EFFECT OF LOW-LEVEL LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION (LASER) THERAPY ON HEMIPLEGIC SHOULDER PAIN AMONG STROKE SURVIVORS

BY

OGUNSOLA BOLAJI ADEMOLA
(BMS1802691)

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 DEGREE

MAY, 2026

CERTIFICATION

This dissertation by OGUNSOLA BOLAJI ADEMOLA is accepted in its presented 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.

____
DR. ADEBISI HAMMED
EXAMINER
SUPERVISOR

____
EXTERNAL

____
DR MRS C.O OBASEKI
HEAD
DEPARTMENT OF PHYSIOTHERAPY
COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN, BENIN CITY

DEDICATION

This dissertation is dedicated to God almighty, which in his infinite mercy and grace have brought me this far.If not for his grace, keeping me alive till now, this work would not have been possible. I also want to use this medium to dedicate this to my mom, Mrs. Monilola Abiodun Ogunsola, my big sisters Bukola Adeola and Bisola Adebimbola.Also to everyone that really make this work to reality.

ABSTRACT

Background: Hemiplegic Shoulder Pain (HSP) is a prevalent and disabling complication for stroke survivors, significantly hindering rehabilitation efforts and diminishing their quality of life. While conventional therapies exist, their efficacy is often limited, highlighting the need for safer and more effective non-invasive interventions. Low-Level Laser Therapy (LLLT) has shown potential for pain management due to its analgesic and anti-inflammatory mechanisms.

Aim: The primary aim of this study was to evaluate the effectiveness of LLLT in reducing hemiplegic shoulder pain among stroke survivors in the University of Benin Teaching Hospital.

Methods: This study employed a randomized controlled trial design involving 42 participants with post-stroke HSP (24 males, 18 females). Participants were randomly assigned to either an experimental group (n=21), which received LLLT combined with conventional physiotherapy, or a control group (n=21), which received conventional physiotherapy alone. The intervention period lasted for six weeks. The primary outcome measure, pain intensity, was assessed using the Visual Analogue Scale (VAS) before and after the treatment period.

Results: The experimental group experienced a statistically significant reduction in pain scores following the intervention ($p < 0.001$). Conversely, the control group did not show any significant change in pain levels ($p = 0.366$). The between-group analysis confirmed that the pain reduction in the LLLT group was significantly greater than that in the control group ($p < 0.001$), demonstrating the superior effect of the adjunctive LLLT treatment.

Conclusion: LLLT, when used as an adjunct to conventional physiotherapy, is an effective intervention for managing hemiplegic shoulder pain in stroke survivors. The findings provide evidence for incorporating LLLT into standard rehabilitation protocols as a non-invasive modality to enhance pain relief, potentially facilitating greater participation in therapeutic exercises and supporting overall functional recovery.

Keywords: Hemiplegic Shoulder Pain, Low-Level LASER Therapy, Stroke, Physiotherapy

ACKNOWLEDGEMENTS

I am grateful to God for the successful completion of this work and for His protection and guidance throughout my stay on this campus.

Special thanks to my supervisor Dr. Adebisi Hammed for his assistance and guidance during the course of the research study. Despite the busy schedule, he devoted his time to listen to me, answer my questions, read through my work and also make corrections. May the good Lord reward you in hundred folds.

I also appreciate the Head of the Department, Dr (Mrs) C.O Obaseki, pioneer Head of the Department, Prof Kayode Oke and all the lecturers of the Department of Physiotherapy, University of Benin, Dr. Nicholas Oghumu, Prof Joseph Umunnah, Prof Obinna Ezeukwu, Dr. Nelson Ezekwu, and Rev Sister Fawole. A special thanks to the Head of Department, Dr. Taiwo Oyewumi, the directors, and also to the chiefs most especially PT Ezekiel for listening ears. I appreciate the interns and other clinicians in the Department of Physiotherapy, University of Benin Teaching Hospital for the knowledge and skills imparted on me during my studentship in the University of Benin Teaching Hospital. I also appreciate the non-academic staffs of the Department of Physiotherapy, University of Benin.

Special thanks goes to my mom,Mrs Monilola Abiodun Ogunsola,my big sisters Bukola Adeola and Bisola Adebimbola for their words of advice, encouragement, prayers and financial support throughout my stay as a student of University of Benin.

I will also like to appreciate my fellowship,Celestial church of Christ student parish uniben/ubth chapter for making it so impactable for me during my stay as a student in university of Benin .

Also want to deeply appreciate my dear friend Rebecca Aghomon for her support and others like Rachael Alabi, Joel Adewole, Daniel, Abdul Rahman Olamilekan, Balogun Akeem Praise ponmile during the course of this work.

My special thanks and gratitude to all my classmates, and all the patients that volunteered to participate in my study and to others which the confines of this page will not permit me to state.

TABLE OF CONTENT

CHAPTER THREE: METHODS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Stroke is a major public health concern and one of the leading causes of adult disability worldwide (Feigin et al., 2021).According to the World Health Organization (2024), approximately 15 million people suffer a stroke each year, with nearly 5 million left permanently disabled. The aftermath of stroke includes various physical, cognitive, and emotional impairments, with hemiplegic shoulder pain (HSP) ranking among the most common and challenging complications. HSP is defined as pain experienced in the hemiplegic (paralyzed) shoulder, and it s[ignificantly interferes with the recovery process, activities of daily living, and overall quality of life of stroke survivors(Adey-Wakeling et al., 2016).

The incidence of HSP has been reported to range from 30% to 84%, depending on the population and stage of recovery. Its pathophysiology is multifactorial and not entirely understood. Contributing factors include muscle spasticity, capsular contracture, adhesive capsulitis (frozen shoulder), brachial plexus injury, and glenohumeral subluxation (Najimi et al., 2021). In many cases, pain develops within the first few weeks post-stroke and, if left untreated, can persist for months or years. HSP leads to decreased upper limb function, limited shoulder mobility, sleep disturbances, and psychological distress, all of which further delay rehabilitation and functional independence(Kumar et al., 2020).

Despite the high prevalence and impact of HSP, its management remains a clinical challenge. Conventional treatment options include analgesics, corticosteroid injections, physical therapy, electrical stimulation, and therapeutic exercises. However, these interventions often provide temporary relief, and their effects are variable. Moreover, the use of medications like opioids or steroids may lead to adverse side effects, especially in older adults with comorbid conditions. Thus, there is an urgent need for non-invasive, effective, and safer treatment alternatives for managing HSP(Zein et al., 2018).

One such promising modality is Low-Level Laser Therapy (LLLT), also known as Photobiomodulation Therapy (PBMT). LLLT involves the application of low-intensity laser light (typically in the red or near-infrared spectrum) to stimulate biological processes in tissues without causing heat or damage. The mechanism of LLLT is based on its ability to stimulate mitochondrial activity, enhance cellular metabolism, increase ATP production, and modulate inflammatory responses(Hamblin et al;2017). It also helps improve microcirculation, reduce muscle spasm, and accelerate tissue repair—factors that are crucial in the treatment of shoulder dysfunction and pain following stroke.

Recent clinical trials have demonstrated the potential of LLLT in alleviating HSP and improving functional outcomes in stroke patients:

A 2025 randomized controlled trial by Başaran and Büyükşireci compared LLLT and neuromuscular electrical stimulation (NMES) in stroke survivors with HSP. Both interventions significantly reduced pain and improved upper extremity function when added to standard physiotherapy. Notably, LLLT was found to be equally effective as NMES, suggesting its usefulness as a non-invasive and comfortable alternative(El-Sayed et al;2025).

Despite these encouraging findings, LLLT is still underutilized in many stroke rehabilitation centers, particularly in low- and middle-income countries like Nigeria. Barriers include lack of awareness, limited availability of laser devices, and insufficient clinical guidelines. Furthermore, while evidence is growing, more high-quality studies are needed to determine the optimal parameters (wavelength, dosage, duration, and frequency) for LLLT in stroke-related shoulder pain.

This study, therefore, seeks to evaluate the effectiveness of low-level laser therapy on hemiplegic shoulder pain among stroke survivors, focusing on outcomes such as pain intensity and functional mobility. The results aim to contribute to evidence-based practice in stroke rehabilitation and potentially support the broader integration of LLLT into routine physiotherapy programs.

1.2 Statement of the Problem

Stroke remains a leading cause of long-term disability globally, with millions of survivors experiencing chronic complications that significantly hinder their recovery. Among these, hemiplegic shoulder pain (HSP) is one of the most prevalent and disabling conditions, affecting up to 84% of stroke survivors. HSP contributes to severe discomfort, limits shoulder mobility, delays functional recovery, and impedes participation in rehabilitation programs—ultimately reducing the overall quality of life of stroke patients.(Adey- Wakeling et al., 2020;

HSP typically occurs on the side of the body affected by paralysis and is associated with limited shoulder mobility, spasticity, joint subluxation, soft tissue injuries, and postural imbalances. This condition causes persistent discomfort, sleep disturbances, and emotional distress, and it significantly reduces patient motivation and participation in therapeutic activities. Consequently, it delays upper limb functional recovery and hampers overall rehabilitation outcomes.

Despite the high burden of HSP among stroke survivors, effective treatment options remain limited and often unsatisfactory. Conventional interventions such as oral analgesics, muscle relaxants, physical therapy, electrical stimulation, and intra-articular corticosteroid injections have been widely used. However, many of these treatments offer only partial or temporary relief, and they are sometimes associated with undesirable side effects, including sedation, dependency, or joint tissue damage in the case of repeated injections. Moreover, the costs and resource requirements of these conventional treatments can be prohibitive, particularly in resource-constrained healthcare settings like Nigeria.

As healthcare systems strive for more effective and safer alternatives, Low-Level Laser Therapy (LLLT) has emerged as a non-invasive, painless, and potentially cost-effective option. LLLT uses specific wavelengths of light to stimulate biological processes that promote tissue repair, reduce inflammation, and modulate pain. Several recent studies have demonstrated its efficacy in treating musculoskeletal pain, improving circulation, and enhancing range of motion, with minimal to no side effects.

Although the application of LLLT has been explored in orthopedic and sports injuries, its use in post-stroke hemiplegic shoulder pain is still under-researched, particularly in developing countries. Moreover, while some clinical trials have reported positive outcomes, the lack of standardized treatment protocols, limited access to laser devices, and insufficient awareness among healthcare professionals have hindered the widespread adoption of LLLT in stroke rehabilitation.

1.3 Research Questions

i. What is the effect of Low-Level Laser Therapy on the intensity of hemiplegic shoulder pain among stroke survivors
ii. What is the effect of Low-Level Laser Therapy on functional independence in stroke survivors with hemiplegic shoulder pain
iii. Is there a significant difference in pain reduction between stroke patients receiving LLLT and those receiving conventional physiotherapy alone.

1.4 Aim and the Study

The aim of this study is to evaluate the effectiveness of Low-Level Laser Therapy (LLLT) in reducing hemiplegic shoulder pain and improving upper limb function among stroke survivors, with the goal of supporting its integration as a non-invasive and evidence-based intervention in post-stroke rehabilitation programs.

1.4.1 Specific Objectives

The specific objectives of this study are to:

i. To evaluate the effect of Low-Level Laser Therapy (LLLT) on the intensity of hemiplegic shoulder pain in stroke survivors using standardized pain assessment tools (e.g., Visual Analogue Scale or Numeric Pain Rating Scale).

ii. To compare the effectiveness of LLLT combined with conventional physiotherapy versus conventional physiotherapy alone in the management of hemiplegic shoulder pain among stroke survivors.

iii. To examine the safety and tolerability of LLLT in stroke patients during the course of rehabilitation.

1.5 Hypotheses

i. There is no significant effect of LLLT on hemiplegic shoulder pain intensity among stroke survivors.

ii. There is no significant impact of LLLT on functional independence in stroke survivors with HSP.

iii. There is no significant difference in pain reduction between the LLLT group and conventional physiotherapy group.

1.6 Significance of the Study

i. Clinical Contribution:

By evaluating the efficacy of Low-Level Laser Therapy (LLLT) in treating hemiplegic shoulder pain, this study could provide strong clinical evidence for integrating LLLT into routine post-stroke rehabilitation. This has the potential to improve patient outcomes by reducing pain, restoring upper limb functionality as well as leading to faster and more effective recovery.

ii. Innovation in Therapy:

LLLT is a modern, non-invasive therapy that has shown promising results in pain management and tissue repair. Unlike pharmacological treatments, LLLT offers pain relief without systemic side effects. This research contributes to the growing global interest in photobiomodulation therapies and supports their expansion into neurological rehabilitation.

iii. Evidence-Based Practice:

There is currently a limited body of research on the application of LLLT for hemiplegic shoulder pain in stroke survivors, especially in African healthcare contexts. This study addresses that gap and will contribute valuable data to support evidence-based physiotherapy practice both locally and internationally.

iv. Policy and Resource Planning

Should LLLT prove effective and safe, this study can serve as a foundation for policy advocacy, encouraging health institutions and rehabilitation centers to invest in laser therapy devices. This would expand therapeutic options in post-stroke care and promote equity in access to modern rehabilitation technologies.

v. Empowerment of Healthcare Professionals:

The findings of this study will benefit physiotherapists and rehabilitation professionals by equipping them with updated knowledge and practical tools to address HSP more effectively. This not only enhances patient care but also advances professional development and clinical innovation within the field.

1.7 Scope and Delimitation of the Study

i. Geographic Scope:

This study was conducted at university of Benin Teaching Hospital, Edo State. In which is limited to generalizability to other regions or healthcare levels.

ii. Population:

Only adult stroke survivors who are medically stable and meet inclusion criteria.

iii. Type of Intervention:

The intervention was focus solely on low level laser therapy (LLLT) and conventional therapy.

iv. Duration of Study

This study was carried out over a defined intervention period of 6weeks, Long-term follow -up beyond this period is not within the scope of the study.

This Study is delimited to:

i. The research involve adult stroke survivors (male and female) diagnosed with hemiplegic shoulder pain, who are medically stable and eligible to undergo physiotherapy. Participants was recruited from physiotherapy and neurorehabilitation units at university of Benin Teaching Hospital.

ii. The study was conducted in clinical rehabilitation settings, at University of Benin Teaching Hospital where both conventional physiotherapy and LLLT equipment are available.

iii. The experimental group receive Low-Level Laser Therapy in addition to routine physiotherapy, while the control group receive only conventional physiotherapy. The laser therapy will be administered following standardized protocols regarding wavelength, dosage, treatment frequency, and duration.

1.8 Definition of Terms

i. Stroke:

A neurological condition that occurs when blood flow to a part of the brain is interrupted or reduced, leading to brain tissue damage. In this study, it refers specifically to ischemic or hemorrhagic stroke survivors who have developed motor impairments and complications like hemiplegic shoulder pain.

ii. Hemiplegia:

A condition characterized by paralysis or severe weakness on one side of the body, typically resulting from damage to the brain's motor areas following a stroke.

iii. Hemiplegic Shoulder Pain (HSP):

Pain experienced in the shoulder on the side of the body affected by hemiplegia after a stroke. It can result from factors such as muscle spasticity, joint subluxation, frozen shoulder, or rotator cuff injuries. This study focuses on patients with post-stroke shoulder pain lasting more than two weeks.

iv. Low-Level Laser Therapy (LLLT):

Also known as Photobiomodulation Therapy (PBMT), this is a non-invasive therapeutic technique that uses low-intensity laser or light-emitting diodes (LEDs) to stimulate healing, reduce inflammation, and relieve pain. In this study, LLLT will be applied to the affected shoulder using a standardized protocol.

v. Conventional Physiotherapy:

A routine rehabilitation program involving therapeutic exercises, joint mobilization, passive/active movements, and pain-relief modalities such as cryotherapy or electrical stimulation, aimed at restoring joint function and mobility.

vi. Pain Intensity:

The subjective experience of physical discomfort, measured using tools like the Visual Analogue Scale (VAS) or Numeric Pain Rating Scale (NPRS) to quantify the level of pain before and after treatment.

vii. Rehabilitation:

A structured, multidisciplinary approach aimed at restoring physical function, reducing pain, and improving quality of life in individuals who have experienced stroke or other.

1.9 Abbreviations:

ADL	Activities of Daily Living
CNS	Central Nervous System
DASH	Disabilities of the Arm, Shoulder and Hand
FMA-UE	Fugl-Meyer Assessment – Upper Extremi
HSP	Hemiplegic Shoulder Pain
LLLT	Low-Level Laser Therapy
LED	Light Emitting Diode
NPRS	Numeric Pain Rating Scale
PBMT	Photobiomodulation Therapy
PT	Physiotherapy
RCT	Randomized Controlled Trial
ROM	Range of Motion
UE	Upper Extremity
VAS	Visual Analogue Scale
WHO	World Health Organization

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Framework

The theoretical foundation for the use of Low-Level Laser Therapy (LLLT) in managing hemiplegic shoulder pain (HSP) is grounded in the Gate Control Theory of Pain and the Photobiomodulation Theory.

i. Gate Control Theory of Pain (Melzack & Wall, 1965)

This theory proposes that non-painful input (e.g., light, touch) can close the "gates" to painful input, preventing pain signals from reaching the brain. LLLT stimulates non- nociceptive A-beta fibers, which may inhibit the transmission of pain via A-delta and C fibers. This helps modulate pain perception in the affected shoulder.

ii. Photobiomodulation Theory

LLLT delivers low-intensity light (typically red or near-infrared) that penetrates tissues and stimulates cellular processes. It enhances mitochondrial activity, ATP production, and cytochrome c oxidase activation, which improve cell repair, reduce inflammation, and modulate nociceptive signaling. These effects contribute to pain relief, tissue healing, and functional recovery. (Chung et al., 2012).

iii. Neuroplasticty

Post-stroke, the brain undergoes reorganization. By relieving pain and improving mobility, LLLT indirectly supports rehabilitation and neuroplastic adaptation by promoting active use of the affected limb.(Nudo, 2006).

2.2 Definition

Stroke is a medical condition characterized by the sudden onset of clinical symptoms indicating either localized or widespread impairment of brain function, lasting more than 24 hours or resulting in death, with no cause other than a vascular origin (WHO, 1970). It occurs due to insufficient blood supply to the brain, leading to cell death, which can result from either a blockage or rupture of cerebral blood vessels (Waqas et al., 2020). Without prompt intervention during the critical "golden hour," the risk of mortality increases significantly. Even with treatment, 70–80% of stroke survivors experience some degree of post-stroke disability (Moon and Keum, 2020). Also known as a cerebrovascular accident (CVA), stroke involves an acute disruption of cerebral blood flow or vascular integrity. Approximately 85% of strokes are ischemic, caused by blocked blood flow to the brain, while the remaining cases are hemorrhagic, resulting from bleeding in the brain (Mozaffarian et al., 2016). The American Stroke Association defines stroke as permanent damage to brain, spinal cord, or retinal cells due to vascular causes, confirmed by pathological or imaging evidence, regardless of the presence of clinical symptoms (Sacco et al., 2013). There are two main types of strokes. Ischemic stroke occurs when blood flow to the brain is obstructed, depriving brain cells of oxygen and nutrients, leading to cell death within minutes. Hemorrhagic stroke results from sudden bleeding in the brain, where leaked blood creates pressure on brain tissue, causing damage. Nearly 90% of while the rest are hemorrhagic. Strokes are further classified based on the location of the blockage or bleeding within the brain.

2.3 Epidemiology

- Incidence and Prevalence: In 2021, there were approximately 11.9 million new stroke cases and 93.8 million individuals living with stroke worldwide.

Mortality and Disability, Stroke was the third leading cause of death globally, accounting for 7.3 million deaths (10.7% of all deaths) in 2021. It was also the fourth leading cause of disability, responsible for 160.5 million disability-adjusted life-years (DALYs).

Trends Over Time: Between 1990 and 2021, the global number of stroke incidents increased by 70%, deaths by 44%, and DALYs by 32%.

- **Regional Disparities**

Low and Middle-Income Countries (LMICs): Approximately 87.2% of stroke deaths and 89.4% of stroke-related DALYs occur in LMICs, highlighting significant disparities in healthcare access and stroke management.

High-Income Countries (HICs): While HICs have better access to stroke interventions, disparities still exist. For instance, in the United States, the prevalence of stroke is about 3% in adults aged 20 years or older, translating to approximately 7 million individuals.

2.4 Pathophysiology

Stroke is a complex neurological event resulting from the disruption of cerebral blood flow, leading to neuronal injury and loss of brain function. The pathophysiology varies depending on the type of stroke ischemic or hemorrhagic each with distinct mechanisms and consequences.

i. Ischemic Stroke

Ischemic strokes account for approximately 85%of all strokes and occur due to an obstruction within a blood vessel supplying blood to the brain. The blockage leads to a cascade of events:

- **Energy Failure:** The interruption of blood flow results in decreased oxygen and glucose delivery, leading to a failure in ATP production.

- **Ion Imbalance:** ATP depletion impairs ion pumps, causing an influx of calcium and sodium ions and efflux of potassium ions, leading to cellular depolarization.

- **Excitotoxicity:** Excessive release of excitatory neurotransmitters, particularly glutamate, overstimulates receptors, exacerbating calcium influx and neuronal injury.

- **Oxidative Stress:** The imbalance between reactive oxygen species (ROS) production and antioxidant defenses leads to lipid peroxidation, protein denaturation, and DNA damage.

- **Inflammation:** Activation of microglia and infiltration of leukocytes release pro-inflammatory cytokines (e.g., IL-1β, TNF-α), contributing to further neuronal damage.

- **Apoptosis and Necrosis:** Depending on the severity and duration of ischemia, cells undergo programmed cell death (apoptosis) or uncontrolled cell death (necrosis).

- **Penumbra Formation:** Surrounding the core infarct is the penumbra, a region of hypoperfused yet viable tissue that is salvageable with timely reperfusion therapies.

ii. Hemorrhagic Stroke

Hemorrhagic strokes, comprising about 15% of all strokes, result from bleeding into the brain tissue (intracerebral hemorrhage) or surrounding spaces (subarachnoid hemorrhage). The pathophysiological processes include:

- **Mechanical Damage:** The accumulation of blood exerts pressure on brain tissue, leading to direct neuronal injury and disruption of neural pathways.

- **Increased Intracranial Pressure (ICP):** The expanding hematoma elevates ICP, reducing cerebral perfusion pressure and potentially causing herniation.

- **Blood-Brain Barrier Disruption:** Hemorrhage compromises the integrity of the blood allowing influx of neurotoxic substances and exacerbating edema.

- **Inflammatory Response:** Blood components activate microglia and astrocytes, releasing inflammatory mediators that contribute to secondary brain injury.

- **Oxidative Stress:** Hemoglobin breakdown products generate ROS, leading to oxidative damage of lipids, proteins, and nucleic acids.

- **Cytotoxic Edema:** Cellular swelling due to ionic imbalances further impairs neuronal function and viability.

2.5 Risk Factors

2.5.1 Modifiable Risks Factors

These are factors that can be managed or avoided to lower the risk of an individual experiencing a stroke.

Hypertension: Hypertension is the most significant modifiable risk factor for stroke, showing a strong and direct relationship between blood pressure levels and stroke risk (Wahab et al., 2017). Persistently high blood pressure exerts excessive strain on cerebral blood vessels, often resulting in lacunar infarcts or intracerebral hemorrhage (Pandian et al., 2018). In Nigeria, hypertension remains the leading modifiable risk factor for stroke (Amu et al., 2005).

Smoking: This is the leading modifiable risk factor for subarachnoid hemorrhage (Wahab et al.,2017). Nicotine and carbon monoxide in tobacco smoke lower oxygen levels in the bloodstream, contributing to vascular damage. While quitting smoking significantly reduces the elevated risk, it does not completely eliminate it (O'Neill et al., 2003). Smoking doubles the likelihood of stroke by promoting atherosclerosis and increasing blood coagulation factors (Bhat et al., 2008).

Obesity: Excess body weight and obesity are linked to an increased risk of conditions like hypertension, diabetes, and stroke (Onabajo, 2016). Obesity is categorized as having a Body Mass Index (BMI) of 30 kg/m² or higher. In Nigeria, the prevalence of obesity is rapidly growing due to inadequate physical activity and poor dietary habits, further increasing the likelihood of stroke (Komolafe et al., 2015).

Diabetes Mellitus(DM: Iabetes mellitus (DM) doubles the risk of stroke compared to non-diabetic individuals, with one in five diabetic patients succumbing to stroke (Pikula et al., 2018; Olesen et al., 2019). Diabetic patients are prone to complications such as myocardial infarctions and peripheral vascular disease, which can ultimately contribute to stroke development (Omotosho et al., 2009).

Physical Inactivity: Leading sedentary lifestyle intensify the threat of developing hypertension, diabetes, obesity and cardiovascular diseases, all of which contribute to stroke risk. Increasing physical activity may help lower the chances of stroke, particularly in older adults (Willey et al., 2017). A meta-analysis by Lee et al. (2003) found that engaging in moderate to high-intensity exercise is linked to a reduced risk of both ischemic and hemorrhagic stroke.

Hypercholesterolemia: Cholesterol, a flexible waxy substance found in blood lipids and all body cells, plays a crucial role in building cell membranes, producing hormones, and supporting various bodily functions (O'Regan et al., 2008). While elevated serum cholesterol levels are strongly associated with increased mortality from ischemic stroke in Western countries (Peters et al., 2013), they do not appear to be a significant risk factor among Africans (Connor et al., 2005).

Excess Alcohol Consumption: Although alcohol is acknowledged as a risk factor for stroke, its exact mechanism of influence remains unclear. Some studies propose that excessive alcohol intake activates the clotting cascade, elevates blood pressure, and reduces cerebral blood flow, thereby heightening the risk of thromboembolic stroke (Ifeanyi et al., 2020). Conversely, another perspective suggests that high to moderate alcohol consumption increases the likelihood of ischemic stroke, while low to moderate intake does not appear to significantly elevate stroke risk (Smyth et al., 2023).

2.5.2 Non-Modifiable Risk Factors

Non-modifiable risk factors are characteristics or conditions that an individual cannot change or control.

Age: The prevalence of stroke risk factors differs among age groups, likely due to the cumulative effects of age-related cardiovascular changes and coexisting health conditions.

Stroke incidence approximately doubles every decade after the age of 55 (Lloyd-Jones et al., 2010; Yousufuddin & Young, 2019). Notably, all other stroke risk factors are influenced by age.

Race: Significant differences exist in stroke incidence and mortality among racial groups, with Black individuals, particularly African Americans, experiencing higher rates compared to whites. The incidence among African Americans is nearly twice that of whites, which may be influenced by factors such as lower socioeconomic status, genetic predispositions, and a greater prevalence of specific risk factors (Bravata et al., 2015).

Genetics: Although the role of genetics in stroke was once uncertain, recent studies suggest that genetic disorders can contribute to the development of individual stroke risk factors. Polygenic conditions may influence multiple bodily systems, leading to the presence of several risk factors and ultimately increasing the likelihood of stroke (Boehme et al., 2017).

Sex: Stroke is generally more prevalent in males across all age groups. However, in younger individuals, women exhibit a slightly higher incidence, which may be influenced by hormonal changes during pregnancy, the postpartum period, and the effects of contraceptives (Boehme et al., 2017). After the age of 30, the risk becomes greater in men but equalizes in older age, possibly due to women's longer lifespan or the impact of postmenopause (Lisabeth & Bushnell, 2012; Rexrode et al., 2022).

2.6 Types of Stroke

2.61 Hemorrhagic Stroke

This type of stroke occurs due to the rupture of blood vessels, leading to bleeding and increased intracranial pressure, sometimes presenting as bleeding through orifices (Parmar, 2018).

Intracerebral Haemorrhage: Involves bleeding and hematoma formation in the brain parenchyma, accounting for 10-15% of all stroke morbidity. Vascular malformations and changes to blood vessels due to hypertension and aging are common causes (Rajashekar & Liang, 2022).

Subarachnoid Haemorrhage: Involves bleeding in the subarachnoid space, often presenting with a thunderclap headache. It is caused by intracranial aneurysm and vascular malformation (Ziu et al., 2017).

2.6.2 Ischemic Stroke

Ischemic stroke occurs when cerebral blood vessels become obstructed by plaques or clots. This process can develop gradually, as plaques accumulate and restrict blood flow over time (Sacco et al., 2013). Ischemic strokes are classified into three main types: large vessel stroke (including thrombotic and embolic strokes), small vessel stroke (lacunar stroke), and cardioembolic stroke.

Thrombotic Stroke: Ischemic stroke is most often caused by atherosclerosis, which leads to the formation of an atheroma in a major cerebral vessel. Fatty deposits accumulate within the vessel 21 lumen, particularly in individuals with risk factors like hypercholesterolemia, gradually narrowing the passage and restricting blood flow to the brain. Over time, the atherosclerotic buildup can fully block the vessel, causing cell death when cerebral blood flow drops below 10 mL/100 g/min (Martin & Kessler, 2007).

Embolic Stroke: This type of stroke occurs when an embolus, originating from a location outside the brain's vascular system, becomes dislodged and travels to cerebral arteries. It is often linked to cardiovascular conditions such as myocardial infarction, dilated cardiomyopathy, atrial fibrillation, or valvular disease. The circulating clot eventually obstructs a major cerebral vessel, disrupting blood flow (Martin & Kessler, 2007).

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).

2.6.3 Transient Ischemic Attack

Although not considered a stroke, a transient ischemic attack (TIA) acts as an early warning for potential future strokes. It results from a temporary disruption of blood flow, causing stroke-like symptoms that resolve within 24 hours without causing focal brain damage or infarction (Panuganti et al., 2022).

2.7 Anatomy of the Brain

2.7.1 The Brain

The brain is an intricate organ responsible for regulating various essential functions, including thought, memory, emotions, sensory perception, motor control, vision, breathing, temperature regulation, and hunger, along with the spinal cord, it forms the central nervous system (CNS) (Ackerman, 1992). In an average adult, the brain weighs about 3 pounds and is composed of about 60% fat, with the remaining 40% comprising of water, proteins, carbohydrates, and salts. Unlike muscle tissue, the brain is a highly specialized structure that integrates blood vessels and nerves, housing vital components such as neurons and glial cells.

2.7.2 Main Parts of the Brain and their Functions

The brain can be broadly categorized into the cerebrum, brainstem, and cerebellum, each serving distinct functions at a high level (Maldonado & Alsayouri, 2023).

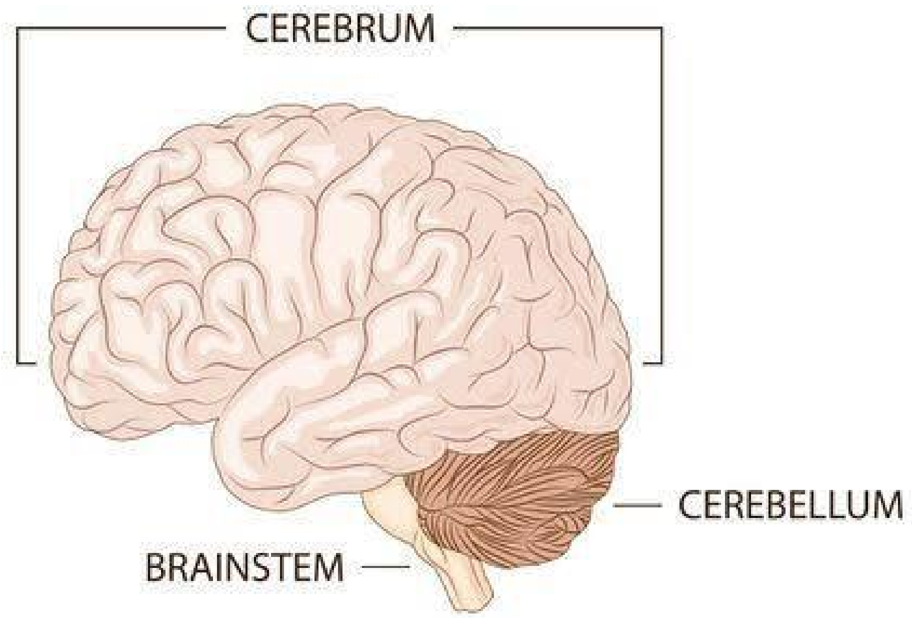

Figure 1: Lateral View of the Brain. Lateral view of the Brain showing the 3 main parts (cerebrum, cerebellum and brainstem).

Image source: https://images.app.goo.gl/MB2ioXhQnZcCqRYf6

Cerebrum: The cerebrum, situated at the front of the brain, is the largest and most prominent region, consisting of gray matter that forms the cerebral cortex and white matter at its core. It plays a crucial role in initiating and coordinating movement, regulating body temperature, and overseeing various cognitive functions (Maldonado & Alsayouri, 2023). These functions include reasoning, speech, judgment, problem-solving, critical thinking, emotional regulation, sensory processing, and learning.

Cerebral Cortex: The term "cortex," originating from the Latin word for "bark," refers to the outer gray matter layer of the cerebrum. Its extensive surface area, created by numerous folds, accounts for nearly half of the brain's weight. The cerebral cortex is divided into two hemispheres, characterized by ridges (gyri) and grooves (sulci), which communicate through the corpus callosum—a C-shaped white matter structure that connects both sides.

Brainstem: Located at the center of the brain, the brainstem acts as a bridge between the cerebrum and the spinal cord. It consists of three main structures: the midbrain, pons, and medulla (Fernández-Gil et al., 2010).

Midbrain: The midbrain is a complex structure containing numerous neuron clusters, neural pathways, and specialized regions. It plays a key role in functions such as hearing, movement, reflex responses, and adaptation to the environment. Additionally, it includes the substantia nigra, a region affected by Parkinson's disease.

Pons: Derived from the Latin word for "bridge," the pons links the midbrain to the medulla and serves as the origin for four cranial nerves. It plays a role in functions such as tear production, chewing, blinking, and other essential activities.

Medulla: Situated at the base of the brainstem, the medulla is essential for survival, controlling vital functions such as heart rhythm, breathing, blood circulation, and reflexes like sneezing and swallowing. The spinal cord extends from the lower part of the medulla, transmitting signals between the brain and the rest of the body.

Cerebellum

Known as the "little brain," the cerebellum is a fist-sized portion located at the back of the head, below the temporal and occipital lobes and above the brainstem. With two hemispheres, it coordinates voluntary muscle movements and plays a role in maintaining posture, balance, and equilibrium (Jimsheleishvili & Dididze, 2023). Ongoing studies explore its potential involvement in thought, emotions, social behavior, and its connection to conditions like addiction, autism, and schizophrenia.

2.7.3 Lobes of the Brain

The cerebrum, consisting of two brain hemispheres, is further divided into four distinct sections known as lobes: frontal, parietal, temporal, and occipital. Each of these lobes governs specific functions within the brain.

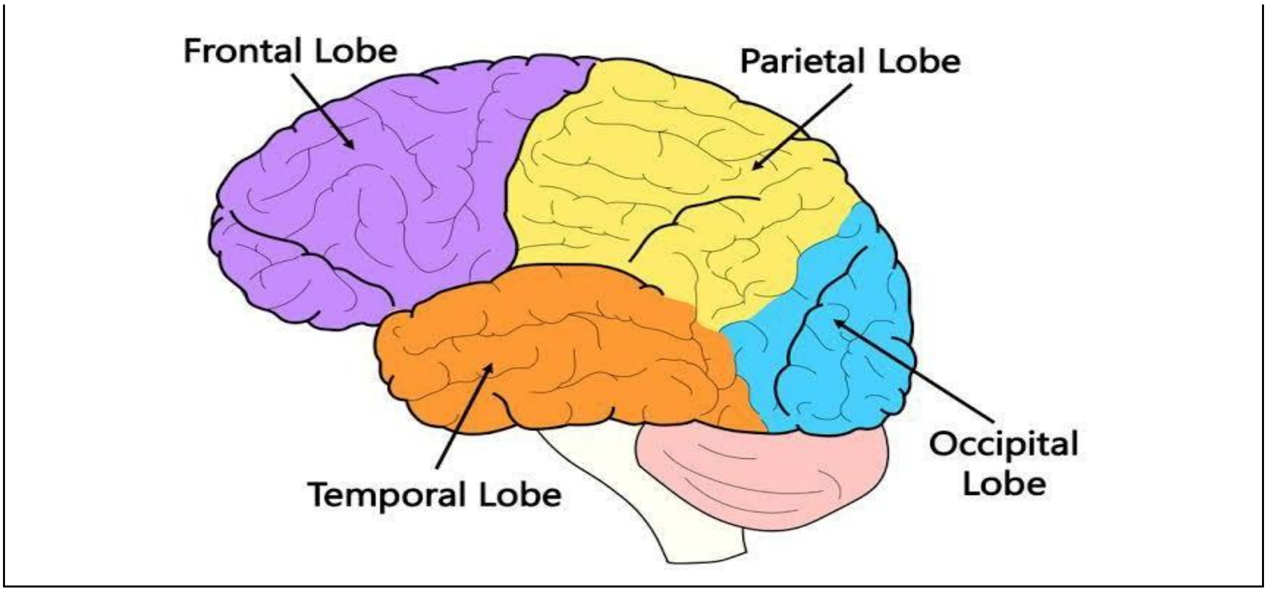

Figure 2: Lateral View of the Brain Showing the Four Lobes.

Image source: https://qbi.uq.edu.au/brain/brain-anatomy/lobes-brain

Frontal Lobe: The frontal lobe, positioned at the front of the head and serving as the largest lobe, engages in shaping personality traits, decision-making processes, and controlling movements. This lobe also plays a role in the recognition of smells and encompasses Broca's area, associated with speech ability (Neulinger et al., 2016).

Parietal Lobe: Situated in the middle part of the brain. It contributes to object identification and spatial relationship comprehension. Additionally, it is involved in the interpretation of pain and touch sensations in the body. Wernicke's area, facilitating the understanding of spoken language, is housed within the parietal lobe (Berlucchi & Vallar, 2018).

Occipital Lobe: Located at the back of the brain, the occipital lobe specializes in vision processing (Huff et al., 2023).

Temporal Lobe: Found on the sides of the brain, the temporal lobes participate in short- term memory functions, speech, musical rhythm, and to some extent, smell recognition (Kiernan, 2012).

2.7.4 Anatomy of the Brain's Blood Supply

Brain cells lack the ability to undergo glycolysis and are unable to store glucose, necessitating a continuous supply of glucose from the bloodstream for sustained cellular activities and optimal functioning. The brain consumes 3.5ml of oxygen per 100g of brain tissue per minute to support its metabolic processes. Notably, the grey matter utilizes twice the amount of oxygen compared to the white matter (Rink and Khanna, 2011).

2.7.5 The Brain's Arterial Supply

The blood supply to the brain is known as the circle of Willis and is categorized into two main circulations: anterior and posterior. The anterior circulation originates from the left and right internal carotid arteries, while the posterior circulation is sourced from the left and right vertebral arteries (Rhoton, 2002).

Anterior Circulation

The anterior circulation plays a vital role in providing blood supply to the following structures:

Cerebrum, Ophthalmic artery, Internal carotid arteries.

Course and Branches

At the C3/C4 vertebrae, both the left and right common carotid arteries split to form the internal carotid arteries (ICA) within the carotid sheath. The ICAs proceed through the carotid canal located in the petrous portion of the temporal bone. After entering the cranial cavity, the ICAs traverse anteriorly through the cavernous sinus. Beyond this point, each internal carotid artery branches into specific arteries:

Ophthalmic artery: Supplies structures in the orbit, along with some structure in the nose, face, and meninges.

Posterior communication artery: Establishes an anterior connection with the internal carotid artery prior to its terminal bifurcation into the anterior cerebral artery and middle cerebral artery. Posteriorly, it forms a communication with the posterior cerebral artery.

Anterior cerebral artery: Deliver oxygenated blood to the majority of the midline regions of the frontal lobes and the superior medial areas of the parietal lobes. Following this, the internal carotid arteries transition into the middle cerebral arteries, which supply blood to the lateral aspects of the cerebral cortex, the anterior regions of the temporal lobes, and the insular cortices.

Posterior circulation: The posterior circulation serves the critical function of supplying blood to the following areas: Occipital lobes, Cerebellum, Brain Stem, Vertebral arteries.

Course and Branches

The left and right vertebral arteries arise from the posterosuperior aspect of their respective subclavian arteries. They ascend through the transverse foramina of the cervical vertebrae, beginning at the C6 level, and continue superiorly. After passing through the transverse foramen of C1. The arteries then enters the cranial cavity via the foramen magnum. Within the cranial vault, the vertebral arteries give rise to several branches:

Posterior Inferior Cerebellar Artery (PICA): This substantial branch, one of the major arteries supplying the cerebellum, emanates from the vertebral artery.

Anterior and Posterior Meningeal Arteies: These arteries supply the dura mater.

Anterior and Posterior Spinal Arteries: These arteries provide blood supply to the spinal cord throughout its entire length.

Subsequently, the vertebral arteries converge to create the basilar artery at the base of the pons, situated inside the cranium.

Basilar Artery

Course and Branches

Upon the fusion of the two vertebral arteries, the resulting basilar artery ascends, issuing various branches:

Anterior Inferior Cerebellar Artery: Provides blood supply to the anteroinferior section of the cerebellum and the 6th, 7th, and 8th cranial nerves.

Pontine Branches: These branches traverse the pons, delivering blood supply to the basilar part of the pons.

Superior Cerebellar Artery: Supplies the superior border of the pons and the superior surface of the middle cerebellar peduncle.

Labyrinthine Artery: Accompanies the 8th cranial nerve, furnishing blood supply to the inner ear.

Posterior Cerebral Artery: Provides blood supply to the superolateral aspect of the cerebrum, including the occipital lobe.

Ultimately, the basilar artery forms connections with the circle of Willis via the posterior cerebral arteries and posterior communicating arteries.

2.7.6 Anatomy of the Circle of Willis

Blood supply to the brain is divided into two main pathways: the anterior and posterior circulations. The anterior circulation is primarily supplied by the paired internal carotid arteries (ICA) and delivers blood to most of the cerebral hemispheres, including the anterior part of the deep cerebral hemispheres. In contrast, the posterior circulation vertebral arteries (VA) and supplies the brainstem, cerebellum, occipital lobes, medial temporal lobes, and the posterior deep hemisphere, particularly the thalamus. Connecting these two circulatory systems, the Circle of Willis is a crucial anatomical structure that enables collateral blood flow to compensate for arterial insufficiency (Rosner et al., 2023).

The terminal branches of the anterior and posterior circulations form an interconnected vascular loop known as the Circle of Willis, located at the base of the brain (Karatas et al., 2015)., the middle cerebral arteries (MCA) branch out from the left and right internal carotid arteries, each giving rise to the anterior cerebral arteries (ACA). The two anterior cerebral arteries are communicates via the anterior communicating artery. Furthermore, the internal carotid arteries give rise to the posterior communicating arteries (PCoA), which connect the middle cerebral arteries (MCA) to the posterior cerebral arteries (PCA).

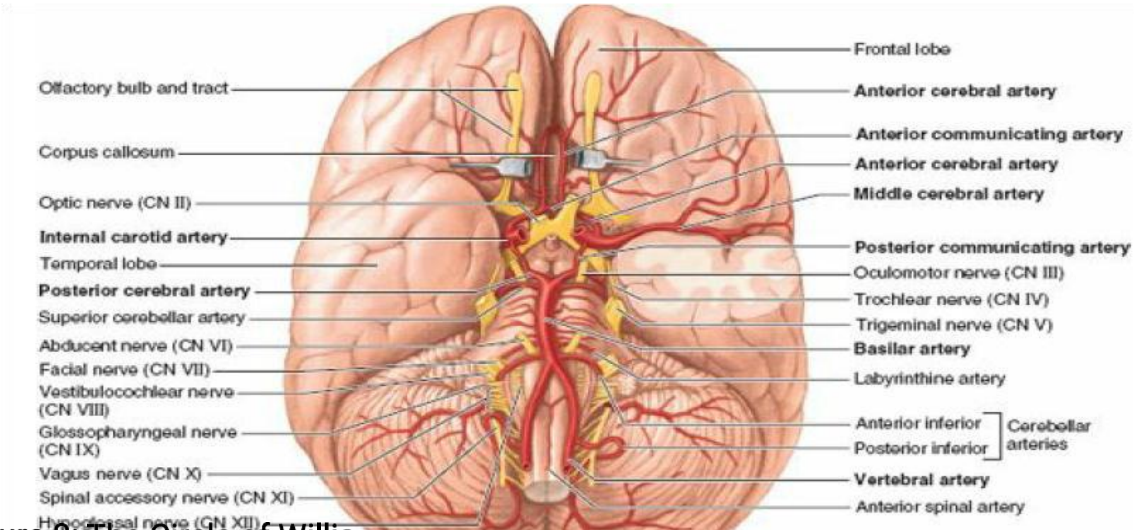

Figure 3: The Circle of Willis.
Image source: Moore et al., 1992: The circle of Willis (circulus arteriosus)

2.8 Clinical Presentation

Stroke presents with a spectrum of neurological deficits, varying based on the type (ischemic and hemorrhagic), location, and extent of cerebral involvement. Prompt recognition of these symptoms is crucial for timely intervention and improved outcomes.

A cross-sectional study conducted in Northwest Ethiopia (2020–2021) involving 555 stroke patients revealed the following prevalent symptoms:

Hemiparesis: Observed in 57.7% of patients, making it the most common presentation

Loss of consciousness: Reported in 20.7% of cases

Aphasia: Noted in 9% of patients

Slurred speech: Present in 4.5% of individuals.

Vomiting: Experienced by 3.6% of patients.

Headache: Reported in 2.7% of cases.

Facial palsy: Observed in 0.9% of patients.

Seizures: Noted in 0.7% of cases.

Differentiating Ischemic and Hemorrhagic Stroke Presentations

The clinical manifestations can vary between ischemic and hemorrhagic strokes:

Ischemic Stroke:

Hemiparesis: 64.4%, Coma: 12%,Aphasia: 10.5%, Slurred speech: 6%

Hemorrhagic Stroke:

Hemiparesis: 47.7%

Loss of consciousness: 34.1% Vomiting: 6.8%

Aphasia: 6.8%

Beyond the classic presentations, strokes can manifest with less obvious symptoms:

Generalized weakness: More prevalent in women (49%) compared to men (36%).

Mental status changes: Observed in 31% of women and 21% of men.

Confusion: Reported in 37% of women versus 28% of men.

Fatigue: More common in women (1.42 times higher risk).

Loss of consciousness: Higher incidence in women (1.30 times higher risk).

These findings highlight the importance of considering sex differences in stroke presentations to avoid misdiagnosis or delayed treatment. NIHSS assesses various domains, including consciousness, vision, motor function, sensation, language, and attention. The acronym BE

FAST aids in the rapid identification of stroke symptoms:

B: Balance – Sudden loss of balance or coordination. E: Eyes – Sudden vision changes in one or both eyes. F: Face – Facial drooping or uneven smile.

A: Arms – Arm weakness or drift.

S: Speech – Slurred or incoherent speech.

T: Time – Immediate action is crucial; call emergency services

2.9 Diagnosis

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: A comprehensive patient history is essential for identifying underlying conditions and informing clinical decision-making. Using open-ended questions encourages patients to share their symptoms, experiences, and concerns, offering valuable insights. Important components of history-taking include the onset of symptoms, their nature, progression, duration, related factors, and the patient's initial response to the illness (Nichol et al., 2023).

Physical examination: Physical examination is a structured and ongoing process focused on objectively evaluating anatomical abnormalities. The clinician assesses the patient's gait, use of assistive devices, speech, and limb movements. The examination begins with observation, followed by palpation, to identify signs such as lacerations, redness, swelling, muscle atrophy, asymmetry, and deformities.

Neurological Assessment: A neurological assessment examines a person's nervous system function, including mental status, cranial nerve function, motor coordination, sensory responses, and gait evaluation.

Mental Status Assessment: Evaluates consciousness, alertness, orientation, cognitive function, memory, speech, and language. Assessment tools such as the Mini-Mental Status Exam (MMSE), Glasgow Coma Scale (GCS), and Grady Coma Scale help measure various aspects of mental status.

Cranial Nerves Examination: Assessing cranial nerves is a key component of neurological evaluation, ensuring their proper function. These nerves, emerging from specific brain regions, are essential for motor, sensory, and autonomic functions in the head and neck. Damage to the corresponding brain areas can result in cranial nerve dysfunction (Reese et al., 2022).

Motor Examination: Evaluating muscle integrity and function is a key aspect of the motor examination. Muscles are inspected for lacerations, bruising, swelling, atrophy, and deformities. Strength and tone are assessed using tools like the Oxford Muscle Grading System and the Modified Ashworth Scale (MAS). Additionally, the range of motion (ROM) is compared between the affected and unaffected sides.

Sensory Examination: This assessment evaluates responses to stimuli, detecting any absent, reduced, heightened, or delayed reactions. Potential causes include dysfunction in peripheral nerve endings, the spinal cord, neural pathways, thalamus, brainstem, or cortex (Shahrokhi & Asuncion, 2022). Sensory perceptions are categorized based on specific 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: 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 evaluating stroke patients, particularly those with acute ischemic stroke. It aids in differentiating strokes from other conditions with similar symptoms, including migraines, tumors, seizures, metabolic disorders, and peripheral or cranial nerve dysfunctions Additionally, neuroimaging facilitates early detection of hemorrhagic stroke, distinguishes between irreversible infarcted tissue and salvageable areas, identifies vascular malformations, assists in planning intravenous thrombolysis and intra-arterial thrombectomy, and aids in outcome prediction (Hand et al., 2006).

Radiological imaging is essential for stroke diagnosis and treatment planning, providing an objective foundation for clinical decisions (Birenbaum et al., 2011). Common imaging techniques include), Angiography, Magnetic Resonance Imaging (MRI), Ultrasonography, and Computed Tomography

(CT).

2.10 Hemiplegic Shoulder Pain

2.10.1 Definition of HSP

HSP is defined as pain experienced in the shoulder area of the hemiplegic side after a stroke. The onset of this pain can occur within the first few days post-stroke and may persist for months.

Studies indicate that HSP affects approximately 16% to 84% of stroke survivors, with variations attributed to differences in study populations and diagnostic criteria. The pain typically develops within the first two weeks to six months post-stroke, and about 65% of those affected continue to experience it for several months thereafter.

2.10.2 Clinical Presentation

i. Pain

- Dull, aching pain at rest
- Worsens with movement or passive range of motion
- Often localized around the deltoid, and rotator cuff

ii. Limited Range of Motion (ROM)

- Especially abduction and external rotation
- Pain-related protective muscle guarding

iii. Muscle Tone Abnormalities

- Early flaccidity → leading to subluxation
- Later increased tone/spasticity → restricts movement

iv. Shoulder Subluxation

- Visible or palpable gap between the head of the humerus and the glenoid fossa
- Due to lack of support from weakened muscles (e.g., supraspinatus, deltoid)

v. Swelling/Edema

- In the hand or upper limb
- May contribute to shoulder-hand syndrome(complex regional pain syndrome)

vi. Sleep Disturbance

- Pain intensifies at night
- May lead to insomnia or frequent awakenings

vii. Functional Impairments

- Difficulty with dressing, hygiene, feeding using the affected arm
- Decreased participation in physiotherapy

2.10.3 Consequences

Hemiplegic shoulder pain is one of the most common and disabling complications after a stroke. It significantly affects the rehabilitation process and the patient's overall quality of life. According to Adey-Wakeling et al. (2015), up to 70% of stroke survivors may experience some form of shoulder pain post-stroke, leading to both physical and psychological consequences.

i. Reduced Upper Limb Function

Pain limits active and passive movements, particularly abduction and external rotation (Kumar et al., 2020). This functional impairment can delay the recovery of arm and hand activities, leading to "learned non-use"

ii. Decreased Participation in Rehabilitation

Patients often avoid therapy due to fear of worsening pain. This avoidance delays motor recovery and reduces overall rehabilitation gains (Rizk et al., 2021).

iii. Emotional and Psychological Impact

Chronic pain can contribute to depression, anxiety, and sleep disturbance, further complicating recovery and quality of life (Adey-Wakeling et al., 2015).

iv. Delayed Return to ADLs

Pain reduces independence in activities of daily living (ADLs) like dressing, grooming, and feeding, prolonging dependency and care needs.

To avoid pain, stroke survivors may adopt abnormal postures or compensatory movements, which can lead to secondary musculoskeletal issues.

2.11 Outcome Measure

Pain Intensity

Visual Analog Scale (VAS): A widely used tool where patients rate their pain on a scale from 0 (no pain) to 10 (worst imaginable pain). Studies have demonstrated significant reductions in VAS scores following LLLT interventions, indicating effective pain relief.

2.12 Empirical Review of Literature

Author/year	**Title**	**Methodology**	**Results**	**Conclusion**
Abdelhakien et al. (2024)	Effectiveness of a High-Intensity Laser for improving Hemiplegic shoulder dysfunction.	A randomized controlled trial with 44 hemiplegic patients. The study group received	Both groups showed significant improvements in shoulder pain	HILT combined with therapeutic exercises provides greater benefits than exercise alone

		high-intensity laser therapy (HILT) combined with therapeutic exercises, while the control group received therapeutic exercises alone, over a three-week period.	(McGill Pain Questionnaire), function (UCLA Shoulder Scale), and handgrip strength. The HILT group demonstrated significantly greater improvements compared to the control group.	in managing hemiplegic shoulder pain and dysfunction.
Basaran et al. (2025)	Comparison of Low-Level Laser Therapy Versus Neuromuscular Electrical Nerve Stimulation at Hemiplegic Shoulder Pain and Upper Extremity Functions.	A prospective randomized controlled study involving 75 stroke patients with hemiplegic should pain. Participants were divided into three groups: LLLT plus conventional physical therapy, NMES plus conventional physical therapy, and conventional physical therapy alone. Treatments were administered over four weeks.	All groups showed significant improvements in pain (VAS), function (SPADI, Barthel Index), and upper extremity motor function. Both LLLT and NMES groups had significantly better outcomes than the control group, with no significant difference between LLLT and NMES.	Adding LLLT or NMES to conventional therapy is more effective than conventional therapy alone in reducing hemiplegic shoulder pain and improving upper extremity function.

Dajpratham et al. (2024)	Comparative Effectiveness of High-Intensity Laser Therapy and Ultrasound Therapy for Hemiplegic Shoulder Pain in Stroke patients.	A double-blind randomized controlled trial involving 30 stroke patients with hemiplegic shoulder pain. Participants were assigned to receive either HILT or ultrasound therapy, along with daily shoulder range of motion exercises, over two weeks.	Both groups showed significant pain reduction and ROM improvement; however, the HILT group had greater improvements in pain (VAS score) and shoulder mobility.	HILT is more effective than ultrasound in managing hemiplegic shoulder pain, and its non-invasive nature makes it a promising adjunct in stroke rehabilitation programs.

2.13 Summary of Literature Review

Stroke is a medical condition characterized by the sudden onset of clinical symptoms indicating either localized or widespread impairment of brain function, lasting more than 24 hours or resulting in death, with no cause other than a vascular origin (WHO, 1970). It occurs due to insufficient blood supply to the brain, leading to cell death, which can result from either a blockage or rupture of cerebral blood vessels (Waqas et al., 2020). Without prompt intervention during the critical "golden hour," the risk of mortality increases significantly. Even with treatment, 70–80% of stroke survivors experience some degree of post-stroke disability (Moon and Keum, 2020).

Stroke is a complex neurological event resulting from the disruption of cerebral blood flow, leading to neuronal injury and loss of brain function. The pathophysiology varies depending on the type of stroke ischemic or hemorrhagic each with distinct mechanisms and consequences.

HSP is defined as pain experienced in the shoulder area of the hemiplegic side after a stroke. The onset of this pain can occur within the first few days post-stroke and may persist for months.

CHAPTER THREE

METHOD

3.1 Materials

3.1.1 Population

The participants for this study consist of adult male and female stroke survivors diagnosed with stroke and attending outpatient physiotherapy at the University of Benin Teaching Hospital (UBTH), Benin City, Edo State, Nigeria. These participants were screened and selected based on inclusion and exclusion criteria relevant to the intervention being studied.

3.1.2 Selection Criteria

This study was conducted amongst stroke survivors referred to neurological physiotherapy at the physiotherapy department in university of Benin teaching hospital (UBTH), Benin city.

3.1.3 Inclusion Criteria

The following participants will be included in this study:

i. Stroke survivors of age 18 and above.
ii. Diagnosed with post stroke hemiplegia
iii. Presence of hemiplegic shoulder pain for at least 3 months
iv. Stroke survivors who could effectively communicate in English Language or Pidgin English fluently

3.1.4 Exclusion Criteria

The following participants were excluded in this study:

i. Severe cognitive impairment or communication difficulties.
ii. History of shoulder trauma or surgery.
iii. Other neuromuscular or musculoskeletal disorders affecting the shoulder.
iv. Use of other pain-modifying treatments during the study.
v. Skin lesions or sensitivity in the laser application area.

3.2 List of Instruments

i. **Low-Level Laser Therapy (LLLT) device:** For administering laser therapy.
ii. **Visual Analog Scale (VAS):** For pain intensity.

3.2.1 Description of Instruments

Low level laser therapy

Description and Uses

LLLT devices, also known as cold lasers or soft lasers, are medical instruments that emit low- intensity light at specific wavelengths (typically 600–1000 nm) to stimulate biological tissues without causing heat or tissue damage. These devices can be handheld or desktop- based, and may use laser diodes or LED clusters to deliver targeted light therapy.

They usually include:

- A power source (battery or AC-powered),
- A laser probe or applicator (for focusing light on specific areas),
- Programmable settings for wavelength, duration, and intensity. It is used for Pain reduction,

Tissue repair and healing, Improve range motion and Reduce muscle spasticity.

Validity: The validity of Low-Level Laser Therapy in clinical practice—especially for treating hemiplegic shoulder pain (HSP) in stroke survivors—refers to how effectively and reliably LLLT achieves its intended outcomes (e.g., pain reduction, improved function) based on scientific evidence.

LLLT is based on well-established physiological mechanisms:

Photobiomodulation: Light energy stimulates mitochondrial activity → increases ATP production → enhances cell repair and anti-inflammatory responses.

Gate Control Theory of Pain: Light input modulates pain signals at the spinal cord level.

These principles support the biological rationale for its clinical use.

Reliability: LLLT devices are machine-controlled and deliver fixed parameters (e.g., wavelength, energy density), making the application highly consistent across therapists.

Minimal human error is involved in the dosage or technique, which increases intra-rater and inter-rater reliability compared to manual therapies.

Visual Analog Scale (VAS)

Description and uses: The Visual Analog Scale (VAS) is a simple, subjective tool used to measure the intensity of pain or other symptoms. It typically consists of a horizontal or vertical line, usually 10 cm (100 mm) long, with endpoints labeled as:

"No pain" (0) on one end, and

"Worst pain imaginable" (10 or 100) on the other.

The patient marks a point on the line that best represents the intensity of their symptom. The score is measured in millimeters from the "no pain" end, giving a value between 0 and 100.It is used for

Pain assessment and monitoring progress.

Validity:

The Visual Analog Scale (VAS) is a widely validated tool for assessing pain intensity. It demonstrates high construct validity, as it accurately measures the concept of subjective pain. It also has strong criterion validity, correlating well with other established pain scales like the Numerical Rating Scale (NRS) and McGill Pain Questionnaire (Hawker et al., 2011).

Reliability: VAS has excellent test-retest reliability, particularly in stable pain conditions.

Studies report an Intraclass Correlation Coefficient (ICC) ranging from 0.71 to 0.99, indicating consistency across multiple measurements (Bijur et al., 2001).

3.3 Methods

3.3.1 Research Design

The study adopt a randomized controlled trial research design

3.3.2 Sampling Techniques

Purposive sampling was used to select eligible participants based on inclusion and exclusion criteria. Participants were then randomly allocated to experimental and control groups

3.3.3 Sample Size

The sample size for this study was calculate using he G*Power 3.1.9.7 software. To achieve a power of 80%, an effect size of 0.8 and a significance level of 5% for a one-tailed test, a sample size of 42 participants was derived for an independent samples t-test.

3.3.4 Ethical Consideration

Ethical approval for this study was being obtained from the Ethics and Research Committee of the University of Benin Teaching Hospital, Benin City. A letter of introduction was submitted to the Department of Physiotherapy, UBTH and the researcher's supervisor. Written informed consent was obtained from all participants before their inclusion in the study. Confidentiality was obtained throughout the research, with all data anonymized and stored securely.

3.3.5 Procedure for Data Collection

i. Baseline data (pain level) was collected.
ii. Intervention phase lasted six weeks with regular monitoring.
iii. Post-intervention assessments were conducted using the same tools.
iv. Data were recorded systematically for analysis

3.3.6 Data Analysis

Data was analyzed using Statistical package for Social science (SPSS). Descriptive statistics (mean, SD) described participant characteristics.

Paired t-tests and independent t-tests evaluated within and between-group differences. A p-value <0.05 will be considered statistically significant.

CHAPTER FOUR

4.1 RESULTS

The primary aim of this study was to determine the effectiveness of an experimental intervention on pain reduction. A total of 42 participants were recruited for the study. They were randomly allocated into two groups: the LLLT Group (n=21) and the Control Group (n=21). (Table 4.1)

4.1.1 Characteristics of the Participants

The mean age for all participants was 61.05 ± 7.278 years. The study included 24 males (57.1%) and 18 females (42.9%). Regarding the side of affliction, 15 participants (35.7%) had their right shoulder affected, while 27 participants (64.3%) had their left shoulder affected. (Table 4.1)

Table 4.1: Characteristics of Participants (N=42)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	24	57.1
	Female	18	42.9
Affected Shoulder	Right	15	35.7
	Left	27	64.3
Continuous Variables		**(Mean ± SD)**	
Age (years)		61.05 ± 7.278	

4.1.2 Within-Group Comparison of Visual Analogue Scale (VAS) Scores at Baseline and Post Intervention

The Wilcoxon Signed-Rank Test was conducted to evaluate the difference in VAS scores from pre-intervention to post-intervention for both the experimental and control groups.
For the LLLT Group, the results show a statistically significant decrease in VAS scores from a pre-intervention median of 7.00 (Interquartile Range = 1.5) to a post-intervention median of 4.00 (Interquartile Range = 1.0), with a Z-value of -4.240 and $p < 0.001$. This indicates that the experimental intervention led to a significant overall improvement in pain.

For the Control Group, there was no statistically significant change in VAS scores from a pre-intervention median of 7.00 (Interquartile Range = 1.5) to a post-intervention median of 6.00 (Interquartile Range = 1.5), with a Z-value of -0.905 and $p = 0.366$. This suggests that the conventional therapy received by the control group did not result in a significant change in pain levels. The results are presented in Table 4.2.

Table 4.2: Within-Group Comparison of VAS Scores using Wilcoxon Signed-Rank Test

Group	Pre-Intervention Median (IQR)	Post-Intervention Median (IQR)	Z-value	p-value
LLLT Group	7.00 (1.5)	4.00 (1.0)	-4.240	<0.001*
Control Group	7.00 (1.5)	6.00 (1.5)	-0.905	0.366

LLLT = Low-Level LASER Therapy, *p < 0.05

4.1.3 Between-Group Comparison of Visual Analogue Scale (VAS) Scores at Pre Intervention

The Mann-Whitney U Test was used to compare the baseline Visual Analogue Scale (VAS) scores between the experimental and control groups to ensure homogeneity before the intervention. The results showed no statistically significant difference in the pre-intervention VAS scores between the LLLT Group and the Control Group (U = 212.500, p = 0.831). This confirms that both groups had similar levels of pain at the start of the study. Table 4.3

Table 4.3: Between-Group Comparison of Pre-Intervention VAS Scores using Mann-Whitney U Test

Group	N	Pre-Intervention Median (IQR)	Mean Rank	U-value	Z-value	p-value
LLLT Group	21	7.00 (1.5)	21.88	212.500	-0.214	0.831
Control Group	21	7.00 (1.5)	21.12			

LLLT = Low-Level LASER Therapy

4.1.4 Between-Group Comparison of Visual Analogue Scale (VAS) Scores at Post Intervention

To determine if the experimental intervention was more effective than the control condition, the post-intervention VAS scores were compared between the two groups using the Mann-Whitney U Test.

The results for the post-intervention scores, detailed in Table 4.4, reveal a statistically significant difference between the experimental and control groups (U = 231.000, $p < 0.001$). The experimental group had a lower median score and mean rank compared to the control group, indicating that the reduction in pain was significantly greater for the participants who underwent the experimental intervention. Table 4.4

Table 4.4: Between-Group Comparison of the Outcomes of Post-Intervention VAS Scores using Mann-Whitney U Test

Group	N	Post-Intervention Median (IQR)	Mean Rank	U-value	Z-value	p-value
LLLT Group	21	4.00 (1.0)	11.00	231.000	-5.694	<0.001*
Control Group	21	6.00 (1.5)	32.00			

LLLT = Low-Level LASER Therapy, *p < 0.05

4.2 Hypotheses Testing

Hypothesis 1: There is no significant difference in VAS scores of participants in the Experimental group at baseline and post-intervention.

Test: Wilcoxon Signed-Rank Test

Significance Level: 0.05

Observed p-value: <0.001

JUDGEMENT: The observed p-value is less than 0.05; the null hypothesis is therefore REJECTED.

Hypothesis 2: There is no significant difference in VAS scores of participants in the Control group at baseline and post-intervention.

Test: Wilcoxon Signed-Rank Test

Significance Level: 0.05

Observed p-value: 0.366

JUDGEMENT: The observed p-value is greater than 0.05; the null hypothesis is therefore NOT REJECTED.

Hypothesis 3: There is no significant difference in the effect of the two treatment groups on VAS scores at post-intervention.

Test: Mann-Whitney U Test

Significance Level: 0.05

Observed p-value: <0.001

JUDGEMENT: The observed p-value is less than 0.05; the null hypothesis is therefore REJECTED.

CHAPTER FIVE

DISCUSSION, CONCLUSION, RECOMMENDATIONS AND IMPLICATIONS

5.1 Discussion

5.1.1 Characteristics of the Participants

The results of the present study showed that the mean age of the participants was 61.05 ± 7.278 years, with a predominance of male participants and a higher incidence of pain in the left shoulder. This suggests that stroke is prevalent among older adults and affects the right cerebral hemisphere more. This finding is corroborated by the results of a study by Dajpratham et al. (2025) and Korkmaz et al. (2022) who investigated similar populations of stroke patients with hemiplegic shoulder pain (HSP) and reported comparable mean ages of 60.8 and 65.7 years, respectively. While the male predominance in the current study aligns with the findings of Dajpratham et al. (2025), it is contrary to the results of a study by Başaran and Büyükşireci (2025), who reported a higher prevalence of stroke among females. This discrepancy in gender distribution may be attributed to regional variations in stroke incidence, as there is a higher prevalence of stoke in men (6.4 in 1000 stroke survivors) than in women (4.4 in 1000 stroke survivors) in Nigeria (Adeloye *et al.*, 2019). The higher frequency of left shoulder pain observed in this study agrees with the results of a study by Prakash et al. (2021). A possible reason for this finding could be the higher incidence rates of strokes occurring in the right cerebral hemisphere, which neurologically corresponds to motor deficits on the left side of the body.

5.1.2 Efficacy of Low-Level Laser Therapy

The results of the present study showed that Low-Level Laser Therapy (LLLT) produced a statistically significant reduction in hemiplegic shoulder pain. This finding is in agreement with a substantial body of literature confirming the efficacy of photo biomodulation for pain management in post-stroke patients. Studies by Karabegović, Kapidžić-Duraković, and Ljuca (2009) and Prakash et al. (2021) both demonstrated that LLLT, when added to a rehabilitation program, was significantly effective in reducing HSP. This is further supported by a systematic review and meta-analysis by Haslerud et al. (2015), who concluded that LLLT provides clinically relevant pain relief for shoulder tendinopathy. The physiological basis for this agreement is the well-documented analgesic and anti-inflammatory effects of LLLT, which works at a cellular level to modulate pain mediators, reduce edema, and alter nerve conduction velocity. The successful outcome in the present study is likely due to the application of appropriate therapeutic parameters, as the literature indicates that the efficacy of LLLT is highly dose-dependent, with studies using inadequate dosages often failing to find a significant effect (Haslerud et al., 2015).

5.1.3 Efficacy of Conventional Therapy

The finding of the present study that the control group, which received only conventional therapy, did not experience a statistically significant change in pain levels suggests that the standard intervention alone was insufficient for significant pain relief within the study's timeframe. This result is comparable with the findings from some studies, such as Abdelhakiem et al. (2024) and Korkmaz et al. (2022), where the control groups receiving therapeutic exercise alone did show a statistically significant, albeit smaller, improvement in pain scores. A potential reason for this difference may lie in the specific composition and intensity of the rehabilitation programs. The "conventional therapy" in the present study may have differed in duration, frequency, or specific exercises compared to the more structured therapeutic exercise protocols in other studies, which could account for the variance in outcomes. However, the lack of significant improvement in the control group serves to emphasize the specific and potent therapeutic contribution of the LLLT intervention over and above the standard care provided.

5.1.4 Comparative Efficacy of LLLT and Conventional Therapy

The results of the present study showed that at post-intervention, the LLLT group had a statistically significant greater reduction in pain compared to the control group. This finding implies that the addition of LLLT to a conventional rehabilitation program is superior to conventional therapy alone for the management of HSP. This conclusion is strongly corroborated by the available literature. A study by Prakash et al. (2021) found that an LLLT group showed "better improvement" than a control group receiving only a standardized rehabilitation program. Similarly, studies investigating High-Intensity Laser Therapy (HILT), a related modality, have consistently found it to be superior to exercise alone. Both Korkmaz et al. (2022) and Abdelhakiem et al. (2024) reported that their HILT groups experienced significantly greater improvements in pain and function than their respective control groups. The reason for the superior outcome of the combined intervention is likely due to a synergistic effect. LLLT directly targets the physiological drivers of pain and inflammation, and this pain reduction may, in turn, enable patients to participate more fully and effectively in their physical therapy exercises, creating a positive feedback loop that enhances functional recovery. This proposed mechanism is supported by Alfredo et al. (2021). Furthermore, research by das Neves et al. (2016) suggests that LLLT may also improve muscle performance and reduce fatigue in spastic muscles post-stroke, which would further enhance the effectiveness of the exercise component of rehabilitation.

5.2 Conclusion

Low-Level Laser Therapy (LLLT) when used as an adjunct to a conventional rehabilitation program, is an effective intervention for managing hemiplegic shoulder pain among stroke survivors in UBTH.

LLLT leads to greater reduction in pain than conventional therapy alone as it provides a therapeutic effect that enhances the outcomes of standard post-stroke physiotherapy care.

As a non-invasive modality, LLLT offers a safe method for pain relief that can be a critical facilitator for functional recovery. By effectively mitigating pain, LLLT allows patients to engage more fully and with greater tolerance in the essential exercise-based components of their rehabilitation, thereby creating a better opportunity for the improvement of upper limb function.

5.3 Recommendation

i. **Integration of LLLT into Clinical Practice:** It is recommended that clinicians, including physiotherapists and rehabilitation specialists, consider the integration of Low-Level Laser Therapy (LLLT) as a standard adjunctive treatment for stroke survivors experiencing hemiplegic shoulder pain (HSP). The evidence from this study demonstrates that LLLT significantly enhances pain relief beyond what is achieved with conventional therapy alone.

ii. **Use as a Priming Modality:** LLLT should be considered as a priming modality before therapeutic exercise. By effectively reducing pain, LLLT can improve a patient's tolerance and ability to participate more actively in functional and strengthening exercises, potentially leading to better overall outcomes in upper limb recovery.

iii. **Patient Education:** Healthcare providers should educate stroke survivors and their caregivers about the benefits of LLLT as a non-invasive, safe, and effective option for managing shoulder pain. This empowers patients and encourages adherence to a comprehensive rehabilitation plan that includes this modality.

iv. **Policy and Guideline Development:** Rehabilitation centers and healthcare institutions are encouraged to review their clinical guidelines for post-stroke care to include LLLT as an evidence-based option for the management of HSP. This will help standardize care and ensure that patients have access to effective pain management strategies.

5.4 Implications for Further Study

i. **Assessment of Functional Outcomes:** This study focused primarily on pain reduction as the main outcome. A significant implication for future research is the need to incorporate comprehensive, objective measures of upper limb function. Future studies should include assessments such as the Fugl-Meyer Assessment for Upper Extremity (FMA-UE), goniometric measurements of range of motion (ROM), and dynamometry for grip strength to directly quantify the impact of LLLT on functional recovery, rather than inferring it from pain relief alone.

ii. **Long-Term Follow-Up:** The present study evaluated the effects of LLLT immediately following the intervention period. The long-term sustainability of the observed pain reduction is unknown. Further studies with extended follow-up periods (e.g., 3-, 6-, and 12-months post-intervention) are essential to determine the durability of LLLT's therapeutic effects and its long-term impact on quality of life and functional independence.

iii. **Inclusion of a Placebo Control:** While this study demonstrated the superiority of adding LLLT to conventional therapy, it did not include a sham LLLT group. To isolate the specific physiological effects of the laser from the placebo effect of receiving an additional intervention, future randomized controlled trials should employ a three-arm design: one group receiving LLLT, a second receiving sham LLLT, and a third receiving only conventional therapy.

iv. **Comparative Effectiveness Studies:** This study confirms the benefit of LLLT against standard care. However, its effectiveness relative to other widely used modalities remains to be established. Future research should conduct head-to-head comparisons of LLLT against other electrotherapeutic interventions, such as High-Intensity Laser Therapy (HILT), Transcutaneous Electrical Nerve Stimulation (TENS), or Neuromuscular Electrical Stimulation (NMES), to determine the most effective and cost-effective treatment strategies for managing hemiplegic shoulder pain.

REFERENCES

Abdelhakiem, N. M., Saleh, M. S. M., Shabana, M. M. A., Abd EL Wahaab, H. A., & Saleh, H.M. (2024). Effectiveness of a high-intensity laser for improving hemiplegic shoulder dysfunction: a randomized controlled trial. Scientific Reports, 14,7346. https://doi.org/10.1038/s41598-024-57453-9

Abdelhakiem, N. M., Mustafa Saleh, M. S., Shabana, M. M. A., Abd El Wahaab, H. A., & Saleh, H. M. (2024). Effectiveness of a high-intensity laser for improving hemiplegic shoulder dysfunction: a randomized controlled trial. *Scientific Reports*, 14(1), 7346.

Alfredo, P. P., Bjordal, J. M., Steagall Junior, W., Marques, A. P., & Casarotto, R. A. (2021). Efficacy of low-level laser therapy combined with exercise for subacromial impingement syndrome: A randomised controlled trial. *Clinical Rehabilitation*, 35(5), 710–720.

Adey-Wakeling, Z., Arima, H., Crotty, M., Leyden, J., Anderson, C. S., & Gilligan, A. (2016). Hemiplegic shoulder pain reduces quality of life after acute stroke: A prospective population-based study. *Australian Health Review,* 40(3), 292–298. https://doi.org/10.1071/AH15078

Başaran, P. Ö., & Büyükşireci, D. E. (2025). Comparison of low-level laser therapy versus neuromuscular electrical nerve stimulation at hemiplegic shoulder pain and upper extremity functions. *Lasers in Medical Science*, 40(42).

Başaran, P. Ö., & Büyükşireci, D. E. (2025). Comparison of low-level laser therapy versus neuromuscular electrical nerve stimulation at hemiplegic shoulder pain and upper extremity functions. *Lasers in Medical Science*, 40(1), 42. https://doi.org/10.1007/s10103-025-04305-1

Bhat, V.M., Cole, J.W., Sorkin, J.D., Wozniak, M.A., Malarcher, A.M., Giles, W.H. and Stern, B.J. (2008) 'Dose-response relationship between cigarette smoking and risk of ischemic stroke in young women', *Stroke*, 39(9), pp. 2439-2443.

Bijur, P. E., Silver, W., & Gallagher, E. J. (2001). Reliability of the visual analog scale for measurement of acute pain. *Academic Emergency Medicine*, 8(12), 1153–1157.

Boehme, A.K., Esenwa, C. and Elkind, M.S.V. (2017) 'Stroke Risk Factors, Genetics, and Prevention', *Circulation Research*, 120(3), pp. 472-495

Chung, H., Dai, T., Sharma, S. K., Huang, Y. Y., Carroll, J. D., & Hamblin, M. R. (2012). The nuts and bolts of low-level laser (light) therapy. *Annals of Biomedical Engineering*, 40(2),516–533. https://doi.org/10.1007/s10439-011-0454-7

Connor, M.D., Walker, R., Modi, G. and Warlow, C.P. (2005) 'Burden of stroke in black populations in sub-Saharan Africa', *The Lancet Neurology*, 6(3), pp. 269-278.

Dajpratham, P., Kuptniratsaikul, V., Thinkhamrop, B., & et al. (2024).Effectiveness of low-level laser therapy on hemiplegic shoulder pain in post-stroke patients: A randomized controlled trial. *Journal of Stroke Rehabilitation*,31(2)112-120

Dajpratham, P., Pongratanakul, R., Satidwongpibool, T., Kluabwang, N., Akkathep, P., & Claikhem, T. (2025). Comparative effectiveness of high-intensity laser therapy and ultrasound therapy for hemiplegic shoulder pain in stroke patients: a randomized controlled trial. *Topics in Stroke Rehabilitation*, 32(1), 52-60.

Das Neves, M. F., dos Reis, M. C. R., de Andrade, E. A. F., de Lima, F. P. S., Nicolau, R. A., Arisawa, E. Â. L., ... & Lima, M. O. (2016). Effects of low-level laser therapy (LLLT 808 nm) on lower limb spastic muscle activity in chronic stroke patients. *Lasers in medical science*, 31(6), 1111-1118.

El-Sayed, A. M., Khalil, A. A., & Ramadan, A. E. (2025). Comparative efficacy of low-level laser therapy and neuromuscular electrical stimulation in managing hemiplegic shoulder pain post-stroke. *Journal of Stroke Rehabilitation Research*, 18(2), 110–118.

Feigin, V. L., Stark, B. A., Johnson, C. O., Roth, G. A., Bisignano, C., Abady, G. G., ... Vos, T. (2021). Global, regional, and national burden of stroke and its risk factors, 1990–2019: A 52 systematic analysis for the Global Burden of Disease Study 2019. *The Lancet Neurology*, 20(10), 795–820. https://doi.org/10.1016/S1474-4422(21)00252-0

Fernández-Gil, M.A., Palacios-Bote, R., Leo-Barahona, M. and Mora-Encinas, J.P. (2010) 'Anatomy of the brainstem: A gaze into the stem of life', *Seminars in Ultrasound, CT and MRI*, 31(3), pp. 196-219.

Hamblin, M. R. (2017). Mechanisms and applications of the anti-inflammatory effects of photobiomodulation. APL Photonics, 2(4), 041501. https://doi.org/10.1063/1.4982612

Hawker, G. A., Mian, S., Kendzerska, T., & French, M. (2011). Measures of adult pain: Visual Analog Scale for Pain (VAS). *Arthritis Care & Research*, 63(S11), S240–S252.

Haslerud, S., Magnussen, L. H., Joensen, J., Lopes-Martins, R. A. B., & Bjordal, J. M. (2015). The Efficacy of Low-Level Laser Therapy for Shoulder Tendinopathy: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Physiotherapy Research International*, 20(2), 108–125.

Huff, T., Murad, M.H. and Omari, A.A. (2023) 'Occipital Lobe Infarction', StatPearls. Available at: https://www.ncbi.nlm.nih.gov/books/NBK532294/ (Accessed: 23 August 2024).

Ifeanyi, O., Anukam, K.C., Otikpo, E., Onyedikachi, O.A., Egbuche, O.A. and Onyeneke, O.A. (2020)'Prevalence of cardiovascular risk factors among students in a private university in Nigeria: A cross-sectional study', *Journal of Applied Sciences*, 20(2), pp. 64-72.

Jimsheleishvili, G. and Dididze, M. (2023) 'Cerebellum', StatPearls. Available at:https://www.ncbi.nlm.nih.gov/books/NBK538299/ (Accessed: 23 August 2024

Karabegović, A., Kapidžić-Duraković, S., & Ljuca, F. (2009). Laser therapy of painful shoulder and shoulder-hand syndrome in treatment of patients after the stroke. *Bosnian journal of basic medical sciences*, 9(1), 59-65.

Korkmaz, N., Gurcay, E., Demir, Y., Tezen, Ö., Korkmaz, İ., Atar, M. Ö., & Yaşar, E. (2022). The effectiveness of high-intensity laser therapy in the treatment of post-stroke patients with hemiplegic shoulder pain: a prospective randomized controlled study. *Lasers in Medical Science*, 37(1), 645-653.

Kiernan, J.A. (2012) 'Anatomy of the Temporal Lobe', *Journal of Clinical Neuroscience*, 19(2), pp. 121-125.

Komolafe, M.A., Olorunsola, E.O., Fehintola, F.O., Olamoyegun, M.A. and Akinyemi, O. (2015) 'Obesity and Hypertension among Church Attendees in Ile-Ife, Nigeria', *Nigerian Medical Journal*, 56(5), pp. 322-326.

Kumar, R., Yadav, R., & Srivastava, A. (2020). Prevalence and management of hemiplegic shoulder pain post - stroke: A review. International Journal of Research in Medical Sciences, 8(4), 1301–1307. https://doi.org/10.18203/2320-6012.ijrms20201320

Lee, C.D., Folsom, A.R. and Blair, S.N. (2003) 'Physical Activity and Stroke Risk: A Meta-Analysis', *Stroke*, 34(10), pp. 2475-2481.

Melzack, R., & Wall, P. D. (1965). Pain mechanisms: A new theory. Science, 150(3699), 971–979. https://doi.org/10.1126/science.150.3699.971

Moon, H.S. and Keum, J. (2020) 'Management of stroke in the acute phase: focus on the golden hour', *Journal of the Korean Medical Association*, 63(9), pp. 566-577.

Mozaffarian, D., Benjamin, E.J., Go, A.S., Arnett, D.K., Blaha, M.J., Cushman, M., and Turner, M.B. (2016) 'Heart disease and stroke statistics—2016 update: a report from the American Heart Association', *Circulation*, 133(4), pp. e38-e360.

Najimi, N., Naseri, N., & Mohammadi, R. (2021). The effect of low-level laser therapy on pain and function in post - stroke hemiplegic shoulder pain: A randomized trial. *Journal of Stroke and Cerebrovascular Diseases, 30*(9), Article 105937. https://doi.org/10.1016/j. jstrokecerebrovasdis.2021.105937

Nudo, R. J. (2006). Mechanisms for recovery of motor function following cortical damage. *Current Opinion in Neurobiology*, 16(6), 638–644. https://doi.org/10.1016/j.conb. 2006.10.004

Pandian, J.D., William, A.G., Prem, R. (2022) 'Rehabilitation for Stroke in India: Current Status and Future Perspectives', *Annals of Indian Academy of Neurology*, 25(4), pp. 602-610.https://doi.org/10.4103/aian.aian_525_22.

Panuganti, K. K., Tadi, P., & Lui, F. (2022). Transient ischemic attack. In StatPearls [Internet]. StatPearls Publishing

Prakash, P. K., Sushmitha, D. S., Thulasi, P. R. S., & Swamy, G. (2021). Effect of low level laser therapy on hemiplegic shoulder pain in post stroke subjects. *International Journal of Scientific Research*, 10(7), 73-76.

Rajashekar, D. & Liang, J.W., (2022). Intracerebral hemorrhage. In StatPearls [Internet]. StatPearls Publishing.

Reese, V., M Das, J., & Al Khalili, Y. (2023). Cranial Nerve Testing. In StatPearls. StatPearls Publishing

Sacco, R.L., Kasner, S.E., Broderick, J.P., Caplan, L.R., Connors, J.J., Culebras, A., Elkind,

M.S., George, M.G., Hamdan, A.D., Higashida, R.T. & Hoh, B.L., (2013). An updated definition of stroke for the 21st century: *a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke*, 44(7), pp.2064-2089.

Zein, R., Selting, W., & Hamblin, M. R. (2018). Review of light parameters and photobiomodulation efficacy: Dose–response relationships and laser therapy. *Journal of Photochemistry and Photobiology B: Biology*, 193, 19–29. https://doi.org/10.1016/j. jphotobiol.2019.02.002

Ziu, E., MZ, K.S. & Mesfin, F.B., (2017). barachnoid hemorrhage. In StatPearls [Internet]. StatPearls Publishing.

APPENDICES

ETHICAL APPROVAL

HEALTH RESEARCH ETHICS COMMITTEE (HREC)

UNIVERSITY OF BENIN TEACHING HOSPITAL
P.M.B. 1111 BENIN CITY NIGERIA Telephone: 052-600418. Website: ubth.org

CHIEF MEDICAL DIRECTOR
Prof. Darlington E. Obaseki
E-mail: drlobaseki@gmail.com

DIRECTOR OF ADMINISTRATION
Jim Uwadie, Esq

CHAIRMAN
Prof. (Mrs.) Antoinette N. Ofili

HREC OFFICE:
Committee email: ubthresearchethics@gmail.com
Registration Number:
NHREC-UBTH-HREC/24/12/2022B

PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/147

PROPOSAL TITLE: "EFFECT OF LOW-LEVEL LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION (LASER) THERAPY ON HEMIPLEGIC SHOULDER PAIN AMONG STROKE SURVIVORS"

PRINCIPAL INVESTIGATOR(S): OGUNSOLA BOLAJI ADEMOLA

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

DATE CONSIDERED: AUGUST 6TH, 2025

DECISION OF THE COMMITTEE: APPROVED

THIS APPROVAL DATES 6/8/2025 TO 5/8/2026. 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: 6/8/2025

UNIVERSITY OF BENIN TEACHING HOSPITAL ETHICS & RESEARCH COMMITTEE Sign. Date. BENIN CITY P.M.B. 1111

SUPERVISOR (S): DR. H.I ADEBISI

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 inform consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the stu In multiyear research, endeavor to submit your annual re-port to the HREC early in order to obtain renewal of yo approval and avoid disruption of your research. No changes are permitted in the research without prior approval by HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit y research site without previous notification

Signature & Date.................................