ACUTE EFFECTS OF SUSTAINED BILATERAL UPPER LIMB ELEVATION EXERCISE PROTOCOLS ON CARDIOVASCULAR PARAMETERS OF HYPERTENSIVE STROKE SURVIVORS: IMPLICATIONS FOR HEMODYNAMIC REGULATION

BY

EKUASE DAISY OSAKPOLOR
(BMS1803138)

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

OCTOBER, 2025.

CERTIFICATION

This dissertation by **EKUASE DAISY OSAKPOLOR** is accepted in its present form as satisfying the dissertation requirement of the degree of Bachelor of Physiotherapy of the School of Basic Medical Sciences, College of Medical Sciences of the University of Benin.

DR. (MRS) C. O OBASEKI ________________________

SUPERVISOR **SIGNATURE AND DATE**

EXTERNAL SUPERVISOR ________________________

SIGNATURE AND DATE

APPROVED

____

DR. (MRS) C.O OBASEKI
HEAD
DEPARTMENT OF PHYSIOTHERAPY
COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN

DEDICATION

To my Lord God Almighty, the maker of Heaven and Earth, from whom all things were, are and will continue to be.

To my parents, Mr and Mrs Ekuase and my maternal grandmother, Late Mrs Comfort Enogiomwan Imarhiagbe (I sincerely miss you every day).

To my uncles and aunties who have all been outstanding, loving and so supportive throughout the course of my undergraduate journey — I could not have done these seven years without you all. Thank you all so much.

ABSTRACT

Background/Purpose of the Study: Stroke is a leading cause of long-term disability and most times, this condition is accompanied by hypertension which challenges the cardiovascular system's regulation. Hypertensive stroke survivors frequently experience impaired hemodynamic control and as such, upper limb elevation exercises have been suggested to influence the cardiovascular parameters of this stated population but the available evidences on the acute effects on the hemodynamic parameters are limited. This study investigates to bridge the knowledge and empirical gap in order to wholesomely understand the acute effects of these exercises on hypertensive stroke survivors

Aim: This study aims to compare the acute effects of sustained bilateral upper limb elevation exercise protocols on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and heart rate in hypertensive stroke survivors.

Methods: A cross-over repeated measure experimental design employing a simple random (ballot) sampling technique was conducted to compare the acute effects of sustained bilateral upper limb elevation exercises at 90° and 180° on SBP, DBP, MAP and HR in hypertensive stroke survivors. 31 participants (mean age = 56.71 ± 12.05years) were recruited. Each participants performed both exercise protocols and cardiovascular parameters were recorded before and immediately after each exercise. Data was analyzed using paired and independent sample T-tests at a significance level of ≤ 0.05.

Results: Significant reductions were observed in SBP ($p= 0.001$) and MAP ($p= 0.011$) following the 90° protocol, while the DBP and HR showed no significant change. After the 180° protocol, SBP ($p< 0.001$), DBP ($p= 0.034$) and MAP ($p= 0.002$) significantly decreased, with HR significantly increasing ($p= 0.014$). No significant differences were found between the two protocols or genders ($p> 0.05$).

Conclusion: Both exercise protocols produce mild, acute and transient reductions in blood pressure, suggesting potential short-term hemodynamic benefits for hypertensive stroke survivors.

Keywords: Sustained bilateral upper limb elevation, cardiovascular parameters, hypertensive stroke survivors, hemodynamic regulation.

ACKNOWLEDGEMENTS

I am deeply grateful to the Lord Almighty for the strength, tenacity, wisdom, sound mind, and excellent spirit He bestowed on me to complete this project work.

My profound gratitude goes to my supervisor and ever-active Head of Department, Dr. (Mrs.) Chigozie O. Obaseki, for her immense support, constant guidance, encouragement, and the needed constructive criticism throughout the course of this project work.

I also wish to appreciate the lecturers and staff of the Department of Physiotherapy, University of Benin — Prof. K. I Oke, Rev. Sis Henrietta Fawole, Dr Adebisi Hammed, Dr Nicholas Oghumu, Dr Nelson Ekechukwu, Prof. Joseph Ummunah, Dr. (Mrs) Aiyegbusi, Dr. (Mrs) Kubeyinje, Dr Bolarinde, Prof. Obinna Ezeukwu, PT. Osayi Nkiruka Obarisiagbon — for their support, guidance, and contribution throughout the years of my undergraduate academic journey. My sincerest gratitude also goes to the non-academic staff, especially Mr Nosa and Mrs Juliet for their support and kindness towards me.

My deepest gratitude also goes to the Head of Department, Physiotherapy, University of Benin Teaching Hospital, Prof Taiwo Oyewumi and to all the chiefs, interns and clinicians who contributed to my clinical growth and development towards making me an all-rounded student. I also extend my thanks to the hospitals with whom I spent the periods of my externships — Irrua Specialist Hospital, Edo State and General Hospital, Gbagada, Lagos — for their immense and countless contributions to my clinical experience and growth.

To my beloved parents, Mr. and Mrs. Ekuase, I remain deeply grateful. Your care, prayers, guidance, and unwavering love have been my anchor. To my siblings — Naomi, Benson, and Nelson — thank you for always being there for me. I could not have done life without you all. Special thanks go to my uncle, Prof. F. A. Imarhiagbe and my auntie, Mrs. Kate Osagie. You both are major blessings in my life, fundamental instruments to my success and your encouragement at every step has been invaluable. I count it a great privilege to be your niece. God bless you, sir and ma. To my dear cousins — Cheeky, Victor, and Faith — I could not have survived UNIBEN without your guidance. Thank you so much.

To my sponsors and benefactors, both far and near, I owe profound gratitude. Your support has made this journey possible, and I do not take it for granted. You are indeed the gifts that keep on giving.

A very big thank you to my pastor, Pastor Collins for always standing by me in prayers and supplications, and for always interceding for me especially in times when I needed it. Thank you so much, sir and may your labour in the Lord continue to yield bountiful blessings.

To my dear friends who stood by me every step of the way — Courage (for never leaving me in the lurch), Henry (a wonderful best friend), Noreos (My princess), Arani, Edidiong, Ruthie (for always listening), Ehis (for the urgent 2k and care), Uzo’m (for the surprise alerts and laughter), Osamudiamen (for always making me laugh), Jeboda (for constant encouragement), Delphine (oh, Chilozie my queen), Yakubu (thank you — you know why), Nosa (for making out time despite your busy schedule), Chibuike (for always making me feel comfortable), Erica (my Rika), Bunmi (for giving me a glimpse of Physiotherapy before I began), Kevwe, Oghenetega, Tobenna (You're a wonderful soul), Waka Physio, Alero (My sweet girl), Olaolu, Dr Nmeso, Dupe my baby, Angelica and my girls — Ebere, Jane and Praise (we made it, you guys) — I say a big thank you.

I also thank all my participants who were responsive and highly vital in the successful completion of this project work.

Lastly, to you, Daisy — for staying dogged for seven years, holding it down in good and bad times — you are a source of inspiration. Thank you for never dulling your shine. You are a star!

To all others whose names I may not have mentioned due to the confines of this page but whose contributions were priceless, I remain sincerely grateful.

TABLE OF CONTENTS

LIST OF TABLES

TITLE **PAGE**

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The World Health Organization (2021) described cardiovascular diseases (CVD) as a leading cause of death globally, taking an estimated 17.9 million lives each year. These cardiovascular diseases include a vast range of disorders that affect the heart and blood vessels, such as coronary heart disease, cerebrovascular disease, and rheumatic heart disease, among other conditions. It also noted that hypertension is one of the leading causes of cardiovascular diseases, and it describes this condition as when the pressure in the blood vessels is very high, as high as 140/90mmHg or even higher (WHO, 2023). It is, in fact, one of the strongest risk factors for the development of almost all cardiovascular diseases acquired during life, including coronary diseases, left ventricular hypertrophy, and valve-related heart diseases (Kjeldsen, 2018)

Statistics show that worldwide, hypertension can be found in about 1.28 billion adults within the age range of 30-79 years (WHO, 2023). In Nigeria, the prevalence has been on an exponential increase over the past decades, with the recent metrics ranging from 22% to 44% and this varies by each region of the country (Ogungbe et al., 2024). The hypertensive state of an individual is a major risk factor for stroke. According to Feigin et al. (2025), stroke remains the second leading cause of death and the third leading cause of death and disability combined. Globally, stroke has a very high prevalence, with about 15 million people suffering the condition annually (WHO, 2023). The prevalence of this condition in Nigeria does not lessen either, as it is a source of major public health concern, with an estimated prevalence of about

1.14 per 1000 persons (Wahab, 2008). Most stroke survivors still experience physical limitations, which may encourage a sedentary lifestyle, further causing secondary issues like cardiovascular deconditioning, and this limits their ability to lead an independent life, maximally carrying out activities of daily living (ADLs), and increasing the energy expenditure of walking (Moore et al., 2013).

Hypertension places a substantial burden on the cardiovascular system, and this is primarily as a result of left ventricular hypertrophy, which may further progress to heart failure (Tackling et al., 2023). This increases the need for the development and implementation of effective management strategies (Whelton et al., 2018). Consequently, physiotherapy interventions like aerobic exercise training, early mobilization, and other modalities, particularly those targeting vascular and autonomic regulation, are fast becoming recognized for their efficacy in managing cardiovascular health (Cornelissen and Smart, 2013). Within the scope of these interventions, upper limb elevation exercises have been cited and hypothesized to influence these hemodynamic responses, such as systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP), and even the heart rate (HR) (Kim et al., 2017).

Upper limb elevation exercises are movements that focus on lifting and raising the arms above the level of the shoulders (Beckman and Cousins, 2019). These submaximal exercises, performed at an intensity below the patient’s maximal capacity, are highly efficient in the improvement of endurance, circulation, and cardiovascular responses (Reed et al., 2020). The significance of these exercises can be attributed to their ability to help strengthen the muscles in the shoulders, arms, and upper back, which are used for many daily activities like reaching for objects, dressing, or carrying items. The use and benefits of upper limb elevation exercises in the treatment and rehabilitation of patients, especially hypertensive stroke survivors, cannot be overemphasized. This is due to their effectiveness in the control of blood pressure, particularly as many patients with hypertension are often limited when carrying out lower limb exercises like cycling and jogging due to musculoskeletal or vascular occlusive diseases (Westhoff et al., 2008). When performed simultaneously and above the heart level (bilateral elevation), these movements can significantly influence the cardiovascular dynamics due to the involvement of postural muscles, altered venous return, and autonomic modulation (Prasertsri et al., 2018; Machado-Vidotti et al., 2014). Elevation exercises will challenge the cardiovascular system by increasing peripheral vascular resistance and altering heart rate (HR) and blood pressure (BP) responses (Nystoriak et al., 2018). Such exercises are common in rehabilitation, particularly in cardiac, neurological, and orthopedic patients, where restoring upper limb function and cardiovascular endurance are essential.

The advancement of physiotherapy practices towards being an autonomous, primary care model makes the screening of cardiovascular risk factors and related serious pathologies, which can be foundationally determinable by the accurate measurement and recording of cardiovascular parameters, more essential. This is even more primary, especially taking into account the alarming number of cardiovascular disease-related deaths. As first contact healthcare practitioners, physiotherapists should ensure timely medical referrals for further investigations through an accurate screening, measurement, and recording (Giacchi et al., 2021).

There exists a plethora of literature about how physical activity affects the cardiovascular parameters (Kunutsor et al., 2024; Franklin et al., 2022; Perry et al., 2023), but the specific influence of upper limb sustained elevation positioning exercise and angle of inclination on hypertensive stroke survivors remains underexplored. These upper limb exercises may seem quite easy and mild, but they are actually quite effective and are low-cost, accessible strategies for the treatment and rehabilitation of patients. An in-depth knowledge and understanding of how this submaximal, isometric exercises influence cardiovascular parameters is highly crucial for physiotherapists and other healthcare professionals, as it is essential to understand how these hemodynamic changes can also lead to fatal outcomes on the health of this established patient population.

The rationale for this exploratory investigation is based on the need for evidence-based caution and a clearer understanding of the physiological responses when prescribing even the most seemingly innocuous submaximal exercises to vulnerable patient populations like hypertensive stroke survivors. As such, this one-off, cross-over repeated measure research is not intended for functional capacity or mobility rehabilitation (as it is ordinarily meant for), but rather to explore and observe the acute cardiovascular responses associated with these exercise interventions on hypertensive stroke survivors.

In addition, one major, unique feature of this study is the comparative approach it employs to two different angles of inclination of arm elevation exercise protocols. This study will investigate whether the alteration in inclination of the upper limbs while carrying out the upper limb elevation above the heart level can increase blood flow back to the heart, especially considering empirical evidence suggesting that exercises done in the upper limbs could significantly increase venous return back to the heart (Hayashi et al., 2018). Therefore, by comparing both angles of elevation, this study aims to determine whether the position of limbs can modulate cardiovascular parameters of hypertensive stroke survivors in any clinically and statistically significant way.

Furthermore, it is imperative to note that this study is not a cause-and-effect investigation; rather, it is an observational and exploratory inquiry as it seeks to provide insight that may further guide safer exercise prescription. The impact of sustained bilateral upper limb elevation on cardiovascular parameters like systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate is yet to be comprehensively studied in various clinical populations. The limitations identified in the empirical studies highlight the major aim and primary objective of this study, which is to bridge the empirical and knowledge gap in the current existing knowledge by comparatively examining the acute effects of sustained bilateral upper limb elevation exercise protocols at two inclination angles on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and heart rate in hypertensive stroke survivors.

1.2 Statement of the Problem

Non-pharmacological treatment interventions, such as sustained upper limb elevation exercises, are considered forms of isometric training and have been noted as essential components of hypertension management (Edwards et al., 2024). Existing knowledge on exercise conditioning is largely based on programs that focus more on the involvement of the lower limbs, given that the performance and execution of many activities of daily living requires not only the hands but also the upper limbs as a whole (Fasoli, 2016). While physiotherapists primarily emphasize the rehabilitation of impaired body structures and function, equal attention is given to promoting motor recovery in patients affected by stroke.

Despite the growing interest in physiotherapeutic interventions for cardiovascular modulations, there is still a lingering lack of well-grounded, comprehensive studies that evaluate the cardiovascular responses to upper limb elevation exercises at varying inclinations and with the use of different modalities to carry out these exercises, and this creates a huge clinical challenge. Understanding how different elevation angles (90^0 and 180^0) affect blood pressure and heart rate across hypertensive stroke survivors could help offer expert management insights into safe and effective exercise prescriptions that will be made by physiotherapists. This further buttresses the need to fill the empirical evidence and knowledge gaps for these individuals.

1.3 Research Questions

This present study, therefore, sought to answer the following research questions raised:

i. What are the acute effects of 90^0 sustained bilateral upper limb elevation exercise protocol on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate of hypertensive stroke survivors?

ii. What are the acute effects of 180^0 sustained bilateral upper limb elevation exercise protocol on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate of hypertensive stroke survivors?

iii. Is there any difference in the cardiovascular response between the 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols in hypertensive stroke survivors?

iv. Is there any difference in cardiovascular response between the 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols between male and female hypertensive stroke survivors?

1.4 Aim of the Study

This study aimed to compare the acute effects of sustained bilateral upper limb elevation exercise protocols at two different angles on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate in hypertensive stroke survivors.

1.4.1 Specific Objectives

The specific objectives of this study were:

i. To explore the acute effects of 90^0 sustained bilateral upper limb elevation exercise protocol on systolic blood pressure, diastolic blood pressure, mean arterial blood and heart rate in hypertensive stroke survivors.
ii. To explore the acute effects of 180^0 sustained bilateral upper limb elevation exercise protocol on systolic blood pressure, diastolic blood pressure, mean arterial blood and heart rate in hypertensive stroke survivors.
iii. To explore the difference in cardiovascular responses between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols in hypertensive stroke survivors.
iv. To explore the difference in cardiovascular responses between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocol in male and female hypertensive stroke survivors.

1.5 Research Hypothesis

1.5.1 Main Hypothesis

There would be no significant difference in the acute effect of sustained bilateral upper limb elevation exercise protocols on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate in hypertensive stroke survivors.

1.5.2 Sub Hypotheses

i. There would be no significant difference in the systolic blood pressure of participants at 90^0 sustained bilateral upper limb elevation exercise protocol.
ii. There would be no significant difference in the systolic blood pressure of participants at 180^0 sustained bilateral upper limb elevation exercise protocol.

iii. There would be no significant differences in the diastolic blood pressure of participants at 90^0 sustained bilateral upper limb elevation exercise protocol.

iv. There would be no significant differences in the diastolic blood pressure of participants at 180^0 sustained bilateral upper limb elevation exercise protocol.

v. There would be no significant differences in the mean arterial blood pressure of the participants at 90^0 sustained bilateral upper limb elevation exercise protocol.

vi. There would be no significant differences in the mean arterial blood pressure of the participants at 180^0 sustained bilateral upper limb elevation exercise protocol.

vii. There would be no significant difference in the heart rate of participants at 90^0 sustained bilateral upper limb elevation exercise protocol.

viii. There would be no significant differences in the heart rate of the participants at 180^0 sustained bilateral upper limb elevation exercise protocol.

ix. There would be no significant difference in the systolic blood pressure of hypertensive stroke survivors between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols.

x. There would be no significant difference in the diastolic blood pressure of hypertensive stroke survivors between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols.

xi. There would be no significant difference in the mean arterial blood pressure of hypertensive stroke survivors between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols.

xii. There would be no significant difference in the heart rate of hypertensive stroke survivors between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols.

xiii. There would be no significant difference in cardiovascular responses between 90^0 and 180^0 sustained bilateral upper limb elevation exercise protocols of male and female hypertensive stroke survivors.

1.6 Significance/Justification of Study

The significance of this study has its foundation in its ability to help bridge the empirical and knowledge gap that is in the determination of the acute effects of sustained bilateral upper limb elevation exercise protocols on hypertensive stroke survivors. The following further buttresses the significance of this study:

i. **For the patients:** The findings of this study will help to explore and observe which exercise protocol method is more effective in the management of hemodynamic stability for the established patient population under study, provide a low-risk, cost-effective means to regulate blood pressure, and overall, improve the quality of life for the patient population.

ii. **For the physiotherapist:** This study will better equip the physiotherapist with comprehensive and comparative data to determine the effectiveness of sustained bilateral upper limb elevation exercise protocols to make informed, evidence-based clinical decisions, and provide accurate guide maps to designing safe and effective exercise prescriptions that will further optimize patients' cardiovascular outcomes.

iii. **To the body of knowledge:** This study will contribute new, meaningful, and comparative data to a much understudied area on how different angles of upper limb elevation exercises can affect cardiovascular health and parameters in various patient populations, strengthening the scientific foundation for integrating upper limb elevation exercise protocols into patients' rehabilitation programs and cardiovascular management protocols.

1.7 Scope and Delimitation of Study

This study was delimited to:

i. **Participants**

Male and female hypertensive stroke survivors aged 18 years and above. It examined their cardiovascular responses to sustained bilateral upper limb elevation exercise protocols at 90^0 and 180^0.

ii. **Independent Variables**

Angle of bilateral upper limb elevation (90^0 and 180^0).

iii. **Dependent Variables**

Cardiovascular parameters (Systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, and heart rate).

1.8 Limitations of the Study

This study was limited due to the following factors:

i. The small sample size and its single clinical population.
ii. Only acute effects were assessed and medication use amongst the participants might have influenced outcomes.

1.9 Operational Definition of Terms

i. **Systolic Blood Pressure:** This is the first number in a blood pressure reading. It represents the maximum pressure within the large arteries when the heart contracts, forcing blood out into the body. The S.I unit is in mmHg.

ii. **Diastolic Blood Pressure:** This is the second number in a blood pressure reading. It represents the pressure in the arteries when the heart is at rest between heart beats. The S.I unit is in mmHg.

iii. **Mean Arterial Blood Pressure:** This is the average pressure in a person's arteries throughout one cardiac cycle. It is calculated using this formula: Diastolic blood pressure + (Systolic blood pressure – Diastolic blood pressure)/3. The S.I unit is in mmHg.

iv. **Heart Rate:** This is the number of times a person's heart beats in a minute. The S.I unit is in beats per minute (bpm).

v. **Hypertensive Stroke Survivors:** These are individuals who have survived a stroke and also have an elevated blood pressure.

1.9.1 List of Abbreviations

i. WHO: World Health Organization

ii. CVD: Cardiovascular Disease

iii. ADLs: Activities of Daily Living

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Frameworks

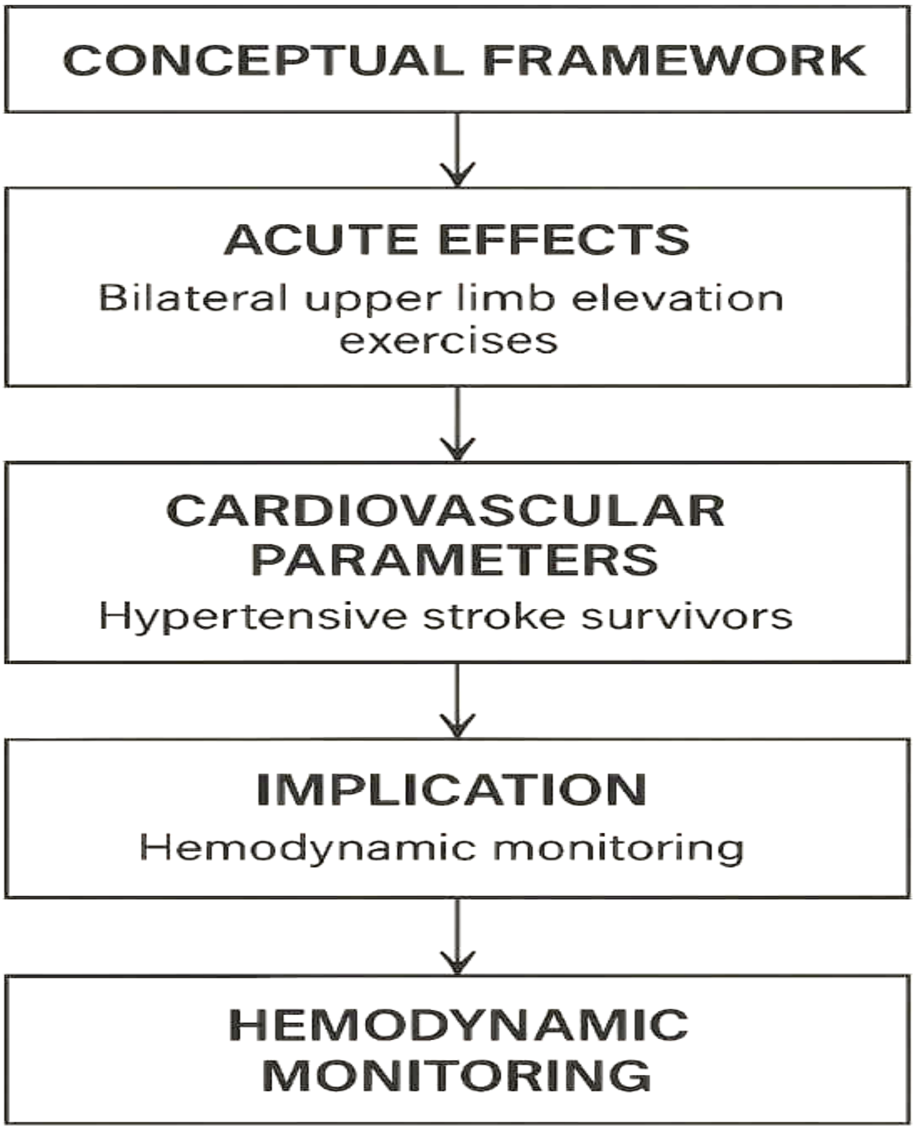

Figure 1: Conceptual Framework

The cardiovascular system responds to physical activity in a distinct and dynamic manner, and the changes induced by exercise in heart rate and blood pressure indicate signs of cardiovascular stress and adaptability. Upper limb elevation can alter venous return, stroke volume, and autonomic responses (Machado-Vidotti et al., 2014). This study is hugely anchored on the hemodynamic and autonomic control framework, which integrates physiological theories explaining the regulation of blood pressure (BP), heart rate (HR) and mean arterial pressure (MAP) in response to changes in posture and limb position. The framework draws primarily from Baroreceptor Reflexes (Suarez-roca et al., 2021), Frank-Starling Mechanism (Kosta et al., 2021), Guyton's Model of Circulatory Regulation (Henderson et al., 2010) as well as Postural Hemodynamics (Oyake et al., 2024). Together, these models help to explain how the observed changes in upper limb elevation angles alter cardiovascular dynamics through neural and mechanical mechanisms.

2.1.1 Physiological Rationale of Hemodynamic and Autonomic Control Framework of Sustained Bilateral Upper Limb Elevation

When both upper limbs are elevated above the level of the heart, venous blood return to the thoracic cavity decreases due to gravitational effects on vascular hydrostatic pressure (Furst, 2019). This transient reduction in venous return lowers cardiac preload and stroke volume, prompting compensatory activation of arterial baroreceptors located in the carotid sinus and aortic arch. These receptors detect changes in arterial wall stretch and trigger autonomic responses through central venous system integration.

A reduction in baroreceptor firing increases sympathetic outflow and decreases sympathetic activity, leading to an elevation in heart rate (HR) and peripheral vascular resistance. Conversely, prolonged limb elevation may also cause a secondary adjustment characterized by a mild hypotensive effect due to vascular adaptation and cardiac output. The Frank Starling's Mechanism postulated by Ernest Starling in 1914 states that "The mechanical energy of contraction, however measured, is a function of the length of the muscle fiber." This shows that there is a predictable relationship between the length between the sarcomere and the tension in the fibers. This law shows clearly that the ventricular output increases as preload (end-diastolic pressure) increases and this plays a very significant role in the compensation of systolic heart failure, buffering the fall in cardiac output in order to help preserve the sufficient blood pressure needed to perfuse the vital organs. The magnitude and direction of these changes depend on the angle of limb elevation, duration, and individual cardiovascular status, particularly in hypertensive stroke survivors whose autonomic control may already have been impaired.

2.1.3 Description of Conceptual Framework

In this framework, the stimulus (independent variable) is the sustained bilateral upper limb elevation exercise administered at two specific angles (90^0 and 180^0) which initiates physiological adjustments. The mediating processes include venous return reduction, baroreceptor activation, and autonomic modulation. These mechanisms ultimately influence the dependent variables are the selected cardiovascular parameters - systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP), and heart rate (HR). The responses observed reflect the body’s capacity for hemodynamic adaptation and autonomic regulation and autonomic regulation during controlled positional stress. It is further hypothesized that these different angles of elevation will produce distinct cardiovascular responses, facilitated by variations in mechanical load, sympathetic activation, and baroreceptor sensitivity in this clinical population (O’Leary et al., 2003).

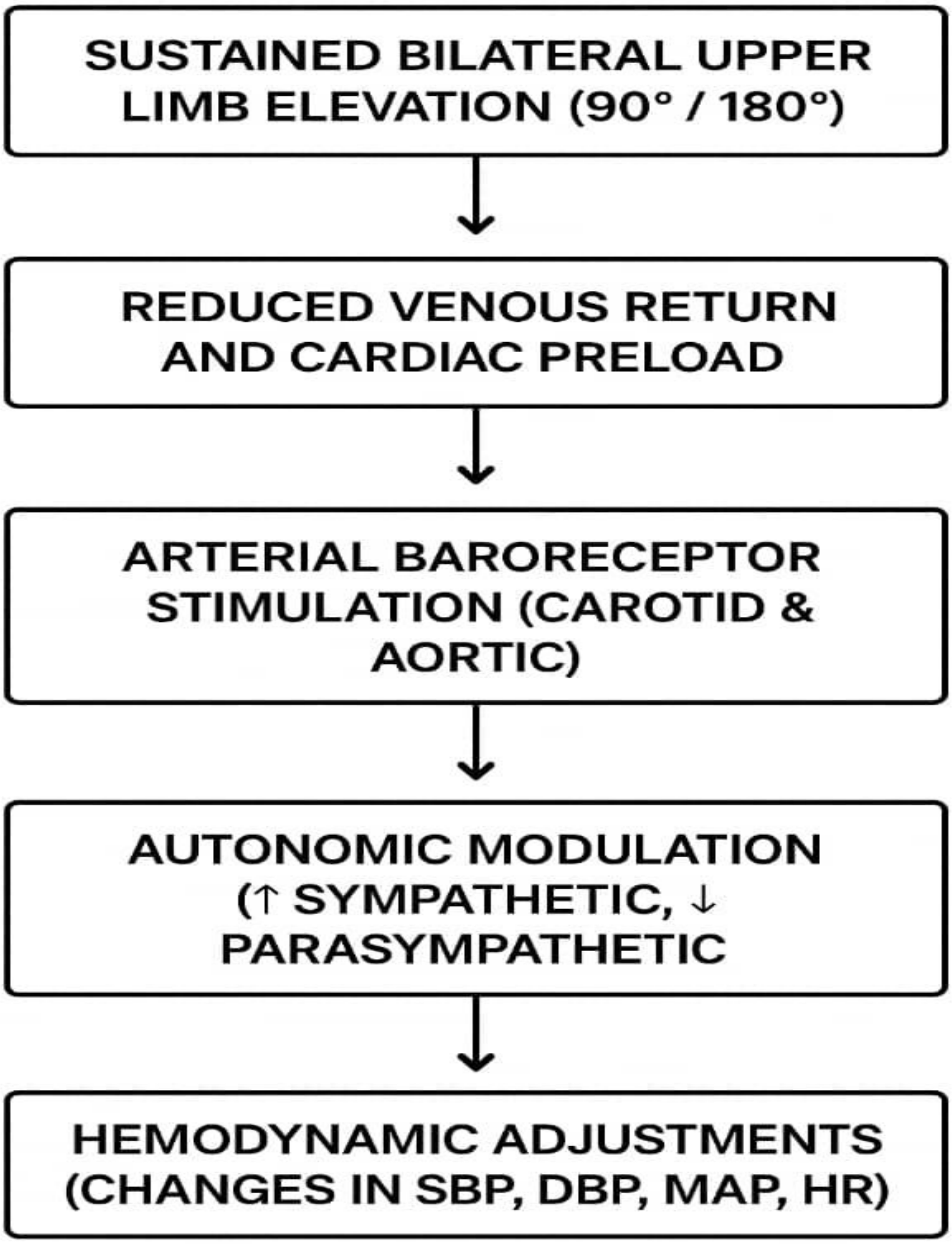

Figure 2: Description of Conceptual Framework

This framework will further recognize the pathophysiology process of the hypertensive stroke survivors whose cardiovascular responses may be different from those of the normotensive individuals due to their altered vascular compliance and autonomic dysfunction. This will help to efficiently and effectively provide clinically grounded evidence on the cardiovascular implications of upper limb elevation exercises, thereby contributing significantly to the optimization of safe and effective rehabilitation techniques for this studied population.

2.1.4 Summary Table of the Conceptual Frameworks

Framework Component	**Description**	**Variable in this Study**
Stimulus	Sustained bilateral upper limb elevation at 90° and 180°.	Independent variable
Physiological Mediators	Venous return, baroreceptor activation, autonomic balance	Mechanistic link
Response	Cardiovascular modulation (BP, HR, MAP)	Dependent variables
Modifying Factors	Stroke status, anti-hypertensive medications, gender, age	Control variables
Outcome	Acute hemodynamic adaptation or dysregulation	Study outcome

2.1.5 Application of the Framework to the Present Study

This current study applies this framework top evaluate the acute hemodynamic responses to 90° and 180° upper limb elevation protocols among hypertensive stroke survivors. It postulates that sustained limb elevation exercises will evoke measurable autonomic adjustments manifested as changes in systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and heart rate. The framework further suggests that these responses occur within the physiological range of adaptation and provide insight into cardiovascular stability during therapeutic upper limb elevation exercises. Moreover, it underscores the interaction between baroreceptor sensitivity, postural mechanism and autonomic modulation in regulating circulation. By the critical observation and examination of these acute responses, this study aims to impress the extent to which these exercises at different angles of elevation can be safely integrated into treatment plans and rehabilitation programs for the already established population in order to enhance their cardiovascular adaptations, emphasizing the balance between cardiovascular load, autonomic control and therapeutic benefits.

2.2 An Overview of Stroke

2.2.1 Definition of Stroke

Stroke can also be known as cerebrovascular accident. It can be defined as rapidly developing clinical signs of focal (global) disturbance of cerebral function, with symptoms lasting 24 hours or longer and leading to death, with no apparent cause other than vascular origin. A mini stroke or transient ischemic attack (TIA) occurs when the symptoms last for less than 24 hours. TIA is traditionally defined as a brief episode of focal neurological impairment not associated with permanent cerebral infarction, and lasting less than 24 hours (Murphy and Werring, 2020). A stroke results from a rupture or blockage of the blood vessels supplying the brain, typically accompanied by thrombus formation, a displacement embolism, cerebral artery stenosis, and bleeding in the brain parenchyma (Campbell et al., 2019). Similarly, the American Heart Association determined that this classification was no longer appropriate for the following reasons: The 24-hour time limit is arbitrary; stroke therapy is time-sensitive and must begin as soon as feasible after diagnosis; cerebral ischemia or infarction is evident in 30–50% of patients with clinically diagnosed TIAs on diffusion-magnetic resonance imaging (Murphy and Werring, 2020). Stroke can further be divided into ischemic and hemorrhagic stroke (Andersen et al., 2009).

2.2.2 Epidemiology of Stroke

According to the most recent estimates of the Global Burden of Disease (2019), stroke continues to be the second most common cause of death overall and the third most common cause of death plus disability. Worldwide, it accounts for approximately 5.5 million deaths annually, with 44 million disability-adjusted life-years lost. Projections indicate that in the absence of efficacious therapies, over 23 million individuals will have suffered their first stroke by 2030, translating into an estimated 7.8 million fatalities (Mukherjee and Patil, 2011). 12·2 million (95% UI 11·0–13·6) incident cases of stroke, 101 million (93·2–111) prevalent cases, 143 million (133–153) stroke-related DALYs, and 6·55 million (6·00–7·02) stroke-related deaths were reported in 2019 (Feigin et al., 2021). Stroke is the second most common cause of disability and death globally, with low- and middle-income countries bearing the greater brunt of the disease's impact. Globally, 70% of strokes and 87% of both stroke-related deaths and disability-adjusted life years occur in low- and middle-income countries. Over the past four decades, the stroke incidence in low and middle-income countries has more than doubled. During these decades, stroke incidence has declined by 42% in high-income countries (Feigin et al., 2014). Stroke is more common in older age, mostly amongst individuals at 65 years and above. Over one-third of deaths from cardiovascular illnesses occur in people under the age of 70, and stroke accounts for more than four out of every five deaths from these conditions (WHO, 2019).

Research on epidemiology of stroke in Africa demonstrated that Africa is the continent with the highest rate of hypertension, the strongest and most prevalent modifiable risk factor for stroke (Owolabi et al., 2018). Stroke has the greatest fatality rate among cardiovascular diseases and is regarded as the second most prevalent cause of death in Africa. A research conducted by (Adeloye et al., 2019), demonstrated that the pooled crude incidence of stroke in Nigeria was 26.0/100,000 person-years, with this higher among men at 34.1/100,000, compared to women at 21.2/100,000. The pooled crude prevalence of stroke survivors in Nigeria was 6.7/1000 population, with this also higher among men at 6.4 /1000, compared to women at 4.4/1000. Additionally, a study by Adeloye et al. (2019), points out regional differences showing that the South-South region had the highest prevalence of stroke survivors (13.4/100,000) and rural residents (10.8/100,000).

2.2.3 Types of Stroke

Ischemic and primary hemorrhagic strokes are the two major subgroups of strokes that can be further subdivided. 15% of strokes are hemorrhagic strokes (Parmar, 2018). The 2020 American Heart Association report on Heart Disease and Stroke Statistics estimated that 87% of strokes are ischemic infarctions, a prevalence which increased substantially between 1990 and 2016 and is attributed to decreased mortality and improved clinical interventions. Primary (first-time) hemorrhages comprise the majority of strokes, with secondary (second-time) hemorrhages constituting an estimated 10–25% (Kuriakose and Xiao, 2020)**.** The fatality rate from hemorrhagic stroke is higher than that from ischemic stroke (Andersen et al., 2009).

2.2.3.1 Ischemic stroke

Cerebral infarction is the main lesion associated with ischemic stroke. When brain tissue does not receive enough blood, there is first a temporary loss of tissue function and, eventually, an infarction that results in the death of neurons and supporting structures (Feske, 2021). The bulk of stroke cases are ischemic strokes, which are brought on by the blockage of blood arteries that supply the brain with insufficient blood flow. Thrombosis, or the production of blood clots inside the cerebral arteries, and embolism, or the movement of blood clots from other areas of the body, are the two main mechanisms causing ischemic stroke. Ischemic stroke specifically refers to central nervous system infarction accompanied by overt symptoms (Sacco et al., 2013).

There are two subtypes of ischemic stroke:

i. **Embolic stroke:** Virchow coined the term "embolic" in 1854 to describe a patient who had clots that appeared to originate from the heart and had obstructed the brain arteries. Based on the research that is now available, most ischemic strokes are believed to be embolic in nature (Ntaios and Hart, 2017). A thrombus that forms in the extra-cerebral arteries and moves into the cerebral artery lumen is the cause of an embolic stroke. A brain blood artery blockage caused by a stuck embolus may cause tissue injury. Heart conditions are frequently linked to these strokes, especially atrial fibrillation (Martin and Kessler, 2015).

ii. **Thrombotic stroke:** This kind of ischemic stroke is mostly brought on by atherosclerosis, which causes a thrombus to form in the cerebral arteries. Plaque buildup in artery walls narrows the lumen of the artery, decreasing blood flow and limiting the delivery of oxygen to areas in the brain. A cerebral infarction may occur if the plaque totally closes off the vessel, supplying the affected region (Martin and Kessler, 2015)

2.2.3.2 Hemorrhagic stroke

A hemorrhagic stroke happens when a blood artery bursts, causing internal bleeding in the brain. The primary pathology of hemorrhagic stroke is an area of bleeding that directly causes damage to the brain tissue. There are two primary forms of this type of stroke: subarachnoid hemorrhage (SAH), which makes up about 5% of all strokes, involves bleeding into the subarachnoid space, and intracerebral hemorrhage (ICH), which involves bleeding into the brain matter and makes up about 10% of all strokes (Parmar, 2018). According to Chen et al. (2014), hemorrhagic stroke has a high fatality rate and is associated with considerable morbidity.

The course of a hemorrhagic stroke frequently results in less favorable consequences. Because the hemorrhage typically spreads quickly, resulting in abrupt decreases in consciousness and neurological function, prompt diagnosis and treatment are essential (Unnithan et al., 2023).

i. **Intracerebral hemorrhage (ICH):** The definition of an ICH-induced stroke is "rapidly developing clinical signs of neurological dysfunction attributable to a focal collection of blood within the brain parenchyma or ventricular system that is not caused by trauma." (Parmar, 2018). It is often as a result of vascular malformation and changes that occur to the blood vessels (e.g, thin lining of vessels) as a result of hypertension and ageing (Martin and Kessler, 2007).
ii. **Subarachnoid hemorrhage (SAH):** SAH is the result of a hemorrhage from a cerebral blood vessel, aneurysm, or vascular malformation into the subarachnoid space, the space surrounding the brain where blood vessels lie between the arachnoid and pia mater. Patients with SAH often have a sharp headache and vomiting, along with non-focal neurological symptoms as a stiff neck and loss of consciousness (Parmar, 2018). It is brought on by vascular malformation and intracranial aneurysm, which are weakening blood vessels that protrude from the brain (Martin and Kessler, 2007).

2.2.4 Stages of Stroke Recovery

According to studies by Li et al. (2024), Winstein et al. (2016), Aderinto et al. (2023), and Powers et al. (2018), there are three main stages of stroke recovery, and the knowledge of the stages forms the basis for the understanding of each stage helps to curate appropriate rehabilitation patterns for stroke recovery. These stages include:

i. **Acute stage of stroke:** The first 24 hours to 1 week following the onset of the stroke make up the acute stage of stroke. During this initial phase, the primary focus is on medical stabilization and the prevention of further brain damage.
ii. **Subacute stage of stroke:** The subacute stage occurs from 1 week to three to 6 months post-stroke. In this phase, there is the use of more intensive rehabilitation efforts, which should be aimed at promoting neurological recovery and improving functional abilities.
iii. **Chronic stage of stroke:** The chronic stage of stroke begins 6 months after the initial event and extends indefinitely. During this phase, the focus shifts to long-term rehabilitation and the management of any residual disabilities.

2.3 An Overview of Hypertension

2.3.1 Definition of Hypertension

Clinically, hypertension is defined as a medical condition in which the pressure in the blood vessels is very high, as high as 140/90mmHg or even exceeds this (WHO, 2023). It is a chronic medical condition characterized by a sustained elevation in the pressure of the blood against the arterial walls. It is expressed in terms of two values: systolic pressure, which is the maximum pressure within the large arteries when the heart muscles contract to propel blood through the body, and diastolic pressure, which is the lowest pressure that is present in the largest arteries during heart muscle relaxation between beats (Shahoud et al., 2023). This condition is further classified into two main types: primary hypertension, which has no identifiable cause and accounts for about 90-95 % of all adult cases of hypertension and secondary hypertension which stems from an underlying condition like kidney disease or even hormonal disorders and accounts for about 2-10% of all adult cases of hypertension (Unger *et al.,* 2020). Hypertension is a leading preventable cause of cardiovascular disease (CVD), disability (damage to the heart, eyes, kidneys, and brain due to stroke), and death worldwide (Moloro et al., 2023).

2.3.2 Epidemiology of Hypertension

Globally, this medical condition has remained a source of significant public health concern. An estimate of about 3.5 billion adults worldwide experience systolic blood pressure levels that are greater than 110 to 115 mmHg, with around 874 million adults having systolic blood pressure levels equal to or greater than 140 mmHg (Forouzanfar et al., 2017). According to the Global Burden of Disease Study, elevated blood pressure remains the leading single risk factor that contributes to the global burden of disease and overall mortality, accounting for about 9.4 million deaths annually and resulting in 212 million lost healthy life years, representing about 8.5% of the global total (Forouzanfar et al., 2016).

In Africa, more than 2 out of 10 people above 18 years suffer from this silent killer. With an estimated 74.7 million people living with the condition in Sub-Saharan Africa, this metric is predicted to increase exponentially to about 125.5 million by 2025, with a further prediction of an increase to 216.8 million by 2030 in Africa (Moloro et al., 2023). The number of disability-adjusted life-years (DALYs) lost due to this condition has also been adjusted to 143.0 million from the previously estimated 95.9 million (Moloro et al., 2023).

In Nigeria, hypertension stands out as one of the most prevalent cardiovascular disease risk equivalents, contributing to approximately a quarter of all emergency admissions in urban hospitals due to its complications (Adeloye et al., 2015). Currently, it is estimated that one in four adult Nigerians suffers from hypertension, and the consistently prevalent lack of awareness about hypertension likely contributes to cardiovascular disease-related deaths in the country (Ogah et al., 2012). According to a study by Ogungbe et al. (2024), the prevalence of the condition varies amongst each region of the country and ranges from 22-44%. The literature further stressed that the awareness, treatments, and control rates remain very low, with only 29% being aware of their condition, 12% are on treatment, and just a measly 3% have achieved control.

2.3.3 Pathophysiology of Hypertensive Stroke

Hypertension can cause stroke through various mechanisms. One of the major mechanisms through which this occurs is via the high pressure in the lumen of the cerebral vessels, which will lead to an increased change in the endothelium and in the smooth muscles of these vessels (Chiara et al., 2022). The change will cause endothelial damage and a dysfunction of the blood cell-endothelium interaction, leading to the formation of thrombosis and ischemia. The subsequent necrosis that occurs as a result of stenosis and occlusions of these vessels will cause the infarction of the cerebral area where this event occurs. The degeneration of the smooth muscle cells and the endothelium gives room for a high susceptibility of the brain to hemorrhagic stroke (Yu et al., 2011).

In another mechanism, the hypertensive state of an individual will increase the process of plaque formation in a condition known as atherosclerosis, thereby increasing the likelihood of the formation of cerebral lesions that will cause serious occlusions and stenosis. This may be linked to the stenosis and embolism that originates from larger extracranial vessels like the aortic arch and the heart (Kim et al., 2016).

Adaptive changes in the structure of the resistance vessels, which on one hand have a positive effect in the reduction of vessel wall tension, will cause a correlative negative consequence by increasing the peripheral vascular resistance of these vessels, which will cause a compromise in the cerebral circulation, and this increases the risk of the occurrence of ischemia.

2.3.4 Hypertension as a Risk Factor for Stroke

The relationship between blood pressure and the event of cardiovascular disease is well established and also very consistent across systolic and diastolic blood pressure, with systolic blood pressure demonstrating a stronger correlation in the adult population (Rapsomaniki et al., 2014). This correlation is well shown across genders, all age groups in adulthood, and for various major forms of cardiovascular diseases, including stroke (both ischemic and hemorrhagic), coronary artery disease, heart failure, peripheral vascular disease, and end-stage renal disease (Goff et al., 2014). Amongst all the numerous cardiovascular diseases caused by hypertension, stroke is one of the most prevalent conditions where hypertension plays a very primary role (Silva et al., 2024; Wajngarten and Silva, 2019). The role it plays in stroke incidence has constantly been reviewed and highlighted by several epidemiological and clinical studies. Due to the association of hypertension with atheromatous deposits that block the brain vessels, this prompts the occurrence of stroke as the atheroma has serious ischemic consequences that may damage the cerebral arterioles and, by extension, the brain tissues these vessels supply (Dickinson and Hypertens, 2003). In addition to the event of the atheromatous plaques, there is the incidence of increased arterial stiffness, narrowing of the arterial lumen, and endothelial injuries, all of which contribute immensely to increasing the likelihood of vascular occlusion or rupture (Bentzon et al., 2014).

Clinical trials and studies have further demonstrated that with effective blood pressure control, the incidence and risk of stroke will be effectively managed, as individuals with poorly managed hypertensive states will have significantly higher rates of the occurrence of stroke.

2.4 Who Is A Stroke Survivor?

According to the American Stroke Association (2020), a stroke survivor is a person who has experienced a stroke and is living with the effects of the stroke. An aging population is predicted to contribute to the projected growth in the number of stroke survivors, which is also predicted to rise (Grefkes and Fink, 2020; Rudberg et al., 2021). A study by Skolarus et al. (2014) showed that stroke survivors are predicted to rise from 7 million to more than 10 million by 2030 as a result of this generation's aging and decreasing stroke mortality. Stroke survivors often face significant challenges in physical, cognitive, and emotional domains. Prior research has shown that there is a reduction in overall quality of life among stroke survivors (Opara and Jaracz, 2010). When compared to age-matched healthy controls, African stroke survivors reported a significantly worse quality of life (Bello et al., 2021). The evaluation of the quality of life of stroke survivors is vital for planning post-stroke therapy strategies (Rachpukdee et al., 2013). Early intervention should concentrate on lowering stroke-related disability and depression to improve the quality of life for stroke survivors in Africa (Bello et al., 2021).

An essential component of recovery following a stroke is stroke rehabilitation. It can help stroke victims reach their full potential, strengthen their functional abilities, and increase their general well-being (Zorowitz et al., 2002). Hypertensive stroke survivors, who represent a large proportion of stroke patients in sub-Saharan Africa, are particularly vulnerable to cardiovascular complications. This underscores the importance of carefully monitored rehabilitative strategies that account for hemodynamic stability. Stroke survivors often present with altered autonomic responses and cardiovascular instability, and so, this study may contribute valuable insights for physiotherapists and rehabilitation specialists involved in the care of this established patient population.

2.5 Overview of the Cardiovascular System

2.5.1 Anatomy of the Heart

At the center of the cardiovascular system is the human heart, which starts beating at the beginning of the third week of intrauterine life. This relentless, hollow, muscular machine can be likened to the size of a human fist and can circulate more than 1,500 gallons of blood per day around the whole body, which is approximately 45 times as much as a bathtub. The cone-shaped heart lies obliquely in the mid-mediastinum, from the second to sixth rib, and sits over the superior aspect of the diaphragm, projecting more leftwards and posterior to the sternum. The right lateral aspect is made of the right atrium (RA), anteriorly by the right ventricle (RV), the left and inferior aspects are made up of the left ventricle (LV), and the posterior aspect is mainly by the left atrium (LA) with a small part of the left ventricle. The posterior aspect is adjacent to the descending aorta, esophagus, and thoracic vertebrae (Al-Sakini, 2022).

2.5.2 Pericardium

In order to maintain maximum function, the heart and great vessels are enclosed within a dual-walled fibrous sac known as the pericardium (Volpe and Makaryus, 2023). The pericardium is a fibrous sac that encloses the heart and great vessels. It keeps the heart in a stable position within the mediastinum, facilitates its movements, and separates it from the lungs and other mediastinal structures. It also supports physiological cardiac function. The pericardium consists of two layers: the fibrous and the serous layers.

The fibrous pericardium is a conical-shaped sac. Its apex is fused with the roots of the great vessels at the base of the heart. The serous pericardium is a layer of serosa. It is divided into the parietal layer that lines the fibrous pericardium and the visceral layer, which is reflected around the roots of the great vessels to cover the entire surface of the heart.

Between the parietal and visceral layers of the pericardium, there is a potential space that may be filled with a small amount of fluid. The part of the visceral layer that covers the heart, but not the great vessels, is called the "epicardium." Functionally, the pericardium functions in order to prevent the excessive dilatation of the heart, and in pathological states, it can limit the overfilling of the heart, which would result in low cardiac output. It also influences the pressure-volume relationships of cardiac chambers by providing limited space for the heart as a whole (Volpe and Makaryus, 2023).

2.5.3 Heart Chambers

The human heart consists of four chambers: the two upper chambers are called the right and left atria. They are divided by the interatrial septum. The two lower chambers are called the right and left ventricles and are divided by the interventricular septum (John, 2014). The right atrium and ventricle together are often called the right heart, and the left atrium and left ventricle together functionally form the left heart. (Reheman and Reheman, 2023).

2.5.4 Heart Valves

To prevent a back rush flow of blood, the heart is anatomically designed with four valves: the atrioventricular valves, which are the mitral and tricuspid valves that separate the atria from the ventricles, and the semilunar valves, which are the aortic and pulmonary valves that enhance the forward movement of blood into the systemic and pulmonary circulations (Hinton and Yutzey, 2011).

2.5.5 Physiology of the Heart

According to a study by Chaudhry et al. (2022), the physiology of the human heart is better understood when there is knowledge of certain parameters that guide the process. These parameters include:

i. **Stroke volume:** This is the amount of blood pumped out after one heart contraction. It is the difference between the end diastolic volume (EDV) and the end systolic volume (ESV). In a normal, adult individual, the stroke volume is approximately 70mls.
ii. **Cardiac output:** The cardiac output is the amount of blood ejected from the left ventricle. It is equivalent to the venous return. It is calculated by stroke volume x heart rate. It can also be calculated by the rate of oxygen consumption divided by the difference in arterial and venous oxygen content. In a normal, adult individual, the cardiac output is approximately 5,000mls or 5 liters.
iii. **Preload:** The preload is the pressure on the ventricular muscle by the end-diastolic volume in the ventricles.
iv. **Afterload:** The afterload is best estimated by the mean arterial pressure. It is the pressure that the left ventricles must exceed to push the blood forward.
v. **Ejection fraction:** This is an index for contractility. The ejection fraction of the heart is calculated by stroke volume divided by end diastolic volume. A normal ejection fraction is greater than 55% and if it is less, it is an indication of heart failure.

In addition to the knowledge of these parameters, it is imperative to also know that the heart circulates blood throughout the human body through two dynamic pathways. These pathways are the systemic and the pulmonary circulation. The systemic circulation provides organs, tissues, and cells with blood so that they get oxygen and other vital substances, preventing hypoxia and every other related complications (Chaudhry et al., 2022). In contrast, the pulmonary circulation is where the fresh oxygen we breathe in enters the blood. At the same time, carbon dioxide is released from the blood (Chaudhry et al., 2022).

The systemic circulation shows how the left ventricle pumps oxygen-rich blood into the aorta. The blood then travels to larger and smaller arteries and into the capillary network, where the blood drops off oxygen, nutrients, and other important substances and picks up carbon dioxide and waste products. The blood, which is now low in oxygen (deoxygenated) is then collected by the veins and travels to the right atrium and into the right ventricle. This event marks the beginning of the pulmonary circulation.

The pulmonary circulation begins as the right ventricle pumps low-oxygen blood into the pulmonary artery, which divides into arterioles (smaller arteries) and capillaries in the lungs, where the capillaries form a fine network called alveoli. This is where carbon dioxide is released from the blood into the air inside the pulmonary vesicles, and fresh oxygen enters the bloodstream.

2.5.6 Blood Supply to the Heart

The blood supply to the heart is primarily from the coronary arterial supply. The coronary arteries are the first vessels to branch from the aorta. They provide a crucial supply of oxygen and nutrients to the layers of the heart. The right coronary artery and its branches mostly supply the right side of the heart, and by extension, part of the left atrium, a posterior portion of the left ventricle, and even the posterior third of the interventricular septum. During periods of increased physiological demands (like exercising), these vessels dilate during exertion to meet the increased metabolic demands of the heart and its fibers (Saxton et al., 2023).

2.5.7 Blood Vessels

Blood vessels are essential components of the circulatory system, functioning as pathways that direct the flow of blood to and from the heart in response to the body's physiological demands. These vessels are broadly classified into three main types: arteries, capillaries, and veins, and each of these structures possesses distinct structural features and roles in circulation.

2.5.7.1 Arteries

Arteries are designed to return blood to carry oxygenated blood away from the heart. Anatomically, they are structured to withstand the high pressures generated during contraction of the heart. In order to be able to facilitate this stress, they have a large amount of elastic tissue with an abundance of elastin and less smooth musculature. The aorta, which is a large artery (the largest in the human body), has thick, elastic walls that enable it to accommodate and absorb the force of each heartbeat. The blood arteries are further divided into two: the elastic arteries and the muscular arteries. The elastic arteries are the arteries very close to the myocardium, while the muscular arteries are the anatomically named arteries, like the brachial artery, radial artery, femoral artery, amongst others (Tucker et al., 2023).

2.5.7.2 Veins

Contrastingly, veins are the vascular structures responsible for returning deoxygenated blood to the heart. Although veins operate under much lower pressure than arteries, they are equipped with specialized one-way valves that prevent the backflow of blood. This is particularly important in the lower limbs, where venous blood must move against gravity. The presence of these valves, along with the surrounding skeletal muscle contractions during movement, ensures efficient venous return and helps maintain overall circulatory balance.

2.5.7.3 Capillaries

Capillaries are the smallest and most numerous blood vessels, serving as the principal sites for the exchange of gases, nutrients, and metabolic waste between the blood and body tissues. These microscopic vessels arise from arterioles and are composed of a single layer of endothelial cells. Their thin walls facilitate the diffusion processes that support cellular metabolism and maintain homeostasis at the tissue level (Tucker et al., 2023).

2.5.7.4 Arterioles

Arteries branch into smaller vessels, which are called arterioles; their structure shifts and contains a greater proportion of smooth muscle and less elasticity. The autonomic nervous system influences the diameter and shape of the arterioles. Due to their smooth muscular layer, it allow them to constrict or dilate in response to neural or hormonal signals, thus regulating blood flow to various tissues and organs. Because of this regulatory function, arterioles are often referred to as the primary resistance vessels of the circulatory system, particularly within the pulmonary circuit. The arterioles range from 8 to 60 micrometers, and they further divide into meta-arterioles (Tucker et al., 2023).

2.5.7.5 Venules

Venules are the smallest veins in the vascular system. They receive blood from the capillaries. They also play a functional role in oxygenation and the exchange of nutrients for water products. They are very thin and can easily rupture if there is an excessive increase in blood volume and pressure (Tucker et al., 2023).

2.5.8 Nervous Control of the Heart

The sympathetic nerve and the parasympathetic nerves control the nervous activities of the myocardium. The sympathetic nerves to the heart are enhancing, and this helps it in fostering contractility of the atria and ventricles, while the parasympathetic nerves are inhibitory as they bring about the relaxation of the atria and ventricles (Levy, 1997). The cardiac cycle starts with one heart contraction after another, and this includes a relaxation period called "diastole" followed by a period of contraction called "systole" (Moore and Agur, 2017).

2.5.9 Cardiovascular Parameters

Cardiovascular parameters are measurable signals that are used by healthcare professionals to monitor and assess the functional status of the heart and the surrounding blood vessels. They provide real-time, critical knowledge on how well the heart and blood vessels supply blood, oxygen, and even nutrients throughout the whole body. The most commonly measured parameters include systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR). (Zhu et al., 2024).

2.5.9.1 Systolic Blood Pressure

The systolic blood pressure is the first value in a blood pressure reading. It can be defined as the blood pressure of the arteries when the heart contracts (systole). It is usually less than 140mmHg. The systolic blood pressure coincides with the first Korotkoff sounds, which are heard when the stethoscope is placed over the brachial artery at the cubital fossa (which is a hollow depression at the anterior elbow region) just below the level of the inflated blood pressure cuff on the arm (Khan, 2006).

2.5.9.2 Diastolic Blood Pressure

The diastolic blood pressure is the second value in a blood pressure reading. It is the pressure in the arteries when the heart is relaxed rhythmically, when the heart chambers are filled with blood (Niakan and Cushman, 2018). This pressure is usually less than 90mmHg.

2.5.9.3 Mean Arterial Pressure

This is the average pressure in a person’s arteries throughout one cardiac cycle. It is calculated using this formula: Diastolic blood pressure + (Systolic blood pressure – Diastolic blood pressure)/3.

2.5.9.4 Heart Rate

Heart rate is a basic but important measure of how well the heart is functioning. It is also known as the pulse rate. It refers to the number of times the heart beats within a minute. A normal resting heart rate for a healthy person typically falls between 60-100 beats per minute (Anon, 2020). Heart rate can be checked at pulse points located at the wrists, elbows, neck region, or the foot tops at their corresponding arteries.

Health care workers monitor cardiovascular parameters of patients, as it is essential for the identification of potential health problems early on. These parameters, such as heart rate and blood pressure, can help doctors detect issues before they become serious. For instance, when someone is exercising or undergoing surgery, these parameters are closely monitored to ensure the heart is not experiencing excessive stress. By staying within a safe range, the individual can avoid complications that might arise from physical strain. This monitoring allows healthcare professionals to make timely adjustments to treatment plans and ensure the person's safety during these activities.

2.6 An Overview of the Upper Limbs

The upper limb is a vital component of the human body. It extends from the shoulder to the fingers and comprises 30 bones, each contributing to the precision and fluid movement which is essential for daily function (Forro et al., 2023). Anatomically, it is divided into three distinct regions: the upper arm, the forearm, and the hand. The upper arm contains a single long bone, which is known as the humerus, while the forearm is structured around to hold two parallel bones, the radius and the ulna (Mostafa et al., 2023). The hand and wrist, together, are composed of 27 bones: eight carpal bones arranged in two rows, with the scaphoid, lunate, triquetrum, and pisiform being proximal and the trapezium, trapezoid, capitate, and hamate being more distal. These carpal bones articulate with five metacarpal bones, which, in turn, support the 14 phalanges that form the fingers (Tang and Varacallo, 2022).

The joints of the upper limb are built to permit varying degrees of mobility and stability. The shoulder joint allows for a wide range of motion but also sacrifices some stability in favor of mobility (Chang et al., 2025). The elbow operates primarily as a hinge joint, facilitating flexion and extension, and the wrist joint is structured to permit movement across multiple anatomical planes (Gupton et al., 2025). Furthermore, these multifaceted joints enable refined gliding motions, while the finger joints function similarly to the hinge joints, thus allowing grasping and fine manipulation (Juneja et al., 2024).

The organization of the muscles in the upper limb reflects its functional demands. In the arm, the anterior compartment houses the biceps brachii, which is a two-headed muscle along with deeper muscles such as the coracobrachialis and brachialis (Snow and Lanik, 2024). In the posterior compartment, the triceps brachii stands as the main extensor muscle (Tiwana and Borodoni, 2023). The muscles of the forearm are layered by depth and function. They are broadly divided into two compartments: the anterior or flexor and posterior or extensor compartments by the intermuscular septum, which originates from the anterior aspect of the radius (Mitchell and Whited, 2023). The anterior compartment is further organized into three layers, namely: the superficial layer (which contains muscles like the pronator teres, flexor carpi radialis, palmaris longus, and the flexor carpi ulnaris), the intermediate layer (which is composed of the flexor digitorium superficialis) and the deep layer (which houses the flexor digitorium profundus, flexor pollicis longus and the pronator quadratus) (Rodrigues et al., 2019). It is of a great significance to know that many of these muscles share a common origin at the medial epicondyle of the humerus (Mitchell and Whited, 2023). On the posterior compartment, the forearm comprises an outer layer with seven muscles, including the brachioradialis, extensor digitorum, and anconeus, and an inner deeper layer of five muscles, such as the abductor pollicis longus and supinator. These extensor muscles share a common origin which is the lateral epicondyle of the humerus (Walkowski and Goldman, 2023) and they coordinate wrist and finger extension as well as the supination action of the forearm.

The muscles of the hand are responsible for the movement of the hands and the fingers. They are subdivided into two: the extrinsic muscles whose muscle belly originates from the forearm and inserts into the hands and fingers via the long tendons and the intrinsic group which consists of smaller muscles and are utilized for movements such as grip strength and pinching (Okwumabua et al., *2023*). The extrinsic group of muscles performs gross movements of the hands and wrist and it is further divided into the superficial layer (which comprises of the flexor carpi radialis which is innervated by the ulnar nerve, palmaris longus and the flexor carpi ulnaris, both of which are innervated by the median nerve), the intermediate layer (made up of the flexor digitorum superficialis which is innervated by the median nerve) and the deep layer (which houses the flexor digitorum profundus which has a mixed innervation and the flexor pollicis longus) (Okwumabua et al., *2023*). The intrinsic muscles of the house also houses four groups of muscles namely the thenar, hypothenar, interossei and lumbrical muscles. The thenar muscles include abductor pollicis brevis, flexor pollicis brevis and opponens pollicis. It is important to note that thumb adduction is via the adductor pollicis muscle and is not part of the thenar eminence. The hypothenar muscle is a collection of three muscles at the base of the pinky finger (fifth digit) on the palmar aspect that acts to exert movement about the pinky. The hypothenar muscles include abductor digiti minimi, flexor digiti minimi brevis and opponens digiti minimi. (Dawson-Amoah and Varacallo, 2023).

The innervation of the upper limbs is done by a group of complex neural network known as the brachial plexus, which is formed by the anterior rami of the spinal nerves C5 through T1 (Bayot et al., 2023). This plexus divides into three trunks namely superior (C5-C6), middle (C7), and inferior (C8-T1) with each dividing into anterior and posterior divisions that regroup into the lateral, medial, and posterior cords. These cords generate five major peripheral nerves which are the musculocutaneous, axillary, median, radial, and ulnar nerves. Each have a distinct motor and sensory territories (Bayot et al., 2023). Additional nerves, such as the dorsal scapular, long thoracic, suprascapular, and thoracodorsal nerves, branch off at various levels, contributing significantly to the extensive neural supply of the upper limb and shoulder girdle (Bertelli and Ghizoni, 2005).

The vascular supply of the upper limb originates from the subclavian artery, which becomes the axillary artery as it courses through the lateral border of the first rib (Thiel et al., 2025; Forro et al., 2023). The axillary artery then goes through the axilla and gives rise to key branches including the anterior and posterior circumflex humeral arteries and the subscapular artery which is the largest branch (Eorvaldi and Varacallo, 2018). Distally, the artery transitions to the brachial artery beyond the lower border of the teres major muscle (Epperson & Varacallo, 2023). The brachial artery, after supplying branches like the profunda brachii to the posterior arm, bifurcates near the cubital fossa into the radial and ulnar arteries (Epperson & Varacallo, 2023). The radial artery which travels along the lateral aspect of the forearm, is a structural part in the deep palmar arch (Marchese et al., *2025*) while the ulnar artery, which courses medially, supplies the superficial palmar arch (Marues & Bordoni, 2023). The broad anastomoses between these vessels facilitate a robust collateral circulation, reducing the impact of vascular occlusions (Bigler et al., *2019*).

Venous return from the upper limb is enabled by both deep and superficial veins. The basilic vein which is formed by the confluence of the radial and ulnar veins, progresses medially and combines with the brachial veins to form the axillary vein (Nguyen and Duong, 2023). Laterally, the cephalic vein courses and drains into the axillary vein after traversing the delto-pectoral groove (Adds and Tomlinson, 2022). Together, these venous pathways sustain efficient circulatory return to the central circulation**.**

2.6.1 The Concept of Bilateral Upper Limb Elevation Exercise Protocols

Elevation exercises involve raising a specific body part, often a limb, above the level of the heart (Beckman and Cousins, 2019). This practice is non-invasive, cost-effective, and easily integrated into daily routines (Shabalow, 2024). Raising both upper limbs above the head is a common movement used in various exercises and daily activities. While it may seem innocuous, this movement can have significant effects on blood pressure and cardiovascular function, particularly in hypertensive individuals (Baird, 2012). The elevation of the upper limbs contributes significantly to the body's hemodynamics system, particularly in the area of the increased stroke volume and cardiac output which is considerably attributed to the Frank-Starling's Mechanism. It can also significantly improve blood flow back to the heart according to studies from Convertino (1997) and Zadeh (2023). A study by Scheucher et al. (2016) using the Wii-based movement therapy for upper limbs shows cardiovascular benefits were evident as it suggests a cardiovascular challenge and improved cardiovascular fitness. The peak heart rate gradient across WMT activities suggests this therapy can be further individualized to address cardiovascular needs.

Studies have shown that physiologically, skeletal muscle pump activity which is done rhythmically in the upper limb, either passively or actively, will promote peripheral venous pressure and drive venous return thus, maintaining stroke volume and cardiac output especially in upright positions (Trinity et al., 2011). This invariably means that the elevation of the upper limbs will efficiently drive blood back to the heart in order to meet the cardiovascular needs of patients who are especially in the phases of rehabilitation.

Interestingly, exercises like upper body ergometry has even been shown to elicit greater stroke volume than the exercises of the lower limb, even when they maintain similar cardiac output. This may be attributed to the balance of a lower stroke volume paired with a higher heart rate and greater peripheral resistance supporting the overall hemodynamic load. Regular arm aerobic exercise leads to a marked reduction in systolic and diastolic blood pressures and an improvement in small artery compliance. Arm-cycling is a reasonable option for hypertensive patients who want to support blood pressure control by sports (Westhoff et al., 2008).

Problems with arm function, especially upper limb impairments, are very common amongst stroke survivors. These upper limb impairments commonly include difficulty moving and coordinating the arms, hands and fingers, often resulting in difficulty carrying out daily activities such as eating, dressing and washing. The improvement of their arm function is of a great significance to the concept of their rehabilitation. The incorporation of upper limb exercises into fitness routines requires a nuanced approach, especially for individuals with hypertension. While these exercises can offer benefits such as improved shoulder mobility and upper body strength, they must be balanced against the potential risks associated with increased systolic blood pressure (Machado-Vidotti et al., 2014). Doctors and therapists use this knowledge when caring for patients with blood pressure problems. By choosing the right angle, they can help reduce the load on the heart without using drugs. These exercises are easy, safe, and can be done under supervision. Patients are often asked to hold the position for a few minutes at a time. Many possible interventions have been developed and these may involve different exercises or training, specialist equipment or techniques, or they could take the form of a drug (pill or injection) given to help arm movement. Upper limb rehabilitation after stroke often involves several different interventions and generally requires the co-operation of the patient, care givers and rehabilitation team (Pollock et al., 2014).

2.6.2 Significance of Comparing 90^0 and 180^0 of Sustained Bilateral Upper Limbs Elevation Exercise Protocols in Hypertensive Stroke Survivors

The understanding of the physiological effects of the different angles of upper limb elevations is highly significant. This is because it helps in the process of determining the best options for treatment of this patient population. When stroke occurs with the mix of hypertension, it disrupts the normal body physiology in several ways like altering cerebral perfusion, vascular compliance and even autonomic responses (Faraco and Iadecola, 2013). The rehabilitation strategies that offer upper limb elevation have indicated positive responses in managing these cardiovascular parameters efficiently but the question still remains the most favorable angles for these exercises to be done as it remains inadequately misunderstood (Paneroni et al., 2018).

The cardiovascular responses that occurs as a result of these upper limb elevation angles are angle-dependent. Elevation of the upper limbs above the level of the heart causes hemodynamic changes via the baroreceptor activation, altered venous return and even systemic vascular resistance adaptation. Hayashi and Abe (2020), in their study, showed that stroke-related hemiplegia will cause poor venous return and even peripheral edema in the affected limb and so, when the unaffected limb is subjected to a particular angle of elevation either in supine or sitting positions, it will increase venous flow to the affected arm. The study also noted that hand grip or exercise patterns in the unaffected limb will influence venous outflow and local blood pressure in order to improve or hinder venous return.

The sympathetic system plays a key role in the maintaining of the cardiovascular system. In the established patient’s population, it is either overworked or under regulated due to the already existing hypertension and the damage to the central nervous system because of the stroke. In a study by Muslumanoglu et al. (2002), there was a significant reduction found in systematic skin response and RR-interval variation which highlighted an impairment in autonomic control even when stroke has progressed to its chronic stage.

Rizvi et al. (2023) highlighted that elevation of the upper limb with dynamic movements might further offer safe cardiovascular loading which will further boost heart rate, autonomic balance and even respiratory efficiency as compared to lower limb exercises which is the major treatment protocol in cardiovascular rehabilitation.

When the limbs are at 90^0 of elevation, they are in moderate elevation and this will lead to a fair decrease in end-diastolic volume and also a slight increase in the sympathetic activity of the patient (Michikami et al., 2002). Contrastingly, when elevation is done at 180^0, it will cause a sustainable and significant increase in these parameters as compared to the 90^0 elevation and this could bring about a greater fluctuation in blood pressure and heart rate especially in the hypertensive patients who struggle with vascular compliance (Zhiyi et al., 2018). This is why the knowledge of these parameters is very significant in order to help inform safer physiotherapy practices that will help stabilize the hemodynamic parameters in order to bring about the best optimization of the patient's rehabilitation process.

Additionally, the knowledge of this cardiovascular responses will help tailor therapy to be individualized because while a 90^0 elevation angle might be more convenient for the very old or more fragile patients, the 180^0 elevation angle could be of immense benefits to the patients who need greater stimulation for recovery. This gives the needed knowledge that the mere comparison of these angles is not just based on the anatomy rather, it holds both clinical and physiological significance which will help in curating more effective rehabilitation interventions in the hypertensive stroke survivors population.

2.6.3 Limitations Surrounding the Comparison of 90^0 and 180^0 Sustained Bilateral Upper Limb Elevation Exercise Protocols in Hypertensive Stroke Survivors

There are several limitations that affect the accuracy, reliability and validity of effects when assessing the effect of bilateral upper limb exercises at varied angles in hypertensive stroke survivors.

One of the major challenges faced is the lack of available sample size for the experiment. The established patient population is a fragile one and this leads to the limitation of recruiting participants and even a further drop-out rate from the already selected population. This reduces the statistical power and may further disrupt the obtaining of the real differences in cardiovascular responses due to the intervention applied (Westhoff et al., 2008; Cornelissen and Smart, 2013). This leads to a very serious deficit in literatures to back up this experimental study.

Furthermore, there is a high chance of exercise intolerance amongst hypertensive stroke survivors as most of them tend to experience fatigue very easily and this invariably leads to an early termination of the intervention especially when these exercises are performed at inclination angles which are highly uncomfortable for them. According to a study by Tafreshi et al. (2020), the participants recruited often struggled to maintain this sustained limb positioning and this leads to the lack of validity of the data obtained.

The use of manual measuring devices such as sphygmomanometer can also affect the validity and reliability of results obtained. Oscillometric devices can even yield inaccurate results in patients with arterial stiffness (Stergiou et al., 2018).

Hypertensive patients often present with white-coat hypertension which causes another layer of complexity, altering the results of findings. According to Whelton et al. (2018), 25% or more of hypertensive patients may exhibit elevated blood pressure in the clinics and hospital environments as compared to when they are in their homes. This can lead to an overestimation of baseline values, ultimately changing the results obtained.

Finally, the research study design might also pose a limitation. Rizvi et al. (2023) stressed the need and importance of a longitudinal or crossover design as opposed to the cross-sectional or single-session trials in order to truly obtain the adaptation of the participant’s cardiovascular parameters to the interventions given over time.

Conclusively, measuring the cardiovascular effects of upper limb elevations at 90^0 and 180^0 in hypertensive stroke survivors is greatly limited by physiological, methodological and even patient-based factors.

2.8 EMPIRICAL STUDIES

S/N	AUTHOR'S NAME/COUNTRY	TITLE	OBJECTIVES	RESEARCH DESIGN	SAMPLE SIZE	STATISTICAL TOOL	FINDINGS	LIMITATIONS
1.	Baffour-Awuah et al (2023) Australia.	An Evidence-Based Guide to the Efficacy and Safety Of Isometric Resistance Training in Hypertension and Clinical Implications.	The major objective of this research is to provide a systematic summary and practical guide to the efficacy and safety of isometric resistance training (IRT) in the management of hypertension, and to offer evidence-based recommendations for clinical practice	Review article supported by evidence from over 30 randomized control trials, meta-analysis (group-level and individual participant data) and a Delphi expert consensus method.	Cumulative evidence includes- 9 meta-analysis 1 individual participant data meta-analysis (N > 320) Multiple RCTs (Sample sizes ranging from 11 to 400).	Meta-analysis (group level and individual participant data). Delphi method was used for expert consensus. Calculation of responder risk, absolute risk reduction (ARR) and number needed to treat (NNT).	- IRT consistently reduces systolic and diastolic blood pressure by approximately 7.4\3.3 mmHg. - The reduction equates to a 13% risk reduction for myocardial infarction and 22% for stroke. - Effective in various	- There is underutilization in clinical practice due to horizontal safety concern. - Some population (e.g perimenopausal women) may require cautious screening. - Lack of long-term data in certain sub-groups (e.g pregnant women with hypertension).

							populations (healthy, hypertensive, coronary artery disease, etc).	- Transition from research to clinical implementation will require structural guidelines and professional training.
2.	Billinger et al (2012)/USA.	Aerobic Exercise in Subacute Stroke Improves Cardiovascular Health and Physical Performance.	To evaluate whether an 8-week program of moderate to high-intensity aerobic exercise could enhance cardiovascular health and physical performance in subacute stroke survivors.	Pre-post intervention study. Participants used a recumbent stepper for three times per week at a target heart rate intensity. Measurements were taken at	10 participants enrolled; 9 completed the program. Mean age: 61.2 Mean post-stroke duration	Pre-post comparisons conducted likely paired tests, though specifics not stated in abstract. Significance level set at $p<0.05$	This study revealed significant improvements exhibited in brachial artery FMD of both arms, resting systolic blood pressure, 6MWT distance. Non-significant trends towards improvements observed in resting diastolic blood pressure, resting	This study has very low sample size, absence of a control group, participants have relatively mild impairments, short follow up window and limited detail on statistical methods reported publicly.

				baseline, immediately post-intervention and at one month follow-up. Key outcome measures included vascular health flow-mediated dilation (FMD) of both arms, cardiovascular capacity of VO2 peak via exercise testing and physical performance using 6-minute walk test.	of 66.7 days Mild motor impairment (average Fugl-,Meyer score is 100)		heart rate and VO2 peak.	

3.	Cornelissen et al (2013)/Belgium.	Exercise Training For Blood Pressure: A Systematic Review and Meta-analysis.	To qualify and compare blood pressure changes for different exercise modalities- endurance. Dynamic resistance, combined endurance and resistance, and isometric resistance training and identify patients subgroups with the largest blood pressure changes.	Systematic review and meta-analysis of randomized controlled trials all lasting less than four weeks.	93 trials included, totaling 5223 participants (3401 in exercise groups and 1822 in control groups)	Random effects models were used with results reported as weighted means and 95% confidence intervbals.	- Endurance, dynamic resistance, and isometric resistance training lowered both systolic and diastolic blood pressures. - Combined training only lowers diastolic blood pressure. - Isometric training shows the largest reduction in systolic blood pressure.	Small number of studies for isometric resistance training, which limits the generalizability of those findings. Variability in exercise modalities, session durations and intensities among included trials.

							- Blood pressure reduction were greater amongst hypertensive subjects than the normohypertensives and prehypertensive subjects.	
4.	Obaseki et al (2022)/Nigeria.	Effects of a Four-week Isometric Exercise Training on Blood Pressure of Hypertensive Stroke Survivors in a Tertiary Health Institution.	This study aims to examine the effects of 4-week isometric exercise on systolic and diastolic blood pressure in hypertensive stroke survivors.	Experimental, randomised and repeated-measure study design.	12 recruited (6 per group); two drop outs leading to 10 completed (6 experimental and 4 control).	Descriptive statistics, repeated-measure ANOVA, Shapiro-Wilk Test, Greenhouse-Geisser Correction.	- Significant reduction in DBP overtime in experimental group. - SBP showed slight reduction which is not significant between the groups.	- The sample size was very small and also had dropouts during the course of the experiment. - Improvised equipment were used. - The duration of the study was short.

								- There was no blinding.
5.	Westhoff, et al (2008)/Germany.	The Cardiovascular Effects of Upper Limb Aerobic Exercises in Hypertensive Patients.	To evaluate whether an aerobic arm-cycling program provides measurable cardiovascular benefits in hypertensive patients who are limited from performing lower limb exercises.	Randomized-control study.	24 participants.	P-values were reported to determine statistical significance. Specific statistical tests are not detailed nut pulse-wave analysis and flow-mediated dilation measurements were used.	The arm-cycling exercise program significantly reduced systolic and diastolic blood pressure and improved small artery compliance. Maximal workload in upper limb ergometry also increased significantly. There were no significant changes in the flow-mediated dilation, augumentation index or large artery compliance. The control group showed no change.	Small sample size Short intervention period of 12 weeks. No significant effect on some vascular parameters like augumentation index, flow-mediated dilataion.
6.	Wieser and Gisler, et al. (2023)/Switzerland	Cardiovascular Control And Stabilization Via Inclination	The study aims at discovering new methods to the safe support of the	Experimental design with healthy subjects and bed	5 healthy subjects (3 females, 2 males)	Model Predictive Control (MPC)	This study is an explorative means of devising another method to help stabilize heart rate and blood pressure	This research showed a lot of promising factors. However, there are a few practical limitations. One of which is the

		And Mobilization During Bed Rest	heart and blood pressure systems of bedridden patients by using gentle physical movements (tilting the body and moving the legs) through a specially designed tilt table. There was also the building and testing of a smart control system that can predict how the patient's heart might respond to these movements and then automatically adjust the	rest patients.	11 stroke patients (6 females, 5 males) 2 patients participated in the feasibility control phase.	Nonlinear Cardiovascular Modeling Observer (Kalman Filter) for state estimation Signal Preprocessing Control Performance which was assessed via mean deviation from desired values and standard deviation (short term variability)	in patients during bed rest by combining passive leg movements and gradual tilting of the body. Both healthy participants and stroke patients responded well as the method helped to maintain their heart rate and blood pressures within clinically safe limits, reducing the risk of orthostatic hypotension as well as syncope. This study also highlighted that the system was good, individual differences such as medications or the effects of the stroke plays a huge role in how people responded.	fact that it only tested short term cardiovascular control so, it is unclear how this strategy might work effectively over longer sessions or days. The patient group was also small and each person responded differently, making it harder to draw broader conclusions.

			titling and leg motion to keep everything within a safe, healthy range.					

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Population

The target population comprised of hypertensive stroke survivors (HSS) in the stroke ward, physiotherapy outpatient clinic and consultant outpatient department aged 18 years and above in the University of Benin Teaching Hospital.

3.1.2 Selection Criteria

3.1.2.1 Inclusion Criteria

i. Hypertensive stroke survivors aged 18 years and above.
ii. Stroke survivors diagnosed as hypertensive.
iii. Hypertensive stroke survivors at the subacute to chronic phase of cerebrovascular accident.
iv. Hypertensive stroke survivors with muscle power ≥ 3.
v. Hypertensive stroke survivors in Brunnstrom Stages 4-7.
vi. Hypertensive stroke survivors who were not at risk using PAR-Q.
vii. Hypertensive stroke survivors who gave informed consent.

3.1.2.2 Exclusion Criteria

This study excluded:

i. Hypertensive stroke survivors with a history of two or more episodes of cardiovascular events.
ii. Hypertensive stroke survivors with musculoskeletal or neurological impairments that may limit arm elevation.
iii. Hypertensive stroke survivors who elevate arms bilaterally with pain or limitation.
iv. Hypertensive stroke survivors who are agitated/anxious.
v. Pregnant women.

3.1.3 List of Instruments

Materials that were used to record the cardiovascular parameters were obtained through the use of validated scales, and this complemented the objective by using a reliable set of instruments to determine the cardiovascular responses of the participants. Non-invasive monitoring and equipment that was used for this research to ensure participants’ safety and comfort included:

i. Swa-life digital sphygmomanometer.
ii. Adjustable goniometer
iii. Chair with backrest
iv. Stopwatch
v. Pro-forma Socio-demographic Form
vi. Physical Activity Readiness Questionnaire (PAR-Q)

3.1.4 Description of Instruments

i. **Digital sphygmomanometer:** The digital sphygmomanometer is an electronic device used to measure blood pressure. It has an inflatable cuff, a pressure sensor and a digital display that shows both systolic and diastolic blood pressures as well as the pulse rate reading. Digital sphygmomanometers are used widely, and they have been shown to offer high reliability, which means they show consistent readings when measurements are taken repeatedly while under standardized conditions. Their validity or their state of being true is also strong, especially according to international protocols like AAMI, ESH, or BHS, as they produce blood pressure readings within 5mmHg of the mercury standard. In studies like Stergiou et al. (2018) and Sharman et al. (2020), they confirmed that validated sphygmomanometers meet the accuracy standards, and the non-validated ones often do not meet these standards. If the cuff is incorrectly used, performance can be reduced.

ii. **Adjustable Goniometer:** The goniometer is an instrument used for the recording of the range of motion at a joint. It has three parts, namely: The fulcrum, the fixed or immovable arm, and the movable arm. An adjustable goniometer is highly reliable and valid for measuring joint range of motion. They are efficient and reproducible, provided the same device and user are consistently used (Hanks and Myers, 2023).

iii. **Chair with Back Rest:** The use of a chair with a back rest when assessing the cardiovascular responses of the already established patients' population helps in emphasizing both reliability and validity. Research has shown that body posture, especially with proper back support, can influence the values to be obtained when measuring these cardiovascular parameters (Singh et al., 2024). By seating participants in a stable chair with consistent back support and arm positioning at heart level, the variabilities due to posture and autonomic shifts are minimized, enhancing the reliability and validity by isolating all cardiovascular effects of upper-limb elevation protocols rather than confounding them with different seating postures.

iv. **Stopwatch:** The stopwatch is an instrument used for timekeeping. It is reliable for timing simple tasks but can also be subject to systematic errors and variability due to human reaction time. In contrast, electronic timing systems like the timing gates offer a much higher precision (Chen et al., 2021).

v. **Pro-forma Socio-demographic Form:** For the purpose of this study, this was used to record socio demographic (age, gender, marital status, highest level of education attained, occupation, duration since stroke broke out, history of hypertension, use of anti-hypertensives as well as if the patient has any other known chronic illness) characteristics of the participants.

vi. **Physical Activity Readiness Questionnaire:** The first Physical Activity Readiness Questionnaire was designed as a screening tool to identify individuals who are at risk when carrying out physical activity. The literature evidence demonstrates that this questionnaire has high sensitivity for detecting contraindications but it suffers from low specificity, especially as regards older adults. Neto et al. (2013) reported sensitivity values of 75-78% but its specificity is as low as 20% and this highlights this questionnaire's tendency to generate false positives and unnecessary participation restriction. This and many more restrictive factors led to the revision of this tool like the revised PAR-Q (Cardinal et al., 1996). With respect to reliability, there has been recent cross-cultural adaptations of the PAR-Q+ which has shown substantial to almost perfect test-retest agreement across most items (Noguiera et al., 2021) and these findings support the reproductibility of the questionnaire across languages and populations and this makes it a more reliable screening instrument. The original PAR-Q is a valid tool, the updated PAR-Q+ is a better balance of sensitivity and specific and shows more robust reliability.

3.2 Methods

3.2.1 Research Design

This study employed a cross-over repeated measure design to investigate the acute effects of bilateral upper limb elevation at 90^0 and 180^0 inclination angles on cardiovascular parameters. Each participant underwent two experimental conditions in randomized order: bilateral upper limb elevation at 90^0 and 180^0. A washout period of 10 minutes was provided between trials, which allowed the cardiovascular parameters to return to baseline.

3.2.2 Sampling Technique

A simple random sampling technique was used to select participants via the ballot method. All case notes of all eligible patients (hypertensive stroke survivors) were compiled and assigned serial numbers. The serial numbers were then written in small slips of papers, folded, mixed in a container and shuffled. Random serial numbers were then picked from the shuffled numbers in the container and until the predetermined sample size was achieved. The selected serial numbers corresponded with the case notes of participants who were used for this research study.

3.2.3 Sample Size

Sample size was determined using G-Power analysis. The following parameters, as illustrated below, were imputed to calculate the sample size.

Two-tailed test

Level of significance or alpha level = 0.05

Power of analysis = 0.90

The sample size required for this study was calculated as 39.

Although, the calculated sample size for this study was 39, only 31 participants were eventually recruited during the duration of this study. This reduction in the predetermined sample size was due to the limited availability of the already balloted participants as well as the withdrawal of some participants who could not properly complete the exercise protocol.

3.2.4 Ethical Considerations

Ethical approval for this study was sought and obtained from the Research and Ethics Committee of the University of Benin Teaching Hospital, Benin City, Edo State, Nigeria with ethical approval number ADM/E 22/A/VOL.VII/2025/125. Informed consent was also sought and obtained from the participants.

3.2.5 Procedure for Data Collection

The data collection process was carried out in a well-structured and standardized manner to ensure consistency, accuracy, and reliability of results. Participants were recruited from the Stroke Ward, Physiotherapy Outpatient Clinic, and the Consultant Outpatient Department of the University of Benin Teaching Hospital, Benin City, Edo State, using the simple random sampling technique to select from those who met the inclusion criteria. Participants were given a thorough explanation of the study’s purpose and procedures before informed consent was obtained from them. All physiological measurements were recorded using the outlined instruments and pro-forma recording sheets. The specific variables that were captured included:

i. Resting heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial blood pressure (MAP).

ii. Immediate post-exercise heart rate, systolic blood pressure, diastolic blood pressure and mean arterial blood pressure.
iii. Calculated mean arterial blood pressure.
iv. The demographic data of participants, including age, sex and other relevant clinical history.

All measurement sessions were conducted under similar environmental conditions and at similar times of day which minimized variability. Finally, confidentiality was ensured throughout the study as no personal identifying information was included in the final dataset used for analysis.

3.2.6 Procedure for Measurements

Participants were seated in a chair with a backrest. Their heads were in a neutral position, with their arms by their sides and their feet flat on the ground. A 5-minute seated rest period was given to allow for the stabilization of all cardiovascular parameters, and thereafter, baseline measurements of the following cardiovascular parameters were taken using a digital sphygmomanometer:

i. Resting Heart Rate (HR)
ii. Systolic Blood Pressure (SBP)
iii. Diastolic Blood Pressure (DBP)
iv. Mean Arterial Blood Pressure (MAP)

Participants were then instructed to perform sustained bilateral upper limb elevation actively to either 90^0 or 180^0, depending on the randomized sequence assigned. Their upper limbs were elevated in the sagittal plane with palms facing forward and maintained in this position for 2 minutes. Immediately after the 2-minute elevation, the following parameters were then recorded again:

i. Heart Rate (HR)
ii. Systolic Blood Pressure (SBP)
iii. Diastolic Blood Pressure (DBP)
iv. Mean Arterial Blood Pressure (MAP)

After completing the first trial, participants were allowed a 10-minute washout (recovery) period. Following this, the same procedure was repeated at the alternate elevation angle (i.e., if 90^0 or 180^0 was previously used and vice versa).

All readings were manually recorded in pro-forma recording sheets for proper documentation and subsequent analysis. The environment was quiet and temperature-controlled, which ensured the consistency, accuracy, and reliability of measurements.

3.2.7 Data Analysis

Data was analyzed using IBM for the Statistical Package of Social Sciences (SPSS version 27). Descriptive statistics (mean and standard deviation) was used to summarize data. Inferential statistics of Paired T-Test was employed to compare pre- and post-exercise values within each angle condition. Independent T-Test was employed to compare cardiovascular responses between the two independent (male and female) groups. A p-value of ≤ 0.05 was be considered statistically significant.

CHAPTER FOUR

RESULTS

4.1 Results

The primary aim of this study was to compare the acute effects of sustained bilateral upper limb elevation exercise protocols on systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and heart rate in hypertensive stroke survivors. A total of 31 participants were included in this study achieving a statistical power of 90%.

4.1.1 Sociodemographic Characteristics of the Participants

The sociodemographic characteristics of the participants are presented in Table 4.1. The majority of the participants were male (54.8%), married (77.4%), and had attained a tertiary level of education (54.8%). The most common occupations were civil servant and retired (both 35.5%). A significant portion of the participants (58.1%) had experienced their stroke over a year ago. All participants had a history of hypertension, with 96.8% currently using antihypertensive medication. The most prevalent comorbidity was diabetes (22.6%). The mean age of the participants was 56.71 ± 12.05 years.

Table 4.1: Sociodemographic Characteristics of Participants (N = 31)

Variable	Category	Frequency (n)	Percentage (%)
	Mean ± SD	Min–Max	
Age (years)	56.71 ± 12.05	30 – 79	
Gender	Male	17	54.8
	Female	14	45.2
Marital Status	Married	24	77.4
	Single	3	9.7
	Widowed	4	12.9
Highest Level of Education	Tertiary	17	54.8
	Secondary	7	22.6
	Primary	7	22.6
Occupation	Civil Servant	11	35.5
	Retired	11	35.5
	Trader	7	22.6
	Other	1	3.2
	Unemployed	1	3.2
Duration Since Stroke	Over a year	18	58.1
	7-12 months	7	22.6
	4-6 months	6	19.4
History of Hypertension	Yes	31	100.0
Use of Antihypertensive Medication	Yes	30	96.8
	No	1	3.2
Other Chronic Illness	None	22	71.0

Diabetes	7	22.6
Asthma	2	6.5

4.1.2 Comparison of SBP, DBP, MAP and HR at pre and post 90° Bilateral Upper Limb Elevation Exercise

A paired samples t-test was conducted between the pre and post 90° Bilateral Upper Limb Elevation Exercise values. There was a statistically significant reduction in the mean for SBP ($t = 3.680$, $p = 0.001$) and MAP ($t = 2.706$, $p = 0.011$) following the intervention. The change in the mean for DBP was not statistically significant ($t = 0.750$, $p = 0.459$), and similarly, the change in the mean for HR was not statistically significant ($t = -1.261$, $p = 0.217$), as shown in Table 4.2.

Table 4.2: Comparison of SBP, DBP, MAP and HR at pre and post 90° Bilateral Upper Limb Elevation Exercise using Paired Samples T-Test

Variable	Pre 90° BULEE (Mean ± SD)	Post 90° BULEE (Mean ± SD)	T	p-value
SBP (mmHg)	143.65 ± 14.66	135.77 ± 14.12	3.680	0.001*
DBP (mmHg)	89.29 ± 9.76	88.48 ± 11.13	0.750	0.459
MAP (mmHg)	107.38 ± 9.18	104.42 ± 9.77	2.706	0.011*
HR (bpm)	82.26 ± 9.74	83.42 ± 9.12	-1.261	0.217

4.1.3 Comparison of SBP, DBP, MAP and HR at pre and post 180° Bilateral Upper Limb Elevation Exercise

A paired samples t-test was used to compare the cardiovascular parameters at baseline and Post 180° Bilateral Upper Limb Elevation Exercise. Following the 180° Bilateral Upper Limb Elevation Exercises, statistically significant reductions in mean were observed in SBP ($t = 4.536$, $p < 0.001$), DBP ($t = 2.227$, $p = 0.034$), and MAP ($t = 3.364$, $p = 0.002$). Conversely, there was a statistically significant increase in the mean for HR ($t = -2.604$, $p = 0.014$), as shown in Table 4.3.

Table 4.3: Comparison of SBP, DBP, MAP and HR at pre and Post 180° Bilateral Upper Limb Elevation Exercise using Paired Samples T-Test

Variable	Pre 180° BULEE (Mean ± SD)	Post 180° BULEE (Mean ± SD)	T	p-value
SBP (mmHg)	139.10 ± 10.07	134.74 ± 11.18	4.536	<0.001*
DBP (mmHg)	87.52 ± 9.49	85.42 ± 9.75	2.227	0.034*
MAP (mmHg)	104.76 ± 8.18	101.80 ± 8.72	3.364	0.002*
HR (bpm)	81.77 ± 8.79	83.74 ± 9.01	-2.604	0.014*

4.1.4 Comparison of SBP, DBP, MAP and HR Outcomes at Post 90° and 180° Bilateral Upper Limb Elevation Exercise

To determine if there was a significant difference in the magnitude of change between the two exercise protocols, a paired samples t-test was conducted on the outcome scores (change from baseline) for Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), and Heart Rate (HR) between the 90° and 180° bilateral upper limb elevation exercises.

The results, as shown in Table 4.4, indicate that there were no statistically significant differences in the changes observed for any of the cardiovascular parameters between the two exercise protocols. The mean change in SBP was not significantly different between the 90° exercise and the 180° exercise (t = -1.434, p = 0.162). Similarly, no significant differences were found for the changes in DBP (t = 0.872, p = 0.390), MAP (t = -0.001, p = 0.999), or HR (t = -0.747, p = 0.461). This suggests that both exercise protocols induced a similar level of change in the measured cardiovascular outcomes.

Table 4.4: Comparison of Cardiovascular Outcomes between 90° and 180° BULEE using Paired Samples T-Test

Variable	Outcome of 90° BULEE (Mean ± SD)	Outcome of 180° BULEE (Mean ± SD)	T	p-value
SBP (mmHg)	-7.87 ± 11.91	-4.35 ± 5.35	-1.434	0.162
DBP (mmHg)	-0.81 ± 5.99	-2.10 ± 5.24	0.872	0.390
MAP (mmHg)	-2.96 ± 6.08	-2.95 ± 4.89	-0.001	0.999
HR (bpm)	1.16 ± 5.13	1.97 ± 4.21	-0.747	0.461

4.1.5 Comparison of SBP, DBP, MAP and HR Outcomes between Genders Post 90° Bilateral Upper Limb Elevation Exercise

An independent samples t-test was used to compare the change scores of SBP, DBP, MAP and HR between male and female participants following the 90° BULEE protocol. There were no statistically significant differences between genders in the change observed for SBP ($t = -1.183$, $p = 0.246$), DBP ($t = 0.480$, $p = 0.635$), MAP ($t = -0.621$, $p = 0.540$), or HR ($t = -1.011$, $p = 0.320$), as shown in Table 4.5.

Table 4.5: Comparison of SBP, DBP, MAP and HR Change Post 90° BULEE Between Genders using Independent Samples T-Test

Variable	Gender	N	Outcome Mean ± SD	T	p-value
SBP (mmHg)	Female	15	-10.47 ± 14.69	-1.183	0.246
	Male	16	-5.44 ± 8.32		
DBP (mmHg)	Female	15	-0.27 ± 6.44	0.480	0.635
	Male	16	-1.31 ± 5.69		
MAP (mmHg)	Female	15	-3.66 ± 7.29	-0.621	0.540
	Male	16	-2.29 ± 4.83		
HR (bpm)	Female	15	0.20 ± 5.09	-1.011	0.320
	Male	16	2.06 ± 5.16		

4.1.6 Comparison of SBP, DBP, MAP and HR Outcomes between Genders Post 180° Bilateral Upper Limb Elevation Exercise

Following the 180° BULEE protocol, an independent samples t-test found no statistically significant differences between genders in the outcomes for SBP (t = 1.172, p = 0.251), DBP (t = 0.990, p = 0.330), MAP (t = 1.031, p = 0.311), or HR (t = 2.017, p = 0.053), as detailed in Table 4.6.

Table 4.6: Comparison of SBP, DBP, MAP and HR Change Post 180° BULEE Between Genders using Independent Samples T-Test

Variable	Gender	N	Outcome Mean ± SD	T	p-value
SBP (mmHg)	Female	15	-3.20 ± 5.71	1.172	0.251
	Male	16	-5.44 ± 4.91		
DBP (mmHg)	Female	15	-1.13 ± 4.07	0.990	0.330
	Male	16	-3.00 ± 6.14		
MAP (mmHg)	Female	15	-2.02 ± 4.36	1.031	0.311
	Male	16	-3.83 ± 5.32		
HR (bpm)	Female	15	3.47 ± 4.22	2.017	0.053
	Male	16	0.56 ± 3.79		

4.2 Hypothesis Testing

Hypothesis 1: There would be no statistically significant difference in SBP pre and post 90° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 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 would be no statistically significant difference in SBP pre and post 180° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: <0.001

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

Hypothesis 3: There would be no statistically significant difference in DBP pre and post 90° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.459

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 4: There would be no statistically significant difference in DBP pre and post 180° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.034

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

Hypothesis 5: There would be no statistically significant difference in MAP pre and post 90° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.011

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

Hypothesis 6: There would be no statistically significant difference in MAP pre and post 180° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.002

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

Hypothesis 7: There would be no statistically significant difference in HR pre and post 90° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.217

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 8: There would be no statistically significant difference in HR pre and post 180° bilateral upper limb elevation exercise.

Test: Paired Samples T-Test

P value: 0.05

Observed p value: 0.014

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

Hypothesis 9: There would be no statistically significant difference in the outcome of SBP post 90° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.246

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 10: There would be no statistically significant difference in the outcome of DBP post 90° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.635

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 11: There would be no statistically significant difference in the outcome of MAP post 90° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.540

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 12: There would be no statistically significant difference in the outcome of HR post 90° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.320

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 13: There would be no statistically significant difference in the outcome of SBP post 180° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.251

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 14: There would be no statistically significant difference in the outcome of DBP post 180° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.330

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 15: There would be no statistically significant difference in the outcome of MAP post 180° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.311

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

Hypothesis 16: There would be no statistically significant difference in the outcome of HR post 180° bilateral upper limb elevation exercise between male and female participants.

Test: Independent Samples T-Test

P value: 0.05

Observed p value: 0.053

JUDGEMENT: The observed p value is greater than 0.05, the null hypothesis is therefore ACCEPTED.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This study investigated the acute effects of sustained bilateral upper limb elevation exercise (BULEE) protocols at 90° and 180° inclinations on the cardiovascular parameters – systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure (MAP) and heart rate (HR) – amongst hypertensive stroke survivors. The results of the present study showed that there were more male than female hypertensive stroke patients. This suggests that there is a higher prevalence of hypertension in male stroke survivors compared to their female counterparts. This is contrary to the findings from a study by Wijono and Pinzon (2018) who found a higher prevalence of hypertension among female stroke survivors compared to males. This discrepancy may be due to the 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 findings provided valuable insights into the hemodynamic responses of the population to bilateral upper limb elevation exercises, which are often used in therapeutic and rehabilitative contexts.

5.1.1 Effects of 90° Bilateral Upper Limb Elevation Exercise on Cardiovascular Parameters of Hypertensive Stroke Survivors

The results of the comparison between pre- and post-90° bilateral upper limb elevation exercise showed a statistically significant reduction in Systolic Blood Pressure (SBP) and Mean Arterial Pressure (MAP), while the changes in Diastolic Blood Pressure (DBP) and Heart Rate (HR) showed no significant changes. The observed reduction in SBP and MAP is suggestive of the phenomenon that moderate limb elevation exerts a mild hypotensive effect, a finding strongly supported by a large body of evidence showing that acute bouts of upper limb exercise can significantly reduce blood pressure in hypertensive stroke survivors (Westhoff et al., 2008, Wang et al., 2018, Obaseki et al., 2025, Liu et al., 2024). The primary mechanisms thought to underlie these acute improvements include reductions in total peripheral resistance, enhanced baroreceptor reflex sensitivity, and improved autonomic modulation, characterized by an increase in parasympathetic activity and a decrease in sympathetic activity post-exercise (Edwards et al., 2022; Taylor et al., 2017). However, the lack of a significant change in DBP in the present study contrasts with the findings of Obaseki et al. (2022), who reported a significant reduction in DBP but not SBP following a comparable four-week isometric exercise training protocol. This discrepancy may be attributable to the different exercise modalities, as sustained limb elevation may be a form of low-intensity isometric work that affects SBP more acutely, whereas protocols involving combined handgrip and quadriceps exercises may have a different impact on peripheral resistance and thus DBP. The absence of a significant change in HR suggests that the 90° elevation protocol did not constitute a substantial cardiovascular stressor for the participants.

5.1.2 Effects of 180° Bilateral Upper Limb Elevation Exercise on Cardiovascular Parameters of Hypertensive Stroke Survivors

Following the 180° bilateral upper limb elevation exercise, the results showed statistically significant reductions in SBP, DBP, and MAP, accompanied with a statistically significant increase in HR. The reduction in all three blood pressure measures is comparable to the findings of Westhoff et al. (2008), who also reported significant decreases in both systolic and diastolic pressures after their arm-cycling intervention. The significant increase in HR observed in this study after the 180° exercise, but not the 90° exercise, suggests a greater physiological demand.

This is corroborated by literature indicating that protocols involving gross motor tasks with targets at or above shoulder height tend to elicit a higher aerobic intensity and greater hemodynamic responses (Trinh et al., 2016; Davidson et al., 2024). The reason for this difference is likely that the 180° elevation engages a larger muscle mass, including shoulder girdle and trunk stabilizing muscles, to a greater extent than the 90° elevation. This increases the metabolic demand and necessitates a compensatory increase in heart rate to maintain adequate cardiac output and meet the greater cardiovascular challenge.

5.1.3 Comparison between the 90° and 180° Bilateral Upper Limb Elevation Protocols

When comparing the hemodynamic changes at post-90° and post-180° of the bilateral upper limb elevation exercise, the findings indicated that there were no statistically significant differences between the two protocols for SBP, DBP, MAP, or HR. This result suggests that while the 180° protocol appeared more physiologically demanding (as evidenced by the significant increase in HR from its own baseline), it did not produce a statistically greater acute hypotensive effect compared to the 90° protocol. A possible reason for this observation is that the physiological threshold required to stimulate post-exercise hypotension was effectively met by the 90° elevation protocol. Mechanisms proposed for exercise-induced blood pressure reduction, such as improved small artery compliance and a reduction in sympathetic tone (Westhoff et al., 2008; Edwards et al., 2022), may have been sufficiently triggered by the 90° elevation. The additional intensity of the 180° elevation did not result in a significantly larger immediate drop in blood pressure, a finding that aligns with research suggesting the magnitude of acute blood pressure reduction can be limited in some protocols (Moran et al., 2024; Mackie et al., 2021).

5.1.4 Gender Differences in Hemodynamic Responses of Hypertensive Stroke Survivors

The present study also investigated the influence of gender on the cardiovascular responses to the exercise protocols. The findings revealed no statistically significant differences in the changes in SBP, DBP, MAP, or HR between male and female participants following either the 90° or 180° sustained upper limb elevation. This suggests that the acute hemodynamic responses to these specific low-intensity exercises are comparable between male and female hypertensive stroke survivors.

The results of the present study showed that there were more male than female hypertensive stroke patients. This suggests that there is a higher prevalence of hypertension in male stroke survivors compared to their female counterparts. This is contrary to the findings from a study by Wijono and Pinzon (2018) who found a higher prevalence of hypertension among female stroke survivors compared to males. This discrepancy may be due to the 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).

5.1.5 Physiological Implications of Sustained Bilateral Upper Limb Elevation Exercise in Hemodynamic Regulation of Hypertensive Stroke Survivors

The combined findings suggest that sustained bilateral upper limb elevation exercises induce mild, transient and hypotensive effects that could be beneficial for the hemodynamic regulation in hypertensive stroke survivors. These sustained exercise protocols may facilitate venous return distribution and transient autonomic regulation which leads to brief reductions in systolic blood pressure as well as the mean arterial blood pressures. Simultaneously, the noted reductions in the diastolic blood pressure points to a reduction in peripheral vascular resistance and the adjustments in heart rate shows the adequately maintained cardiac outputs. These physiological responses, in line with the performance of these exercises, are essentially useful in stroke rehabilitation where the concept of managing the fluctuations in blood pressure is highly important in order to reduce the risks of several recurrent stroke events thereby optimizing patient safety. The acute nature of these hypotensive effects emphasizes the importance of clinicians ensuring the incorporation of these upper limb elevation exercises in a controlled system in order to leverage these transient hemodynamic adjustments without the adverse effects and consequences which are associated with sustained hypotension.

5.2 Summary of Findings

i. Sustained bilateral upper limb elevation at 90° produced significant reductions in SBP and MAP but no significant change in DBP or HR.
ii. Sustained bilateral upper limb elevation at 180° resulted in significant reductions in SBP, DBP and MAP and a significant increase in HR.
iii. There were no significant differences which were observed between the 90° and 180° protocols in terms of magnitude of hemodynamic changes.
iv. The gender of participants did not significantly influence on the cardiovascular responses to either the 90° or 180° exercise protocols.

5.3 Conclusion

This study concluded that sustained bilateral upper limb elevation at either 90° or 180° are viable, non-pharmacological maneuvers that can acutely reduce blood pressure in hypertensive stroke survivors, irrespective of gender. The both protocols induce mild reductions in systolic and mean arterial pressures, indicating favourable cardiovascular modulations without undue cardiac stress. The choice of protocol to be incorporated into treatment plans are heavily guided by the individual patient's tolerance and rehabilitation goals.

5.3 Recommendations

Based on the findings of this study, the following recommendations are proposed for clinical practice:

i. **Incorporate sustained bilateral upper limb elevation exercises into rehabilitation:** Physiotherapists should incorporate sustained bilateral upper limb elevation exercises at both 90° and 180° into rehabilitation programs. It is a simple, low-cost and effective methods for achieving acute reductions in blood pressure.

ii. **Continuous monitoring of cardiovascular vitals:** Continuous monitoring of blood pressure and heart rate during the performances of these exercises is highly essential in order to enable researchers and clinicians and researchers identify any abnormality in responses that may pose a risk to the health of the patients or even trigger a reoccurrence of the cardiovascular events.

iii. **Education and Clinical Awareness:** Health care professionals should be adequately educated on the physiological benefits of these exercises such as their ability to modulate the hemodynamic regulation of patients in order for them to safely integrate these exercises into the management of hypertensive or post-stroke patients.

iv. Comparative studies with non-hypertensive populations or even other patient populations should be conducted in order to have in-depth understanding of the physiological effects of these exercises. This would help researchers and clinicians understand and determine whether the observed changes are peculiar to the hypertensive stroke survivor populations or if the changes represent a physiological response.

v. The incorporation of longitudinal studies to explore the chronic effects of these exercises on the cardiovascular endurance of this established target population should be carried out in order to provide insights into whether the long term performance of these exercises will lead to lasting adaptations in the cardiovascular system.

5.5 Implications for Hemodynamic Regulation and Clinical Practice

The findings of this study have important clinical implications which include:

i. **For physiotherapists:** The results provide empirical evidence that both 90° and 180° sustained bilateral upper limb elevation exercises can be safely integrated into treatment plans and rehabilitation sessions.

ii. **For patient management:** These innocuous, simple and low-cost exercise protocols may serve as simple, non-pharmacological adjuncts to help maintain blood pressure regulation.

iii. **For clinical research:** This research provides foundational data to guide further research into the chronic effects of repeated upper limb elevation training.

REFERENCES

Adedoyin, R.A., Adeyanju, S.A. and Balogun, M.O., Akintomide, A.O., Adebayo, R.A., Akinwusi, P.O. and Awotidebe T.O. (2010). 'Assessment of Exercise Capacity in African Parents with Chronic Heart Failure Using the Six-minute Walk Test', Internal Journal General Medicine, 3, PP. 109-113.

Adeloye, D., (2014). An Estimate of the Incidence and Prevalence of Stroke in Africa: A Systematic Review and Meta-Analysis. PLOS ONE 9, e100724. https://doi.org/10.1371/journal.pone.0100724

Adeloye, D., Basquill, C., Aderemi, A.V., Thompson, J.Y. and Obi, F.A. (2015). 'An estimate of the prevalence of hypertension in Nigeria: A systematic review and meta-analysis', Journal of Hypertension, 33(2), pp. 230–242.

Adeloye, D., Ezejimofor, M., Auta, A., Mpazanje, R.G., Ezeigwe, N., Ngige, E.N., Harhay, M.O., Alemu, W., Adewole, I.F., (2019). Estimating morbidity due to stroke in Nigeria: a systematic review and meta-analysis. J. Neurol. Sci. 402, 136–144. https://doi.org/10.1016/j.jns.2019.05.020

Akinbo, S.R.A., Odebiyi, D.O. and Ajayi, A.A. (2015). 'Influence of passive movement on blood pressure and heart rate variability', Physiotherapy Research International, 20(1), pp. 30–37.

Akinbo, S.R.A., Odebiyi, D.O. and Ajayi, A.A. (2015). 'Influence of passive movement on blood pressure and heart rate variability', Physiotherapy Research International, 20(1), pp. 30–37.

Al-Sakini, N. (2023). 'Anatomy of the heart', Medicine, 50(6), pp. 317–321.

Alarsan, S.F., Mohd Saat, NZ., Abd Talib, R., Saadeh, N. and Shahrour, G. (2024) 'Validity and Reliability of A Questionnaire Assessing Changes in Dietary Behaviour Amongst School Children Admist the COVID-19 Pandemic in Jordan', Curerus, 16 (8), p. e66980.

Aziz Zadeh, M. (2023) "The Effect of Upper Limb Elevation on Limb Edema and Central Venous Pressure in ICU Patients", Archives of Critical Care Medicine, 1(2). Available at: https://journals.sbmu.ac.ir/index.php/accm/article/view/43694 (Accessed: 26 June 2025).

Baricich, A., Borg, M.B., Battaglia, M., Facciorusso, S., Spina, S., Invernizzi, M., Scotti, L., Cosenza, L., Picelli, A. and Santamato, A. (2024). 'High-intensity exercise training impact on cardiorespiratory fitness, gait ability, and balance in stroke survivors: A systematic review and meta-analysis', Journal of Clinical Medicine, 13(18), p. 5498. Available at: https://doi.org/10.3390/jcm13185498 (Accessed: 19 June 2025).

Bayot, M.L., Nassereddin, A. and Varacallo, M.A. (2023). Anatomy, Shoulder and Upper Limb, Brachial Plexus. [online] Updated 24 Jul 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK500016/

Beckman, S.L. and Cousins, S. (2019). 'Hypertension: Management and care', Nursing Clinics of North America, 54(4), pp. 551–563.

Bertelli, J.A. and Ghizoni, M.F. (2005). Long Thoracic Nerve: Anatomy and Functional Assessment. The Journal of Bone and Joint Surgery. American Volume, 87(5), pp.993–998. Available at: https://doi.org/10.2106/JBJS.D.02383

Bigler, M.R., Buffle, E., Siontis, G.C.M., Stoller, M., Grossenbacher, R., Tschannen, C. and Seiler, C. (2019). Invasive assessment of the human arterial palmar arch and forearm collateral function during transradial access. Circulation: Cardiovascular Interventions. [online] Available at: https://doi.org/10.1161/CIRCINTERVENTIONS.119.007490

Billinger, S.A., Arena, R., Bernhardt, J., Eng, J.J., Franklin, B.A., Johnson, C.M., MacKay-Lyons, M., Macko, R.F., Mead, G.E., Roth, E.J., Shaughnessy and M., Tang, A., American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Lifestyle and Cardiometabolic Health, Council on Epidemiology and Prevention & Council on Clinical Cardiology, (2014). Physical activity and exercise recommendations for stroke survivors: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke, 45(8), pp.2532–2553. Available at: https://doi.org/10.1161/STR.0000000000000022

Campbell, B.C.V., De Silva, D.A., Macleod, M.R., Coutts, S.B., Schwamm, L.H., Davis, S.M., Donnan, G.A. (2019). Ischaemic stroke. Nat. Rev. Dis. Primer 5, 1–22. https://doi.org/10.1038/s41572-019-0118-8

Caminiti, G., Volterrani, M., Iellamo, F., Marazzi, G., D'antoni, V., Calandri, C., Vadalà, S., Catena, M., Di Biasio, D., Manzi, V., Morsella, V., & Perrone, M. (2024). Acute Changes in Myocardial Work during Isometric Exercise in Hypertensive Patients with Ischemic Heart Disease: A Case–Control Study. *Journal of Clinical Medicine*, 13.

Chang, L.R., Anand, P. and Varacallo, M.A. (2025). ‘Anatomy, shoulder and upper limb, glenohumeral joint’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK537018/ (Accessed: 19 June 2025).

Chaudhry, R., Miao, J.H. and Rehman, A. (2022). ‘Physiology, cardiovascular’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK493197/ (Accessed: 19 June 2025).

Chen, J.-K., Chen, T.-W., Chen, C.-H., Huang, M.-H. (2010). Preliminary Study of Exercise Capacity in Post-acute Stroke Survivors. Kaohsiung J. Med. Sci. 26, 175–181. https://doi.org/10.1016/S1607-551X(10)70026-7

Chen, R., Ovbiagele, B., Feng, W. (2016). Diabetes and Stroke: Epidemiology, Pathophysiology, Pharmaceuticals and Outcomes. Am. J. Med. Sci., The Diabetes Initiative of South Carolina Celebrates Over Twenty Years of Professional Diabetes Education 351, 380–386. https://doi.org/10.1016/j.amjms.2016.01.011

Chiara, T., Stefania, G., Elisa, R., Chiara, A., and Giorgio, C. (2022). Cardiovascular regulation and autonomic nervous system responses during postural challenges. Frontiers in Physiology, [online] Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8910319/ [Accessed 20 Jun. 2025].

Cornelissen, V.A. and Smart, N.A. (2013). ‘Exercise training for blood pressure: A systematic review and meta-analysis’, Journal of the American Heart Association, 2(1), e004473. Available at: https://doi.org/10.1161/JAHA.112.004473 (Accessed: 19 June 2025).

Davidson, S., Bischof-Bockbrader, A., Zimmerman, E., Rosenfeldt, A., Alberts, J., & Linder, S. (2024). Characterizing Heart Rate Response During Upper Extremity Repetitive Task Practice in Chronic Stroke. *The American Journal of Occupational Therapy*, 78.

Dawson-Amoah, K. and Varacallo, M.A. (2023). 'Anatomy, shoulder and upper limb, hand intrinsic muscles', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539810/ (Accessed: 19 June 2025).

De Souza, E.O., Tricoli, V., Rauch, J., Alvarez, M.R., Laurentino, G., Brum, P.C. and Aoki, M.S. (2013). Resistance exercise leading to failure versus not to failure: effects on cardiovascular control. European Journal of Applied Physiology, [online] Available at: https://www.researchgate.net/publication/258766035 [Accessed 20 Jun. 2025].

DeMers, D. and Wachs, D. (2023). Physiology, Mean Arterial Pressure. [online] Updated 10 Apr 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK538226/

Doehner, W. Mazighi, M., Hofmann B., Lautsch D., Hindricks G., Bohula E., Byrne R., Camm A., Casadei B., Caso V., Cognard C., Diener H. (2020). 'Cardiovascular care of patients with stroke and high risk of stroke: The need for interdisciplinary action: A consensus report from the European Society of Cardiology Cardiovascular Round Table', European Journal of Preventive Cardiology, 27(7), pp. 682–692. Available at: https://doi.org/10.1177/2047487319873460 (Accessed: 19 June 2025).

Edwards, M.K., Choi, J. H, Patel and Smith, D. (2024). 'The impact of exercise on cardiovascular risk in hypertensive adults: An updated review', Current Hypertension Reports, 26, pp. 45–55.

Edwards, J., Wiles, J., & O'Driscoll, J. (2022). Mechanisms for blood pressure reduction following isometric exercise training: a systematic review and meta-analysis. *Journal of Hypertension*, 40, 2299 - 2306.

Epperson, T.N. and Varacallo, M.A. (2023). Anatomy, Shoulder and Upper Limb, Brachial Artery. [online] Updated 24 Jul 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK537145/

Faletra, A., Bellin, G., Dunning, J. (2022). 'Assessing cardiovascular parameters and risk factors in physical therapy practice: Findings from a cross-sectional national survey and implication for clinical practice', BMC Musculoskeletal Disorders, 23, 749. Available at: https://doi.org/10.1186/s12891-022-05661-3 (Accessed: 19 June 2025).

Familoni, O.B. and Olunuga, T.O. (2005). Comparison of the effects of arm position and support on blood pressure in hypertensive and normotensive subjects. Cardiovascular Journal of South Africa, 16(2), pp.85–88.

Faraco, G. and Iadecola, C. (2013). Hypertension: a harbinger of stroke and dementia. Hypertension, [online] 62(5), pp.810–817. Available at: https://www.ahajournals.org/doi/full/10.1161/HYPERTENSIONAHA.113.01063 [Accessed 20 Jun. 2025].

Fasoli, S.E. (2016). 'Exercise and hypertension', in ACSM's Guide to Exercise and Hypertension. Champaign, IL: Human Kinetics, pp. 35–54.

Feigin, V.L., Forouzanfar, M.H., Krishnamurthi, R., Mensah, G.A., Connor, M., Bennett, D.A., Moran, A.E., Sacco, R.L., Anderson, L., Truelsen, T., O'Donnell, M., Venketasubramanian, N., Barker-Collo, S., Lawes, C.M.M., Wang, W., Shinohara, Y., Witt, E., Ezzati, M., Naghavi, M., Murray, C. (2014). Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. The Lancet 383, 245–255. https://doi.org/10.1016/S0140-6736(13)61953-4

Feske, S.K. (2021). Ischemic Stroke. Am. J. Med. 134, 1457–1464. https://doi.org/10.1016/j.amjmed.2021.07.027

Forouzanfar, M.H., Liu, P., Roth, G.A., Ng, M., Biryukov, S., Marczak, L., Alexander, L., Estep, K., Abate, K.H., Akinyemiju, T.F. and Ali, R. (2017). ‘Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990–2015’, JAMA, 317(2), pp. 165–182.

Forro, S.D., Munjal, A. and Lowe, J.B. (2023). ‘Anatomy, shoulder and upper limb, arm structure and function’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK538302/ (Accessed: 19 June 2025).

Franklin, B.A., Brook, R. and Pope, C.A. (2022). ‘Cardiovascular disease prevention: The role of exercise, air pollution, and other environmental exposures’, Progress in Cardiovascular Diseases, 69, pp. 69–80.

Fulghum, K. and Hill, B.G. (2018). Metabolic mechanisms of exercise-induced cardiac remodeling. Frontiers in Cardiovascular Medicine. [online] Available at: https://www.frontiersin.org/articles/10.3389/fcvm.2018.00069/full

Gabriel Khan, M. (2006). Encyclopedia of heart diseases [online]. Elsevier. Available at: https://www.sciencedirect.com/book/9780124060616/encyclopedia-of-heart-diseases (Accessed: 19 June 2025).

Global Burden of Diseases (2013). Risk Factors Collaborators (2015) ‘Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: A systematic analysis for the Global Burden of Disease Study 2013’, The Lancet, 386(10010), pp. 2287–2323.

Gorelick, P.B, Waddy, S.P., White, C. L., Williams, L.S., Yancy, C.W., Bravata, D.M and Hill, C.V. (2021). ‘Management of hypertension in patients with stroke: A scientific statement from the American Heart Association’, Hypertension, 77(4), pp. 1029–1039. Available at: https://doi.org/10.1161/HYPERTENSIONAHA.120.14653 (Accessed: 19 June 2025).

Gupton, M., Munjal, A. and Terreberry, R.R. (2023). ‘Anatomy, hinge joints’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK518967/ (Accessed: 19 June 2025).

Guyton, A.C. and Hall, J.E. (2016). Textbook of Medical Physiology. 13th ed. Philadelphia: Elsevier.

Han, J. (2022). The Journal of Physiology. [online] Available at: https://physoc.onlinelibrary.wiley.com/doi/full/10.1113/JP283632

Hayashi, H., Abe, M. and Matsuoka, B. (2018) Handgrip Exercise By The Non-affected Hand Increases Venous Return In The Contralateral Axillary Vein In Patients With Stroke: A Pilot Study. BMC Res Notes 11, 374. https://doi.org/10.1186/s13104-018-3475-6

Henderson, W.R., Griesdale, D.E. and Walley, K.R. Clinical Review: Guyton – the role of mean circulatory filling pressure and right atrial pressure in controlling cardiac output. Crit Care 14, 243 (2010). https://doi.org/10.1186/cc9247.

Hinton, R.B. and Yutzey, K.E. (2011). 'Heart valve structure and function in development and disease', Annual Review of Physiology, 73, pp. 29–46.

Johansson, B.B. (1999). 'Hypertension mechanisms causing stroke', Clinical and Experimental Pharmacology and Physiology, 26(7), pp. 563–565. Available at: https://doi.org/10.1046/j.1440-1681.1999.03081.x (Accessed: 19 June 2025).

Juneja, P., Munjal, A. and Hubbard, J.B. (2024). 'Anatomy, joints', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK507893/ (Accessed: 19 June 2025).

Kim, D.Y., Lee, J.H. and Lim, H.J. (2017). 'Effects of limb elevation on arterial and venous hemodynamics: Implications for physiotherapy', Journal of Physical Therapy Science, 29(5), pp. 894–899.

Kim, J., Lee, D.H., Kim, J.H., Kang, D.W., Choi, M., Kim, S. and Cho, Y.J. (2017). 'Effect of aerobic exercise on blood pressure in hypertensive patients: A meta-analysis of randomized controlled trials', Journal of Hypertension, 35(4), pp. 718–726.

Kjeldsen, S.E. (2018). 'Hypertension and cardiovascular risk: General aspects', Pharmacological Research, 129, pp. 95–99.

Kunutsor, S.K. (2024). 'Physical activity and incident hypertension: Updated evidence from cohort studies', Hypertension, 81(5), pp. 1001–1010. Available at: https://doi.org/10.1161/HYPERTENSIONAHA.123.XXXXX (Accessed: 19 June 2025). (Replace Xs with actual DOI if known.)

Kuriakose, D., Xiao, Z., (2020). Pathophysiology and Treatment of Stroke: Present Status and Future Perspectives. Int. J. Mol. Sci. 21, 7609. https://doi.org/10.3390/ijms21207609

Levy, M.N. (1997). 'Neural control of cardiac function', Bailliere's Clinical Neurology, 6(2), pp. 227–244.

Mackie, P., Crowfoot, G., Janssen, H., Holliday, E., Dunstan, D., & English, C. (2021). The Effects of Interrupting Prolonged Sitting With Frequent Bouts of Light-Intensity Standing Exercises on Blood Pressure in Stroke Survivors: A Dose Escalation Trial. Journal of physical activity & health, 1-10.

Machado-Vidotti, H.G., Mendes, R. G., Simoes, V., Catai, A.M., and Borghi-Silva, A. (2014). Cardiac autonomic responses during upper versus lower limb resistance exercise in healthy elderly men. Brazillian journal of physical therapy, 18(1), 9-18. https://doi.org/10/1590/s1413-35552012005000140

Marchese, R.M., Launico, M.V. and Geiger, Z. (2025). Anatomy, Shoulder and Upper Limb, Forearm Radial Artery. [online] Updated 3 Mar 2025. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK546626/

Marques, E. and Bordoni, B. (2023). Anatomy, Shoulder and Upper Limb, Ulnar Artery. [online] Updated 24 Jul 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK546619/

Marterer, N., Mugele, H., Schäfer, S.K. and Faulhaber, M. (2023). 'Effects of upper body exercise training on aerobic fitness and performance in healthy people: A systematic review', Biology, 12(3), 355. Available at: https://doi.org/10.3390/biology12030355 (Accessed: 19 June 2025).

Mitchell, B. and Whited, L. (2023). ‘Anatomy, shoulder and upper limb, forearm muscles’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK536975/ (Accessed: 19 June 2025).

Miyai, N., Shiozaki, M., Yabu, M. (2013). Increased mean arterial pressure response to dynamic exercise in normotensive subjects with multiple metabolic risk factors. Hypertension Research, 36, pp.534–539.

Moloro, A.H., Seid, A.A. and Jaleta, F.Y. (2023). ‘A systematic review and meta-analysis protocol on hypertension prevalence and associated factors among bank workers in Africa’, SAGE Open Medicine, 11, p. 20503121231172001. Available at: https://doi.org/10.1177/20503121231172001 (Accessed: 19 June 2025).

Moore, K.L., Dalley, A.F. and Agur, A. (2017). Clinically oriented anatomy. 8th edn. Philadelphia, PA: Lippincott Williams and Wilkins.

Moore, S.A., Hallsworth, K., Plötz, T., Ford, G.A., Rochester, L., Trenell, M.I. and Watson, P.M. (2013). Physical activity, sedentary behaviour and metabolic control following stroke: a cross-sectional and longitudinal study. PLoS ONE, [online] 8(1), p.e55263. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC3558428/ [Accessed 20 Jun. 2025].

Moran, V., Nila, I., Madhuvilakku, R., Sumsuzzman, D., Khan, Z., & Hong, Y. (2024). Elucidating the role of physical exercises in alleviating stroke-associated homeostatic dysregulation: a systematic review and meta-analysis. *BMJ Open Sport & Exercise Medicine*, 10.

Mostafa, E., Imonugo, O. and Varacallo, M.A. (2023). ‘Anatomy, shoulder and upper limb, humerus’, in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK534821/ (Accessed: 19 June 2025).

Mourad, A., Carney, S., Gillies, A., Jones, B., Nanra, R. and Trevillian, P. (2003). Arm position and blood pressure: a risk factor for hypertension? Journal of Human Hypertension, 17(6), pp.389–395.

Murphy, S.JX., and Werring, D.J. (2020). Stroke: causes and clinical features. Medicine (Baltimore) 48, 561–566. https://doi.org/10.1016/j.mpmed.2020.06.002

Nguyen, J.D. and Duong, H. (2023). Anatomy, Shoulder and Upper Limb, Veins. [online] Updated 14 Aug 2023. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK546676/

Niakan, A. and Cushman, W.C. (2018). ‘Glossary’, in Encyclopedia of endocrine diseases [online]. Elsevier. Available at: https://www.sciencedirect.com/referencework/9780128122006/encyclopedia-of-endocrine-diseases (Accessed: 19 June 2025).

Ntaios, G., and Hart, R.G. (2017). Embolic Stroke. Circulation 136, 2403–2405. https://doi.org/10.1161/CIRCULATIONAHA.117.030509.

Nystoriak, M. A., and Bhatnagar, A. (2018). Cardiovascular Effects and Benefits of Exercise. Frontiers in cardiovascular medicine, 5, 135. https://doi.org/10.3389/fcvm.2018.00135

Obaseki, C., Imarihagbe, F., Adodo, M., & Agbonlahor, I. (2025). Noninvasive myocardial oxygen consumption alterations in hypertensive stroke survivors after 4 weeks of isometric exercise training protocols: a randomized controlled trial. *Bulletin of Faculty of Physical Therapy.*

Obaseki, C. O., Samuel, M. A., Sunday, S. E., & Agbonlahor, E. I. (2022). Effects of a Four-Week Isometric Exercise Training on Blood Pressure of Hypertensive Stroke Survivors in a Tertiary Health Institution. *Journal of Hypertension and Management,* 8(1).

Ogah, O.S., Okpechi, I., Chukwuonye, I.I., Akinyemi, J.O., Onwubere, B.J., Falase, A.O., Stewart, S. and Sliwa, K. (2012). 'Blood pressure, prevalence of hypertension and hypertension-related complications in Nigerian Africans: A review', World Journal of Cardiology, 4(12), pp. 327–340.

Ogungbe, O.A., Ojo, T.A., Adebayo, R.A., Balogun, M.O., Akintomide, A.O. and Adedoyin, R.A. (2024). 'Effect of moderate intensity continuous training on blood pressure control in Nigerian hypertensive patients: A randomized controlled trial', African Health Sciences, 24, pp. 356–364.

Okwumabua, E., Sinkler, M.A. and Bordoni, B. (2023). 'Anatomy, shoulder and upper limb, hand muscles', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK537229/ (Accessed: 19 June 2025).

Owolabi, M., Olowoyo, P., Popoola, F., Lackland, D., Jenkins, C., Arulogun, O., Akinyemi, R., Akinyemi, O., Akpa, O., Olaniyan, O., Uvere, E., Kehinde, I., Selassie, A., Gebregziabher, M., Tagge, R., Ovbiagele, B. (2018). The epidemiology of stroke in Africa: A systematic review of existing methods and new approaches. J. Clin. Hypertens. 20, 47–55. https://doi.org/10.1111/jch.13152

Paneroni, M., Vitacca, M., Bernocchi, P., Bertacchini, L., Scalvini, S., Simonelli, C. and Troosters, T. (2018). Exercise training in patients with chronic respiratory diseases: clinical impact and mechanisms. Multidisciplinary Respiratory Medicine, [online] 13, Article number: Available at: https://pubmed.ncbi.nlm.nih.gov/29684979/ [Accessed 20 Jun. 2025].

Parmar, P.P. (2018). Stroke: classification and diagnosis [WWW Document]. Pharm. J. URL https://pharmaceutical-journal.com/article/ld/stroke-classification-and-diagnosis (accessed 1.6.24).

Patel, K., Rössler, A., Lackner, H.K., Trozic, I., Laing, C., Lorr, D., Green, D.A., Hinghofer-Szalkay, H. and Goswami, N. (2016). Effect of postural changes on cardiovascular parameters across gender. Medicine, 95(28).

Pendergast, D.R. (1989). Cardiovascular, respiratory, and metabolic responses to upper body exercise. Medicine and Science in Sports and Exercise, 21(5 Suppl), pp.S121–S125.

Perry, B.G., Coombes, J.S. and Nosaka, K. (2023) 'Resistance exercise and hypertension: An updated systematic review and meta-analysis', Journal of Hypertension, 41(3), pp. 473–483.

Rapsomaniki, E., Timmis, A., George, J., Pujades-Rodriguez, M., Shah, A.D., Denaxas, S., White, I.R., Caulfield, M.J., Deanfield, J.E., Smeeth, L. and Williams, B. (2014) 'Blood pressure and incidence of twelve cardiovascular diseases: Lifetime risks, healthy life-years lost, and age-specific associations in 1.25 million people', The Lancet, 383(9932), pp. 1899–1911.

Rehman, I. and Rehman, A. (2023). 'Anatomy, thorax, heart', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK538305/ (Accessed: 19 June 2025).

Saxton, A., Chaudhry, R. and Manna, B. (2023). 'Anatomy, thorax, heart right coronary arteries', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/sites/books/NBK537357/ (Accessed: 19 June 2025).

Shahoud, J.S., Sanvictores, T. and Aeddula, N.R. (2023). 'Physiology, arterial pressure regulation', in: StatPearls [online]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK538254/ (Accessed: 19 June 2025).

Snow, E.L. and Lanik, W.E. (2024). 'Structural and functional analysis of bilateral five-headed biceps brachii muscles with clinical insights', Translational Research in Anatomy, 35, [no page numbers].

Suarez-Roca H., Mamoun N., Martin I. S. and Maixner, W (2021). Baroreceptor Modulation of the Cardiovascular System, Pain, Consciousness, and Cognition. Comprehensive Physiology, 11(2), 1373-1423. https://doi.org/10.1002/cphy.c190038.

Tackling, G. (2023). 'Lifestyle interventions for hypertension: An updated review', Current Opinion in Cardiology, 38(4), pp. 370–376.

Tang, A. and Varacallo, M.A. (2022). 'Anatomy, shoulder and upper limb, hand carpal bones', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK535382/ (Accessed: 19 June 2025).

Taylor, K., Wiles, J., Coleman, D., Sharma, R., & O'Driscoll, J. (2017). Continuous Cardiac Autonomic and Hemodynamic Responses to Isometric Exercise. *Medicine & Science in Sports & Exercise,* 49, 1511–1519.

Thiel, R., Munjal, A. and Daly, D.T. (2025). Anatomy, Shoulder and Upper Limb, Axillary Artery. [online] Updated 20 Jan 2025. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Available at: https://www.ncbi.nlm.nih.gov/books/NBK482174/

Tian, Y., Guo, F. and Liu, B. (2019). Influence of venous return on the Frank-Starling mechanism in postural changes. European Journal of Physiology, 371(2), pp.487–496.

Tiwana, M.S., Sinkler, M.A. and Bordoni, B. (2023). 'Anatomy, shoulder and upper limb, triceps muscle', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK536996/ (Accessed: 19 June 2025).

Trinh, T., Scheuer, S., Thompson-Butel, A., Shiner, C., & McNulty, P. (2016). Cardiovascular fitness is improved post-stroke with upper-limb Wii-based Movement Therapy but not dose-matched constraint therapy. *Topics in Stroke Rehabilitation*, 23, 208 - 216.

Tucker, W.D., Arora, Y. and Mahajan, K. (2023). 'Anatomy, blood vessels', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK470401/ (Accessed: 19 June 2025).

Volpe, J.K. and Makaryus, A.N. (2025). 'Anatomy, thorax, heart and pericardial cavity', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK538295/ (Accessed: 19 June 2025).

Wajngarten, M. and Silva, G.S. (2019). 'Hypertension and stroke: Update on treatment', European Cardiology, 14(2), pp. 111–115. Available at: https://doi.org/10.15420/ecr.2019.11.1 (Accessed: 19 June 2025).

Walkowski, A.D. and Goldman, E.M. (2023). 'Anatomy, shoulder and upper limb, forearm extensor carpi radialis brevis muscle', in StatPearls [online]. Treasure Island (FL): StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539719/ (Accessed: 19 June 2025).

Wang, C., Redgrave, J., Shafizadeh, M., Majid, A., Kilner, K., & Ali, A. (2018). Aerobic exercise interventions reduce blood pressure in patients after stroke or transient ischaemic attack: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 53, 1515 - 1525.

Westhoff, T.H., Franke, N., Schmidt, S., Vallbracht-Israng, K., Meissner, R., Yildrim, H. and Zidek, W. (2008). 'Resistance training induces changes in heart rate variability in patients with chronic kidney disease and hypertension', Nephrology Dialysis Transplantation, 23(3), pp. 985–991.

Westhoff, T., Schmidt, S., Gross, V., Joppke, M., Zidek, W., Van Der Giet, M., & Dimeo, F. (2008). The cardiovascular effects of upper-limb aerobic exercise in hypertensive patients. *Journal of Hypertension*, 26, 1336–1342.

Whelton, P.K., Carey, R.M., Aronow, W.S., Casey, D.E., Collins, K.J., Dennison Himmelfarb, C. (2018). '2017 ACC/AHA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults', Journal of the American College of Cardiology, 71(19), pp. e127–e248.

World Health Organization (2021). Cardiovascular diseases. Available at: https://www.who.int/health-topics/cardiovascular-diseases (Accessed: 19 June 2025).

Yu, J.G., Zhou, R.R. and Cai, G.J. (2011). 'From hypertension to stroke: Mechanisms and potential prevention strategies', CNS Neuroscience and Therapeutics, 17(5), pp. 577–584. Available at: https://doi.org/10.1111/j.1755-5949.2011.00264.x (Accessed: 19 June 2025).

Zhiyi, Z., Baoxin, L., Lingjun, J., and Jianping, L. (2018). Effects of arm elevation on radial artery pressure in post-cardiac surgery patients. Blood Pressure Monitoring, [online] 23(3), pp.130–134. Available at: https://journals.lww.com/bpmonitoring/abstract/2018/06000/effects_of_arm_elevation_on_radial_artery.2.aspx [Accessed 20 Jun. 2025].

Zhu, Z., Tang, Y., Chen, Y., Zhou, J., Guo, L. and Zhang, X. (2024). Cardiovascular health and stroke: A mechanistic overview of blood pressure control and vascular remodeling. Frontiers in Cardiovascular Medicine, [online] Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC11088431/ [Accessed 20 Jun. 2025].

APPENDIX I

INFORMED CONSENT

Title of study: Acute Effects of Sustained Bilateral Upper Limb Elevation Exercise Protocols on Cardiovascular Parameters of Hypertensive Stroke Survivors: Implications For Hemodynamic Regulation.

Investigator: Ekuase Daisy Osakpolor

Supervisor: Dr. (Mrs) Chigozie O. Obaseki.

Financial Sponsorship: This research project is self-sponsored

Purpose of the research: The purpose of the research is to compare the acute effects of sustained bilateral upper limb elevation exercise protocols in systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and heart rate of hypertensive stroke survivors.

Procedures and protocol involved in the study

You will be politely asked to sit comfortably with your back supported and your both feet flat on the floor. You will rest quietly for 5 minutes in order to allow your body relax. After this rest, your blood pressure and heart rate will be measured using a digital device. You will then be politely asked to raise both of your arms in front of you (with your palms facing forward) and hold them up at a specific angle (either 90^0 or 180^0). You will maintain this position for 2 minutes after which, your heart rate and blood pressure will be measured again. You will then be allowed to rest for 10 minutes before the exercise is repeated again. All your readings will be recorded and the environment will be quiet and comfortable in order to ensure accuracy of results.

Compensation

There will be no financial compensation for participating in this study.

Voluntary Participation

Please note that your participation in this research is entirely voluntary. No form of discrimination will be meted to you, should you decide not to participate in this study; You are entirely free to change your mind and stop participating even if you agreed earlier.

Side Effects

There is no anticipated adverse effect associated with participating in this study.

Benefits

This study will help healthcare professionals have a better understanding of how these simple upper limb exercises can affect the blood pressure and heart rate of individuals who have experienced stroke and also live with hypertension.

Confidentiality

All information and data obtained in the course of this study will be treated confidentially. The names of the participants will not be written on the questionnaire, and all information collected will be encoded in a file in my personal computer and passworded.

CONTACT INFORMATION

EKUASE DAISY OSAKPOLOR
PROJECT STUDENT
Email: daisyekuase33@gmail.com

Ethics and Research Committee
University of Benin Teaching Hospital
Benin City.
Phone Number: 08067740735

CERTIFICATE OF CONSENT

I have read the above information (or it has been read to me). I had the opportunity to ask questions about it and the questions were answered to my satisfaction.

I consent voluntarily to take part as a participant in this study ( )

I do not consent to participate in this study (   )

Signature of participant: ___________________________________

Date: ____

APPENDIX II

SOCIODEMOGRAPHIC FORM

Section A: Demographic Information:

1. Age (in years): ______
2. Sex:
   ( ) Male ( ) Female
3. Marital Status
   ( ) Single ( ) Married ( ) Widowed ( ) Divorced
4. Highest Level of Education Attained:
   ( ) No Formal Education
   ( ) Primary
   ( ) Secondary
   ( ) Tertiary
5. Occupation:
   ( ) Retired ( ) Civil Servant ( ) Trader ( ) Artisan ( ) Unemployed
   ( ) Others (Please specify) ________
   Section B: Clinical Information
6. Duration Since Stroke Broke Out:
   ( ) 1-3 months ( ) 4-6 months ( ) 7-12 months ( ) Over 12 months
7. History of Hypertension
   ( ) Yes ( ) No
8. Use of Antihypertensive Medication
   ( ) Yes ( ) No
9. Any Other Known Chronic Illness?
   ( ) Yes ( ) No
   If yes, specify: ______

APPENDIX III

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. If you are planning to become much more physically active than you are now, start by answering the seven questions below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor. Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

Check **YES** or **NO.**

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor? YES ( ) NO ( )

2. Do you feel pain in your chest when you do physical activity? YES ( ) NO ( )

3. In the past month, have you had chest pain when you were not doing ng physical activity? YES ( ) NO ( )

4. Do you lose your balance because of dizziness or do you ever lose consciousness? YES ( ) NO ( )

5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity? YES ( ) NO ( )

6. Is your doctor currently prescribing drugs (for example, pills) for your blood pressure or heart condition? YES ( ) NO ( )

7. Do you know of any other reason why you should not do physical activity? YES ( ) NO ( )

APPENDIX IV

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: [illegible]@gmail.com

DIRECTOR OF ADMINISTRATION
Jim Uwadia, Esq

CHAIRMAN
Prof. (Mrs.) Antoinette N. Ofili

HREC OFFICE:
Committee email: ubthresearchethics@gmail.com
Registration Number:
NHREC-UBTH-HREC/24/12/20228

PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/125

PROPOSAL TITLE: "ACUTE EFFECTS OF SUSTAINED BILATERAL UPPER LIMB ELEVATION PROTOCOLS ON CARDIOVASCULAR PARAMETERS OF HYPERTENSIVE STROKE SURVIVORS: IMPLICATIONS FOR HEMODYNAMICS REGULATION"

PRINCIPAL INVESTIGATOR(S): EKUASE, DAISY OSAKPOLOR

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

DATE CONSIDERED: JULY 14TH, 2025

DECISION OF THE COMMITTEE: APPROVED

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

REMARK:

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

SUPERVISOR (S): DR. (MRS) C.O OBASEKI

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

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

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