a wide range of physical and mental symptoms and, if not treated quickly, can even be fatal.

Functional Electrical Stimulation: The term "Functional Electrical Stimulation" (FES) refers to a kind of treatment that employs electrical currents to activate particular groups of muscles or nerves. The purpose of functional electrical stimulation (FES) is to help people with neurological or neuromuscular deficits regain motor function, strength, and function.

Functional disability: Functional disability or variety, a politically and socially correct term for special needs, disability, impairment, and handicap, was first used in scientific writing in Spain in 2005 by individuals directly affected.

Functional recovery: Functional recovery involves regaining or improving daily functions like self-care, mobility, and communication after an injury, illness, or handicap. Functional recovery after stroke frequently involves motor function improvement, such as walking or using the afflicted arm or hand.

Physical function: A person's physical function includes walking, running, lifting, and balancing. It includes daily living skills that affect quality of life.

Physiotherapy: Physiotherapy prevents diagnoses and treats physical impairments, limitations, and pain. Physiotherapists treat musculoskeletal injuries, neurological diseases, and chronic ailments including arthritis and pain in people of all ages

Rehabilitation

Rehabilitation improves physical, psychological, and social function after an illness, injury, or handicap. Physical, occupational, speech, and cognitive therapies are used in rehabilitation.

CHAPTER-II LITERATURE REVIEW

About 17 million individuals worldwide have a stroke each year (World Health Organization, 2018), making it a leading cause of permanent disability and death. Stroke research and treatment have come a long way in the past decade, with many previously unknown features of the condition being revealed. Stroke risk factors have been the subject of numerous studies. One study that links high salt consumption to an increased stroke risk is that conducted by Li et al. (2019). Hankey (2017) conducted another study that confirmed atrial fibrillation to be a major risk factor for stroke. Recent medical progress has centered on immediate therapies to lessen the extent of brain damage after a stroke. Thrombolysis is a treatment option in which clot-busting medicines are used to dissolve brain blood clots. Patients with acute ischemic stroke have a considerably lower risk of disability and mortality after receiving thrombolysis, according to a meta-analysis by Emberson et al. (2014).

Stroke survivors also benefit greatly from rehabilitation. Strength training, gait retraining, and task-specific training were all found to be effective rehabilitation treatments in a comprehensive review by Pollock et al. (2014). Technology's potential in managing stroke patients has also been investigated in recent years. Zbogar et al. (2019), for instance, looked into whether or not VR therapy could help stroke patients regain use of their upper extremities.The incidence of stroke is increasing rapidly, making it a major public health problem worldwide. Over the past few years, a plethora of studies have sought to improve stroke outcomes by discovering effective ways for stroke prevention and management. Thrombolytic therapy, the use of medications to dissolve blood clots restricting blood flow to the brain, is one field that has seen significant development. Patients with acute ischemic stroke can benefit from thrombolytic therapy, according to a study and meta-analysis by Wang et al. (2015).

Rehabilitation methods have been demonstrated to aid in recovery from stroke in addition to medical interventions. Lohse et al. (2016) conducted a meta-analysis to evaluate the efficacy of various rehabilitation modalities, such as VR and robotic treatment, in facilitating recovery of upper limb function following stroke. Motor function and activities of daily living for stroke survivors were reported to improve with the use of these therapies. According to research conducted by Kwakkel et al. (2016), over 80% of stroke survivors exhibit upper limb motor disability. Up to 70% of stroke survivors have issues with upper limb motor function during the acute phase of stroke, according to another study by Langhorne et al. (2019).

The literature also indicates that motor functional impairment in the upper limbs can be long-lasting. Half of stroke survivors still have motor deficits in their upper limbs six months after the event, according to research by Lawrence et al. (2017). Similarly, Buma et al. (2016) found that even a year after their stroke, 40-50% of patients still had significant motor deficits in their upper limbs. The literature also underscores the fact that the site of the stroke might affect the severity and impact of motor functional impairment in the upper limbs. Stroke survivors with cortical lesions are more likely to experience significant upper limb motor deficits than those with subcortical lesions, according to a study by Yancosek et al. (2018).

Up to 85% of stroke survivors report some degree of upper limb motor impairment (Bennett et al., 2017; Kwakkel et al., 2017), which can impact their capacity to conduct daily activities independently. Several methods, such as constraint-induced movement therapy (CIMT), virtual reality therapy, and robot-assisted therapy, have been investigated for their potential to enhance motor function in the upper limbs of stroke survivors. Virtual reality therapy uses computer-generated simulations to provide feedback and boost motor learning, whereas constraint-induced movement therapy (CIMT) entails constraining the unaffected arm and aggressively training the affected arm to improve its function. Kim et al. (2018) and Laver et al. (2015) describe robot-assisted therapy as "the use of robotic devices to guide and assist movements of the affected arm." About 60% of stroke survivors in Bangladesh had upper limb motor impairment, according to a study published in the Journal of Neurology, Neurosurgery, and Psychiatry by Ahmed et al. (2017). Kamal et al.'s (2019) research in the International Journal of Stroke reported an even higher prevalence of upper limb motor impairment, at 85%. Furthermore, Islam et al. (2018) found that 71% of stroke survivors in Bangladesh had poor upper limb function, which was published in the Journal of Physical Therapy Science. Upper limb motor impairment was reported to be present in 64.4% of stroke survivors, according to research published in the Bangladesh Medical Research Council Bulletin by Sarker et al. Quality of life can be negatively impacted by the high incidence of upper limb motor impairment among stroke patients in Bangladesh. It emphasizes the importance of long-term care and rehabilitation for stroke survivors to enhance their functional abilities and quality of life. Studies have indicated that many stroke survivors continue to endure persistent upper limb motor disability, which can significantly influence their quality of life, despite the availability of these therapies.

The prevalence of stroke has been rising in recent years, and it is responsible for about 10% of all DALYs lost in India (Jeyaraj et al., 2020). The most common sign of upper limb motor functional impairment after a stroke was weakness, according to a study conducted in Southern India (Sureshkumar et al., 2018). A similar situation exists in Pakistan, where the prevalence of stroke among adults is estimated to be 4.5% (Khan et al., 2019). Upper limb motor functional impairment was reported by 54% of stroke patients in a research conducted in Karachi (Khan et al., 2019). The most prevalent symptoms were weakness and stiffness. There is a dearth of standardized rehabilitation protocols in both India and Pakistan, despite the high prevalence of upper limb motor functional impairment following stroke (Dorsey et al., 2020). Also, many people, especially those living in rural regions, lack easy access to rehabilitation programs (Hafeez et al., 2019). This emphasizes the need of both countries making greater financial investments in stroke rehabilitation services and creating rehabilitation protocols that are sensitive to local customs and values.

Research results indicate that upper limb motor functional impairment is common among stroke survivors in Asian nations. Five-fifths of Chinese stroke survivors had motor functional impairment in their upper limbs, according to a 2016 study (Hu et al. Another Indian study found that 49% of stroke patients had some sort of motor functional deficit in their upper limbs (Sureshkumar et al., 2017). A research conducted in Japan found that 61% of stroke survivors had some sort of motor functional deficit in their upper limbs

(Takekawa et al., 2015). Similarly, Ong et al. (2016) found that 53% of stroke survivors in Malaysia had some sort of motor functional deficit in their upper limbs. About 80% of stroke survivors have upper limb motor functional disability, according to a research by Langhorne et al. (2017). The severity of this disability varies from person to person. Similarly, Wang et al. (2015) revealed that over 70% of stroke survivors exhibit upper limb motor functional handicap, and Kwakkel et al. (2016) reported that roughly 60% of stroke survivors had trouble using their afflicted upper limb. The research study also shows that difficulties with upper limb motor functional impairment are a major impediment to stroke survivors' ability to do everyday tasks and engage in community life. Stroke survivors with upper limb motor functional impairment have considerably worse levels of independence and quality of life, according to research by Nor Azlin et al. (2019). The researchers also discovered that there was a positive correlation between the severity of the handicap and the level of reliance.

Motor impairment in the upper extremities, for example, has been linked to an increase in caregiving responsibilities and depression in stroke survivors (Barker et al., 2017; Hsieh et al., 2016). In recent years, functional electrical stimulation (FES) has emerged as a promising rehabilitation strategy for improving motor function after a stroke. Both Hara et al. (2015) and Alon et al. (2017) found that FES improved motor function in the upper limbs of stroke patients. Several more studies have looked into the impact of lifestyle factors on stroke prevention and treatment in addition to these interventions. For example, Li et al. (2016) reported that physical activity is linked to a lower risk of stroke, while Kernan et al. (2016) reviewed the literature and concluded that controlling risk factors including hypertension and diabetes is crucial for preventing subsequent strokes.

Stroke patients frequently experience motor functional impairment in their upper limbs, which can have a devastating effect on their daily lives. Functional electrical stimulation (FES) is a potential strategy for enhancing motor function in the upper limbs of stroke patients. Several studies have shown that FES can improve motor function in the upper limbs of stroke patients. For instance, Hara et al. (2015) conducted a randomized controlled experiment that showed that when FES was used in conjunction with traditional therapy, it significantly improved motor function in stroke patients' upper limbs. Similarly, a meta-analysis by Fu et al. (2018) found that functional electrical stimulation (FES) was superior to other therapies like repetitive transcranial magnetic stimulation (rTMS) in enhancing motor function in the upper limbs. Stroke victims frequently have difficulties with motor function in their upper limbs. Recent years have seen a lot of study into different therapies for enhancing upper limb function in these people. Task-oriented training, electromyogram-triggered neuromuscular stimulation, robot-assisted therapy, and constraint-induced movement therapy were all found to be beneficial in improving upper limb function in stroke survivors by Mehrholz et al.'s (2015) systematic review and meta-analysis. Langhorne and Bernhardt (2018) conducted a meta-analysis and found that training with repetitive tasks and electrical stimulation were also beneficial therapies.

One promising technology treatment for restoring mobility to stroke patients' upper extremities is virtual reality therapy. Laver et al. (2017) conducted a randomized controlled experiment to determine whether or not virtual reality therapy is superior to normal care for improving upper limb function. Rehabilitation of the upper limbs with therapies performed at home is another area of research. Both home-based self-administered therapy and therapist-administered therapy were shown to be successful in increasing upper limb function, but the former was more cost-effective, according to a randomized controlled experiment conducted by Jolliffe et al. (2015). In addition, the positive effects of aerobic exercise on upper limb function in stroke survivors have been the subject of a number of research efforts. Saunders et al. (2016) conducted a systematic study and concluded that aerobic exercise improved upper limb function in stroke survivors in a mild to moderate way. studies on the value of tailored rehabilitation programs for the affected upper extremities have been conducted among those who have suffered a stroke. Results from upper limb rehabilitation were better when patients were treated as individuals, according to a study by Wolf et al. (2016).

Virtual reality (VR) and robot-assisted therapy are two more approaches that have showed promise in restoring motor function in stroke patients' upper limbs. Laver et al. (2015) conducted a comprehensive review and meta-analysis and concluded that VR-based therapies were helpful in enhancing motor function in the upper limbs of stroke survivors. Robot-assisted therapy has also been shown to be successful in enhancing motor function in the upper limbs of stroke patients, according to a systematic review conducted by Mehrholz et al. (2018). Therapies has been studied for improving motor functional recovery in the upper limbs of stroke patients. More progress was seen in upper limb motor function when FES was used in conjunction with robot-assisted therapy, according to research by Reinkensmeyer et al. (2016). Choi et al. (2019) found that when stroke patients used VR in conjunction with FES, they saw higher gains in their upper limb motor function than when they used VR alone.

The prevalence of stroke has been rising in recent years, and it is responsible for about 10% of all DALYs lost in India (Jeyaraj et al., 2020). The most common sign of upper limb motor functional impairment after a stroke was weakness, according to a study conducted in Southern India (Sureshkumar et al., 2018). A similar situation exists in Pakistan, where the prevalence of stroke among adults is estimated to be 4.5% (Khan et al., 2019). Upper limb motor functional impairment was reported by 54% of stroke patients in a research conducted in Karachi (Khan et al., 2019). The most prevalent symptoms were weakness and stiffness. There is a dearth of standardized rehabilitation protocols in both India and Pakistan, despite the high prevalence of upper limb motor functional impairment following stroke (Dorsey et al., 2020). Also, many people, especially those living in rural regions, lack easy access to rehabilitation programs (Hafeez et al., 2019). This emphasizes the need of both countries making greater financial investments in stroke rehabilitation services and creating rehabilitation protocols that are sensitive to local customs and values.

In review of the research emphasizes the importance of therapies that help stroke patients regain motor functional use of their upper limbs. Combining therapies like functional electrical stimulation (FES), virtual reality (VR), and robot-assisted therapy (RAT) may lead to even larger gains in upper limb motor function. More study is required to identify the most helpful therapies, or the best mix of therapies, for restoring motor function in the upper limbs after a stroke. A randomized control trial study was carried out to examine the effect of mirror therapy combined with functional electrical stimulation on upper limb motor recovery and functional for inpatient stroke patients in New Zealand. A total of 50 participants were allocated to one of three treatment groups: Functional Electrical Stimulation, Mirror therapy or a combined intervention of Functional Electrical Stimulation with Mirror therapy. The FES groups were provided with 30-minute session of FES-assisted wrist extension of the affected arm twice a day, five days a week, for three weeks. The mirror therapy group were provided 30-minute mirror therapy sessions twice a day, five days a week, for three weeks and the combined FES and mirror therapy group were provided with 30-minute session twice a day, five days a week, for three weeks. The FES group was found to be most effective compared to the other two groups (Mathieson et al., 2018). A four-week single blind randomized controlled trial study was undertaken with sixty participants who experienced a stroke to compare the long-term effectiveness between Theta Burst Stimulation (TBS) and Functional Electrical Stimulation (FES) combined with physiotherapy as compared to physiotherapy alone for improving arm functions in. There were 3 groups, Group A, Group B and Group C. Group A was intervene with TBS along with PT, Group B (FES) was FES along with PT and Group C was provided PT alone, intervention period was for 1month. Patients were assessed at baseline, after intervention at 1 month and follow-up assessments at 3 months, 6 months and at 1 year. The participants were consecutively recruited from the outpatient clinics and inpatient wards at tertiary care neurology center, Trivandrum, Kerala, India. The FES session was for 30 minutes each day, three times in a week (alternate days) for four weeks. The results showed that both Theta burst stimulation and functional electrical stimulation has similar efficacy (Khan et al., 2019).

An observer-blinded block-randomized controlled multicenter trial conducted with people who had experienced a stroke was carried out. In the experimental group the FES was applied to support impaired movements while the participant was working on task-oriented activities under guidance of the therapist. In the control group, participants were treated with standard rehabilitation care that included task-oriented activity. The intervention protocol for both groups consisted of 25 sessions, lasting 45 minutes each, applied 5 days per week for 8 weeks. In addition to the 25 sessions, all participants received usual care physiotherapy. The findings suggest FES was a safe adjunct to physiotherapy that could promote recovery of upper limb function in persons after stroke, particularly when applied in the subacute phase (Jonsdottir et al., 2017). Smania et al. (2018) observed that when FES was used in conjunction with standard therapy, patients recovered significantly more motor function in their affected upper limbs compared to when standard therapy was used alone. Another study by Lee et al. (2016) found that when FES was used in conjunction with task-specific training, motor function and ADLs in stroke survivors' upper limbs improved significantly. The literature review further notes that FES has been demonstrated to enhance not only muscle strength and stiffness, but also motor function in the upper limbs. FES increased muscle strength and decreased stiffness in the damaged upper limb of stroke survivors, according to a study by Johansson et al. (2016). Zhou et al. (2019) found that in stroke survivors, FES combined with mirror treatment significantly improved motor function, muscle strength, and stiffness in the affected upper limbs. Wu et al. (2018) observed that when conventional therapy was paired with FES, the results were much better than when conventional therapy was used alone in terms of improving motor function in the upper limbs. Similarly, Chen et al. (2019) found that when FES was used in conjunction with occupational therapy, patients saw significant gains in their ability to do daily tasks requiring use of their upper limbs.

Furthermore, FES's impact on improving motor function in the upper limbs of stroke patients has been the subject of multiple systematic reviews. Reviewers Ambrosini et al. (2018) concluded that FES has the potential to improve muscle strength and motor function, making it a promising supplementary therapy for upper limb rehabilitation. Similarly, Jin et al.'s (2019) meta-analysis found that FES in addition to traditional therapy is more effective than traditional therapy alone in enhancing motor function in the upper limbs.

FES has not been validated by all research. For instance, Timmermans et al. (2016) found no statistically significant differences in motor function or daily activities between the FES and traditional therapy groups. FES has been demonstrated to be effective for stroke patients in a number of studies. As one example, Kowalczewski et al. (2018) conducted a randomized controlled experiment and showed that when FES was used in conjunction with conventional therapy, motor function in the upper limbs improved by a greater amount than when either modality was used alone. In addition, FES therapy enhanced motor function in the arms and hands and reduced stiffness in stroke patients, as described by Chae et al. (2015). Zhou et al. (2019) conducted a meta-analysis of 19 randomized controlled studies and found that FES significantly enhanced upper limb motor function, decreased spasticity, and enhanced patients' ability to perform activities of daily living after stroke. Similarly, FES was found to be helpful in restoring motor function in the upper limbs of stroke patients in a recent meta-analysis by Ma et al. (2021). The effectiveness of FES has been demonstrated not just in individuals with acute stroke but also in those with chronic stroke. Zhang et al. (2019) found that chronic stroke patients' upper limb motor performance was considerably enhanced when FES was paired with rTMS.

A randomized controlled trial was conducted by Huang et al. (2021) to compare the effectiveness of contralateral functional electrical stimulation and neuromuscular electrical stimulation on upper limb motor function recovery in people who were within 6 months post-stroke. Both groups underwent routine rehabilitation plus 20 minutes stimulation on wrist extensors per day for five days a week, for 3 weeks, including posture management (sitting, standing, and sit to stand), abnormal reflex inhibition, proprioceptive neuromuscular facilitation, and occupational therapy. Provided to the respective cohorts at the end of the 3-week intervention. The group demonstrated greater improvement in Root Mean Square value of extensor carpi radialis than the NMES group.

Another randomized clinical trial explored the efficacy of task-oriented electromyography triggered multichannel functional electrical stimulation compared to single-channel cyclic neuromuscular electrical stimulation on regaining control of voluntary and the ability to execute arm-hand-activities for people in subacute stroke phase who had moderate arm paresis. Twelve iparticipants (Fugl-Meyer Assessment Arm Section score: 19–47) with comparable demographics were block-randomized to receive 15 sessions of or over three weeks. In addition, they all received conventional neurorehabilitation treatment including task-oriented arm training. Box-and-Block Test and Stroke-Impact-Scale were recorded at baseline and follow-up. All participants demonstrated significant improvement in and.

Participants treated with had a higher mean gain in than those treated with. In the SIS daily activities domain, both groups improved non-significantly; participants in the group had higher improvement in arm-hand use and stroke recovery. treatment demonstrated a higher gain of and self-reported daily activities, arm-hand use, and stroke recovery compared to cNMES treatment of the wrist only.

CHAPTER-III METHODOLOGY

3.1. Study Design

The study was a single blinded where data assessor was masked. There was two parallel groups. One arm received FES along with usual physiotherapy entitled as experimental group and another arm received only usual physiotherapy which was entitled as control group

The baseline, ten sessions, and twenty sessions of treatment was assessed by a blinded assessor who were not related to the treatment providers.

The design could be shown as follow:

r o x o (experimental group)

r o o (control group)

3.2 Study Site

The study was conducted in single center. The setting was outdoor Neurology unit of CRP, Savar.

3.3 Study population

The study population was the patients with stroke attended at the outdoor department of Neurology, CRP from September 30, 2022 to April 30, 2023.

3.4 Sample size calculation

A power analysis to determine sample size with 1.14% prevalence of stroke in Bangladesh (Mondal et al., 2021) where a 5% type – I error (α), 90% power (1 – type II error/β) and a clinically acceptable margin, δ = 0.1, then according to Zhong (2009).

Here,

$$N = 2 \times \left(\frac{z_{1-\alpha} + z_{1-\beta}}{\delta} \right)^2 \times p \times (1-p)$$

$$= 23.66 \approx 24$$

Allowing a dropout rate of 20%, we recruit 30 participants (15 participants for each group).

3.5 Duration of Study

7 months: September 1, 2022 to April 30, 2023

3.6 Sampling Scheme

All of the patients with a history of stroke and having an evident medical record of stroke in any level and attended at CRP Physiotherapy outdoor have been chosen as subject. From the subjects, screening procedure has been performed by qualified Physiotherapist to examine the inclusion and exclusion criteria. From the eligible respondents, consecutive 30 patients have been taken as a sample by hospital randomized sampling. The setting was CRP- Savar. The setting in CRP-Savar has a connectivity and access to patients from all over the country. From this setting, as these patients attained in these CRP randomly without the choice of CRP authority or the researcher‘s choice, so they may be considered as a random sample entitled as hospital randomization.

3.7 Sampling Technique

Computerized Random sampling technique was used in this study. A single blinded (assessor) randomized clinical trial with pre-measurements and post-measurements were conducted. Participants were measured by a blinded assessor once before randomization and intervention and again once 4 weeks after randomization and getting intervention. The assessor were responsible for conducting the baseline assessments had checked that each participant meets the inclusion criteria and had collected demographic information including date of birth, sex. A secure random allocation schedule had been generated prior to commencement of the trial by an independent person. The randomization schedule had blocked (1:1) to ensure equal numbers of participants are randomised to the treatment and control group.

3.8 Eligibility Criteria of participant of RCT:

The trial had a broad inclusion criteria in keeping with a pragmatic approach.

Inclusion Criteria:
A person will be eligible to participate if they have:

1. Diagnosis of a first- ever stroke confirmed by CT or MRI scanning through physician.
2. Stabilized vital signs and normal consciousness (Chen et al., 2019)
3. Age 18 years or above
4. Unilateral lesion indicated by CT or MRI
5. Brunnstrom recovery stage one to four for the affected upper limb
6. Between 2 months to 4 months post stroke

   (Huang et al., 2021).

Exclusion Criteria:

1. Reversible stroke.
2. Hemorrhagic stroke
3. Comorbidities (e.g., heart, lung, liver, and kidney dysfunction)
4. Severe diagnosed cognitive dysfunction
5. History of mental disease and unable to cooperate in treatment
6. People who are deaf and/or have non-verbal communication
7. Unable to commit for receiving treatment at trial duration
8. Implanted with cardiac pacemaker with upper limb dysfunction due to other causes

3.9 Informed Consent Process:

Potential and eligible participants were encouraged to listen the participant information sheet which was provided to the patient's caregiver for reading and if caregiver is illiterate then person who are responsible for screenings read the consent form in favor of patient/ caregiver.

3.10 Enrolment: Total enrolment procedure of the participants has been disclosed in Figure-1. An assessor (clinical physiotherapist) was responsible for conducting the baseline assessments who had checked that each participant meets the inclusion criteria. Information about each potential participant was collected from the medical records including date of birth, sex, duration of stroke and classification of stroke.

3.11 Randomisation Procedures:

Subject with stroke who was meet the inclusion criteria were randomly chosen from outdoor neurology unit of CRP, Savar and then they were assigned by simple randomization process. The study was single blinded. Computer generated random number was using in Microsoft Office Excel 2013 which was improved internal validity of experimental research for this randomized clinical trial study. The samples were given numerical number E1, E2, E3 etc. for the Multi-angle exercise group and C1, C2, C3 etc. for the control group.

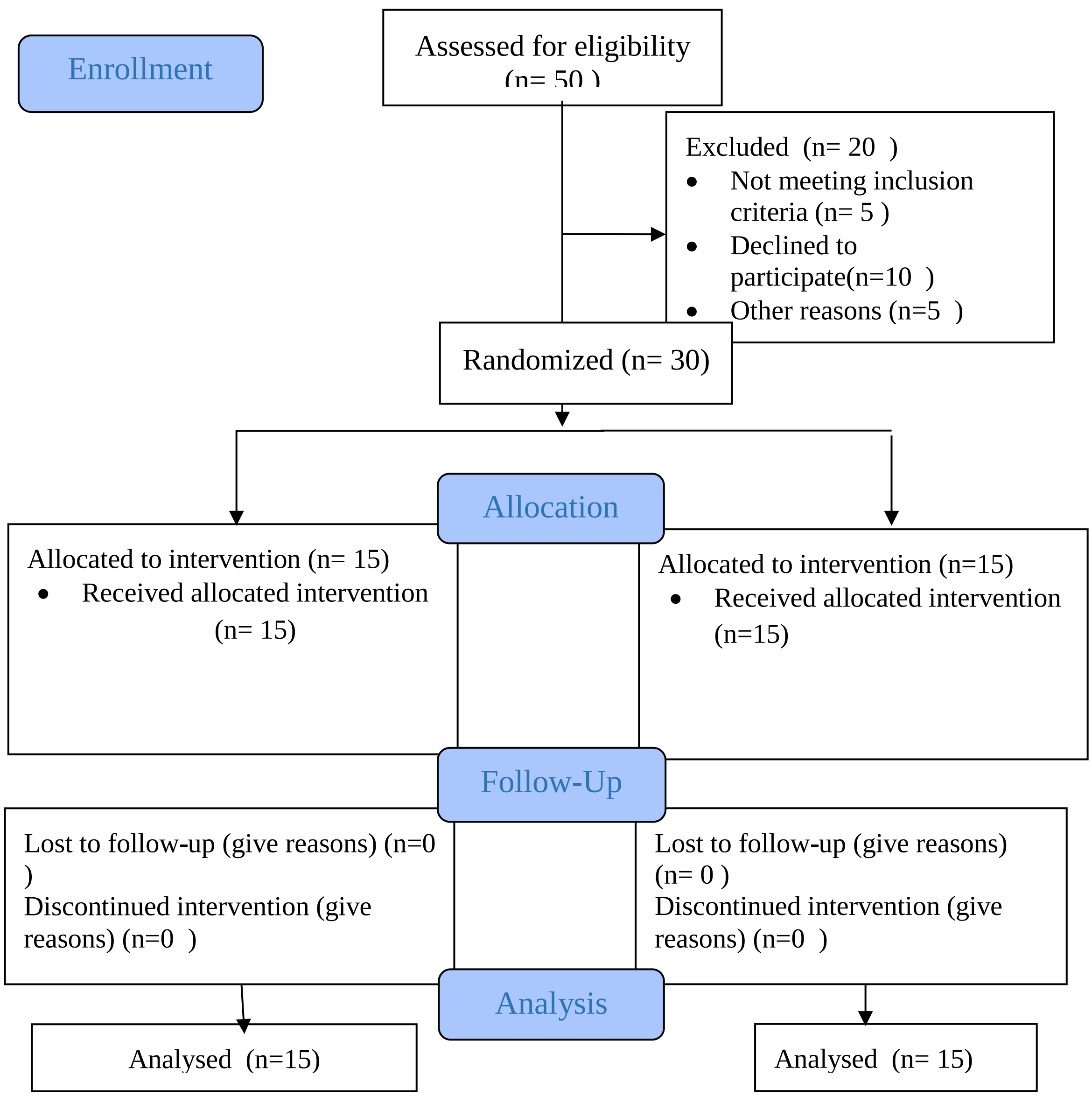

Figure 2: Consort diagram of the phases of randomized controlled trial

3.12 Interventions of the study:

Intervention Group:

Intervention group received the functional electrical stimulation (FES) along with standard physiotherapy (Figure-2). A training had been provided to the physiotherapists on FES application before starting the intervention on stroke patients. This training was conducted by senior physiotherapist who had experienced on FES application. FES was delivered through portable neurostimulator commonly used in clinical practice for this purpose. Participants were given a standard warning for the use of electrical stimulation, which includes watching for signs of skin burn. The electrodes of FES was placed on wrist extensors—extensor carpi radialis longus and brevis, and extensor carpi ulnaris. The duration of FES stimulation for extensor muscle group was 30 minutes and five sessions in a week and total session was twenty sessions. Stimulation parameter was be set at 50 Hz frequency, 350 microseconds pulse width, on:off ratio of 3:3 seconds and can be delivered at up to 100 mA stimulation amplitude (according to the individual's tolerance to FES current density. Electrode size was 5x5 cm or 7x13 cm (Huang et al., 2021).

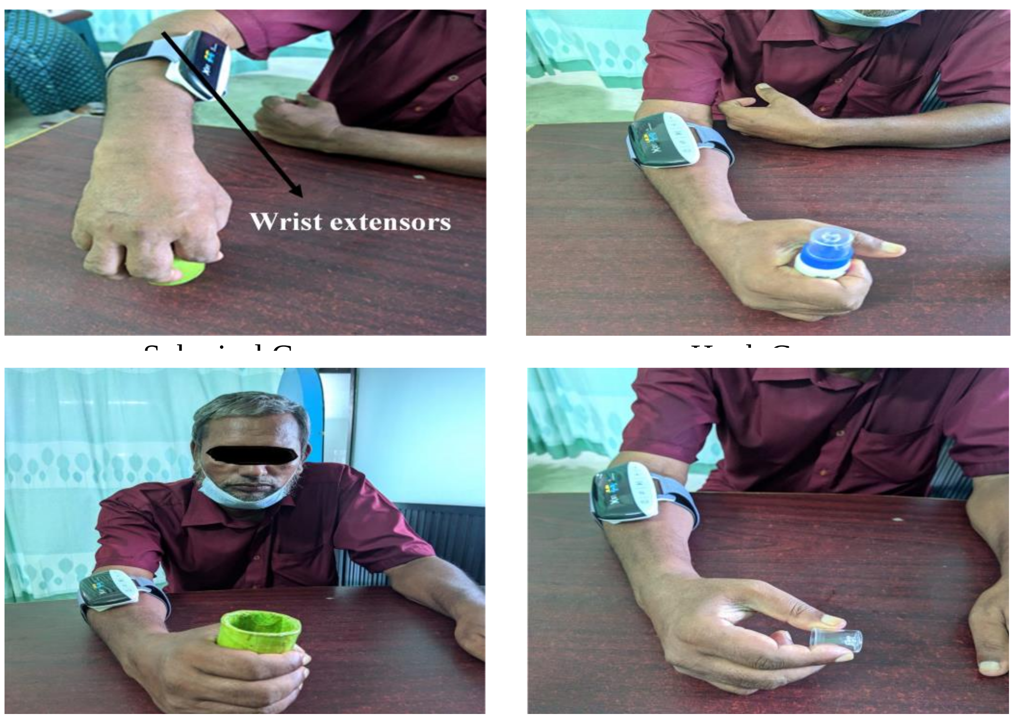

Figure-3: Participants getting treatment by FES and doing grasping tasks

Control group:

Control group received the standard physiotherapy.

Standard physiotherapy intervention:

Participants in the control group received standard physiotherapy. This therapy focused on providing passive range of motion exercises in those segments where no active movement was detected to meticulously reproduce a range of articular movements and muscle and soft tissue elongation. These exercises was manually administered on the affected joints of the hemiparetic side, with the participants in either supine, sitting or standing position, as appropriate. In those segments where residual active movement capability was detected, the participants were encouraged to perform movements with the assistance of the therapists. The type of exercises, intensity and duration of the exercises will be customized to the particular needs of each participant. (Appendix-A)

Sub-acute stage: Active, active assisted, passive and accessory range of motion exercise, Active resisted exercise, isometric, stretching, active weight bearing exercise, reaching practice and fine motor task activities of hand etc.

3.13 Outcome measurements tools

All outcomes were measured at baseline, halftime assessment after 10 sessions of intervention, and after completing rehabilitation intervention for 20 sessions (Table-1). Baseline data included socio-demographics like age, gender, occupation, BMI; health-related information e.g., types of strokes, affected side and history of comorbidities etc. The outcome measures were:

- FUGL-MEYER Assessment Upper Extremity (FMA-UE)
- Modified Ashworth Scale

Table-1: Outcome measurement plan

	Baseline (Before beginning of rehabilitation)	**Post-test assessment (After 10 sessions of Therapy)**	**After rehabilitation (Completing 20 sessions of Therapy)**
Socio-demographic information	√		
Spasticity measurement Modified Ashworth grading scale	√	√	√
Upper Limb Function measurement FUGL-MEYER Assessment Upper Extremity (FMA-UE)	√	√	√

Modified Ashworth Scale: Modified Ashworth Scale (MAS) measures spasticity. During the administration of MAS (Bohannon & Smith, 1987), the examiner passively moves the joint being tested and rates the perceived level of resistance in the muscle groups opposing the movement. Both scales are single-item measures ranging from 0 to 4, where 0 indicates no increase in muscle tone and 4 indicates that the affected part is rigid in flexion or extension. The MAS is considered a nominal scale due to ambiguity created by the addition of the 1+ grade between 1 and 2 (Pandyan et al., 1999).

FUGL-MEYER Assessment Upper Extremity (FMA-UE): The FMA-UE was used as an outcome measure in the clinical trials. The FMA-UE consists of 30 items assessing motor function and 3 items assessing reflex function. The score was most applicable to task performance is given from “0, inability,” “1, beginning ability,” to “2, normal” (total score range, 0–66) (Hijikata et al., 2020). Based on the standardized guideline developed by Platz et al. (2005) the FMA-UE will be administered by trained physiatrists.

Data storage: All information collected from this study at the case report form (CRF) was kept confidential and secure in a locked cupboard. All files containing the participant's personal details remained at the site where the data are collected. The original files was stored at the office of physiotherapy stroke unit in a locked drawer on completion of the study and only contained participant's ID codes. Electronically transcribed data and copy of the CRF was stored in the data base of the BHPI department. Access to data will only be granted to the Principal Investigator (PI) and other Research staff directly involved in the study.

Data Confidentiality:

All information was re-identifiable which is necessary for measuring the authenticity of data mining and further communication with the participants. Collected data was measured at utmost priority and unable to access by unauthorized persons. Consent forms and all files containing the participant's personal details remained at the site where the participant was recruited. The data was kept in the password-protected computer of Principle investigator. In case of further study with this collected data, it must be enforced to appeal to the data management committee for approval.

3.14 Data analysis procedure:

Participant's individual socio-demographical data was analysed using descriptive statistics where inferential statistical plan was set after checking the normal distribution of the gathered data. All statistical analyses was performed using the principles of 'Intention to treat'.

3.15 Level of Significance:

To find out the significance of the study, the "p" value was calculated. The p values refer to the probability of the results for experimental study. The word probability refers to the accuracy of the findings. The level of significant was set at 95% ($p<0.05$). A p value is called level of significance for an experiment and a p value of <0.05 was accepted as significant result for health service research. If the p value is equal or smaller than the significant level, the results are said to be significant (De Poy and Gitlin, 2013).

3.16 Ethical consideration

This study has the ethical permission from CRP ethics Committee [CRP-R&E-0401-0401]. Also, the trial is registered to Clinical Trial Registry India, the primary trial site of World Health Organization [CTRI/2022/09/046013]. The study must follow the Helsinki declaration as per ethical guidelines. The participation is voluntary, and participants will have the right to withdraw from the trial anytime during the trial. The trial's participants were given the assurance that their usual treatment regimen would not affected by their participation in or withdrawal from the study.

CHAPTER IV	RESULTS

Table 2: Comparison of baseline characteristics of the participants

Variable	**Control group (n=15)**	**Experimental group (n=15)**
Age, mean (SD),years	58.53 ±15.491	53.87 ±11.60
Gender	Male=08 (53%) Female=7 (47%)	Male=14 (93%) Female=1 (7%)
FUGL-MEYER Assessment Upper Extremity (FMA-UE) mean(SD), pretest (baseline)	19.87±8.015	17.87±4.838

Table 2 compares the base line characteristics of participants between control and experimental group. In addition, two groups did not show significant differences at baseline regarding demographic characteristics instead of *FMA-UE* test 0.00. In control group the mean age (±SD) of the participants was 58.53 (±15.491) years and in experimental group 53.87 (±11.60) years. In control and experimental group, male female ratio was (Male: Female=8:7). Mean (±SD) pretest FMA-UE score was in control group was 19.87±8.015 and in contrast mean (±SD) in experimental group was 17.87±4.838.

4.1. Socio-demographic Information

4.1.1. Age range distribution among participants

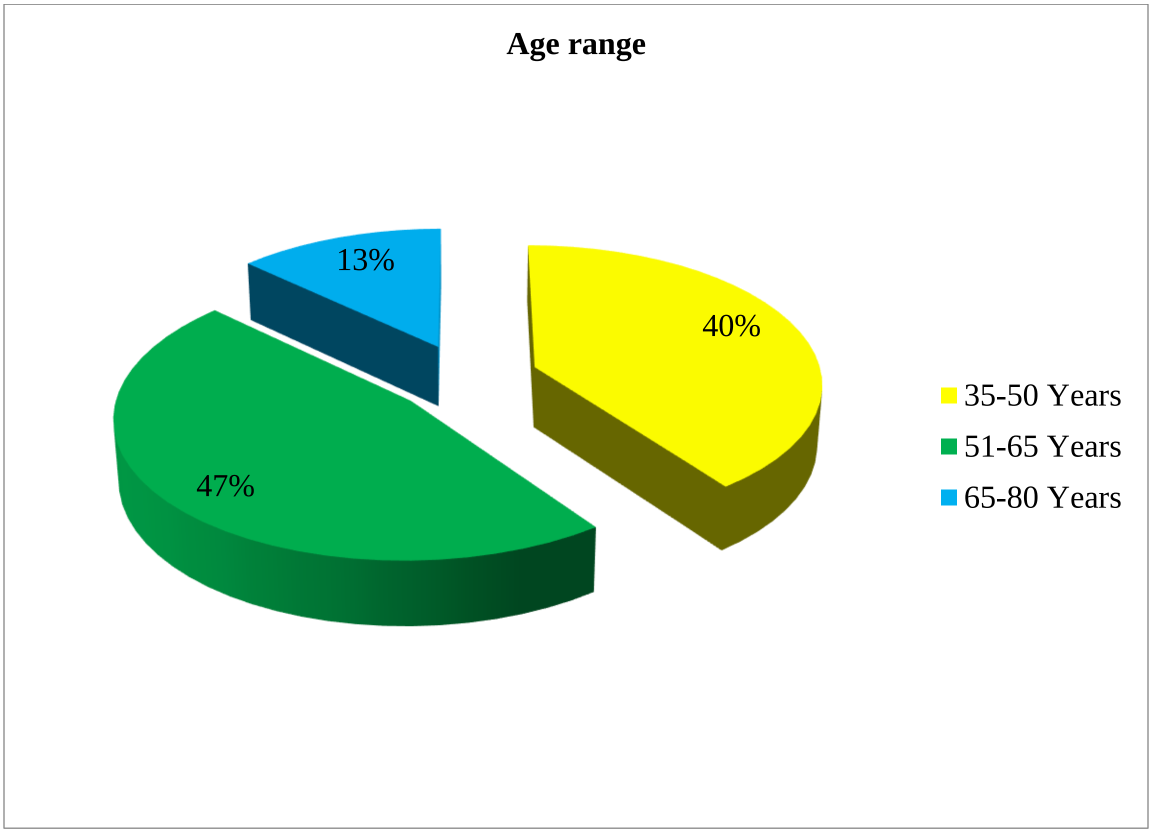

Figure 4: Age range distribution among participants

Figure 4 described that among the 30 participants, age ranges were grouped into 2 categories such as below 51 years were 14 (n=47%), and 52 years and above were 16 (53%).

4.1.2. Gender Distribution among participants

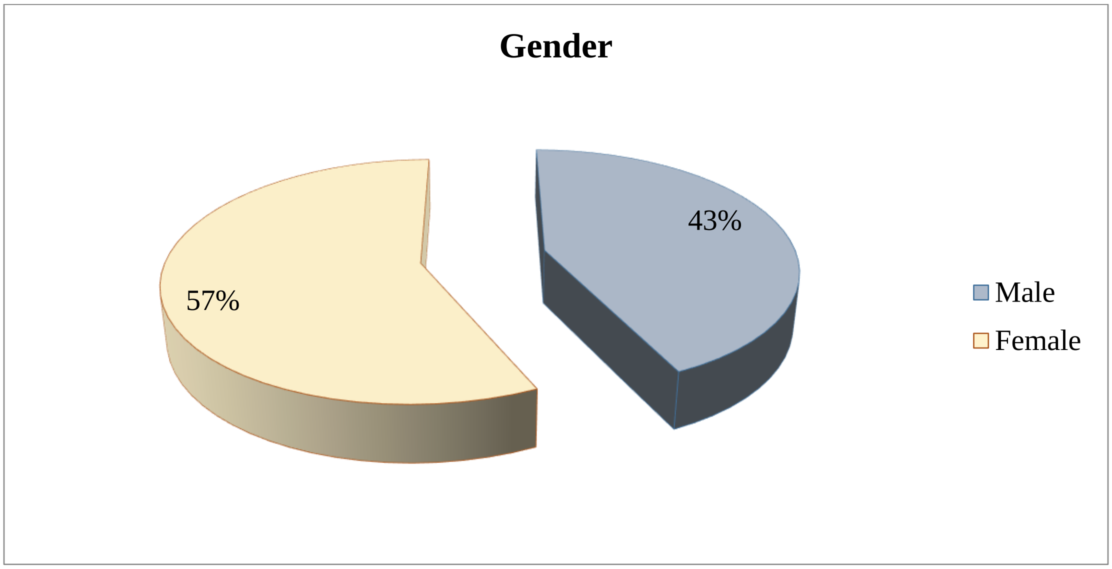

Figure 5: Gender distribution among participants

Figure 5 described that among 30 participants, 22 (73%) participants were male and 8 (27%) participants were female. In control group male participants were 53% and female participants were 47%. In experimental group male participants were 93% and female participants were 1 %.

4.1.4. Educational qualification distribution among participants

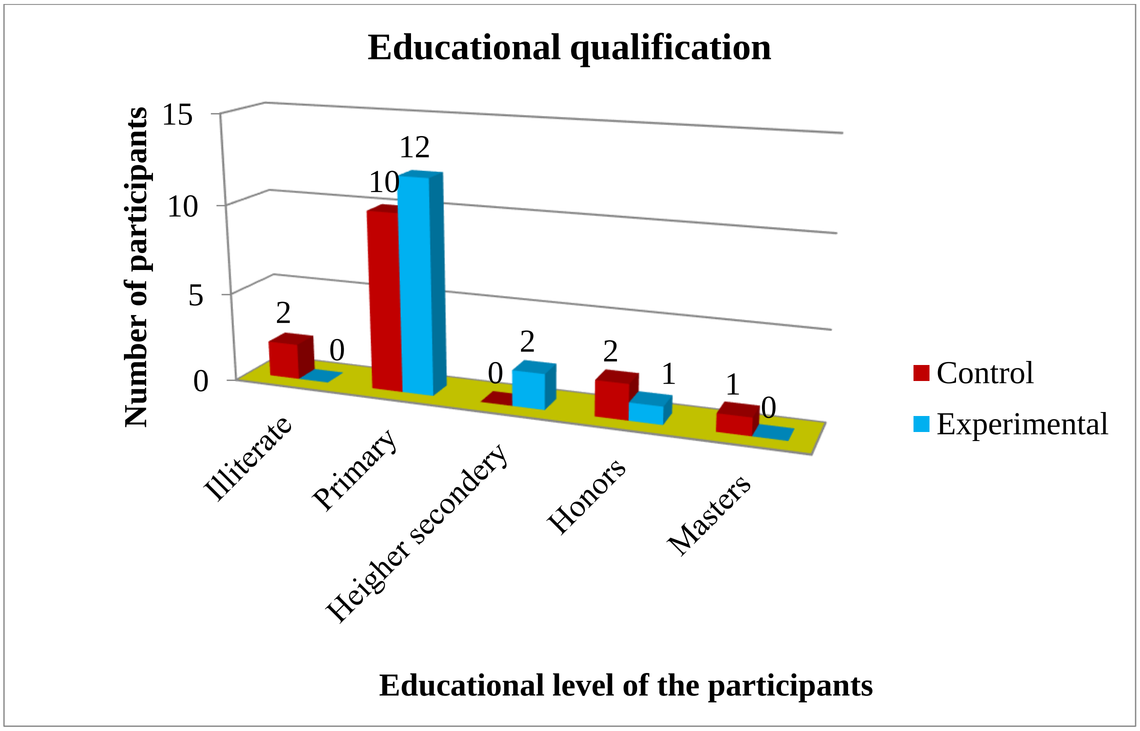

Figure 6: Educational qualification of participants

In this study, among the 30 participants 6% (n=2) were illiterate (0% in experimental group and 6% in control group), 73% (n=12) had completed primary studies (7% in experimental group and 66% in control group), 7% (n=2) has completed higher secondary level (7% in experimental group and 0% in control group, and 10% (n=3) has completed honors level (3% in experimental group and 7% in control group), and 4% (n=1) has completed masters level (0% in experimental group and 4% in control group).

4.2.3. Distribution of the respondents by type of stroke

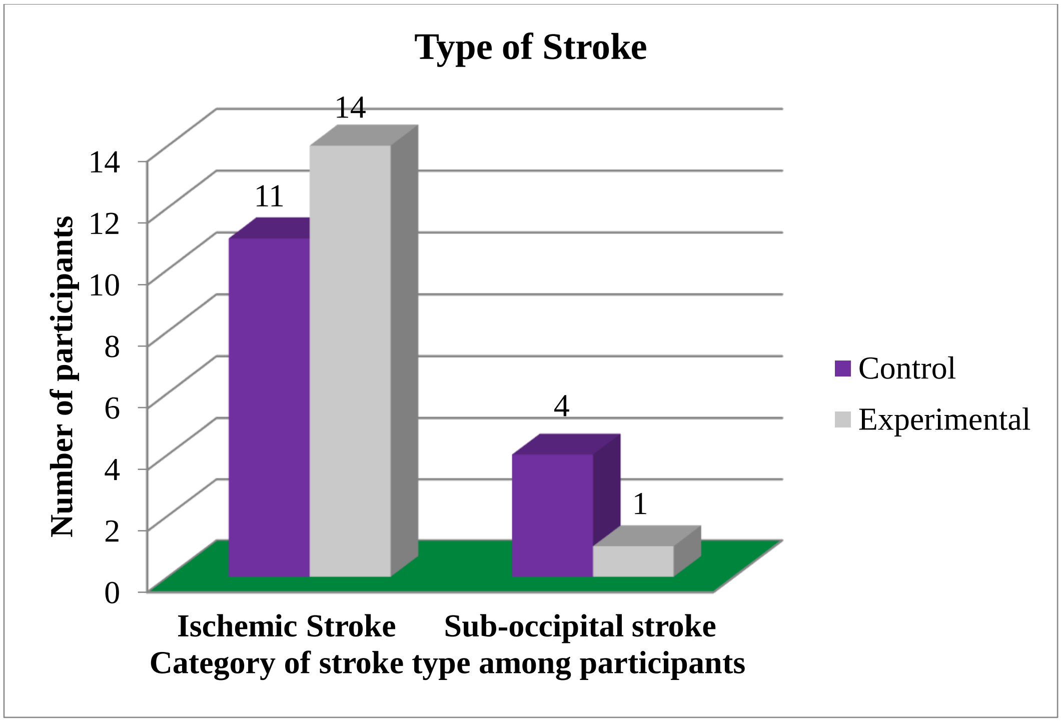

Figure 7: Distribution of the respondents by type of stroke

Among the all 30 participants ischemic type was 86% (n=13) and Sub-occipital stroke type was 14% (n=2) in experimental group. In control group, ischemic type was 73.3% (n=11)and Sub-occipital stroke type was 26.7%(n=4). On the other hand in experimental group, ischemic type was (n=14) 93%, Sub-occipital stroke type was (n=1) 6.7%.

Chronicity:

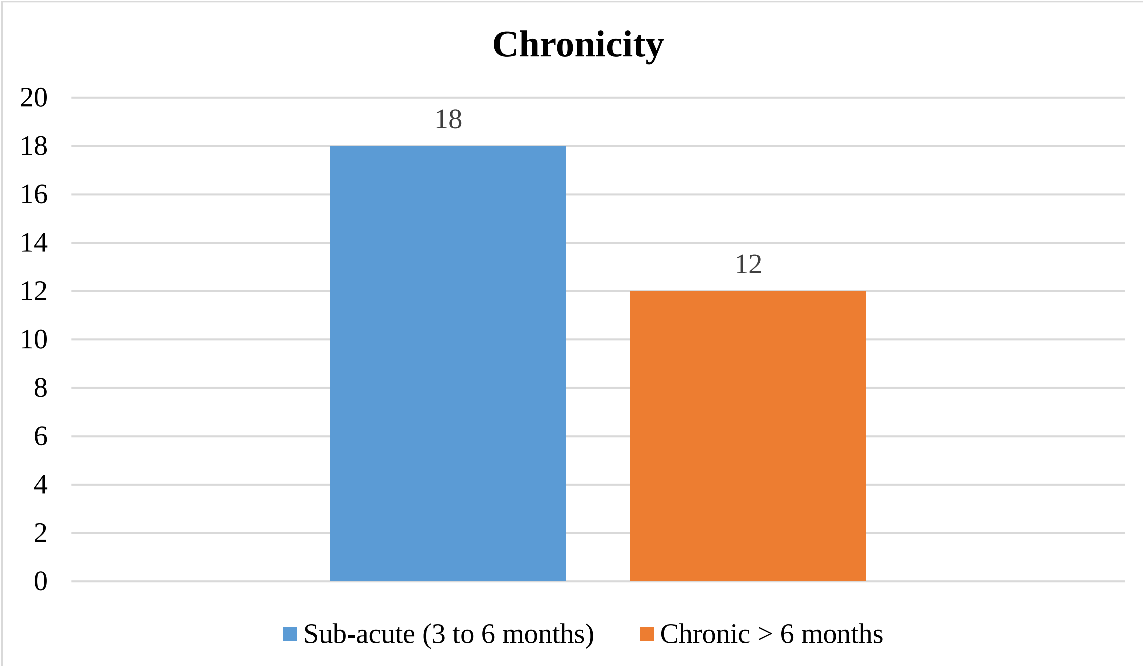

Figure 8: Distribution of the respondents by Chronicity

Figure 8 represented that among 30 participants in this study 18 participants (n=60%) had sub-acute stroke and rest of 12 participants (n=40%) had chronic stroke.

Affected hemisphere

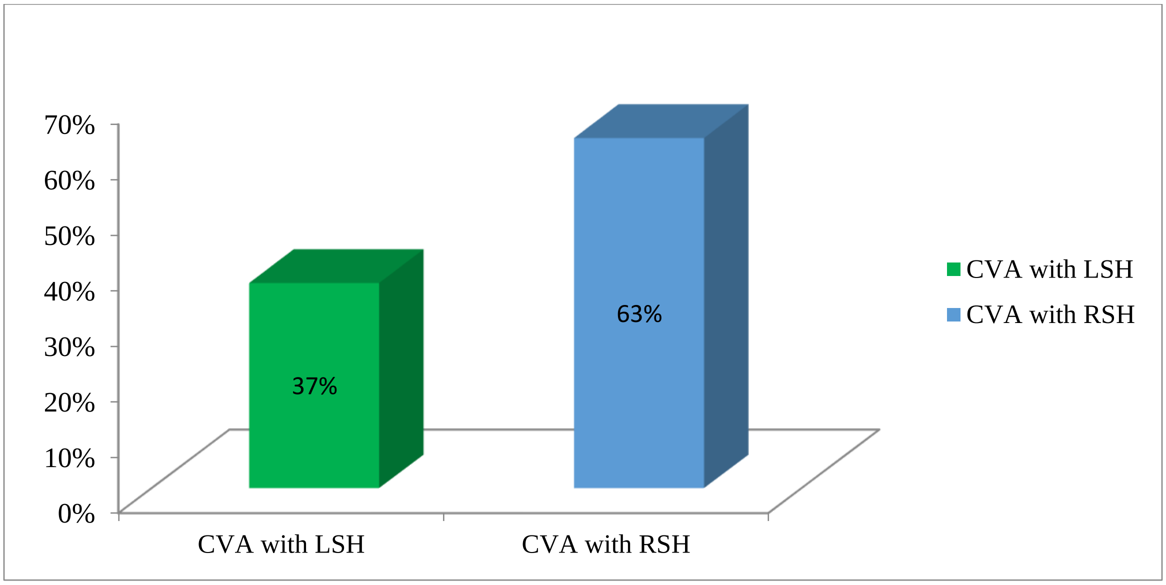

Figure 9: Distribution of the affected hemisphere

Figure 9 illustrated that among 30 participants in this study 11 participants (n=37%) had CVA with LSH whereas 19 participants (n= 63%) had CVA with RSH.

Pain status

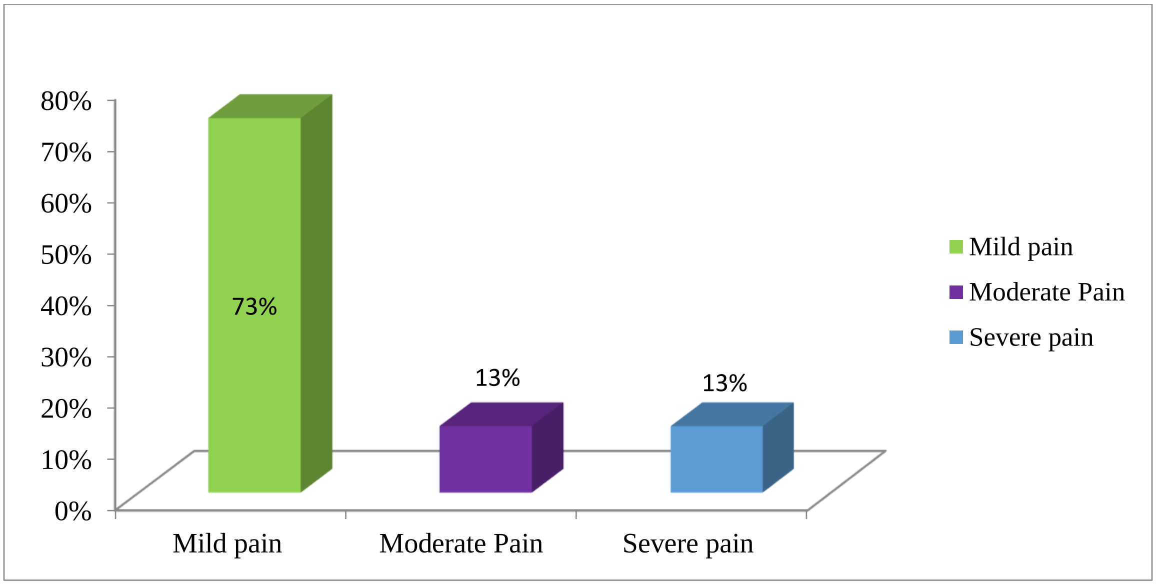

Figure 10: Distribution of the Pain status

In figure 10 showed that 22 participants (n=73%) had mild pain, 4 participants (n=13%) had moderate pain, 4 participants (n=13%) had severe pain.

4.3. Comorbidities related information:

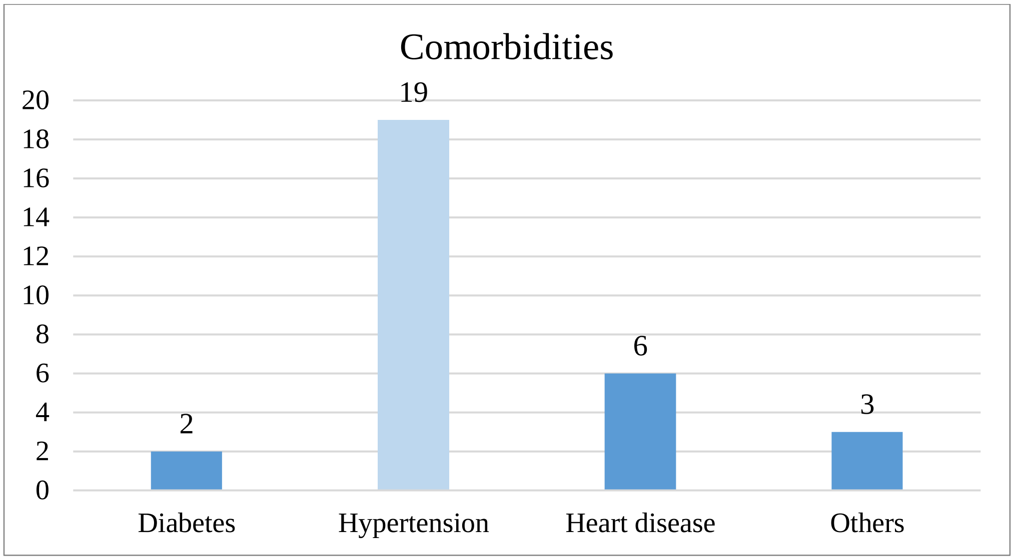

Figure-11: Comorbidities of the participants

Figure 11 narrated that among 30 participants in this study 2 participants (n=7%) had diabetes, 19 participants had (n=63%) had hypertension, 6 participants (n=20%) had heart disease and 3 (n=10%) had others disease.

4.3.2. Mann Whitney U test

Table 3: Mann Whitney U test for between group analysis for total FMA-UE

Post test analysis of total Fugl-Meyer Upper limb Score (n=30) after 20 session

Between group analysis (Mann-whitney U test)

Table 3: Post test analysis of total Fugl-Meyer Upper limb Score

Group no	N	Mean Rank	Z	P
Experimental	15	19.23	2.327	0.020
Control	15	11.77		
Total	30			

Table 8 showed that the calculated value of z is 2.327 for Fugl-Meyer Upper limb Score. From the calculated z value, it was clear that for 95% confidence level it is higher than the critical value of z (1.96). The level of significance is 0.020 which is less than 0.05. Therefore, the result is significant for two tailed hypothesis. Since the p value is less than 0.05, the result is significant and the null hypothesis (no relationship) is now rejected and the alternative hypothesis is accepted. So, it can conclude that functional electrical stimulation along with conventional physiotherapy is effective for upper limb functional activity for stroke patients.

4.3.4. Wilcoxon signed rank test

Table 4: Intra group analysis of total Fugl-Meyer Upper limb Score

Group no	N	Z	P
Experimental	15	3.183	0.001
Control	15	3.413	0.001
Total	30		

Table- 4 described the comparison of participant's before (pre) and after (post) pain score. The table's legend showed that any participants did not have increased pain after application of conventional physiotherapy.

By examining the final test statistics portion of table by Wilcoxon signed-rank test it was discovered that both experimental and control group for 4 weeks, five times weekly FES treatment with usual care and usual treatment course showed a statistically significant change in wrist extensor muscle group among individuals with stroke patients (Z=3.183, p=0.001; Z= 3.413, p= 0.001).

CHAPTER V	DISCUSSION

The purpose of the study was to determine the effectiveness of functional electrical Stimulation (FES) along with conventional physiotherapy on upper limb motor functional recovery in stroke patients. The result of the study found combined FES training to be more beneficial in comparison to only conventional physiotherapy alone in improving the hand functional activity ambulant stroke subjects. The outcome of this study showed significant difference in both group. Following 8 weeks' FES intervention session there was a significant improvement in hand functional activity.

In this study among the 30 participants, the majority of the participnats were between 51-65 year. The mean age for experimental group was 49.60 and SD was ±8.903 years and control group was 58.53and SD was ±15.491 years where Islam et al., (2012) reported that 0·20%, 0·30%, 0·20%, 1·00%, and 1·00% for the age range 40–49 years, 50–59 years, 60-69 years, 70–79 years, and approximately 80 years and above in that order.Most of the participants were female , where all the female participants were housewife. In contrast an epidemiological study in Bangladesh showed that 74% were male patients and 26% were female patients were in stroke in their study (Islam et al., 2012). Male are more affected than female in stroke according to many studies, but in this study, female participated more.

Functional multichannel neuromuscular electrostimulation can be considered to induce grasp-release or finger-hand extension and shoulder-elbow function with the training of selective movements and activities of daily living. It can also enhance the recovery of selective movements in arm paresis after stroke (Platzz et al., 2020). . However, one must also interpret these findings in light of the risk of bias of included studies. All studies in less than two month group lack adequate participant blinding, whilst two out of the three included studies in the one year group used sham treatment. Furthermore, the overall evidence quality, assessed using GRADE criteria, was very low as a result of the substantial heterogeneity, low participant numbers and lack of blinding in most studies.Analysis of Kanekar & Aruin (2013) sessment, the most commonly reported measurement instrument, showed a statistically significant benefit of FES corresponding to a moderate effect size. Additional analysis of FMA found a significant benefit for FES applied within 2 months of stroke but not for FES applied 1 year or more after stroke. Most included studies in these analyses were not adequately blinded and overall evidence quality was very low. Even a small improvement in function may be clinically significant, since upper limb function is so important for daily activities. It is possible that FES is beneficial only when applied using certain stimulation parameters or when applied to a specific patient population. Indeed, variation in FES parameters including current, frequency, duration of stimulation and also in baseline function of participants both between and within studies were noted. It appears that there are no agreed stimulation parameters, and it is likely that none of the included studies employed exactly the same stimulation protocol. Potential benefits could thus be hidden among the inter-study variability between studies in this study. This variability in FES parameters could influence results in this review and may be a contributing factor to the heterogeneity in the analyses. The current study found that after intervention with upper limb Functional Electrical Stimulation (FES) there was a significant improvement in FMA (Functional Motor Assessment; Smith et al., 2023) scores. However, Meilink et al. (2014) did not discover any noteworthy enhancement in FMA. There may be a disparity between the results because Meilink et al. only included three trials whereas the current meta-analysis includes eight. A recent systematic review by Howlett et al. (2020) indicated that upper limb FES significantly outperformed control based on a single research that pooled primary and secondary outcomes. However, it's not clear if this method would permit separate testing of primary, secondary, and tertiary results.

In this study the mean pretest total Fugl-Meyer Upper limb Score was 19.63 with a mean after 8-week rehabilitation of 31.33. This balance gain is significant ($p<0.05$). In compare a study the admission mean Fugl-Meyer Upper limb Score was 35.75 ± 11.55. All the patients were chronic (Srivastava et al., 2010). The duration of treatment followed in this study was limited to 8 weeks. The evidence was that the rate of recovery in the relevant impairments and the recovery of function were highest during the period when active treatment was applied. However, as soon as this therapy was discontinued, the rate of recovery between groups was not equalised. While it is not possible to comment on how long the duration would normally be required, it can be hypothesized that any treatment should be continued until the patient achieves a threshold of function that can be built on by the patient and the therapist. Again, here is a need for much more work to elucidate the minimum duration of treatment. It is possible that the high attrition rate (nearly 30%) and the resultant reduction in the sample size may have also contributed in part to the lack of significance.

The result showed for FMA test calculated by Mann-Whitney U test in between group at 5% level of significant described that the calculated *Z* value is 2.327 and P value 0.02. 5% level of significant at 14(fourteen) degrees of freedom Z value was 1.96. This indicated that FES treatment approach was more effective for improving upper limb functional status for the patients with stroke. In this study hand function improved significantly. In comparison with another study proved that FES oriented training can improve mobility early after stroke (Outermense et al, 2010). The present study determined the effects of FES along with conventional physiotherapy for improving hand function, mobility and functional status of patients with cerebro vascular disease or as well as stroke. Some studies have found that FES is effective for stroke patients. In comparison with one study conducted by Liu et al, 2019 stated that FES and cognitive behavior therapy is decreased the fear of falling of the stroke survivors.

In this study, in experimental group, the mean difference of FMA pre-test (mean=35.70) and post-test (mean=37.51) and in control group, the mean difference of pre-test (mean= 43.09) and post-test (mean=41.04) and it showed that mean difference of FMA higher in experimental group than control group. After final statistical test, it was observed that in experimental group p value was 0.001 and in control group 0.001 which was less than 0.05 that indicates that in both group the amount of upper limb function was increased. Another research Kusunoki et al. (2011) was conducted where 10 participants were involved who received 9 weeks training program and revealed that resistance exercise benefits cardiovascular fitness of spinal cord injured patients. That study also showed that amount of oxygen consumption after resistance training was improved due to changing of resting heart rate. Similarly 16 participants received heavy strengthening training (10 repetitions in 5 sets) in where there was also seen improving amount of oxygen consumption (Turbanski et al., 2010).

Limitations

The study has several limitations. The sample size was very small, so the result is difficult to generalize among whole population. Researcher has taken help from one assessor for data collection purpose, it may vary result. Data was collected one clinical setting CRP Savar, it can influence the result. Sometimes treatment sessions were interrupted due to public holiday mistaken in appointment schedule may interrupt the result. 6% participants were illiterate; it may give data error way. Therefore, the duration of the effect after the experimental intervention is unknown. Also, further research is needed to confirm the effectiveness of FES along with conventional physiotherapy for patients with stroke. The rehabilitation period was small only 8 week for total 24 sessions of intervention for the two groups that experimental group and control group. Similar studies with longer intervention time are required for conclusive results. However, the present study is meaningful because it suggests that simple FES therapy can improve hand functions of patients with stroke. Owing to limitations of the present study further studies are needed.

CHAPTER VII CONCLUSION

Functional electrical stimulation (FES) is a modern scientific treatment approach which is evidenced based. Day by day it covers a vast area of medical science. For stroke patients, there are so many effective approaches are used worldwide. Among them FES has been a popular approach. It has a vital component for improving many functional motor activities including upper limb function for sub-acute stroke patient. It helped promoting gripping, grasping.It encouraged the patients to willing participate in the treatment session and dramatically outcome can be observed. The result of the study has shown that the effectiveness of FES along with conventional physiotherapy is superior to the conventional physiotherapy alone after twenty four sessions of treatment for patients with stroke. Considering the final assessment the all variables of upper limb motor function has been improved in both groups instead of some variables while comparing to the initial assessment where FES along with conventional physiotherapy treatment group has found a greater benefit of the participants. FES with usual therapy will add new knowledge to manage stroke patients. Improvement of upper limb motor function will reduce the burden of stroke patients as well as their families. Hopefully this research will update and include a new dimension in the rehabilitation process of stroke patients in Bangladesh.

Recommendations

- The sample size should be increased since, while it is sufficient for the purposes intended, there is room for improvement in terms of statistical power and generalizability.
- The current strategy calls for a 6-week intervention time with FES, however a longer treatment term would be preferable. However, better results could be achieved by continuing treatment for a longer period of time.
- To learn how FES performs in the long run, it's important to do follow-up examinations after the intervention period has ended.
- In order to better understand how successful FES is, it can be compared to other procedures used in the rehabilitation of the upper limb.
- Using quantitative metrics, such as electromyography or kinematic analysis, would provide for more objective evidence on the impact of FES on the recovery of motor functioning upper limbs.
- Increasing the study's external validity requires recruiting individuals from a wide range of demographics and stroke subtypes.
- The ideal timing of FES intervention after a stroke is something to look into, as this knowledge could inform clinical decision making and lead to better patient outcomes.

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APPENDIX

Questionnaire

CONSENT FORM

(Please read out to the participants)

Assalamualaikum. My name is **Furatul Haque** and I am conducting this study for a M. Sc in Physiotherapy project study dissertation titled "**Effectiveness of Functional Electrical Stimulation (FES) on Upper Limb Motor Functional Recovery in Stroke Patients: A Randomized Controlled Trial".** under Bangladesh Health Professions Institute (BHPI), University of Dhaka. I would like to know about some personal and other related information regarding after stroke. You will perform some tasks which are mention in this form. This will take approximately 30-40 minutes.

I would like to inform you that this is a purely academic study and will not be used for any other purpose. The researcher is not directly related with this Neurological area, so your participation in the research will have no impact on your present or future treatment in this area (Neurology unit). All information provided by you will be treated as confidential and in the event of any report or publication it will be ensured that the source of information remains anonymous and also all information will be destroyed after completion of the study. Your participation in this study is voluntary and you may withdraw yourself at any time during this study without any negative consequences. You also have the right not to answer a particular question that you don't like or do not want to answer during interview.

If you have any query about the study or your right as a participant, you may contact with me, researcher and/or with my supervisor **Ehsanur Rahman,** Associate Professor, department of physiotherapy, CRP, Savar, Dhaka. Do you have any questions before I start?

So, may I have your consent to proceed with the interview or work?

Yes ☐

No ☐

Signature of the Participant ______________________

Signature of the Witness ______________________

Signature of the Interviewer ______________________

Questionnaires:

Modified Ashworth Scale:

The modified Ashworth scale is a 6-point rating scale that is used to measure muscle tone. Modified Ashworth scale ask the examiner to move a limb through its full range of movement and rate the amount of resistance felt according to descriptions

Grade	Description
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension
1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM
2	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
3	Considerable increase in muscle tone, passive movement difficult
4	Affected part(s) rigid in flexion or extension

FUGL-MEYER ASSESSMENT UPPER EXTREMITY (FMA-UE)
Assessment of motor function (Baseline data)
(Put ✓ mark on answer)

<table>
<tr><td colspan="6">A. UPPER EXTREMITY, sitting position</td></tr>
<tr><td colspan="3">a. Reflex activity</td><td>None</td><td colspan="2">Can be elicited</td></tr>
<tr><td colspan="3">Flexors: biceps and finger flexors (at least one)</td><td>0</td><td colspan="2">2</td></tr>
<tr><td colspan="3">Extensors: triceps</td><td>0</td><td colspan="2">2</td></tr>
<tr><td colspan="3">Sub-total a (max 4)</td><td colspan="3"></td></tr>
<tr><td colspan="3">b. Volitional movement within synergies, without gravitational help</td><td>None</td><td>Partial</td><td>Full</td></tr>
<tr><td rowspan="6">Flexor synergy: Hand from contralateral knee to ipsilateral ear.</td><td rowspan="4">Shoulder</td><td>retraction</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>elevation</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>abduction (90°)</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>external rotation</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>Elbow</td><td>flexion</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>Forearm</td><td>supination</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td rowspan="3">Extensor synergy: Hand from ipsilateral ear to the contralateral knee.</td><td>Shoulder</td><td>Adduction/internal rotation</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>Elbow</td><td>extension</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>Forearm</td><td>pronation</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td colspan="3">Sub-total b (max 18)</td><td colspan="3"></td></tr>
<tr><td colspan="3">c. Volitional movement mixing synergies, without compensation</td><td>None</td><td>Partial</td><td>Full</td></tr>
<tr><td rowspan="3">Hand to lumbar spine
hand on lap</td><td colspan="2">cannot perform or hand in front of ant-sup iliac spine</td><td>0</td><td></td><td></td></tr>
<tr><td colspan="2">hand behind ant-sup iliac spine (without compensation)</td><td></td><td>1</td><td></td></tr>
<tr><td colspan="2">hand to lumbar spine (without compensation)</td><td></td><td></td><td>2</td></tr>
<tr><td rowspan="3">Shoulder flexion 0°-90°
elbow at 0°
pronation-supination 0°</td><td colspan="2">immediate abduction or elbow flexion</td><td>0</td><td></td><td></td></tr>
<tr><td colspan="2">abduction or elbow flexion during movement</td><td></td><td>1</td><td></td></tr>
<tr><td colspan="2">flexion 90°, no shoulder abduction or elbow flexion</td><td></td><td></td><td>2</td></tr>
<tr><td rowspan="3">Pronation-supination
elbow at 90°
shoulder at 0°</td><td colspan="2">no pronation/supination, starting position impossible</td><td>0</td><td></td><td></td></tr>
<tr><td colspan="2">limited pronation/supination, maintains starting position</td><td></td><td>1</td><td></td></tr>
<tr><td colspan="2">full pronation/supination, maintains starting position</td><td></td><td></td><td>2</td></tr>
<tr><td colspan="3">Sub-total c (max 6)</td><td colspan="3"></td></tr>
</table>

d. Volitional movement with little or no synergy		None	Partial	Full
Shoulder abduction 0 - 90° elbow at 0° forearm pronated	immediate supination or elbow flexion	0		
	supination or elbow flexion during movement		1	
	abduction 90°, maintains extension and pronation			2
Shoulder flexion 90° - 180° elbow at 0° pronation-supination 0°	immediate abduction or elbow flexion	0		
	abduction or elbow flexion during movement		1	
	flexion 180°, no shoulder abduction or elbow flexion			2
Pronation/ supination elbow at 0° shoulder at 30°- 90° flexion	no pronation/supination, starting position impossible	0		
	limited pronation/supination, maintains start position		1	
	full pronation/supination, maintains starting position			2
	Sub-total d (max 6)			
e. **Normal reflex activity** assessed only if full score of 6 points is achieved in part d; compare with the unaffected side		**0 (d), Hyper**	**Lively**	**Normal**
biceps, triceps, finger flexors	2 of 3 reflexes markedly hyperactive or 0 points in part d	0		
	1 reflex markedly hyperactive or at least 2 reflexes lively		1	
	maximum of 1 reflex lively, none hyperactive			2
	Sub-total e (max 2)			
	Total A (max 36)			
B. **WRIST** support may be provided at the elbow to take or hold the starting position, no support at wrist, check the passive range of motion prior testing		**None**	**Partial**	**Full**
Stability at 15° dorsiflexion elbow at 90°, forearm pronated, shoulder at 0°	less than 15° active dorsiflexion	0		
	dorsiflexion 15°, no resistance tolerated		1	
	maintains dorsiflexion against resistance			2
Repeated dorsifexion / volar flexion elbow at 90°, forearm pronated, shoulder at 0°, slight finger flexion	cannot perform volitionally	0		
	limited active range of motion		1	
	full active range of motion, smoothly			2

Stability at 15° dorsiflexion elbow at 0°, forearm pronated slight shoulder flexion /abduction	less than 15° active dorsiflexion	0		
	dorsiflexion 15°, no resistance tolerated		1	
	maintains dorsiflexion against resistance			2
Repeated dorsifexion / volar flexion elbow at 0°, forearm pronated slight shoulder flexion /abduction	cannot perform volitionally	0		
	limited active range of motion		1	
	full active range of motion, smoothly			2
Circumduction elbow at 90°, forearm pronated shoulder at 0°	cannot perform volitionally	0		
	jerky movement or incomplete		1	
	complete and smooth circumduction			2
	Total B (max 10)			
C. HAND support may be provided at the elbow to keep 90° flexion, no support at the wrist, compare with unaffected hand, the objects are interposed, active grasp		**None**	**Partial**	**Full**
Mass flexion from full active or passive extension		0	1	2
Mass extension from full active or passive flexion		0	1	2
GRASP				
a. Hook grasp flexion in PIP and DIP (digits II-V), extension in MCP II-V	cannot be performed	0		
	can hold position but weak		1	
	maintains position against resistance			2
b. Thumb adduction 1-st CMC, MCP, IP at 0°, scrap of paper between thumb and 2-nd MCP joint	cannot be performed	0		
	can hold paper but not against tug		1	
	can hold paper against a tug			2
c. Pincer grasp, opposition pulpa of the thumb against the pulpa of 2-nd finger, pencil, tug upward	cannot be performed	0		
	can hold pencil but not against tug		1	
	can hold pencil against a tug			2

d. Cylinder grasp cylinder shaped object (small can) tug upward, opposition of thumb and fingers	cannot be performed	0		
	can hold cylinder but not against tug		1	
	can hold cylinder against a tug			2
e. Spherical grasp fingers in abduction /flexion, thumb opposed, tennis ball, tug away	cannot be performed	0		
	can hold ball but not against tug		1	
	can hold ball against a tug			2
	Total C (max 14)			
D. COORDINATION/SPEED, sitting, after one trial with both arms, eyes closed, tip of the index finger from knee to nose, 5 times as fast as possible		**marked**	**slight**	**none**
Tremor	at least 1 completed movement	0	1	2
Dysmetria at least 1 completed movement	pronounced or unsystematic	0		
	slight and systematic		1	
	no dysmetria			2
		≥ 6s	**2 – 5s**	**< 2s**
Time start and end with the hand on the knee	at least 6 seconds slower than unaffected side	0		
	2-5 seconds slower than unaffected side		1	
	less than 2 seconds difference			2
	Total D (max 6)			
	Total A-D (max 66)			
Impairment level	○ Mild (score 66 - 49) ○ Moderate (score 48 - 22) ○ Severe (score 21 - 0)			

Permission Letter

Date: October 31, 2022

Head

Department of Physiotherapy

Centre for the Rehabilitation of the Paralysed (CRP)

CRP-Chapain, Savar, Dhaka-1343.

Subject: Prayer for seeking permission to collect data for conducting research project.

Sir,

With due respect and humble submission to state that I am Md. Furatul Haque, student of M.Sc. in Physiotherapy Part-II at Bangladesh Health Professions Institute (BHPI). The Ethical committee has approved my research project entitled: **"Effectiveness of Functional Electrical Stimulation (FES) on Upper Limb Motor Functional Recovery in Stroke Patients: A Randomized Controlled Trial"** under the supervision of Ehsanur Rahman, Associate Professor and M.Sc PT Coordinator, Department of Physiotherapy, BHPI, I want to collect data for my research project from the Outpatient Neurology and Stroke Rehabilitation Unit, Department of Physiotherapy at CRP. So, I need permission for data collection from the honorable Head, Department of Physiotherapy, CRP, Savar. I would like to assure that anything of the study will not be harmful for the participants.

I, therefore pray and hope that your honor would be kind enough to grant my application and give me permission for data collection and oblige thereby.

Yours Obediently,

Md. Furatul Haque

Md. Furatul Haque

Part II M.Sc. in Physiotherapy

Reg No: 4733

Session: 2020-21

Bangladesh Health Professions Institute (BHPI)

CRP-Chapain, Savar, Dhaka-1343.

Forwarded & Recommended

E. Rahman

01.11.2022

Approved

20/11/22

MOHAMMAD ANWAR HOSSAIN

Senior Consultant &

Head of Physiotherapy Dept

Associate Professor, BHPI

CRP, Savar, Dhaka-1343

CRP Centre for the Rehabilitation of the Paralysed

Centre for the Rehabilitation of the Paralysed (CRP)
Department of Physiotherapy

Head Office: CRP- Savar, CRP- Chapain, Savar Dhaka-1343, Bangladesh
Tel: +880 02 7745464-5, Fax: 7745069, E-mail: contact@crp-bangladesh.org, www. crp-bangladesh.org

Ref: Date:

Treatment protocol for stroke Patient
Neurology Unit, CRP, Savar

PT Rx:

- Positioning maintain in any starting position.
- Stabilization of the pelvic girdle, knees and shoulder girdle 10 mins
- Sensory stimulation of U/L 5 mins and L/L 5 mins
- Proprioceptive exercise of U/L 10 mins and L/L 10 mins
- CHOR practice 10 mins
- Body schema exercise 10 mins
- Scapular setting exercise 10 mins
- Proximal stability exercise 10 mins
- Selective mvt practice of U/L 10 repetition separately, L/L repetition separately.
- Midline orientation exercise 10 mins
- Bobath trunk mob 10 mins, pelvic girdle mob 10 mins and shoulder girdle mob 10 mins
- Bobath hand mob 10 mins and foot mob10 mins.
- Selective mvt practice/ Functional strengthening of U/L 10-20 reps and L/L 10-20 reps
- Coordination practice in formative way 10 min/session
- Core strengthening per set of exercise 10 reps.
- PNF stretching 10 rep each diagonal movement
- STS practice 10 reps
- Dynamic sitting/ standing balance 10-20 mins
- Stepping practice 10 mins
- SPG/ CPG practice 10 mins
- Gait reeducation 10-20 mins
- Stair up and stair down practice 10 mins
- Electrotherapy (TENS/ Tropic stimulator) 10-15 mins

Gym activity: CPM 5-10 min, ET 10 rep, SR 10 rep, Cycling 5 mins, Hamstring/ Coards strengthening 5-15 kg/10 reps, Leg press 10-20 reps, Static runner 5-10 mins, Chest or Shoulder Press 10-15 reps. Hand cycling 5-10 mins.

Rashid 21.05.23

Harun-Or-Rashid
Consultant & In-charge
Neurology Unit, Physiotherapy Dept.
CRP, Savar, Dhaka

CRP-Mirpur, Dhaka, Plot: A/5, Block- A, Section- 14, Mirpur, Dhaka- 1206, Tel: 02 9025562-4, Fax: 02 9025561, Email: dgm-mirpur@crp-bangladesh.org. **CRP-Ganakbari,** PO: Dhamsena, P.S: Ashulia, Savar, Dhaka, Tel: 02 7789227, Email: ganakbari@crp-bangladesh.org. **AK Khan CRP- Chittagong,** Kalurghat, Mohra, Chadgaon, Chittagong, Tel: 031- 2573412, Email: chittagong@ crp-bangladesh.org. **Afsar Hussain CRP- Rajshahi,** House no: 11, Mohishbathan, Rajshahi Court Rajpara, Rajshahi, Tel: 0721 771709, Email: rajshahi@crp-bangladesh.org. **CARSA Foundation- CRP, Barisal,** 12 Gonopara, Barisal Sadar, Barisal, Phone: 0431 71556, Email: barisal@crp-bangladesh.org. **CRP- Moulvibazar,** 836 Sayed Muztaba Ali Road, Poschim Bazar, Tel: 0861 52469, E-mail: moulvibazar@crp-bangladesh.org

বাংলাদেশ হেল্‌থ প্রফেশন্স ইনস্টিটিউট (বিএইচপিআই)

Bangladesh Health Professions Institute (BHPI)

(The Academic Institute of CRP)

BANGLADESH HEALTH PROFESSIONS INSTITUTE

Ref: CRP/BHPI/IRB/10/2022/664

Date: 25/10/2022

Md. Furatul Haque
M.Sc. in Physiotherapy (Part-II)
Session: 2020-2021, DU Reg No. 4733
BHPI, CRP, Savar, Dhaka-1343, Bangladesh

Subject: Approval of the thesis proposal **"Effectiveness of Functional Electrical Stimulation (FES) on Upper Limb Motor Functional Recovery in Stroke Patients: A Randomized Controlled Trial"** by ethics committee.

Dear Md. Furatul Haque,
Congratulations.
The Institutional Review Board (IRB) of BHPI has reviewed and discussed your application to conduct the above-mentioned dissertation, with yourself, as the principal investigator and Ehsanur Rahman, Associate Professor and M.Sc. PT Coordinator, Department of Physiotherapy, BHPI, as thesis supervisor. The Following documents have been reviewed and approved:

Sr. No.	Name of the Documents
1	Dissertation Proposal
2	Questioner (English and Bengali version)
3	Information sheet & consent form

The purpose of the study is to identify the effectiveness of Functional Electrical Stimulation (FES) on Upper Limb Motor Functional Recovery in Stroke Patients by ensuring the current and available evidence. Should there any interpretation, typo, spelling, and grammatical mistake in the title, it is the responsibility of investigator. Since the study involve questionnaire that may take 25 to 30 minutes and have no likelihood of any harm to the participants. Data collector will receive informed consents from all participants, The members of the Ethics committee approved the study to be conducted in the presented form at the meeting held at 09.00 AM on 24th September 2022 at BHPI.

The institutional Ethics committee expects to be informed about the progress of the study, any changes occurring during the study, any revision in the protocol and ask to be provided a copy of the final report. This Ethics committee is working accordance to Nuremberg Code 1947, World Medical Association Declaration of Helsinki, 1964 - 2013 and other applicable regulation.

Best regards,

Muhammad Millat Hossain
Associate Professor, Dept. of Rehabilitation Science
Member Secretary, Institutional Review Board (IRB)
BHPI, CRP, Savar, Dhaka-1343, Bangladesh

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