EFFECTIVENESS OF CONSTRAINT-INDUCED MOVEMENT THERAPY ON UPPER-LIMB FUNCTION AMONG HEMIPLEGIC STROKE SURVIVORS IN UNIVERSITY OF BENIN TEACHING HOSPITAL, BENIN CITY

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PHYSIOTHERAPY, SCHOOL OF BASIC MEDICAL SCIENCES, COLLEGE OF MEDICAL SCIENCES, UNIVERSITY OF BENIN, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF PHYSIOTHERAPY (B.PT) DEGREE

OCTOBER, 2025

CERTIFICATION

This dissertation by Aizenosa, Overcomer Oghomwenomase is accepted in its present form as satisfying the dissertation requirement of the degree of Bachelor of Physiotherapy of the School of Basic Medical Sciences, College of Medical Sciences of the University of Benin.

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DEDICATION

I dedicate this dissertation to almighty God for giving me the grace and the strength to start and finish this work, I also want to dedicate this work to my lovely mother Mrs Patricia Ogunsuyi who always encouraged and supported me from the beginning to end of this work and my aunt Mrs. Paulina Obazee who I stayed at her place throughout my stay in school.

ABSTRACT

Background / Purpose: The upper limb function of a stroke survivor following stroke recovery is essential for their functional independence and quality of life. Several studies have been done on the effectiveness of CIMT on upper limb function among hemiplegic stroke patients, however published articles on the effectiveness of CIMT on upper-limb function among hemiplegic stroke survivors in Nigeria are scanty or not available.The study aimed to evaluate the effectiveness of Constraint-Induced Movement Therapy (CIMT) on upper limb function among hemiplegic stroke survivors in a tertiary institution in Benin City.

Methods: Simple random sampling technique was used based on the inclusion and exclusion criteria to recruit the 52 participants and they were randomly assigned into a control group and an experimental group. Descriptive and Inferential statistics using One-Way ANOVA Tukey's post-hoc test to pinpoint specific differences. Alpha level was 0.05.

Results: The results showed that CIMT demonstrated significant improvements in upper limb function compared to those who received conventional therapy. The CIMT group showed higher gains in all measured parameters after the eight- week intervention. Statistical analysis revealed a significant difference at $p < 0.05$ between the groups.

Conclusion: The experimental group demonstrated significant increase in muscle strength, muscle endurance, joint flexibility and hand function. Participants also reported higher engagement and motivation throughout the intervention period. These results suggest that CIMT enhances motor recovery and functional performance among stroke survivors, promoting a more effective rehabilitation experience.

Keywords: Stroke, CIMT, hemiplegic, upper-limb function.

ACKNOWLEDGEMENTS

I am grateful to God for been able to successfully complete this work and for His protection and Guidance throughout my stay in school.

Special appreciation to my supervisor Dr. Adebisi I. Hammed for his assistance and guidance during the course of the research study. Despite his busy schedule he devoted his time to listen to me, answer questions, read through my work, made corrections and also put me through on how to go about my data analysis. May the almighty God bless and reward you in hundred folds.

I also appreciate the Head of the Department, Dr. Mrs. C. Obaseki, the pioneer Head of the Department Prof Kayode Oke and all the lecturers of the Department of Physiotherapy, University of Benin, both past and present who imparted knowledge in me during my stay in school. A special thanks to the Head of Department, Mr Taiwo Oyewumi, the directors, and also to the chiefs, interns and other clinicians in the Department of Physiotherapy, University of Benin Teaching Hospital, A special thanks also to the hospitals I did my vacation posting FMC Owo, Ondo State and University of Port Harcourt Teaching Hospital, Portharcourt. I appreciate the knowledge and skills they all imparted on me. I also appreciate the non-academic staffs, of the Department of Physiotherapy, University of Benin.

I also give a special thanks to my parents, Mr. and Mrs. Ogunsuyi, my sister Mrs. Adeghosa Odunayo, her husband Yusuf Odunayo and my little niece Stephanie Odunayo, my brothers Aiseosa Oghomwenomase, Osaivbie Oghomwenomase and David Bamidele, and all my siblings, relatives for their words of advice, encouragement, prayers and financial support and help throughout my stay as a student of University of Benin. I will also like to appreciate my classmate who did similar project work with me, Daniel, Zabdiel, Rachel and Martina for their assistant during the period of my data collection. My special thanks and gratitude to all my classmates, and all the participants that volunteered to participate in my study and to others which the confines of this page will not permit me to state.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Stroke is objective evidence of permanent brain, spinal cord or retinal cells death due to vascular cause based upon pathological or imaging evidence with or without the presence of clinical symptoms (American Heart Association, American Stroke Association, 2013). Despite numerous preventive efforts over the years, the incidence of stroke remains a significant public health concern. Stroke is the second biggest cause of death worldwide, and the third major cause of disability (Collaborators, 2021). In-hospital stroke death rates for general ward and stroke unit admissions are approximately 14.7% and 6.9%, respectively (Shah *et al*., 2017). Stroke-related mortality and disability-adjusted life years in low- and middle-income countries continue to rise (Owolabi *et al*., 2015). Age, stroke type, side and location of the lesion, level of consciousness, degree of neurological impairment and disability at baseline, medical risk factors (hypertension, diabetes), premorbid state, fever, baseline blood pressure, and prior stroke have all been shown to predict outcome, including independence after stroke (Nakibuuka *et al*., 2015).

Low- and middle-income nations have greater rates of stroke-related disability and mortality than high-income ones (Lanas *et al*., 2021). Individuals of African descent are more likely to get a stroke than Caucasians (Prapiadou *et al*., 2021). The slow pace of acute stroke management in low- and middle-income countries makes it difficult to reduce the burden of acute strokes in hospitals. To adequately manage individuals who have had an acute stroke, it is necessary to understand the underlying risk factors and the origin of the stroke (Berkowitz *et al*., 2016).

Some of the consequences of stroke include paralysis or weakness, dysphagia, pain, spasticity and contracture, Aphasia, memory loss, depression, urinary incontinence, etc. Strokes are classified into two types based on blood flow disruption: ischaemic stroke (blockages in blood vessels supplying the brain caused by blood clots or plaque) and haemorrhagic stroke (when an artery in the brain leaks or ruptures, causing pressure on brain cells and damage) (Centres for Disease Control and Prevention,2022).

Early stroke therapies date back to the 1800s, when surgeons began operating on the carotid arteries, which feed blood to the brain (Karenberg, 2020). Traditional stroke medicine in Nigeria relies heavily on herbal care and spiritual interventions, with scant available literature (Jarvis, 2022). In Nigeria, traditional medicine is frequently preferred over medical care due to its perceived availability and the idea that it is safer due to its natural origin (Okoro *et al*., 2021). Modern medical stroke management takes a multidisciplinary approach, with doctors, nurses, physiotherapists, occupational therapists, neuropsychologists, speech specialists, audiologists, and nutritionists all contributing at different stages of the process (Sanchetee, 2021). Recognising the need of assisting stroke survivors in regaining mobility, strength, and coordination, which are typically compromised following a stroke, physical therapy was adopted as an integral component of stroke management. Physical therapy aims to enhance range of motion, balance, and functional abilities while improving motor control, reducing muscle stiffness, and promoting neuroplasticity and the relearning of essential movements (Shahid *et al*., 2023).

According to the CDC (2022), stroke management consists of three stages: diagnosis, treatment, and rehabilitation. The diagnostic phase includes studies to determine the kind of stroke, while therapy consists of preserving or restoring homeostasis, delivering thrombolytic medicines, anticoagulants (which are contraindicated in haemorrhagic CVA), and surgery (Jarvis, 2022). Rehabilitation begins early after the stroke and can span weeks, months, or even years, focussing on speech, physical, and occupational therapy to retrain speech, movement, coordination, and daily tasks (Babawale *et al*., 2022). The primary goal of stroke rehabilitation is to restore limb motor function, thus it is critical to investigate effective ways that can aid in the rehabilitation of limb motor function after a stroke (Zhang *et al*., 2020). Rehabilitation techniques that promote neuroplasticity and functional recovery are critical for regaining upper-limb function in affected patients.

The global burden of stroke has shifted from industrialised to developing countries in recent decades (Kalkonde *et al*., 2018). In Nigeria, the increased stroke burden can be linked to a lack of facilities and human resources for stroke prevention, diagnostic procedures, acute care, and rehabilitation. As a result, patients had restricted access to rehabilitation treatments and overall stroke care (Kalavina, 2019). Furthermore, the lack of established national guidelines for stroke therapy has resulted in decreased coordination among healthcare practitioners and the use of varied stroke management treatment modalities (Abdullahi 2020).

Upper limb function recovery following a stroke is critical for patients' independence and quality of life (Johnson *et al*., 2016;GBD, 2016;Bernhardt *et al*., 2020). An accurate and complete assessment of bilateral upper extremity use in everyday life is required (Schwarz *et al.*, 2019). The degree of impairment in the patient's paretic upper limb is determined by comparing it to the non-paretic side (Kwakkel *et al.*, 2019). The Fugl-Meyer Assessment (FMA) tests motor separation and coordination, whereas the Action Research Arm Test (ARAT) assesses grab and manipulation skills (Santisteban *et al.*, 2016). Evaluating upper limb function on both the paretic and non-paretic sides is also necessary for forecasting the bilateral upper limbs' efficient usage potential in ADL.

Hemiplegia is partial or full paralysis of one side of the body caused by impairment to the brain's motor circuits (Fan *et al.*, 2020). This neurological illness typically develops after a stroke, traumatic brain injury (TBI), or other central nervous system problems that impair motor control on one side of the body (Fu *et al.*, 2020). Stroke, whether ischaemic or haemorrhagic, is the leading cause of hemiplegia, accounting for a sizable number of cases worldwide (Barthels & Das, 2020). Other causes include traumatic brain injuries from accidents, tumours affecting the brain regions responsible for motor control, and infections such encephalitis or meningitis (Boulton and Al-Rubaie, 2024). These disorders cause a loss of voluntary control over the muscles on the affected side of the body, limiting patients' capacity to perform ADLs. The effects of hemiplegia go beyond muscle weakness and paralysis. Patients frequently have stiffness, poor coordination, and sensory abnormalities on the affected side, which limits their movement and independence (Costa *et al.*, 2023).

Despite the well-established efficacy of rehabilitation in improving stroke survivors' outcomes, rehabilitative health initiatives are frequently overlooked in favour of treatment-focused approaches (Momsen *et al.*, 2022). Traditional rehabilitation treatments such as neurodevelopmental treatment, proprioceptive neuromuscular facilitation, constraint-induced movement therapy (CIMT), and task-oriented training continue to be important in stroke recovery, with the goal of improving functional capacities and quality of life. CIMT, in particular, which involves restraining the unaffected limb to encourage use of the affected limb, has showed promise not just in improving upper extremity function but also in balance, implying a broader application in motor function enhancement (Tedla *et al.*, 2022).

Motor recovery often plateaus between 3 and 6 months after stroke, emphasising the significance of optimising rehabilitation therapies during the subacute phase. CIMT has been shown to improve motor function in stroke patients, particularly those in chronic phases, by targeting the phenomena of "learnt non-use," in which patients become unduly reliant on their unaffected limb for daily activities. The therapy, which consists of restricting the unaffected limb for a set period of time (typically 6 hours per day), encourages the use of the affected limb in motor tasks. This strategy is both practicable for residential settings and cost-effective, making it an appealing alternative for widespread adoption (Nesin *et al.*, 2019). The continuation of upper limb impairments in around two-thirds of stroke survivors, with a minority reaching full recovery six months after the stroke, emphasises the need for appropriate rehabilitation procedures (Doumas *et al.*, 2021). Both CIMT and proprioceptive neuromuscular facilitation can improve upper limb function, although CIMT is more effective for addressing chronic deficits (Abba *et al.*, 2020).

Constraint-induced movement therapy (CIMT) is a neurological rehabilitation technique that enhances upper extremity motor function after stroke (Dong *et al.*, 2022). The goal of CIMT is to improve the function of the affected limb following a stroke by limiting the use of the healthy limb and forcing the use of the affected side. The primary strategy of CIMT is to use movement techniques, behavioural techniques, and restriction methods to increase the frequency of use of the affected limb in stroke patients, improve the quality of movement of the affected limb in real-life scenarios, prevent or correct learnt non-use of the affected limb, and promote motor function recovery in the affected limb. This therapy encourages the use of the dysfunction limb, corrects or reverses chronic disuse and neglect, and provides structural and functional training as well as opportunities for repeated practice. Many studies have confirmed the efficacy of CIMT, a rehabilitation strategy that involves repetitive rigorous unilateral limb training, in improving motor function in the afflicted limb (Hu & Bai, 2020). According to Simon-Martinez *et al*. (2020) and Ramey *et al*. (2021), constraint-induced movement therapy (CIMT) is a successful rehabilitation treatment for injured upper limbs.

1.2 Statement of the problem

One of the main causes of disability is stroke, which frequently leaves victims with hemiplegia, or weakness or paralysis on one side of their body. One frequent outcome is upper limb dysfunction, which severely lowers a patient's quality of life and makes it difficult for them to carry out daily tasks. By restricting the unaffected limb, CIMT, an evidence-based intervention, promotes the use of the affected limb to enhance motor function. Several studies have been done on the effectiveness of CIMT on upper limb function among hemiplegic stroke patients (Areerat *et al*., 2004, Sana *et al*., 2015, Raj *et al*., 2016, Muhammad *et al*. 2020). To the best of the researcher’s knowledge, published articles on effectiveness of

CIMT on upper limb function among hemiplegic stroke survivors in Nigeria, especially in Benin City are either scanty or not available.

The study was designed to evaluate the effectiveness of CIMT on upper limb function among hemiplegic stroke survivors in University of Benin Teaching Hospital, Benin City.

1.3 Research Questions

The following research questions were raised to guide this study:

i. What is the effect of CIMT on upper extremity muscle strength among stroke survivors ?

ii. What is the effect of CIMT on upper extremity muscle endurance among stroke survivors ?

iii. What is the effect of CIMT on upper extremity joint flexibility among stroke survivors ?

iv. What is the effect of CIMT on upper extremity hand function (grip strength and pinch strength) among stroke survivors ?

1.4 Aim of the study

To evaluate the effectiveness of CIMT on upper limb function among hemiplegic stroke survivors in a tertiary institution in Benin City.

1.4.1 Specific Objectives

The specific objectives are to:

i. Determine whether there is a difference in upper extremity Muscle strength in stroke survivors who undergo CIMT compared to those who do not.

ii. Determine whether there is a difference in upper extremity Muscle endurance in stroke survivors who undergo CIMT compared to those who do not.

iii. Determine whether there is a difference in upper extremity Joint flexibility in stroke survivors who undergo CIMT compared to those who do not.

iv. Determine whether there is a difference in upper extremity Hand function (Grip strength and pinch strength) in stroke survivors who undergo CIMT compared to those who do not.

1.5 Hypotheses

1.5.1 Main Hypotheses

There is no significant effect of CIMT on upper limb function among hemiplegic stroke survivors.

1.5.2 Sub Hypotheses

The following Hypotheses were formulated and tested at 0.05 level of significance:

i. There is no significant difference in upper extremity Muscle strength in stroke survivors who undergo CIMT compared to those who do not.

ii. There is no significant difference in upper extremity Muscle endurance in stroke survivors who undergo CIMT compared to those who do not.

iii. There is no significant difference in upper extremity Joint flexibility in stroke survivors who undergo CIMT compared to those who do not.

iv. There is no significant difference in upper extremity Hand function (Grip strength and pinch strength) in stroke survivors who undergo CIMT compared to those who do not.

1.6 Significance/Justification of the study

Clinical practice and stroke patient rehabilitation tactics can be greatly impacted by knowledge of how well CIMT improves upper limb function. The purpose of this study are:

This study could present empirical evidence showing CIMT improves upper limb function in hemiplegic stroke patients. It would therefore be of assistance to clinicians within Nigeria and also similar settings. They could then be able to make educated judgments which are based on local facts.

Rehabilitation protocols at UBTH along with elsewhere may see future improvements from the study's findings. The adoption of CIMT may be able to be helped. It may then be a standard part of stroke care.

This study shows that it can improve motor recovery, also quality of life, for hemiplegic stroke survivors since it proves all the benefits of CIMT, especially in situations where rehabilitation alternatives are limited.

Study findings are helpful to policymakers and administrators at hospitals for allocating resources to CIMT plus therapies that work well, improving recovery results plus burden of impairment.

This study could be a platform for academic research later because Nigeria has had few CIMT investigations, and clinical trials on stroke rehabilitation in low- and middle-income nations.

1.7 Scope and Delimitation of the study

The study concentrated on hemiplegic stroke survivors undergoing rehabilitation at a tertiary hospital (University of Benin Teaching Hospital) in Benin City, Edo State, Nigeria. The study measured the impact of CIMT on upper limb function before and after the intervention. Adult patients with hemiplegia following a stroke was included in the trial.

The study is delimited to:

- Adult patients diagnosed with hemiplegia after a stroke and undergoing rehabilitation at a single tertiary healthcare centre in Benin City.
- Primarily upper-limb rehabilitation; lower-limb function was not evaluated.
- Patients with significant cognitive impairment, aphasia, or any other comorbid condition that would preclude participation in CIMT was excluded from the trial.
- The therapy and follow-up was confined to a specific time frame of 8 weeks.

1.8 Limitations of the study

Difficulty in monitoring participants' home activities, which could have positively or negatively influenced the study outcomes, was a limitation of this study .

1.9 Definition of Terms

Stroke: Stroke occurs when there is a rupture in the blood vessels of the brain (haemorrhagic) or a blockage to the blood vessels supplying the brain (ischemic).

Constraint Induced Movement Therapy (CIMT): CIMT is a rehabilitation technique used to improve the use of an affected limb while restricting the unaffected limb.

Hemiplegia: Total weakness or paralysis of one side of the body.

Upper-limb Function: Upper-limb function is the use of the upper extremities to carryout activities of daily living without any restriction or impairment.

Muscle Strength: Muscle strength is defined as the maximal force a muscle or muscle group can generate at a specified or determined velocity. (Knuttgen and Kraemer, 1987).

Muscle Endurance: Muscle endurance is the ability of a muscle or muscle group to exact force over a period of time.

Joint Flexibility: Joint flexibility is the ability of a joint to go through it’s full range without any restriction or pain.

Hand Function: Hand function is the use of the hand to perform activities like grasping, holding, pinching etc.

1.10 List of Abbreviations

ADL- Activities of Daily Living

AHA- American Heart Association

ASA- American Stroke Association

CDC- Center for Disease Control and Prevention

CIMT- Constraint-induced Movement Therapy

CVA- Cerebrovascular Accident

TBI- Traumatic Brain Injury

UBTH- University of Benin Teaching Hospital

CHAPTER 2

LITERATURE REVIEW

CONCEPTUAL FRAMEWORK

CIMT therapy is based on research by psychologist, Dr. Edward Taub and collaborators at the University of Alabama. Dr. Taub demonstrated that monkeys with a surgical deafferentation (i.e. where somatic sensation was abolished) of a forelimb, ceased using the affected extremity. Through failed attempts to use the deafferented forelimb, the monkeys developed compensation methods to avoid using the affected limb, that is, they effectively learned not to use their affected extremity. Dr. Taub hypothesized that the non-use was a learning mechanism and calls this behavior "Learned non-use". [(Uswatte *et al.*, 2006), (Taub and Uswatte)]

In the original concept and application in patients, the less affected arm-hand of a patient was immobilized in a sling (Wolf *et al.*, 1989;Taub *et al.*, 1993). This soon progressed to an emphasis on intensive, repetitive training - massed practice - of the more affected arm-hand. In the current application of the method, patients wear a mitt on the less-affected arm 90% of their waking hours and perform repetitive exercises with the more affected arm six to seven hours per day during two to three weeks (Taub & Wolf, 1997;Taub *et al.*, 2002).

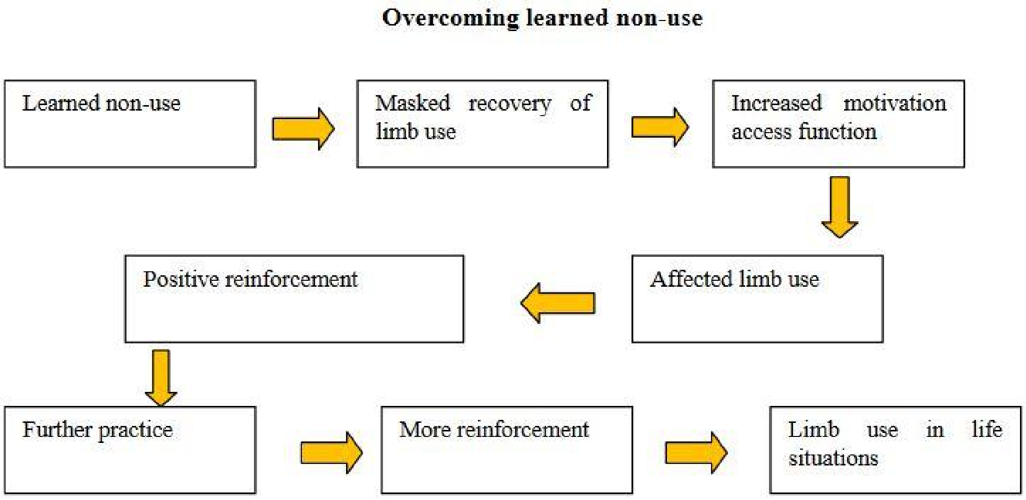

Figure 1: Overcoming learned non-use

Imagesource:

https://www.physiopedia.com/Constraint_Induced_Movement_Therapy

2.1 STROKE

2.1.1 Introduction

In 1970, the World Health Organization defined stroke as 'rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with apparent cause other than of vascular origin' (Aho *et al.*,1980).Although still widely used, the World Health Organization definition relies heavily on clinical symptoms and is now considered outdated by the American Heart Association and American Stroke Association due to significant advances in the 'nature, timing, clinical recognition of stroke and its mimics, and imaging findings that require an updated definition' (Sacco *et al.*, 2013). In 2013, the American Heart Association/American Stroke Association updated their endorsed definition of stroke to one that includes silent infarctions (inclusive of cerebral, spinal and retinal) and silent haemorrhages (Sacco *et* *al*.,2013). The 'traditional' clinical definition of stroke is still included by the American Heart Association/American Stroke Association, but the inclusion of 'silent' pathology is a significant addition. The rationale behind such a change was to move towards a radiological demonstration (tissue-based definition) of infarction or haemorrhage. According to the Centres for Disease Control and Prevention (CDC), common stroke symptoms observed in both men and women include sudden weakness, numbness, or paralysis affecting the arm, leg, or a specific part of the body, abrupt confusion, difficulty speaking, facial drooping on one side, vision impairment in one or both eyes, difficulty walking, dizziness, loss of balance and coordination, and a sudden, severe headache.

2.1.2 Epidemiology

Globally, stroke is the second leading cause of death and a significant contributor to long-term disability (Mira & Luft, 2018). According to the Global Burden of Disease Study 2020, the global prevalence of all stroke subtypes of 89.13 million cases and the age-standardized stroke prevalence rates were highest in sub-Saharan Africa and in certain regions of the Southeast United States and East and Southeast Asia. More specifically the global prevalence of ischemic stroke was 68.16 million cases and the age-standardized stroke prevalence rates were highest in sub-Saharan Africa and in the Eastern United States. The global prevalence of intracerebral hemorrhage was 18.88 million cases with the age-standardized stroke prevalence rates being highest in Southeast Asia, western sub-Saharan Africa, and Oceania. Subarachnoid hemorrhage has a global prevalence of 8.09 million cases and the age-standardized stroke prevalence rates were highest in Latin, America and Japan (Tsao *et al*., 2022). Regarding incidence, the global incidence of stroke was 11.71 million people, and the incidence of ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage was 7.59 million, 3.41 million, and 0.71 million people, respectively (Tsao *et al*., 2022). Globally, in terms of mortality, of the 7.08 million people who died from stroke in 2020, 49% of total deaths were due to ischemic stroke. Intracerebral hemorrhage and subarachnoid hemorrhage were the cause of 46% and 5% of total stroke-related deaths, respectively (Tsao *et al*., 2022). In the United States alone in 2021, 1 in 6 cardiovascular disease-related deaths were due to stroke. Furthermore, someone has a stroke every 40 seconds and someone dies from a stroke every 30 minutes and 14 seconds (CDC, 2023). Undoubtedly, on a local and international level, stroke has placed a significant burden on the lives of stroke patients and the surrounding community.

In Africa, the occurrence of stroke is 316 per 100,000 individuals, while in Nigeria it was reported to be 26 per 100,000 individuals annually (Akinyemi *et al*., 2021). Stroke has emerged as the leading cause of adult neurological admissions in various studies conducted within the West African sub-region, constituting as much as 65 percent of such admissions (Ekenze, 2010). Additionally, it stands out as the primary reason for admissions linked to hypertension-related issues, contributing to 40% of hypertensive complications (Onwuchekwa & Chinenye, 2010)

Research on the epidemiology of stroke in Nigeria has been limited. Enwereji *et al*, (2014) reported a prevalence of stroke at 1.63 per 1,000 population in 2011. They found a higher prevalence in males, reaching 1.99 per 1,000 compared to females at 1.28 per 1,000 population In a study conducted by Adeloye *et al.* (2019), the annual incidence of stroke in Nigeria was reported at 26.0/100,000 population, with a higher rate observed among men (34.1/100, 000 population per year) compared to women (21.2/100,000 population per year). Additionally, Adeloye *et al*. (2019) noted that the prevalence of stroke survivors in Nigeria was 6.7/1000 population of stroke victims, with a higher prevalence among men (6,4/1000) compared to women (4.4/1000 population of stroke victims). Furthermore, Adeloye *et al*. (2019) highlighted regional disparities, indicating that the prevalence of stroke survivors was highest in the South-south region at 13.4/100,000 population and among, rural dwellers at 10.8/100,000.

2.1.3 Pathophysiology

A stroke is described as an abrupt neurological outburst caused by inadequate blood vessel perfusion to the brain. Understanding neurovascular anatomy is essential for studying the clinical manifestations of stroke. The blood supply to the brain is controlled by two internal carotids anteriorly and two vertebral arteries posteriorly (the Willis circle). Ischaemic strokes are caused by insufficient blood and oxygen delivery to the brain, whereas hemorrhagic strokes are caused by bleeding or leaky blood vessels.

Ischemic occlusions contribute to around 85% of casualties in stroke patients, with the remainder due to intracerebral bleeding. Ischemic occlusion generates thrombotic and embolic conditions in the brain (*Musuka et al., 2015)*. In thrombosis, the blood flow is affected by narrowing of vessels due to atherosclerosis. The build-up of plaque will eventually constrict the vascular chamber and form clots, causing thrombotic stroke. In an embolic stroke, decreased blood flow to the brain region causes an embolism; the blood flow to the brain reduces, causing severe stress and untimely cell death (necrosis). Necrosis is followed by disruption of the plasma membrane, organelle swelling and leaking of cellular contents into extracellular space (*Broughton et al., 2009)* and loss of neuronal function. Other key events contributing to stroke pathology are inflammation, energy failure, loss of homeostasis, acidosis, increased intracellular calcium levels, excitotoxicity, free radical-mediated toxicity, cytokine-mediated cytotoxicity, complement activation, impairment of the blood–brain barrier, activation of glial cells, oxidative stress and infiltration of leukocytes *(Woodruff et al., 2011;Gelderblom et al., 2009;Suh et al., 2008;Qureshi et al., 2003;Wang et al., 2007).*

Hemorrhagic stroke accounts for approximately 10–15% of all strokes and has a high mortality rate. In this condition, stress in the brain tissue and internal injury cause blood vessels to rupture. It produces toxic effects in the vascular system, resulting in infarction (*Flaherty et al., 2005).* It is classified into intracerebral and subarachnoid hemorrhage. In ICH, blood vessels rupture and cause abnormal accumulation of blood within the brain. The main reasons for ICH are hypertension, disrupted vasculature, excessive use of anticoagulants and thrombolytic agents. In subarachnoid hemorrhage, blood accumulates in the subarachnoid space of the brain due to a head injury or cerebral aneurysm (*Testai et al., 2008;Aronowski et al., 2011).*

2.1.4 Risk factor

Non-modifiable risk factors

i. Age

Advanced age is a non-modifiable risk factor for stroke. Risk increases with age due to the cumulative effect of other risk factors. As individuals grow older, changes occur in blood vessels, increasing susceptibility to stroke (Sacco *et al.*, 2013). Stroke is a disease of aging. The incidence of stroke increases with age, with the incidence doubling for each decade after age 55 (Roger *et al*., 2012).

ii. Sex

The relationship of sex to stroke risk depends on age. At young ages, women have as high or higher risk of stroke as men, though at older ages, the relative risk is slightly higher for men (*Kapral et al., 2005).* The higher stroke risk among women at younger ages likely reflects risks related to pregnancy and the post-partum state, as well as other hormonal factors, such as use of hormonal contraceptives. Overall, more strokes occur in women than men, due to the longer lifespan of women compared to men (*Roger et al., 2012;Reeves et al., 2009)* . A study performed in 8 different European countries found that the risk of stroke increased by 9% per year in men, and 10% per year in women (*Asplund et al., 2009)*

iii. Race

There are well-documented racial disparities in stroke (Cruz-Flores *et al*., 2011). African Americans are at twice the risk of incident stroke when compared to their white counterparts, and have higher mortality associated with stroke (Cruz-Flores *et al*., 2011). Black race has been identified as a factor in the relationship between rurality and stroke risk, (Howard *et al*., 2011; Joubert *et al*., 2008), but this could be attributed to issues with access to healthcare [(Cruz-Flores *et al*., 2011), (Stansbury *et al*., 2005), (Kimball *et al*., 2014). Other factors that may influence racial-ethnic differences in stroke risk include other social determinants of disease, language, and nativity [(Kleindorfer *et al*., 2012), (Moon *et al*., 2012)]. The racial disparity in stroke mortality is being driven by the racial disparities in stroke incidence, highlighting the importance of stroke prevention interventions aimed at minority groups (Howard *et al*., 2016). Interestingly, the association seen between black race and stroke, while strong for incident stroke, does not remain for recurrent stroke (Howard *et al*., 2016). This could be due to stroke risk factors being addressed upon discharge from the primary stroke event.

iv. Genetics

Genetic factors are also known to be non-modifiable risk factors for stroke with parental history and family history increasing the risk of stroke. (Seshadri *et al*., 2010;Schulz *et al*., 2004;Touze *et al*., 2008).

Modifiable risk factors

The modifiable risk factors are of utmost importance, as intervention strategies aimed at reducing these factors can subsequently reduce the risk of stroke. Early identification and modification of risk factors is imperative (Testai *et al*., 2008). Modifiable risk variables are further classified into medical illnesses and behavioural risk factors. Many "traditional" risk factors for stroke, such as hypertension, diabetes, hyperlipidaemia, and smoking, have long been recognised.

i. **Hypertension**

Respondents who have a history of hypertension are at risk of 75% strokes (Wayunah & Saefulloh, 2016). High blood pressure can cause severity in atherosclerosis and cause intracerebral lesions due to affected autoregulation of blood flow to the brain (Martiningsih, 2016). Hypertension is also one of the most severe stroke risk factors encountered in stroke patients (Nugraha *et al*., 2018).

ii. Diabetes Mellitus and Blood Sugar Levels

The relative risk of stroke in people with DM ranges from 1.8-6 with a tendency to occur in young patients (Nugraha *et al*., 2018). The explanation of diabetes mellitus also states that DM triggers atherosclerosis and increases hypertension event because of the 2-fold risk of cerebral infarction resulting in changes in the vascular system (Martiningsih, 2016).

iii. Smoking

Smoking is one of the bad lifestyles and can increase the risk of stroke by 1.5 times (Simbolon *et al*., 2018;Faisal *et al*., 2015). Smoking also results in atherosclerosis, thus increasing the occurrence of thrombus, (Wayunah & Saefulloh, 2016). In addition, smoking can cause blood viscosity, fibrinogen, and platelet aggregation as well as lower HDL cholesterol and raise blood pressure (Nugraha *et al*., 2018).

iii. Dyslipidaemia and Cholesterol Levels

Plasma lipids and proteins increase the risk of cerebral infarction (Nugraha *et al*., 2018). LDL levels exceeding 150 mg/dL increase the risk of brain blood vessel blockage (Wayunah & Saefulloh, 2016).

iv. **Obesity**

The World Health Organisation (WHO) defines obesity as an excess accumulation of body fat, commonly defined as having a body mass index (BMI) greater than 30 kg/m². Obesity has become a major global public health concern in recent decades, and adopting healthy lifestyle choices alone can significantly reduce the risk of developing cerebrovascular diseases like stroke by up to 55% (Horn *et al*., 2021). Reducing the risk of obesity includes exercising, being physically active, eating a diet high in fruits and vegetables, losing excess weight, and changing lifestyle choices by cutting back on alcohol and quitting smoking.

vi. Alcohol

One of an unhealthy lifestyle is consuming alcohol. Alcohol consumed will enter the blood and damage body tissues, especially the liver, trigger stress, thrombosis in the blood circulation, atherosclerosis, the rhythm of circadian is disrupted causing sleep disturbances, decreased memory, and increasing the sugar and fat levels (Cahyati & Rosdiana, 2017)

vii. Physical Inactivity

Living a sedentary lifestyle increases the risk of hypertension, diabetes, obesity, and cardiovascular disease, all of which are risk factors for stroke. Increased physical activity levels may reduce the risk of stroke in older persons (Willey *et al*. 2017).

2.1.5 Types of Stroke

Ischaemic stroke is the most common kind, accounting for more than 80% of all stroke occurrences, while haemorrhagic stroke accounts for less than 20% (Grysiewicz *et al*., 2008). However, there is continuous discussion among scholars about these figures. A study found that the occurrence of haemorrhagic stroke increased significantly in a specific population when compared to previous findings (Shiber *et al*., 2010). This increase was ascribed to greater accessibility and use of CT scans. It is worth noting that haemorrhagic stroke has a greater death rate than ischaemic stroke (Andersen *et al*., 2009).

Ischaemic Stroke

Ischemic stroke results from the blockage of cerebral vessels by plaques or clots. This process can be progressive, with plaques slowly forming and decreasing blood flow (Sacco *et al*., 2013). Ischaemic stroke is divided into three types: bigger vessel stroke (thrombotic and embolic), smaller vessel stroke (Lacunae stroke), and cardioembolic stroke.

i. Thrombotic Stroke: This type of ischaemic stroke results from the formation of a thrombus within the cerebral arteries, which is mostly caused by atherosclerosis. Plaque buildup in arterial walls narrows the lumen, lowering blood flow and limiting oxygen supply to brain areas. If the plaque fully stops the arterial, the tissue supplied by the artery may experience a cerebral infarction (Martin & Kessler, 2015).

iii. **Embolic Stroke:** An embolic stroke occurs when a thrombus forms in extracerebral arteries and lodges in the lumen of cerebral arteries. The stuck embolus might block a brain blood artery, causing tissue injury. These strokes are frequently related with cardiovascular conditions, particularly atrial fibrillation (Martin & Kessler, 2015).

iv. **Lacunae Stroke:** Arises from occlusion of smaller deep-penetrating branches of cerebral vessels. While often without symptoms, an accumulation of multiple infarcts can result in symptom manifestations (Gore *et al*., 2020).

v. **Cardioembolic Stroke:** This group comprises patients with arterial blockages likely caused by an embolism originating in the heart. Cardiac sources are categorized into high-risk and medium-risk groups based on their propensity for embolism. At least 1 cardiac source of an embolus must be identified to consider a possible or probable diagnosis of cardioembolic stroke. Clinical and brain imaging findings resemble those described for large-artery atherosclerosis. Evidence of a previous transient ischemic attack (TIA) or stroke in more than 1 vascular territory or systemic embolisms supports a clinical diagnosis of cardiogenic stroke. Possible large artery atherosclerotic sources of thrombosis or embolism should be ruled out. A stroke occurring in a patient with a medium-risk cardiac source of embolism and no other apparent cause of stroke is categorized as a possible cardioembolic stroke (Spence, 2018).

Haemorrhagic Stroke

This type of stroke happens when blood arteries rupture, causing bleeding and increased intracranial pressure. It can also manifest as bleeding from orifices (Parmar, 2018).

i. Intracerebral Haemorrhage (ICH): ICH stands as the second most prevalent form of stroke. ICH is typically caused by the rupture of small arteries, often due to hypertensive vasculopathy, cerebral amyloid angiopathy (CAA), coagulopathies, and other vasculopathies. Hypertensive vasculopathy is predominantly associated with non-lobar ICH (in regions such as the basal ganglia, thalamus, cerebellum, and brainstem), whereas CAA is more commonly linked to lobar ICH (Kremer *et al*., 2015). Several risk factors contribute to ICH, including advancing age, hypertension, CAA, smoking, excessive alcohol intake, sympathomimetic drugs, anticoagulants, and antiplatelet drugs (An *et al*., 2017;Magid-Bernstein *et al*., 2022).

ii. Subarachnoid Haemorrhage (SAH): Approximately 5% of all strokes are caused by spontaneous SAH due to a ruptured aneurysm in 85% of patients. Other causes of spontaneous SAH include drug use (such as amphetamines and cocaine), coagulopathy, a ruptured arteriovenous malformation, and vessel rupture due to a dural venous sinus thrombosis. Various risk factors are associated with SAH, including smoking, hypertension, excessive alcohol consumption, advancing age, personal history of another type of aneurysm or SAH, and family history of an intracranial aneurysm (Sweeney *et al*., 2016;Mahar *et al*., 2020).

Transient Ischemic Attack (TIA)

This is a type of stroke which involves a transient or temporary obstruction of blood flow, presenting with symptoms similar to a stroke but resolving within 24 hours, without signs of focal brain damage or infarction (Panuganti *et al*., 2022).

2.1.6 Anatomy of the brain

The Brain

The human brain is perhaps the most complex of all biological systems, with the mature brain consisting of around 100 billion information-processing cells known as neurones. (Stiles & Jernigan, 2010). The brain is an organ made up of nerve tissue that controls task-related responses, movement, senses, emotions, language, communication, thinking, and memory. The human brain has three primary parts: the cerebrum, cerebellum, and brainstem.

The Cerebrum

The cerebrum is the largest component of the brain. It is divided into right and left hemispheres. The corpus callosum is the collection of white matter fibers that joins these hemispheres.

Each of the cerebral hemispheres is further divided into four lobes: the frontal, parietal, temporal, and occipital lobes. The medial temporal lobe structures are considered by some to be part of the so-called limbic lobe. Some texts divide the brain into five lobes, insula being the fifth one (Chauhan *et al*., 2021).

Frontal lobe - The frontal lobe is distinguished from the parietal lobe posteriorly by the central sulcus (see the image below). It is involved in high-order cognitive processes, control of voluntary movement, and perception of sensory stimuli. The precentral gyrus within the frontal lobe houses the primary motor cortex, essential for voluntary movement. The frontal lobe also plays a key role in speech (Broca's area). (Netter, 2022;Herculano-Houzel, 2013;Chauhan *et al*., 2021).

Parietal lobe - It is located posterior to the frontal lobe and is separated from the frontal lobe by the central sulcus and from the occipital lobe by the parieto-occipital sulcus on the medial surface. The parietal lobe processes sensory information such as touch, temperature, and pain. The postcentral gyrus here contains the primary somatosensory cortex. (Netter, 2022;Herculano-Houzel, 2013;Chauhan *et al*., 2021).

Temporal lobe - It is located inferior to the frontal and parietal lobes, separated by the lateral sulcus (or the Sylvian fissure). The temporal lobe is crucial for auditory processing and memory formation, particularly via the hippocampus. It has other important roles, including speech, hearing, and vision (temporooccipital junction). (Netter, 2022;Herculano-Houzel, 2013;Chauhan *et al*., 2021).

Occipital lobe - It is located in the posterior part of the cerebrum. The occipital lobe is primarily responsible for visual processing, including color perception, visuospatial processing, facial recognition, and memory formation. (Netter, 2022;Herculano-Houzel, 2013;Chauhan *et al*., 2021).

The Cerebral Cortex

The outermost layer of the cerebrum is the cortex, which has a slightly gray appearance — hence the term "gray matter." The cortex has a folded structure; each fold is termed as a gyrus, while each groove between the folds is termed as a sulcus. This cortical folding is now known to enhance cognitive functions and neural connectivity (Netter, 2022;Dziedzic *et al.*, 2021;Chauhan *et al.*, 2021).

The Brain Stem

Positioned in the middle of the brain, the brainstem serves as a link connecting the cerebrum to the spinal cord, comprising the midbrain, pons, and medulla (Fernández- Gil *et al.*, 2010).

Midbrain

The midbrain, also termed as the mesencephalon, is the superior most aspect of the brainstem and plays a crucial role in various functions, particularly related to movement, vision, and hearing. Structurally, the midbrain consists of several key components. (Netter, 2022;Ruchalski and Hathout, 2012).

Cerebral peduncles - These are bundles of nerve fibers that connect the forebrain to the hindbrain. They contain motor pathways that transmit signals from the cortex to the spinal cord, facilitating movement control. Between these peduncles, the third cranial nerve (oculomotor nerve) exits ventrally, contributing to eye movement control. (Netter, 2022;Ruchalski and Hathout, 2012).

Tectum - The posterior region contains two pairs of protrusions known as the superior and inferior colliculi. The superior colliculi are involved in processing visual information and mediating eye movements, while the inferior colliculi manage auditory information and sound localization. (Netter, 2022;Ruchalski and Hathout, 2012).

Cranial nerves - The third cranial nerve (oculomotor) exits from the ventral aspect, and the fourth cranial nerve (trochlear) exits dorsally — this unique dorsal exit is one of the distinguishing features of the trochlear nerve. The trochlear nerve then wraps around the brainstem to assist in eye movement. (Netter, 2022;Ruchalski and Hathout, 2012).

The posterior aspect of the midbrain has two pairs of characteristic protrusions, the superior and inferior colliculi. The superior colliculi are involved in mediating the vestibulo-ocular reflex, whereas the inferior colliculi are involved in sound localization. The midbrain also houses several important nuclei and gray matter structures, including the substantia nigra, which produces dopamine that is crucial for motor function and is affected in Parkinson's disease. Additionally, it contains the red nucleus, which plays a role in motor coordination. Overall, the midbrain integrates sensory information and coordinates motor responses, playing a pivotal role in maintaining bodily functions and facilitating interaction with our environment. (Netter, 2022;Ruchalski and Hathout, 2012).

Pons

The pons is a critical structure in the brainstem, located above the medulla and below the midbrain. It plays a significant role in connecting various parts of the brain, notably acting as a bridge between the cerebellum and cerebrum. The blood supply to the pons primarily comes from branches of the basilar artery [(Netter, 2022), (Árraga *et al.*, 2016)]. Its ventral surface has a characteristic band of horizontal fibers. These fibers are the pontocerebellar fibers that are in turn projections from the corticopontine fibers. They cross to enter the contralateral middle cerebellar peduncle and thus enter the cerebellum.

On either side of the midline, there are bulges that are produced by the descending corticospinal tracts. At the pontomedullary junction, the sixth cranial nerve (abducens) can be seen exiting the brainstem. Laterally, but anterior to the middle cerebellar peduncle, the fifth cranial nerve (trigeminal) is seen exiting the brainstem. Below the middle cerebellar peduncle, the seventh and eighth cranial nerves (facial and vestibulocochlear) can be seen exiting. Dorsally, the pons forms the floor of the fourth ventricle.

The pons is divided into two main parts: the ventral (basilar) pons and the pontine tegmentum. The ventral pons contains the pontine nuclei and the transverse pontocerebellar fibers, while the pontine tegmentum houses the cranial nerve nuclei and various ascending and descending tracts. (Netter, 2022;Árraga *et al.*, 2016).

The pons is a vital component of the brainstem anatomy, serving as a conduit for signals between various parts of the nervous system while housing critical nuclei that influence numerous physiological functions. (Netter, 2022;Árraga *et al.*, 2016).

Medulla oblongata

The medulla oblongata, or simply medulla, is continuous and superior to the cervical spinal cord. There are several external anatomical features of the medulla that can be visible grossly. Ventrally, the pyramids and pyramidal decussation is visualized just below the pons. These are the descending corticospinal tracts. Just lateral to the pyramids, the rootlets of the hypoglossal nerve can be seen as they exit the brainstem. Lateral to the rootlets of the hypoglossal nerve is the inferior olive. Dorsolateral to the inferior olive, the rootlets of the ninth and tenth cranial nerves (glossopharyngeal and vagus) exit.

Dorsally, two pairs of protrusions are visible, which are the gracile tubercles medially and the cuneate tubercles just lateral to those. These represent the nuclei where sensory information from the dorsal columns is relayed onto thalamic projection neurons. Just superior to these protrusions is the floor of the fourth ventricle, which bears several characteristic impressions. The vagal trigone is the dorsal nucleus of the vagus nerve (cranial nerve X) and lies inferiorly, just below the hypoglossal trigone.

The medulla oblongata also houses the nuclei of the four inferior most cranial nerves: the glossopharyngeal nerve (CN IX), vagus nerve (CN X), accessory nerve (CN XI), and hypoglossal nerve (CN XII). The medulla oblongata serves as a critical hub for autonomic control and sensory-motor integration. Its complex anatomy reflects its multifaceted roles in maintaining homeostasis and facilitating communication between various parts of the nervous system. (Netter, 2022;Diek *et al.*, 2022).

The Cerebellum

The cerebellum occupies the posterior fossa, dorsal to the pons and medulla. It is involved primarily in modulating motor control to enable precisely coordinated body movements. Similar to the cerebrum, which has gyri and sulci, the cerebellum has finer folia and fissures that increase the surface area.

The cerebellum is divided into three main lobes — anterior, posterior, and flocculonodular — each of which contributes to various functional regions such as the vestibulocerebellum (involved in balance and eye movements), spinocerebellum (posture and coordination), and cerebrocerebellum (planning and voluntary movements). (Netter, 2022;Zhang *et al.*, 2023;Aparicio *et al.*, 2021).

The cerebellum consists of two hemispheres, connected by a midline structure called the vermis. In contrast to the neocortex of the cerebrum, the cerebellar cortex has three layers: molecular, Purkinje, and granular. There are four deep cerebellar nuclei: the fastigial, globose, emboliform, and dentate nuclei, in sequence from medial to lateral. These deep nuclei interact with other brain regions to coordinate movement (Netter, 2022;Zhang *et al.*, 2023;Aparicio *et al.*, 2021). The afferent and efferent pathways to and from the cerebellum exist within the three cerebellar peduncles: superior, middle, and inferior. These pathways carry both afferent and efferent signals essential for motor coordination and sensory processing. (Netter, 2022;Zhang *et al.*, 2023;Aparicio *et al.*, 2021).

2.1.7 Arterial Blood supply of the Brain

The brain receives blood from two sources: the **internal carotid arteries**, which arise at the point in the neck where the common carotid arteries bifurcate, and the **vertebral arteries** . The internal carotid arteries branch to form two major cerebral arteries, the anterior and **middle cerebral arteries**. The right and left vertebral arteries come together at the level of the pons on the ventral surface of the brainstem to form the midline **basilar artery**. The basilar artery joins the blood supply from the internal carotids in an arterial ring at the base of the brain (in the vicinity of the hypothalamus and cerebral peduncles) called the circle of Willis. The **posterior cerebral arteries** arise at this confluence, as do two small bridging arteries, the **anterior and posterior communicating arteries**.

Conjoining the two major sources of cerebral vascular supply via the circle of Willis presumably improves the chances of any region of the brain continuing to receive blood if one of the major arteries becomes occluded (Purves *et al.*, 2001).

Circle of Willis

Structure and Function

Structure

The circle of Willis is a ring of vessels connecting the anterior and posterior circulations of the brain. The ring is bounded anteriorly by a single anterior communicating artery (ACom), which connects the bilateral anterior cerebral arteries (ACA). The ACAs course posterolaterally until reaching their lateral-most connection to the ICA, which runs cephalically through the neck and into the brain. As each Internal Carotid Artery (ICA) runs its course, they individually give off an ophthalmic artery. At the point of connection between the ACA and the ICA, the lateral continuation of the ICA becomes the middle cerebral artery (MCA). Coursing posteromedially from each ACA-ICA junction is the posterior communicating artery (PCom). The PCom connects the MCA with the posterior cerebral arteries (PCA), which form the posterior-most aspect of the CoW. The bilateral PCAs fuse to become the basilar artery (BA). The BA courses caudally along the anterior pons, giving off many branches, including the superior cerebellar arteries, and pontine arteries, and the anterior inferior cerebellar artery. The BA then divides into the bilateral VAs, which each gives off a posterior inferior cerebellar artery (PICA) and contributes to the formation of a single anterior spinal artery. (Prince and Ahn, 2013;Menshawi *et al.*, 2015;Krishnaswamy *et al.* 2010;Robben *et al.*, 2016).

Function

The circle of Willis acts to provide collateral blood flow between the anterior and posterior circulations of the brain, protecting against ischemia in the event of vessel disease or damage in one or more areas.

2.1.8 Clinical Signs, Symptoms and Complications of Stroke

The common manifestations of an ischemic stroke include the abrupt onset of weakness or numbness in the face, arm, or leg, challenges in speech or comprehension, visual disturbances, dizziness, lack of balance and coordination, and intense headaches. Conversely, a hemorrhagic stroke is identified by a sudden and severe headache, accompanied by symptoms like nausea, vomiting. weakness or numbness in the arms, legs, or face, seizures, and a loss of consciousness (Johnston *et al*., 2018). Additional indications of a stroke encompass difficulties in swallowing, difficulty speaking, sensory and cognitive deficit, hemineglect, and a tendency to push away from the weaker side (Martin & Kessler, 2015).

When the blood supply to an area of the brain is compromised, it leads to dysfunction in the functions controlled by that specific region. The clinical manifestations of arterial occlusion can vary depending on the affected artery.

2.1.9 Diagnosis of Stroke

A review of medical history, coupled with a thorough physical examination and several diagnostic tests, can aid in the diagnosis of a stroke, determining its type, location, and severity (Choi *et al*., 2022).

Patient History: Gathering a thorough patient history is crucial for uncovering underlying pathology and guiding clinical decisions. Open-ended questions allow patients to express their thoughts, symptoms, and concerns, providing essential information. Key aspects of history taking include the onset, symptoms, course, duration, associated factors, and the initial response to illness (Nichol *et al*., 2023).

Physical Examination: A systematic and continuous process, physical examination involves objectively assessing anatomical deviations. The clinician observes the patient's gait, use of ambulatory aids, orthotic devices, speech, and extremity manipulation. Beginning with observation and followed by palpation, the examination aims to identify signs such as lacerations, redness, swelling, muscle atrophy, asymmetry, and deformities.

Neurological Assessment: Neurological assessment evaluates an individual's neurological integrity, covering mental status, cranial nerves, motor coordination, sensory examination, and gait assessment.

Mental Status Assessment: Assesses consciousness, alertness, orientation, cognitive ability, memory, speech, and language. Tools like mini-mental status exam scale (MMSE), Glasgow coma scale (GCS), Grady coma scale, and others aid in assessing different aspects of mental status.

Cranial Nerves Examination: The evaluation of cranial nerves, an integral aspect of neurological assessment, ensures the proper functioning of cranial nerves. These nerves. originating from distinct areas of the brain play crucial roles in motor, sensory, and autonomic functions within the head and neck. Any compromise in the associated brain regions can lead to impaired cranial nerve function (Reese *et al*., 2023).

Motor Examination: Assessing muscle integrity and function is central to the motor examination. Overlying muscles are carefully examined for signs of lacerations, bruises, swelling, muscle atrophy, and deformities. Muscle strength and muscle tone testing using the Oxford Muscle Grading System and the modified Ashworth scale (MAS) are some outcome measures used. Additionally, ROM is compared between the affected and unaffected sides.

Sensory Examination: This examination involves assessing responses to stimuli, identifying any absent, diminished, exaggerated, or delayed responses. Possible causes include issues with peripheral nerve endings, the spinal cord, tracts, thalamus, brainstem, or cortex (Shahrokhi & Asuncion, 2023). Distinct sensations are classified

based on sensory receptors.

- Superficial Sensation: Originating from the environment, these stimuli are detected by exteroceptors, including pain, temperature, and touch.

Assessment methods include pin-prick for pain, thermal discrimination testing for temperature, and light touch using the tail end of a cotton swab.

- Deep Sensation: Arising from joints, muscles, ligaments, tendons, and fasciae, responses are elicited by proprioceptors. Kinesthesia, vibration sense, and position sense (proprioception) are evaluated using joint movement tests and Romberg's test.

Cortical Sensation: Generated from both proprioceptors and exteroceptors, sensations like stereognosis, barognosis two-point discrimination, graphesthesia, recognition of texture, and tactile localization are assessed.

Coordination:

Assesses motor coordination through tests like dysmetria and dysdiadochokinesia, evaluating rhythm and rapidly alternating movements.

Gait:

Begins with the patient's entrance, observing gait abnormalities that may indicate underlying issues. Specific gait patterns, such as high steppage gait, provide insights into potential weaknesses or abnormalities.

Radiological investigations

Neuroimaging is crucial in the assessment of stroke patients, particularly those with acute ischemic stroke. It serves a vital role in distinguishing stroke from other conditions that mimic its symptoms, such as migraine headaches, tumors, seizures, metabolic disturbances, and peripheral or cranial nerve disorders. Additionally, neuroimaging aids in the early detection of hemorrhagic stroke, differentiation between irreversible infarcted tissues and salvageable tissue, identification of vascular malformations, planning for intravenous thrombolysis and intra-arterial thrombectomy, and predicting outcomes (Hand *et al*., 2006).

Some radiological imaging techniques include Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasonography, and Angiography.

Laboratory Investigations

Laboratory investigations are a good tool for diagnosing stroke and ruling out other conditions as well as guiding treatment choices. Some of these laboratory tests include:

- Full Blood Count (FBC): This involves assessing platelet levels, crucial for blood clotting. The examination also includes measuring clectrolyte levels to evaluate kidney function.
- Coagulation Assessment: Through tests like Prothrombin Time (PT) and Partial

Thromboplastin Time (PTT), the rate of blood clotting can be determined. Prolonged clotting time may indicate potential bleeding issues.

2.1.10 Management of Stroke

Physiotherapy management

Rehabilitative physiotherapy main goal is to lessen impairment and disabilities so that stroke victims can resume their regular selfcare and daily activities as independent as possible(Dobkin & Dorsch, 2013). There are different physiotherapy approaches or concepts that have been developed to manage stroke patients. Generally, physiotherapy techniques in stroke management include: Strengthening exercises, Functional Electrical Stimulation, Balance and coordination training, Proprioceptive Neuromuscular Facilitation, Sustained Passive Stretching, Mirror Therapy, Virtual Reality (Dobkin & Dorsch, 2013).

Constraint-induced movement therapy (CIMT): CIMT seeks to counteract "learned non-use" by restricting the movement of the unaffected limb while intensively training the affectedlimb. By doing so, it encourages the use and relearning of motor skills in the affected limb, promoting functional recovery (Dobkin & Dorsch, 2013).

2.2 CIMT

2.2.1 Definition

Constraint-Induced Movement Therapy (CIMT), also known as CI, is a "rehabilitative strategy". It is aimed at improving the functional use of an affected extremity for those who are impacted by stroke or other neurological conditions. It uses principles of mass practice while restraining the neurologically stronger limb.(Fritz *et al.*, 2012) It has also been defined as a **behavioural approach** to neurorehabilitation, making use of simple behavioural techniques - shaping being a predominant theme. (Taub & Uswatte, 2006)

CIMT has been described as including the essential components of rehabilitation following neurological injury, which comprise of: (Taub & Uswatte, 2006)

- **Repetition** - task orientated in manner.
- **Constraining** of patients, so as to induce use of the impaired limb or function.
- **Application** of a "package of behavioural methods" which allow the transference of skills learned in the clinical settings to that of the real-world environment.

While initially developed for the stroke population, it is also being used in populations affected by cerebral palsy, traumatic brain injury, phantom limb pain, focal hand dystonia in musicians and multiple sclerosis.(Barghi *et al.*, 2017)

2.2.2 CIMT Candidates

Diagnoses which may benefit most from CIMT are:

- Stroke (Cerebrovascular accidents)
- Traumatic Brain Injury
- Spinal cord injury
- Multiple sclerosis
- Cerebral palsy (Hemiplegia)

Stroke

In a Swedish paper published in 2006, participants who benefitted from CIMT were those who had suffered a stroke and had: (Brogårdh, 2006)

- Some hand function
- High motivation
- Minimal cognitive dysfunction
- Adequate balance
- Adequate walking ability while wearing the restraint to be eligible to participate in CIMT interventions. In a paper published in 2006 by Taub & Uswatte, commenting on CIMT on the upper limb for stroke patients, the 10 x 10 x 10 eligibility criteria could be used in selecting a patient for CIMT:
- 10 degrees active wrist extension on the affected hand
- 10 degrees active thumb abduction on the affected hand
- 10 degrees active extension of any other two digits on the affected hand

Also in order for CIMT be most beneficial in the stroke population, it was suggested that these candidates demonstrated the following: (Brogårdh, 2006)

- Limited spasticity ($0,1,1^+$) according to modified Ashworth scale.
- Ability to move the affected arm 45 degrees of shoulder flexion and abduction, and 90 degrees of elbow flexion and extension.
- Adequate balance.
- Minimal cognitive dysfunction.

2.2.3 Components of CIMT

There are 3 major components of CIMT:(Uswatte *et al.*, 2006)

- Shaping

- Task practice

- Packaging of behavioural techniques.

- **Shaping** is a training method in which a motor task is gradually made more difficult. Shaping programs are individualized, consisting of 10-15 tasks selected primarily from a basic battery of tasks. Each task is usually performed in a set of 10-30 sec trials. At the end of each set of 10 trials, the task is changed. Only one shaping parameter is changed at a time. *Requires shaping constant therapist involvement.*

- **Task practice** is repetitive practice of individual functional tasks that takes roughly 15-20mins. Rest is provided as required. Encouragement is given on an infrequent basis (i.e. every 5 mins) with feedback at the end of the task as well about how they performed. Task practice requires less therapist involvement.

- **Packaging** of behavioural techniques (or the administration of a transfer package) is designed to transfer gains from the clinic to daily life. It includes a behavioral contract that improves adherence to the rehabilitation process. It also includes components such as a log book daily assignments and engaging patients in problem solving. Furthermore, this allows for the identification of barriers and problem-solving to overcome these obstacles. The daily administration of a motor activity log promotes adherence.

2.2.4 Restraints

The restraints commonly used for CIMT includes (Charles *et al.*, 2005):

- Sling

- Plaster cast

- Triangular bandage
- Splint
- Sling combined with a resting hand splint
- Half glove
- Mitt

2.2.5 Models of CIMT

The treatment models are commonly explained in two methods:

1. **Unmodified CIMT**: Uses a variety of approaches that promote the affected limb for 90% of the individuals waking hours. Only activities involving toileting, hygiene and bathing are permitted. This is done by constraining or reducing the use of the unaffected extremity for 2-3 weeks. The most common form of constraints used for the upper extremity are slings, mitts with velcro or resting hand splints. (Gauthier *et al.*, 2009;Page *et al.*, 2002)

2. **Modified CIMT**: This is more pragmatic model. The program consists of 3 hour per day for 5 days/week, for a minimum of 4 successive weeks. In total there will be 20 treatment sessions totaling to 60 hours. The client is expected to use his/her affected extremity for a minimum of the five "top arm use hours" at home during each week day. (Brogårdh & Sjölund, 2006)

2.2.6 Advantages to CIMT

The following have been identified as advantages in the use of CIMT: (Richards *et al.*, 2006;Sterr *et al.*, 2002)

- Overall greater improvement in function than traditional treatment.

- Highly researched and highly credible treatment approach.
- There are brain activity and observed gray matter reorganization in primary motor, cortices and hippocampus.
- Increase social participation.
- Decrease in medical cost over lifetime.

2.2.7 Side Effects

Few studies have reported harms associated with CIMT, such as burns, minor skin lesions and muscle soreness (stiffness and discomfort) in the affected upper extremity (Hakkennes & Keating, 2005). Shoulder pain in the acute phase after stroke has not been shown to increase after wearing a constraint. Patient endures many hours of frustration (Ploughman & Corbett)

2.3 EMPIRICAL REVIEW OF LITERATURE

Azevedo *et al*. carried out a study in 2022 to Identify whether CIMT is superior to usual techniques to enhance activity and participation outcomes in stroke survivors. Systematic Review & Meta-Analysis were used as the study design. A total of 21 studies were included for analysis. The results show that CIMT results in more significant gains in the functional use of the upper limb in ADL and functional independence, demonstrating superior activity and participation results in stroke survivors when compared to conventional therapies.

Ghanzafar *et al.*, carried out a study in 2024 to assess and compare the effectiveness of Constraint-Induced Movement Therapy (CIMT) and Proprioceptive Neuromuscular Facilitation (PNF) in improving upper limb function in patients with hemiplegic stroke, based on randomized controlled trials (RCTs) conducted between 2020 to 2024. The inclusion criteria focused on randomized controlled trials (RCTs) involving hemiplegic patients who received either Constraint-Induced Movement Therapy (CIMT) or Proprioceptive Neuromuscular Facilitation (PNF). Four studies were selected based on the inclusion criteria. The primary assessment tools were the Fugl-Meyer Assessment (FMA), Motor Activity Log (MAL), functional motor, and spasticity tests. The review identified and compared the effects of Constraint-Induced Movement Therapy (CIMT) and Proprioceptive Neuromuscular Facilitation (PNF) on upper limb motor function in stroke patients. All four studies reported improvements in motor function, with results favoring CIMT over PNF. The Functional Mobility Assessment (FMA) scores indicated significantly greater improvements in patients receiving CIMT than those undergoing PNF.

Hyoseon Choi and Hyun Jung Kim carried out a study in 2024 to evaluate the effect of constraint-induced movement therapy (CIMT) on arm function and daily living compared with conventional rehabilitation in stroke patients with hemiplegia, a systematic review and meta-analysis were the study design used. A total of 34 randomized controlled trials (RCTs) were included herein. Specifically, 21 RCTs regarding arm motor function, 13 on upper limb motor impairment, and 12 on activities of daily living (ADL) performance were analysed. The results of the meta-analysis demonstrated that CIMT was significantly more effective than conventional therapy in improving arm motor function, reducing upper limb motor impairment, and enhancing ADL performance.

Lingling Marinda Palupi *et al.*, carried out a study in 2020 to discover the combination effects of Range of Motion Exercise (ROM) and Constraint Induced Movement Therapy (CIMT) to the changes of upper extremity functional ability by using a measuring tool Chedoke Arm and Hand Activity Inventory form (CAHAI) to stroke patients with hemiparesis. The research uses Quasi Experimental with non-Equivalent Control Group design. The respondents were chosen by using Consecutive Sampling technique with a total of 34 respondents divided into two groups. 17 respondents as the treatment group were given combination therapy of ROM and CIMT and 17 respondents as control group were given ROM therapy only.. The Statistical test was done by using Paired T-test and Independent T-test. The research concluded that the combination of Range of Motion Exercise (ROM) and Constraint Induced Movement Therapy (CIMT) can increase the upper extremity functional ability so that it can be used as an alternative of exercise therapy to increase the upper extremity functional ability of stroke patients.

Miki Kurnia Fitrizah *et al.*, carried out a study in 2025 to determine the effect of Constraint Induced Movement Therapy on gripping strength in stroke patients. The study used a type of quantitative research with a pre-experimental design approach with a one-group pre-test-post test design, namely research carried out for a population group of 60 patients and a sample of 10 patients. The bivariate statistical analysis method used in this study is the Paired T Test.The results of the study obtained the average value of grasping strength before Constraint Induced Movement Therapy, which was 9,150. The results obtained the average value of grasping strength after Constraint Induced Movement Therapy which was 12,950. The results of the bivariate analysis test with the T test showed that there was an effect of Constraint Induced Movement Therapy on grasping strength in stroke patients with a p value = 0,000. The results of the study suggest to provide Constraint Induced Movement Therapy exercises with longer application and are expected to be used to administer Constraint Induced Movement Therapy to stroke patients who experience grasping weakness.

Rodriguez *et al.*, carried out a study in 2024 to determine the effectiveness of CIMT through Telerehabilitation for upper extremity function in stroke patients. 30 post-stroke participants were selected on the basis of inclusion and exclusion criteria, and allocated into group A and group B. Group A was treated with CIMT in the physiotherapy department and group B was treated with CIMT through TR. Outcome measures were the Fugl-Meyer Assessment scale for upper extremities (FMA-UE), the Wolf Motor Function Test (WMFT), and the Motor Activity Log (MAL).CIMT via TR was equally effective than CIMT in physiotherapy department for upper extremity function in stroke.

Vandhana carried out a study in 2012 to investigate the effectiveness of constraint induced movement therapy and conventional physiotherapy in improving hand and wrist function in the hemiparetic stroke patients. Descriptive analytical study was done by using paired‘t’ test and unpaired‘t’ test. 20 patients with hemiparetic stroke were included in this study and randomly divided into two groups A and B each group consist of 10 subjects. Group A was treated with Constraint induced movement therapy. Group B was treated with Conventional physiotherapy. Wrist and hand functions were assessed before and after intervention by Fugl-meyer scale. The statistical result shows that there is improvement in both the groups. But when comparing both it was found that Constraint induced movement therapy is more effective than conventional physiotherapy in hemiparetic stroke patients.

Zafar *et al*., carried out a study in 2023 to compare the effectiveness of CIMT and traditional OT in enhancing upper limb function in stroke survivors. The comparison was based on changes in the Fugl-Meyer Assessment for Upper Extremity (FMA-UE) and the Stroke Impact Scale (SIS). Randomized clinical trial involved 40 adult stroke survivors, who were assigned to either CIMT (n=20) or traditional OT (n=20). Assessments using FMA-UE and SIS were conducted before and after the intervention. Both CIMT and traditional OT were effective in improving upper limb function and reducing stroke impact. Traditional OT, however, demonstrated a slightly greater improvement.

2.4 SUMMARY OF REVIEWED LITERATURE

This chapter offered a comprehensive overview of the theoretical, clinical, and rehabilitative circumstances around stroke and Constraint-Induced Movement Therapy (CIMT). It began talking about the theoretical underpinning of CIMT, which is based on Dr. Edward Taub's concept of "learnt non-use" and the importance of intensive practice in rehabilitating the damaged limb following a stroke. It also covered the definition, epidemiology, pathophysiology, risk factors, and forms of stroke, stressing both ischemic and hemorrhagic strokes, their processes, and clinical implications. It emphasised the global and local prevalence of stroke, notably in Sub-Saharan Africa and Nigeria, and identified both modifiable and non-modifiable risk factors for stroke occurrence. A complete anatomical review of the brain and its arterial blood supply was presented. Additionally, clinical indicators, diagnostic techniques, and sequelae of stroke were investigated, as well as detailed neurological and functional assessments important to physiotherapy. This chapter then turned focus to stroke management, with a special emphasis on physiotherapy. Several rehabilitation approaches were presented, with a major focus on CIMT. CIMT was defined, along with its fundamental components (shaping, task practice, and behavioural packing), appropriate patient profiles, and treatment models (modified and unmodified CIMT). This chapter also discussed the benefits and potential adverse effects of CIMT.

Finally, an empirical evaluation of current studies found that CIMT is more effective than standard rehabilitation approaches and alternative physiotherapy procedures. These trials consistently shown CIMT's greater effect on upper limb function and daily activity performance in stroke patients. Most of these studies where carried out among the Caucasian population, this study was therefore done to know the effectiveness of CIMT among the black population especially in Benin City.

CHAPTER 3

MATERIALS AND METHODS

3.1 Participants

This study population consist of 60 hemiplegic stroke survivors treated at the Physiotherapy Department of the University of Benin Teaching Hospital (UBTH) in Benin City, (UBTH Medical Records, 2025). Participants included both male and female survivors between the ages of 18 to 65 years, who had hemiplegia. They were recruited from the outpatient stroke rehabilitation clinic and educated about the study's nature before giving their agreement.

3.1.1.1 Inclusion Criteria

i. Adults between ages of 18 to 65 diagnosed with their first stroke.
ii. Hemiplegia combined with mild to moderate upper limb motor impairment.
iii. Capable of actively extending the wrist and fingers by at least 10°.
iv. The ability to understand and follow simple directions.

3.1.1.2 Exclusion Criteria

i. Severe stiffness or contractures in the affected upper limb (modified Ashworth Scale >2).
ii. Cognitive impairments or aphasia causing difficulty understanding.
iii. Upper limb problems that coexist with neurological or orthopaedic disorders.
iv. Unstable medical conditions (e.g., uncontrolled hypertension, cardiac conditions).

3.2 Materials

3.2.1 Apparatus/Instruments

Medical Research Council (MRC) Scale for Muscle Strength

Universal Goniometer

Handheld Dynamometer

Pinch Gauge

Soft Mitt Restraint (Bandage)

3.2.2 Description of Instruments

Medical Research Council (MRC) Scale for Muscle Strength

The MRC Scale for Muscle Strength is a commonly used scale for assessing muscle strength from Grade 5 (normal) to Grade 0 (no visible contraction). It was originally described by the Medical Research Council in 1943. It helps clinicians determine the level of muscle function by testing against resistance or gravity.

Validity: Bohannon (2005) noted its clinical utility but emphasized its inability to detect small, clinically important changes, especially in moderate strength ranges.

Reliability: Vanhoutte *et al*. (2012) showed inter-rater reliability improved significantly with training and standardized protocols but remained moderate for grade 4.

Score: The score is graded from grade 0 to 5.

0: No contraction

1: Flicker or trace of contraction

2: Active movement, with gravity eliminated

3: Active movement against gravity

4: Active movement against gravity and resistance

5: Normal power

Universal Goniometer

Description: Goniometry is the art and science of measuring joint ranges in all planes of the joint. (viraj *et al*., 2020). The term 'goniometry' is derived from the Greek words 'gonia' meaning angle and 'metron' meaning measure; thus, goniometry refers to the measurement of angles, which in rehabilitation contexts means the measuring of angles in each plane at the body's joints. The goniometer is the most commonly used instrument for measuring range of motion. (viraj *et al*., 2020) To assess a patient's range of motion in a specific joint, the therapist can use a goniometer at the initial assessment and again in subsequent sessions to ensure the intervention is effective. It has movable arm, fulcrum and a stationery arm.

Validity: Gajdosik *et al*. (2015) in a systematic review concluded that while more sophisticated tools exist (like motion capture), universal goniometry demonstrates "good criterion validity" when compared to radiographic measurements for many joints, especially when strict protocols and anatomical landmarks are followed.

Reliability: Rothstein *et al*. (1983) demonstrated that standardized training significantly improves inter-tester reliability for elbow flexion/extension measurements.

Score: The score is the measured angle in degree.

Electronic Handheld Dynamometer (EHD)

Description: Camry EHD, EH101 Model (Camry Scale-USA, 2020) is a portable device which was used to the grip strength. Grip strength is a measure of muscular strength or the maximum force/tension generated by one's forearm muscles. It can be used as a screening tool for the measurement of upper body strength and overall strength.

Validity: Validity refers to how accurately the dynamometer measures what it is intended to measure. Wikholm and Bohannon (1991) found a high correlation (r = 0.90) between hand-held dynamometer scores and isokinetic dynamometry in measuring quadriceps strength.

Reliability: Reliability refers to the consistency of the measurement across time and different assessors. Katoh and Yamasaki (2009) found intra-rater ICCs > 0.90 when using a hand-held dynamometer to measure hip abductor strength.

Score: The device would be recorded in kilograms.

Mechanical Pinch Gauge (MPG)

Description: MPG, PG-30 Model (North Coast Medical, Inc., 2020) is a hand-held instrument used to measure the strength of the pinch grip, typically in pounds (lbs.) or kilograms (kg). It is a clinical instrument used to measure the force generated by the fingers and thumb during pinch grips, providing an objective assessment of fine motor strength and hand function. The device typically measures force during various pinch types—such as tip pinch (thumb pulp to fingertip), key or lateral pinch (thumb pulp to lateral aspect of index finger), and palmar or three-jaw pinch (thumb pulp to index + middle finger pulps) by registering the maximal voluntary contraction when the patient pinches the gauge.

Validity: The extent to which the instrument measures what it is supposed to measure (i.e. true pinch strength, and how well it correlates with related constructs). In 2024 systematic review observed strong to very strong correlations between pinch strength and grip strength (r = 0.72 to 0.92) across studies, which supports convergent validity (i.e. pinch strength is related to general hand strength). They also reported moderate to strong correlations between pinch strength and dexterity assessments (e.g. fine motor tasks) (r ≈ 0.78–0.80). However, correlations with patient-reported outcome measures (PROMs) are weaker (r ≈ 0.03–0.50), suggesting that pinch strength is only one component of patient-perceived hand function. (American Society of Hand Therapists, 2024).

Reliability: The consistency or repeatability of the measurements (e.g. test–retest, inter-rater, intra-rater). In 2024 systematic review “Reliability, validity, and responsiveness of pinch strength assessment” found that most reliability studies report good to excellent reliability (ICC > 0.75) for both healthy and clinical populations. In healthy or musculoskeletal populations, reliability can reach excellent levels (ICC > 0.90). For neurological populations, reliability is more variable, but generally still good (ICC > 0.75). (American Society of Hand Therapists, 2024).

Score: It is measured in Kilograms (Kg).

Soft mitt restraint (Bandage)

It was used to restrict the unaffected upper-limb in the CIMT group.

3.3 Methods

3.3.1 Research Design

A Randomized Controlled Trial, pretest-posttest control group experimental design was used in this study. The design was adopted because it was appropriate for comparing the differences in upper extremities muscle strength, muscle endurance, joints ROM and hand function (grip strength and pinch strength) of stroke survivors prior to and following 8-week CIMT. The design provided avenue through which differences were checked. The design is illustrated as follows:

R	O_1		O_2
R	O_1	X	O_2

Where;

R= Randomization

O_1=Pretest

O_2= Posttest

X= CIMT

3.3.2 Sampling Technique

A total of 52 participants were recruited using a simple random sampling technique based on specific inclusion and exclusion. In this method, every patient had an equal chance of being selected in the sample from the population. Simple random sampling ensures that each patient in a population has an equal chance of being chosen. Furthermore, in this strategy, participants picked a group symbolized by letters A or B written on a piece of paper from a bag with A representing control and B representing experimental. Participants were randomly assigned into either the experimental (CIMT) or control group, with 28 participants in the experimental group and 24 participants in the control group.

About 12 of the participants (8 experimental and 4 control) withdrew from participating in the research, leaving the total number of participants that participated in the research to 40 (20 experimental and 20 control).

The sample size was determined using cochran's formula (Cochran, 1977).

3.3.3 Sample size

Calculated using Cochran's formula (Cochran, 1977)

To calculate the sample size using Cochran's formula, we use the following formula:

$n_0 = (Z^2 * p * (1 - p)) / e^2$

Where:

- n_0 = initial sample size (before finite population correction)

-n = population size is 110 (UBTH Medical Records, 2025)

- Z = Z-score (1.96 for 95% confidence level)

- p = estimated proportion of an attribute (use 0.5 if unknown for maximum variability)

- e = desired level of precision (margin of error, e.g., 0.05 for ±5%)

Step 1: Calculate n_0

Assuming:

- Z = 1.96

- p = 0.5

- e = 0.05

$n_0 = (1.96)^2 * 0.5 * (1 - 0.5) / (0.05)^2$

$= 3.8416 * 0.25 / 0.0025$

$= 0.9604 / 0.0025$

$= 384.16$

So, $n_0 \approx 384$

Step 2: Apply Finite Population Correction

Since the population size (n) is 60, we apply the finite population correction formula:

$n = n_0 / [1 + ((n_0 - 1) / N)]$

$n = 384 / [1 + ((384 - 1) / 60)]$

$= 384 / [1 + (383 / 60)]$

$= 384 / [1 + 6.38]$

$= 384 / 7.38$

$= 52.03$

Sample size ≈ 52 participants (rounded up)

3.3.4 Research Procedure/Procedure for Data Collection

Following ethical approval and permission, baseline assessments were carried out using the MRC scale, goniometer, electronic handheld dynamometer and mechanical pinch gauge. The experimental group underwent CIMT, which involved: Using a bandage to restrain the unaffected hand for 30 minutes. Performing task-specific training with the affected limb for 30 minutes each day, three times per week, for eight weeks. The control group received conventional physiotherapy (infra red radiation, functional electrical stimulation, soft tissue mobilization, muscle strengthening exercises, active and passive range of motion exercises). Following the eight weeks intervention, both groups underwent post-test assessments using the same tools (MRC scale, goniometer, electronic handheld dynamometer and mechanical pinch gauge).

3.3.5 Procedure for Assessment/Measurements

Medical Research Council (MRC) scale was used to access the patient's muscle strength, the patient was put in a right and comfortable position for testing the specific muscle group. The patient was then asked to perform specific movements, like flexing elbow or extending the elbow etc. If the patient can move fully against gravity, the researcher will slowly push against the limb, at the distal end, to test how strong the muscle is. How much resistance a patient can handle helps show the difference between grades 3, 4, and 5. If the patient cannot move against gravity, the patient will then have to lie on their side, where gravity has less effect. This helps to check for some movement (grade 2) or feel the muscle contract (grade 1). If there is no muscle activity, the muscle gets a grade of 0.

Goniometric measurement (for ROM). The patient was placed in a comfortable, relaxed, and in the right anatomical position. The joint that was measured was exposed and placed according to standard measuring rules. Usually, the joint was placed in a neutral position, allowing it to move fully in the direction being measured. The anatomical landmarks was identified by the researcher, that guided the placement of the goniometer's arms. These are usually the axis of rotation (fulcrum) and the proximal and distal bony landmarks. The center (fulcrum) of the goniometer is carefully aligned with the joint's axis (for example, the lateral epicondyle for elbow flexion). The stationary arm was then aligned with the proximal segment of the limb, and the movable arm was aligned with the distal segment. The patient was then instructed to perform the desired active or passive movement, such as flexion, extension, while the researcher maintained the position of the fulcrum and stationary arm. Once the movement was complete, the movable arm was adjusted to match the new position of the limb, and the angle of motion was read from the goniometer's scale. The measurement was documented.

Muscle endurance (Arm curl up). The patient sat on a chair, with their back straight, feet flat on the floor, the arm was stationary while the forearm was placed in a supine position, the patient was asked to bend the elbow towards him or herself and returning back to the starting position which completed one repetition this was done for 30 seconds. After 30 seconds the number of repetition was recorded.

Electronic hand-held dynamometer (for grip strength). The patient was placed in a stable, standardized posture that focused on the muscle group that was tested, usually seated or lying down to minimize compensatory movements. The researcher then placed the dynamometer's sensor pad against the distal portion of the limb segment being tested, such as just above the wrist for elbow flexion. While stabilizing the proximal part of the limb to prevent movement, the clinician instructed the patient to exert maximal isometric force against the device for a set duration, usually 3 to 5 seconds. Counter-resistance was provided, either by holding the dynamometer stationary or resisting the patient's forceful movement. After the contraction, the force displayed on the dynamometer was recorded in kilograms.

Mechanical pinch gauge (pinch strength). The patient was seated with the shoulder adducted and neutrally rotated, the elbow flexed at 90 degrees, the forearm in a neutral position, and the wrist slightly extended, as this posture minimizes compensatory movement and promotes consistency in testing. The pinch gauge was positioned between the appropriate fingers, and the patient was asked to squeeze with maximum effort without using the other hand or body for support. The researcher then stabilized the device without adding resistance or support that can affect the reading, and ensured the patient maintains correct form throughout the attempt. The patient held the pinch for about 3–5 seconds while the gauge registers the peak force, which was then recorded. This process was typically repeated two more times with rest intervals to prevent fatigue, and the average of the three trials was calculated to represent the patient’s pinch strength.

All instruments was administered and the scores obtained for each group was recorded for pre intervention and post intervention.

3.3.6 Ethical Considerations

The University of Benin Teaching Hospital (UBTH) Research Ethics Committee provided ethical approval. All subjects provided informed consent prior to enrolment. The confidentiality of participants' information was preserved by giving identifying codes rather than utilising names. Participants were informed of their right to withdraw from the study at any time, with no impact on their ongoing treatment.

3.3.7 Data Analysis

The frequency and constituent ratio (%) were used to describe the categorical data. The measurement data used the Shapiro-Wilk normality test. The mean ± standard deviation was used to describe the data that conforms to a normal distribution. One-way ANOVA was used to analyse the effect of CIMT on upper limb function among hemiplegic stroke survivors. Moreover, $p < 0.05$ indicated a statistical significance. All the analyses were performed with the use Statistical Package for the Social Sciences (SPSS) version 27.

CHAPTER 4

RESULTS

4.1 Results

The main purpose of this study was to evaluate the effectiveness of Constraint-Induced Movement Therapy (CIMT) on upper limb function among hemiplegic stroke survivors. A total of 40 participants with 20 per group were recruited from the neurology out-patient unit, Department of Physiotherapy, University of Benin Teaching Hospital. Participants were randomly distributed into 2 groups of experimental (CIMT) and control.

4.1.1 Sociodemographic characteristics of the participants

A total of 40 participants were recruited for this study. 52.5% of the participants were male and 47.5% of the participants were female. The age of the participants ranged between 27 and 65 years with a mean value of 55.78 and standard deviation of 8.30. About 70% of the participants had Ischemic stroke while 30% of the participants had Hemorrhagic stroke. This is reflected in Table 1.

Table 1: Descriptive Statistics of the Demographic Parameters of the Participants N = 40

Variables	Frequency	Percentage(%)	Mean	Standard Deviation
Gender				
Male	21	52.5		
Female	19	47.5		
Age			55.78	8.30
Types of Stroke				
Ischemic	28	70.0		
Hemorrhagic	12	30.0		

4.1.2 Overall Main Effects of CIMT on Upper - Limb Muscle Strength (One -Way ANOVA)

In table 2, the overall effect of intervention between the two groups and their corresponding pretest and posttest treatment scores showed that the ANOVA results were consistent and significant across all 6 assessed parameters of upper limb muscle strength. The F-statistics of shoulder flexion muscle strength (10.069) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of shoulder extension muscle strength (10.178) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of elbow flexion muscle strength (12.830) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of elbow extension muscle strength (10.117) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of elbow flexion muscle strength (13.100) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of wrist extension muscle strength (9.185) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$.

Table 2: One -Way ANOVA showing the Main and Interaction Effects of CIMT on Muscle Strength of Upper Limb of the Participants

		Sum of Squares	df	Mean Square	F	Sig.
Shoulder flexion MS	Between Groups	12.938	3	4.313	10.069	<.001
	Within Groups	32.550	76	.428		
	Total	45.488	79			
Shoulder extension MS	Between Groups	11.450	3	3.817	10.178	<.001
	Within Groups	28.500	76	.375		
	Total	39.950	79			
Elbow flexion MS	Between Groups	12.737	3	4.246	12.830	<.001
	Within Groups	25.150	76	.331		
	Total	37.887	79			
Elbow extension MS	Between Groups	12.500	3	4.167	10.117	<.001
	Within Groups	31.300	76	.412		
	Total	43.800	79			
Wrist flexion MS	Between Groups	24.200	3	8.067	13.100	<.001
	Within Groups	46.800	76	.616		
	Total	71.000	79			
Wrist extension MS	Between Groups	15.137	3	5.046	9.185	<.001
	Within Groups	41.750	76	.549		
	Total	56.887	79			

MS- Muscle Strength

4.1.3 Post-Hoc Comparison of Mean Difference for Muscle Strength

Table 2 shows the results of the variate test. A statistically significant ($p<0.05$) difference was found in the muscle strength of the participants exposed and not exposed to CIMT. Since the result is significant the hypothesis 1 is rejected. This therefore, brought about probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on muscle strength of the participants. The results of these interactions are presented in Table 3.

Table 3: Tukey's Honestly Significant Difference (HSD) Post-Hoc Comparison of Mean Difference for Muscle Strength of Upper Limb Function of the Participants

Dependent Variable	(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Shoulder flexion MS	Pretestcont	Posttestcont	-.350	.207	.335
		Pretestexp	-.150	.207	.887
		Posttestexp	-1.050*	.207	.000
	Posttestcont	Pretestcont	.350	.207	.335
		Pretestexp	.200	.207	.769
		Posttestexp	-.700*	.207	.006
	Pretestexp	Pretestcont	.150	.207	.887
		Posttestcont	-.200	.207	.769
		Posttestexp	-.900*	.207	.000
	Posttestexp	Pretestcont	1.050*	.207	.000
		Posttestcont	.700*	.207	.006
		Pretestexp	.900*	.207	.000
Shoulder extension MS	Pretestcont	Posttestcont	-.150	.194	.866
		Pretestexp	.350	.194	.278
		Posttestexp	-.700*	.194	.003
	Posttestcont	Pretestcont	.150	.194	.866
		Pretestexp	.500	.194	.056
		Posttestexp	-.550*	.194	.029
	Pretestexp	Pretestcont	-.350	.194	.278
		Posttestcont	-.500	.194	.056
		Posttestexp	-1.050*	.194	.000
	Posttestexp	Pretestcont	.700*	.194	.003
		Posttestcont	.550*	.194	.029
		Pretestexp	1.050*	.194	.000
Elbow flexion MS	Pretestcont	Posttestcont	-.350	.182	.227
		Pretestexp	-.400	.182	.133
		Posttestexp	-1.100*	.182	.000
	Posttestcont	Pretestcont	.350	.182	.227
		Pretestexp	-.050	.182	.993
		Posttestexp	-.750*	.182	.001
	Pretestexp	Pretestcont	.400	.182	.133
		Posttestcont	.050	.182	.993
		Posttestexp	-.700*	.182	.001
	Posttestexp	Pretestcont	1.100*	.182	.000
		Posttestcont	.750*	.182	.001
		Pretestexp	.700*	.182	.001
Elbow extension MS	Pretestcont	Posttestcont	-.350	.203	.318
		Pretestexp	-.200	.203	.758
		Posttestexp	-1.050*	.203	.000
	Posttestcont	Pretestcont	.350	.203	.318
		Pretestexp	.150	.203	.881
		Posttestexp	-.700*	.203	.005

	Pretestexp	Pretestcont	.200	.203	.758
		Posttestcont	-.150	.203	.881
		Posttestexp	-.850*	.203	.000
	Posttestexp	Pretestcont	1.050*	.203	.000
		Posttestcont	.700*	.203	.005
		Pretestexp	.850*	.203	.000
Wrist flexion MS	Pretestcont	Posttestcont	-1.100*	.248	.000
		Pretestexp	.000	.248	1.000
		Posttestexp	-1.100*	.248	.000
	Posttestcont	Pretestcont	1.100*	.248	.000
		Pretestexp	1.100*	.248	.000
		Posttestexp	.000	.248	1.000
	Pretestexp	Pretestcont	.000	.248	1.000
		Posttestcont	-1.100*	.248	.000
		Posttestexp	-1.100*	.248	.000
	Posttestexp	Pretestcont	1.100*	.248	.000
		Posttestcont	.000	.248	1.000
		Pretestexp	1.100*	.248	.000
Wrist extension MS	Pretestcont	Posttestcont	-.300	.234	.578
		Pretestexp	.200	.234	.829
		Posttestexp	-.950*	.234	.001
	Posttestcont	Pretestcont	.300	.234	.578
		Pretestexp	.500	.234	.152
		Posttestexp	-.650*	.234	.034
	Pretestexp	Pretestcont	-.200	.234	.829
		Posttestcont	-.500	.234	.152
		Posttestexp	-1.150*	.234	.000
	Posttestexp	Pretestcont	.950*	.234	.001
		Posttestcont	.650*	.234	.034
		Pretestexp	1.150*	.234	.000

MS- muscle strength, Pretestcont- Pretest control, Posttestcont- Posttest control, Pretestexp- Pretest experiment, Posttest experiment

4.1.4 Interpretation of Post-Hoc Comparison of Mean Difference for Muscle Strength

Tukey's Honestly Significant Difference (HSD) Post-Hoc Test was carried out to determine the interaction effects of the independent intervention groups on muscle strength of upper limb of the participants. The upper limb muscle strength, some of the pair wise of mean difference were found to be statistically insignificant ($p>0.05$) except Shoulder flexion pretestcont versus posttestexp (-1.050^*), Shoulder flexion posttestcont versus posttestexp ($-.700^*$), Shoulder flexion pretestexp versus posttestexp ($-.900^*$), Shoulder flexion posttestexp versus pretestcont (1.050^*), Shoulder flexion posttestexp versus posttestcont ($.700^*$), Shoulder flexion posttestexp versus pretestexp ($.900^*$), Shoulder extension pretestcont versus posttestexp ($-.700^*$), Shoulder extension posttestcont versus posttestexp ($-.550^*$), Shoulder extension pretestexp versus posttestexp (-1.050^*), Shoulder extension posttestexp versus pretestcont ($.700^*$), Shoulder extension posttestexp versus posttestcont ($.550^*$), Shoulder extension posttestexp versus pretestexp (1.050^*), Elbow flexion pretestcont versus posttestexp (-1.100^*), Elbow flexion posttestcont versus posttestexp ($-.750^*$), Elbow flexion pretestexp versus posttestexp ($-.700^*$), Elbow flexion posttestexp versus pretestcont (1.100^*), Elbow flexion posttestexp versus posttestcont ($.750^*$), Elbow flexion posttestexp versus pretestexp ($.700^*$), Elbow extension pretestcont versus posttestexp (-1.050^*), Elbow extension posttestcont versus posttestexp ($-.700^*$), Elbow extension pretestexp versus posttestexp ($-.850^*$), Elbow extension posttestexp versus pretestcont (1.050^*), Elbow extension posttestexp versus posttestcont ($.700^*$), Elbow extension posttestexp versus pretestexp ($.850^*$), Wrist flexion pretestcont versus posttestcont (-1.100*), Wrist flexion pretestcont versus posttestexp (-1.100*), Wrist flexion posttestcont versus pretestcont (1.100*), Wrist flexion posttestcont versus pretestexp (1.100*), Wrist flexion pretestexp versus posttestcont (-1.100*), Wrist flexion pretestexp versus posttestexp (-1.100*), Wrist flexion posttestexp versus pretestcont (1.100*), Wrist flexion posttestexp versus pretestexp (1.100*), Wrist extension pretestcont versus posttestexp (-.950*), Elbow extension posttestcont versus posttestexp (-.650*), Wrist extension pretestexp versus posttestexp (-.1.150*), Wrist extension posttestexp versus pretestcont (.950*), Wrist extension posttestexp versus posttestcont (.650*), Wrist extension posttestexp versus pretestexp (1.150*) as shown in the Table 3. This implies that the entire pair wise mean had variation. Therefore, conventional treatment had no substantial influence on the upper limb muscle strength of the participants. However, CIMT had substantial influence on the upper limb muscle strength of the participants.

4.1.5 Overall Main Effects of CIMT on Upper - Limb Muscle Endurance (One -Way ANOVA)

A highly significant main effect was found across the comparison groups in the muscle endurance ANOVA (Table 4). A significant level of $p<0.001$ was linked to the resulting F- statistics of 7.179.

Table 4: One-Way ANOVA showing the Main and Interaction Effects of CIMT on Muscle Endurance of Upper Limb of the Participants

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	637.237	3	212.412	7.179	<.001
Within Groups	2248.650	76	29.587		
Total	2885.887	79			

4.1.6 Post-Hoc Comparison of Mean Difference for Muscle Endurance

Table 4 shows the results of the variate test. A statistically significant ($p<0.05$) difference was found in the muscle endurance of the participants exposed and not exposed to CIMT. Since the result is significant the hypothesis 2 is rejected. This therefore, brought about probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on muscle endurance of the participants. The results of these interactions are presented in Table 5.

Table 5: Tukey's Honestly Significant Difference (HSD) Post-Hoc Comparison of Mean Difference for Muscle Endurance of Upper Limb Function of the Participants

(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Pretestcont	Posttestcont	-3.300	1.720	.229
	Pretestexp	-.400	1.720	.996
	Posttestexp	-7.050*	1.720	.001
Posttestcont	Pretestcont	3.300	1.720	.229
	Pretestexp	2.900	1.720	.338
	Posttestexp	-3.750	1.720	.138
Pretestexp	Pretestcont	.400	1.720	.996
	Posttestcont	-2.900	1.720	.338
	Posttestexp	-6.650*	1.720	.001
Posttestexp	Pretestcont	7.050*	1.720	.001
	Posttestcont	3.750	1.720	.138
	Pretestexp	6.650*	1.720	.001

Pretestcont- Pretest control, Posttestcont- Posttest control, Pretestexp- Pretest experiment, Posttest experiment

4.1.7 Interpretation of Post-Hoc Comparison of Mean Difference for Muscle Endurance

Tukey's Honestly Significant Difference (HSD) Post-Hoc Test was carried out to determine the interaction effects of the independent intervention groups on muscle endurance of upper limb of the participants. The upper limb muscle endurance, all the pair wise of mean difference were found to be statistically insignificant ($p>0.05$) except pretestcont versus posttestexp (-7.050^*), pretestexp versus posttestexp (-6.650^*), posttestexp versus pretestcont(7.050^*), posttestexp versus pretestexp (6.650^*) as shown in Table 5. This implies that the entire pair wise mean had variation. Therefore, conventional treatment had no substantial influence on the upper limb muscle endurance of the participants. However, CIMT had substantial influence on the upper limb muscle endurance of the participants.

4.1.8 Overall Main Effects of CIMT on Upper - Limb Joint Flexibility (One -Way ANOVA)

In table 6, the overall effect of intervention between the two groups and their corresponding pretest and posttest treatment scores showed that the ANOVA results were consistent and significant across all 6 assessed parameters of upper limb joint flexibility. The F-statistics of shoulder flexion joint flexibility (6.040) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of shoulder extension joint flexibility (7.744) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of elbow flexion joint flexibility (10.521) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p<0.001$. The F-statistics of elbow flexion joint flexibility (3.901) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p=0.012$. The F-statistics of wrist extension joint flexibility (4.746) was large implying that the variance between groups is much larger than the variance within groups and a significant level of $p=0.004$.

Table 6: One-Way ANOVA showing the Main and Interaction Effects of CIMT on Joint Flexibility of Upper Limb of the Participants

		Sum of Squares	df	Mean Square	F	Sig.
Shoulder flexion RM	Between Groups	6212.500	3	2070.833	6.040	<.001
	Within Groups	26055.700	76	342.838		
	Total	32268.200	79			
Shoulder extension RM	Between Groups	1467.850	3	489.283	7.744	<.001
	Within Groups	4802.100	76	63.186		
	Total	6269.950	79			
Elbow flexion RM	Between Groups	7099.938	3	2366.646	10.521	<.001
	Within Groups	17095.750	76	224.944		
	Total	24195.688	79			
Wrist flexion RM	Between Groups	2343.937	3	781.312	3.901	.012
	Within Groups	15222.550	76	200.297		
	Total	17566.488	79			
Wrist extension RM	Between Groups	1608.737	3	536.246	4.746	.004
	Within Groups	8586.750	76	112.984		
	Total	10195.488	79			

RM- Range of Motion

4.1.9 Post-Hoc Comparison of Mean Difference for Joint Flexibility

Table 6 shows the results of the variate test. A statistically significant ($p<0.05$) difference was found in the joint flexibility of the participants exposed and not exposed to CIMT. Since the result is significant the hypothesis 3 is rejected. This therefore, brought about probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on joint flexibility of the participants. The results of these interactions are presented in Table 7.

Table 7: Tukey's Honestly Significant Difference (HSD) Post-Hoc Comparison of Mean Difference for Joint Flexibility of Upper Limb Function of the Participants

Dependent Variable	(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Shoulder flexion RM	Pretestcont	Posttestcont	-7.900	5.855	.535
		Pretestexp	-1.850	5.855	.989
		Posttestexp	-22.450*	5.855	.001
	Posttestcont	Pretestcont	7.900	5.855	.535
		Pretestexp	6.050	5.855	.731
		Posttestexp	-14.550	5.855	.070
	Pretestexp	Pretestcont	1.850	5.855	.989
		Posttestcont	-6.050	5.855	.731
		Posttestexp	-20.600*	5.855	.004
	Posttestexp	Pretestcont	22.450*	5.855	.001
		Posttestcont	14.550	5.855	.070
		Pretestexp	20.600*	5.855	.004
Shoulder extension RM	Pretestcont	Posttestcont	-5.750	2.514	.110
		Pretestexp	3.500	2.514	.508
		Posttestexp	-7.050*	2.514	.032
	Posttestcont	Pretestcont	5.750	2.514	.110
		Pretestexp	9.250*	2.514	.002
		Posttestexp	-1.300	2.514	.955
	Pretestexp	Pretestcont	-3.500	2.514	.508
		Posttestcont	-9.250*	2.514	.002
		Posttestexp	-10.550*	2.514	.000
	Posttestexp	Pretestcont	7.050*	2.514	.032
		Posttestcont	1.300	2.514	.955
		Pretestexp	10.550*	2.514	.000
Elbow flexion RM	Pretestcont	Posttestcont	-7.900	4.743	.349
		Pretestexp	-7.850	4.743	.355
		Posttestexp	-25.700*	4.743	.000
	Posttestcont	Pretestcont	7.900	4.743	.349
		Pretestexp	.050	4.743	1.000
		Posttestexp	-17.800*	4.743	.002
	Pretestexp	Pretestcont	7.850	4.743	.355
		Posttestcont	-.050	4.743	1.000
		Posttestexp	-17.850*	4.743	.002
	Posttestexp	Pretestcont	25.700*	4.743	.000
		Posttestcont	17.800*	4.743	.002
		Pretestexp	17.850*	4.743	.002
Wrist flexion RM	Pretestcont	Posttestcont	-4.450	4.475	.753
		Pretestexp	8.150	4.475	.272
		Posttestexp	-5.650	4.475	.589
	Posttestcont	Pretestcont	4.450	4.475	.753
		Pretestexp	12.600*	4.475	.031
		Posttestexp	-1.200	4.475	.993

	Pretestexp	Pretestcont	-8.150	4.475	.272
		Posttestcont	-12.600*	4.475	.031
		Posttestexp	-13.800*	4.475	.015
	Posttestexp	Pretestcont	5.650	4.475	.589
		Posttestcont	1.200	4.475	.993
		Pretestexp	13.800*	4.475	.015
Wrist extension RM	Pretestcont	Posttestcont	-4.200	3.361	.598
		Pretestexp	6.550	3.361	.217
		Posttestexp	-4.600	3.361	.523
	Posttestcont	Pretestcont	4.200	3.361	.598
		Pretestexp	10.750*	3.361	.011
		Posttestexp	-.400	3.361	.999
	Pretestexp	Pretestcont	-6.550	3.361	.217
		Posttestcont	-10.750*	3.361	.011
		Posttestexp	-11.150*	3.361	.007
	Posttestexp	Pretestcont	4.600	3.361	.523
		Posttestcont	.400	3.361	.999
		Pretestexp	11.150*	3.361	.007

RM- Range of Motion, Pretestcont- Pretest control, Posttestcont- Posttest control, Pretestexp- Pretest experiment, Posttest experiment

4.1.10 Interpretation of Post-Hoc Comparison of Mean Difference for Joint Flexibility

Tukey's Honestly Significant Difference (HSD) Post-Hoc Test was carried out to determine the interaction effects of the independent intervention groups on joint flexibility of upper limb of the participants. The upper limb joint flexibility, all the pair wise of mean difference were found to be statistically insignificant ($p>0.05$) except Shoulder flexion pretestcont versus posttestexp (-22.450*), Shoulder flexion pretestexp versus posttestexp (-20.600*),Shoulder flexion posttestexp versus pretestcont(22.450*),Shoulder flexion posttestexp versus pretestexp (20.600*), Shoulder extension pretestcont versus posttestexp (-.7.050*), Shoulder extension posttestcont versus pretestexp (9.250*), Shoulder extension pretestexp versus posttestcont (-9.250*), Shoulder extension pretestexp versus posttestexp (-10.550*),Shoulder extension posttestexp versus pretestcont(7.050*),Shoulder extension posttestexp versus pretestexp (10.550*), Elbow flexion pretestcont versus posttestexp (-25.700*), Elbow flexion posttestcont versus posttestexp (-17.800*), Elbow flexion pretestexp versus posttestexp (-17.850*), Elbow flexion posttestexp versus pretestcont (25.700*), Elbow flexion posttestexp versus posttestcont (17.800*), Elbow flexion posttestexp versus pretestexp (17.850*), Wrist flexion posttestcont versus pretestexp (12.600*), Wrist flexion pretestexp versus posttestcont (-12.600*), Wrist flexion pretestexp versus posttestexp (-13.800*), Wrist flexion posttestexp versus pretestexp (13.800*), Wrist extension posttestcont versus pretestexp (10.750*), Wrist extension pretestexp versus posttestcont (-10.750*), Wrist extension pretestexp versus posttestexp (-11.150*), Wrist extension posttestexp versus pretestexp (11.150*), as shown in Table 5. This implies that the entire pair wise mean had variation. Therefore, conventional treatment had no substantial influence on the upper limb joint flexibility of the participants. However, CIMT had substantial influence on the upper limb joint flexibility of the participants.

4.1.11 Overall Main Effects of CIMT on Upper - Limb Hand Function (One -Way ANOVA)

The ANOVA for hand function (Table 8) demonstrated highly significant overall effects for both grip strength. The F-statistics for grip strength (F= 16.436) and pinch strength (F= 14.047) yielded a p value < 0.001.

Table 8: One-Way ANOVA showing the Main and Interaction Effects of CIMT on Hand function (Grip strength and Pinch strength) of Upper Limb of the Participants

		Sum of Squares	df	Mean Square	F	Sig.
Grip Strength	Between Groups	13.300	3	4.433	16.436	<.001
	Within Groups	20.500	76	.270		
	Total	33.800	79			
Pinch Strength	Between Groups	11.700	3	3.900	14.047	<.001
	Within Groups	21.100	76	.278		
	Total	32.800	79			

4.1.12 Post-Hoc Comparison of Mean Difference for Hand Function

Table 8 shows the results of the variate test. A statistically significant ($p<0.05$) difference was found in the hand function of the participants exposed and not exposed to CIMT. Since the result is significant the hypothesis 4 is rejected. This therefore, brought about probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on hand function of the participants. The results of these interactions are presented in Table 9.

Table 9: Tukey's Honestly Significant Difference (HSD) Post-Hoc Comparison of Mean Difference for Hand function (Grip strength and Pinch strength) of Upper Limb Function of the Participants

Dependent Variable	(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Grip Strength	Pretestcont	Posttestcont	-.500*	.164	.017
		Pretestexp	.050	.164	.990
		Posttestexp	-.950*	.164	<.001
	Posttestcont	Pretestcont	.500*	.164	.017
		Pretestexp	.550*	.164	.007
		Posttestexp	-.450*	.164	.038
	Pretestexp	Pretestcont	-.050	.164	.990
		Posttestcont	-.550*	.164	.007
		Posttestexp	-1.000*	.164	<.001
	Posttestexp	Pretestcont	.950*	.164	<.001
		Posttestcont	.450*	.164	.038
		Pretestexp	1.000*	.164	<.001
Pinch Strength	Pretestcont	Posttestcont	-.150	.167	.805
		Pretestexp	.050	.167	.991
		Posttestexp	-.900*	.167	<.001
	Posttestcont	Pretestcont	.150	.167	.805
		Pretestexp	.200	.167	.629
		Posttestexp	-.750*	.167	<.001
	Pretestexp	Pretestcont	-.050	.167	.991
		Posttestcont	-.200	.167	.629
		Posttestexp	-.950*	.167	<.001
	Posttestexp	Pretestcont	.900*	.167	<.001
		Posttestcont	.750*	.167	<.001
		Pretestexp	.950*	.167	<.001

Pretestcont- Pretest control, Posttestcont- Posttest control, Pretestexp- Pretest experiment, Posttest experiment

4.1.13 Interpretation of Post-Hoc Comparison of Mean Difference for Hand Function

Tukey's Honestly Significant Difference (HSD) Post-Hoc Test was carried out to determine the interaction effects of the independent intervention groups on hand function (grip strength and pinch strength) of upper limb of the participants. The upper limb hand function (grip strength and pinch strength), some of the pair wise of mean difference were found to be statistically insignificant ($p>0.05$) except Grip strength pretestcont versus posttestcont (-.500*), pretestcont versus posttestexp (-.950*), posttestcont versus pretestcont (.500*), posttestcont versus pretestexp (.550*), posttestcont versus posttestexp (-.450*), pretestexp versus posttestcont (-.550*), pretestexp versus posttestexp (-.1000*), posttestexp versus pretestcont (.950*), posttestexp versus posttestcont (.450*), posttestexp versus pretestexp (.1000*). Then for the Pinch strength pretestcont versus posttestexp (-.900*), posttestcont versus posttestexp (-.750*), pretestexp versus posttestexp (-.950*), posttestexp versus pretestcont (.900*), posttestexp versus posttestcont (.750*), posttestexp versus pretestexp (.950*) as shown in Table 7. This implies that the entire pair wise mean has no variation. Therefore, conventional treatment had substantial influence on the upper limb grip strength but not on the pinch strength of the participants. However, CIMT had substantial influence on the upper limb grip strength and pinch strength of the participants.

4.2 Hypothesis Testing

Hypothesis 1: There is no significant difference in upper extremity Muscle Strength in stroke survivors who undergo CIMT compared to those who do not.

Alpha level: 0.05

Test Statistics: One-Way ANOVA

Observed: $p<0.05$

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

Hypothesis 2: There is no significant difference in upper extremity Muscle Endurance in stroke survivors who undergo CIMT compared to those who do not.

Alpha level: 0.05

Test Statistics: One-Way ANOVA

Observed: $p<0.05$

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

Hypothesis 3: There is no significant difference in upper extremity Joint Flexibility in stroke survivors who undergo CIMT compared to those who do not.

Alpha level: 0.05

Test Statistics: One-Way ANOVA

Observed: $p<0.05$

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

Hypothesis 4: There is no significant difference in upper extremity Hand function (Grip strength and Pinch strength) in stroke survivors who undergo CIMT compared to those who do not.

Alpha level: 0.05

Test Statistics: One-Way ANOVA

Observed: $p<0.05$

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

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This study examined how upper limb function was affected by Constraint-Induced Movement Therapy (CIMT) in hemiplegic stroke survivors at the University of Benin Teaching Hospital, Benin City. Muscle strength, muscle endurance, joint flexibility (range of motion), and hand function (grip and pinch strength) were the primary variables that were accessed. Comparing participants who received CIMT to those who received conventional physiotherapy, the results showed statistically significant improvements in all evaluated variables. This section discusses the findings of the present study in relationship to some previous empirical findings. For clarity, the findings of this study are discussed under the following sub-headings;

- Effect of CIMT on muscle strength
- Effect of CIMT on muscle endurance
- Effect of CIMT on joint flexibility
- Effect of CIMT on hand function (grip strength and pinch strength)

Effect of CIMT on Muscle Strength

The results of the One-Way ANOVA, the experimental group's shoulder, elbow, and wrist muscle strength significantly increased after the intervention ($p < 0.05$). This is in agreement with the findings of Azevedo et al. (2022), who found that CIMT produces better improvements in upper limb functional use and independence in activities of daily living (ADL) than conventional therapy.

Their meta-analysis and systematic review of 21 studies supported their findings and the outcome measure used were Fugl-Meyer Assessment, Wolf motor function test, Modified Barthel Index, Motor Activity log, Amount of use, Quality of movement, Action research arm test, and FIM. From these studies the outcome measure used were different from the ones used in this study, but even with the different in outcome measure CIMT still had a better improvement than the conventional therapy. The study findings show that repetitive, task-specific training, which is a component of CIMT, successfully restores voluntary motor control are supported by the observed increase in muscle strength. In a comparable manner, Ghanzafar et al. (2024) found that CIMT improved motor function scores on the Fugl-Meyer Assessment (FMA) more than proprioceptive neuromuscular facilitation (PNF). This is supported by the current study, which demonstrates that subjects exposed to CIMT had greater post-test strength values than control who received conventional therapy. This implies that the rigorous, focused methodology of CIMT more effectively promotes muscle re-education and motor unit recruitment.

Effect Of CIMT on Muscle Endurance

The results of the One-Way ANOVA on the effectiveness CIMT on muscle endurance of the experimental group showed considerable improvement. This result is in line with Choi and Kim (2024), in a meta-analysis of randomized controlled trials, confirmed that CIMT improves both movement quality and task endurance in hemiplegic patients, they explained that the repeated and prolonged use of the affected limb in CIMT strengthens muscle fibers and improves their ability to resist fatigue during daily living tasks.

Effect of CIMT on Joint Flexibility

The results of the One-Way ANOVA on the effectiveness of CIMT on joint flexibility in experimental group's shoulder, elbow, and wrist joint range of motion significantly improved following CIMT. This result is consistent with that of Lingling Marinda Palupi et al. (2020), who found that CIMT in conjunction with Range of Motion (ROM) exercises resulted in a higher functional improvement of the upper extremities than ROM exercises alone. The coherence of these results emphasises the dual advantage of CIMT, which involves repeated, intentional activity that strengthens muscles and restores joint mobility. Choi and Kim (2024), who performed a meta-analysis of 34 randomised controlled trials and came to the conclusion that CIMT significantly improves upper limb motor function and reduces impairment, provide further credence to this finding. The present study's improvement in range of motion may be explained by the repetitive, goal-oriented movements that are promoted during CIMT sessions, which improve joint flexibility and coordination.

Effect of CIMT on Hand Function

The results of the One-Way ANOVA on the effectiveness of CIMT on hand function in the experimental group showed notable improvement in grip and pinch strength over the control group. This study is in alignment with Vandhana (2012), who discovered that CIMT improved hand and wrist function more than conventional physiotherapy. By increasing the frequency and quality of use of the affected hand in daily tasks, CIMT can improve fine motor skills, as demonstrated by the improved hand function seen here.

Similarly, Fitrizah et al. (2025) found that CIMT significantly increased grip strength from 9.15 to 12.95 ($p < 0.001$), which is consistent with the improvement in grip strength of F-statistics (F= 16.436). Both studies highlight how CIMT reverses learnt non-use and promotes neuroplastic recovery by effectively activating underused muscles by requiring functional use of the affected limb. Rodriguez et al. (2024) also showed that CIMT significantly improved upper extremity function and motor activity log scores in stroke patients, even when it was administered through telerehabilitation. As long as patient adherence and intensity are maintained, CIMT can improve hand coordination and strength regardless of the delivery setting, according to the results of the current study.

Furthermore, findings of this study support the superiority of CIMT over conventional rehabilitation techniques and are in line with the majority of the empirical studies that were reviewed. This study found that the CIMT group had better overall motor outcomes, which may be related to differences in study duration, participant adherence, and session intensity. Zafar et al. (2023) found that traditional OT produced slightly greater improvement in some ADL scores. Similar to Azevedo et al. (2022) and Choi & Kim (2024), but the current study shows that CIMT's advantages go beyond motor recovery to include increased independence and functional participation. Together, these results show that CIMT is both clinically successful and sufficiently adaptable to be used in Nigerian rehabilitation environments.

5.2 Conclusion

It was found that hemiplegic stroke survivors upper limb function considerably enhanced by CIMT than conventional physiotherapy alone, CIMT demonstrated a significant improvement in hand function, joint flexibility, muscle strength, and muscle endurance. According to the results, CIMT may be a realistic and successful treatment choice for stroke recovery in tertiary hospitals in Nigeria and elsewhere. Its methodical, task-oriented approach promotes the affected limb's neuroplastic adaptation and functional recovery.

5.3 Recommendations

The findings of this study suggest that CIMT would need to be incorporated into the standard physiotherapy treatment of stroke patients in Nigerian medical facilities, especially those who have upper limb hemiplegia.

To meet the needs of each patient, physiotherapists should receive specialised training in the application, monitoring, and modification of CIMT.

Hospitals and rehabilitation centres need to allocate resources on the supplies and schedules needed to carry out CIMT procedures effectively.

To achieve the best results, stroke patients and their carers should be informed about the importance of motivation and compliance during CIMT.

Health policymakers should support the inclusion of CIMT in national stroke rehabilitation guidelines in order to guarantee uniformity of care across institutions.

5.4 Implication for Physiotherapy

The study's conclusions have multiple implications for physical therapy:

To improve upper limb function and independence in stroke survivors, physiotherapists can employ CIMT as their main rehabilitation technique.

This study reinforces evidence-based decision-making in stroke rehabilitation by offering empirical support for the application of CIMT in Evidence-Based Practice.

Physiotherapists can use neuroplasticity-promoting CIMT, which emphasises repetitive, task-specific training, to promote brain reorganisation and recovery.

This study supports the integration of behavioural, cognitive, and physical aspects of rehabilitation in holistic patient care, which is comparable to the biopsychosocial approach in physiotherapy.

5.5 Contribution to knowledge

This study contributes to knowledge in the following ways:

It presents empirical evidence that CIMT improves upper limb motor function among hemiplegic stroke patients in Nigeria.

It contributes to current literature by demonstrating that CIMT can be successfully implemented in resource-constrained settings, such as the University of Benin Teaching Hospital.

It provides support to the hypothesis of learnt non-use and how it can be reversed through task-specific motor retraining.

It provides a foundation for local comparative research in stroke rehabilitation that employ advanced therapy modalities.

5.6 Suggestion for future studies

Future research should:

Look into the long-term impact of CIMT on functional independence and quality of life following a stroke.

Consider comparing CIMT with other therapeutic approaches including mirror therapy, electrical stimulation, or VR (Visual Reality).

Investigate the applicability of CIMT in patients with conditions other than stroke, such as multiple sclerosis, cerebral palsy, traumatic brain injury, and spinal cord injury.

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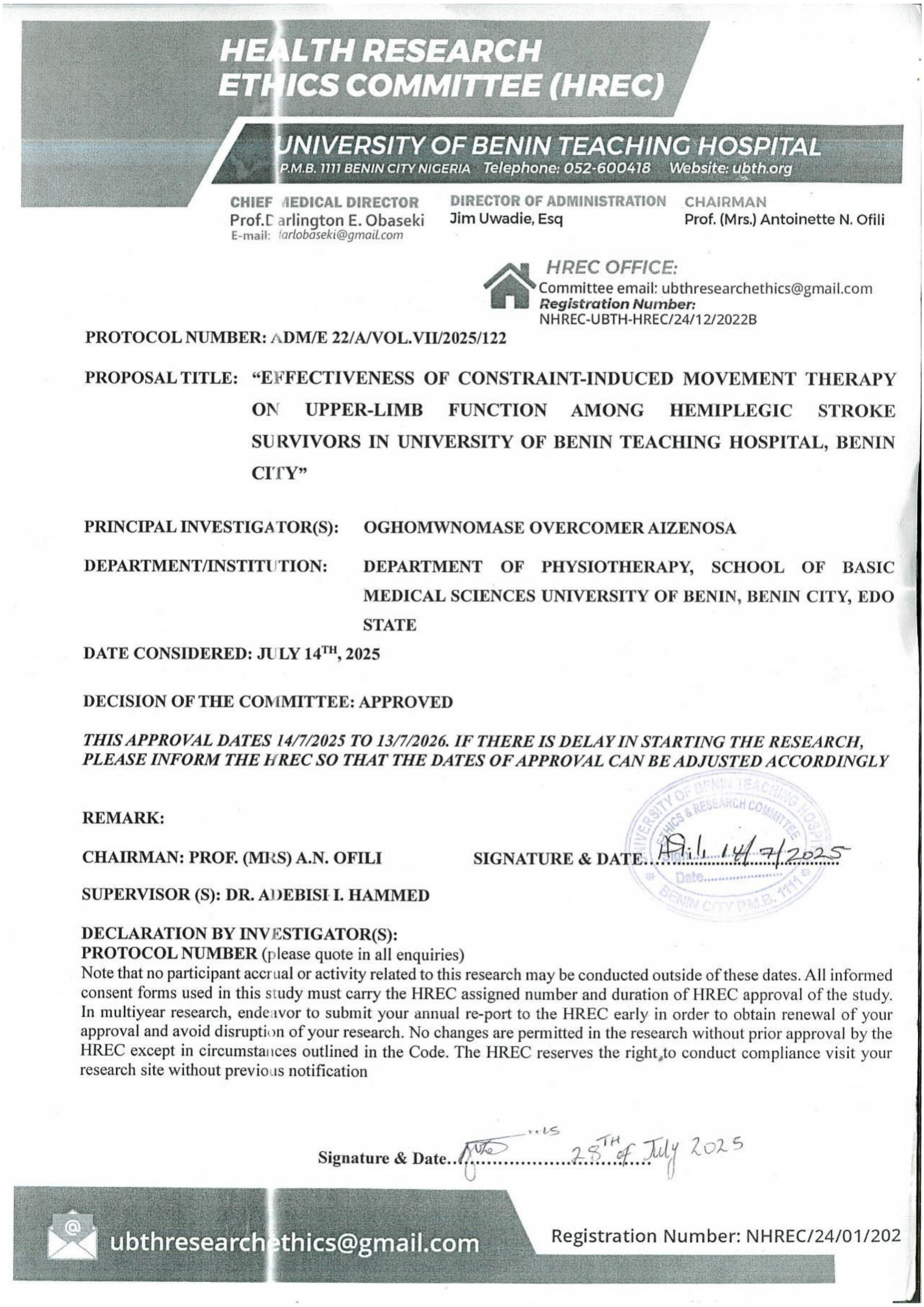
APPENDICES

APPENDIX I

ETHICAL APPROVAL



HEALTH RESEARCH ETHICS COMMITTEE (HREC)

UNIVERSITY OF BENIN TEACHING HOSPITAL

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Registration Number:
NHREC-UBTH-HREC/24/12/2022B

PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/122

PROPOSAL TITLE: "EFFECTIVENESS OF CONSTRAINT-INDUCED MOVEMENT THERAPY ON UPPER-LIMB FUNCTION AMONG HEMIPLEGIC STROKE SURVIVORS IN UNIVERSITY OF BENIN TEACHING HOSPITAL, BENIN CITY"

PRINCIPAL INVESTIGATOR(S): OGHOMWNOMASE OVERCOMER AIZENOSA

DEPARTMENT/INSTITUTION: DEPARTMENT OF PHYSIOTHERAPY, SCHOOL OF BASIC MEDICAL SCIENCES UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

DATE CONSIDERED: JULY 14TH, 2025

DECISION OF THE COMMITTEE: APPROVED

THIS APPROVAL DATES 14/7/2025 TO 13/7/2026. IF THERE IS DELAY IN STARTING THE RESEARCH, PLEASE INFORM THE HREC SO THAT THE DATES OF APPROVAL CAN BE ADJUSTED ACCORDINGLY

REMARK:

CHAIRMAN: PROF. (MRS) A.N. OFILI **SIGNATURE & DATE**......14/7/2025......

SUPERVISOR (S): DR. ADEBISI I. HAMMED

DECLARATION BY INVESTIGATOR(S):
PROTOCOL NUMBER (please quote in all enquiries)
Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the study. In multiyear research, endeavor to submit your annual re-port to the HREC early in order to obtain renewal of your approval and avoid disruption of your research. No changes are permitted in the research without prior approval by the HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit your research site without previous notification

Signature & Date......25TH of July 2025......

ubthresearchethics@gmail.com Registration Number: NHREC/24/01/202

APPENDIX II

Figure 2: Participant using the affected upper limb to peg a book with the unaffected restricted with a bandage.

Figure 3: Participant using the affected upper limb to stack cups with the unaffected restricted with a bandage.

Figure 4: Participant using the affected upper limb to try to drink water with the unaffected restricted with a bandage.

Figure 5: Participant using the affected upper limb to pick Ayo seeds and transfer it with the unaffected restricted with a bandage.