A CLINICAL INVESTIGATION OF HEART RATE RECOVERY AS AN INDEX OF AUTONOMIC FUNCTION IN HEALTHY YOUNG ADULTS: IMPLICATIONS FOR PREVENTIVE SCREENING"

BY

OMOROTIONMWAN EFOSA MARTINS
(BMS2005165)

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

OCTOBER, 2025.

CERTIFICATION

This dissertation by OMOROTIONMWAN, EFOSA MARTINS 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 **SIGN & DATE**

PROF UAC OKAFOR _____

EXTERNAL EXAMINER **SIGN & DATE**

APPROVED

_____

DR. (MRS.) CHIGOZIE .O. OBASEKI

AG. HEAD OF DEPARTMENT

DEPARTMENT OF PHYSIOTHERAPY

COLLEGE OF MEDICAL SCIENCES

UNIVERSITY OF BENIN, BENIN CITY

DEDICATION

This dissertation is dedicated to God Almighty for strength, grace and courage to finish this project. To my ever-loving Mother, Father and Siblings for providing me with prayers and financial support to see it through. To Mrs Darlington Fred, Mrs Osuyi Enobakhare for strength and morale support and Dr. Mrs.C. O. Obaseki who made this work a reality.

ABSTRACT

Background: Heart rate recovery (HRR) following exercise serves as a simple, non-invasive indicator of autonomic function and cardiovascular fitness. Impaired HRR has been linked with increased cardiovascular risk, even in apparently healthy individuals. However, there is limited data on HRR among young adults in the Nigerian population.

Aim: This study aimed to characterize typical HRR values among undergraduate students of the University of Benin and to examine their relationship with key lifestyle and stress-related factors, including physical activity and perceived academic stress.

Methods: A total of 346 apparently healthy male and female undergraduate student aged 18 – 25 years with a mean age of 21.09 ± 1.87 years participated in this cross-sectional observational study. Of the total respondents, 167 (48.3%) were male and 179 (51.7%) were female. Resting and exercise heart rate, and blood pressure were recorded. HRR was determined at 1, 2, and 5-minutes post-exercise. Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ), while perceived stress was evaluated with the Perceived Stress Scale (PSS). Data was summarize using descriptive statistics. Independent t-tests, ANOVA, correlation, and linear regression, with significance set at $p < 0.05$ were used to test the hypothesis.

Results: The participants had mean HRR values of 50.34 ± 19.61 bpm (1-minute), 65.32 ± 21.27 bpm (2-minute), and 75.35 ± 22.72 bpm (5-minute). No significant gender differences were observed in HRR ($p > 0.05$). Physical activity showed a significant negative correlation with 5-minute HRR ($r = –0.15$, $p = 0.005$), while perceived academic stress showed no significant relationship with HRR across time points. HRR significantly predicted maximum heart rate ($B = 0.737$, $p < 0.001$), but not resting cardiovascular parameters.

Conclusion: The findings suggest that HRR after 6MWT among healthy young adults at the University of Benin reflects generally normal autonomic recovery patterns, independent of gender and academic stress levels. However, reduced physical activity may influence delayed autonomic recovery. Regular physical activity and preventive cardiovascular screening are recommended to promote optimal autonomic health.

Keywords: Heart rate recovery, Autonomic function, Physical activity, Academic stress, Healthy young adults, Preventive screening.

ACKNOWLEDGEMENTS

I am grateful to God for the successful completion of this work and for his protection and guidance throughout my stay on this campus. Special thanks to my supervisor Dr. Mrs. Chigozie O. Obaseki for her assistance and guidance during the course of the research study. Despite the busy schedule she devoted her time to listen to me, answer my questions, read through my work and also made corrections. May the good lord reward you in hundred folds.

I also appreciate all the Lecturers of the department of Physiotherapy, University of Benin, Prof. Kayode I. Oke, Rev. Sr (Dr) Herrientta Fawole, Prof. Joseph Umunnah, Prof. Obinna Ezeukwu, Prof. Mohammed Jubril, Dr. Mrs. Ayiegbusi, Dr.Mrs.Chigozie O. Obaseki, Dr. Hammed I. Adebisi, Dr.S.O Nicholas, Dr. Mrs. Kubeyinje, Dr. S. UO. Bolarinde, Dr. Nelson Ekechukwu, Mr. R.E. Okhuahesuyi and Miss Osayi Obarisiagbon who impacted knowledge in me during my stay in school. A special thanks to the Head of Department Dr.Taiwo Oyewumi and also the directors, the chiefs, interns and other clinicians in the department of physiotherapy, University of Benin teaching hospital. I also appreciate the non-academic staffs, especially Mr. Nosa and Mrs. Juliet, of the Department of Physiotherapy, University of Benin. I also give thanks to my mother Mrs. Omorotionmwan Susan, and my father Mr. Lucky Omorotionmwan, my brothers Mr.Omorotionmwan Osazee and Osasuyi, my Sister Omorotionmwan Osahenrunmwen and relatives for their word of advice, encouragements, their prayers and financial support throughout my stay as a student of University of Benin. I also like to appreciate my friends Jojo, Sammy, Godday, David, Valerie, Victoria, Ada-jolly and Esosa and a special thanks to Oisamoje Daniel, Afoke, Daisy, Esther, Christian, Odimbu Jane and Oloye for their assistance during my period of data collection. A special thanks and gratitude to all my classmates and students who volunteered to participate in my study and others which the confines of this page will not permit me to state.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Heart rate recovery is crucial for revealing the autonomic health in every population. It is significant in physiotherapy as it is often linked to the symmetry of the autonomic nervous system and its cardiovascular implications. Physiotherapists often give treatment to individuals who have impairment, disability, or injuries, and improve their physical fitness, which directly includes heart rate recovery, which can be a vital aspect of their well-being (Lee et al., 2012; Maria et al., 2017). There are several methods of assessing autonomic function, one of which is HRR, a non-invasive method used to assess autonomic and cardiovascular function. This method has been used in different populations, including older adults and athletes, to determine their autonomic function. Therefore, the clinical investigation of Heart rate recovery is important to identify individuals who may be at risk of developing diseases and to develop interventions to improve their physical fitness, which directly improves HRR.

Heart rate recovery (HRR), defined as the rate at which heart rate decreases after the cessation of exercise, has emerged as a valuable, non-invasive marker of cardiac autonomic function, particularly reflecting the efficiency of parasympathetic reactivation and the withdrawal of sympathetic tone (Okutucu et al., 2011). The human body's ability to adapt and maintain internal equilibrium, or homeostasis, is largely organized by the autonomic nervous system (ANS). This complex network operates beneath the realm of conscious control, diligently regulating a cascade of

vital physiological functions, including the rhythmic beating of the heart, the dynamic regulation of blood pressure, and the essential processes of respiration and digestion (John, 2006). The ANS is characterized by two delicate primary branches that often engage in reciprocal interplay: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is a crucial component of the ANS, mainly known for its role in initiating the "fight-or-flight" response. When active, it triggers a cascade of physiological changes characterized by increased heart rate and blood pressure, faster breathing, heightened alertness, and release of energy reserves. Conversely, the PNS functions in the opposite manner of the SNS and acts as the body's brake, promoting "rest and digest" activities leading to a slowing of heart rate, relaxation of muscles, and conservation of energy. The dynamic balance between these two branches, often referred to as sympathovagal balance or autonomic tone, is paramount for maintaining optimal cardiovascular health. Heart rate recovery (HRR) after exercise is a well-established marker of autonomic nervous system (ANS) function and cardiovascular health. It reflects the body's ability to transition from a state of sympathetic dominance (during exercise) to a state of parasympathetic dominance (during recovery).

The heart rate is primarily regulated by the ANS; the SNS increases heart rate in response to stress or exercise, while the PNS slows it down during rest or recovery. During exercise, there’s a withdrawal of parasympathetic activity and an increase in sympathetic activity, leading to a rise in heart rate, which is an autonomic shift in the nervous system. After the cessation of exercise, the sympathetic drive gradually decreases, following a rapid reactivation of parasympathetic tone to promote a quicker slowing of the increased heart rate. This indicates a healthy heart rate

recovery. A faster HRR generally indicates a good sympathovagal balance where the parasympathetic system can effectively dampen the sympathetic effects of exercise and quickly restore the heart rate to its normal resting state (Arena et al., 2006).

The clinical significance of HRR has been well-established in various populations. Studies have consistently demonstrated that an impaired HRR is a potent predictor of adverse cardiovascular events and increased all-cause mortality in individuals with pre-existing cardiovascular disease (Jouven et al., 2000; Omar et al., 2016). An efficient and adaptable ANS allows the cardiovascular system to respond appropriately to various physiological demands in changes, from the exertion of physical activity to the emotional responses engendered by daily life. Disruptions in this delicate balance, characterized by either excessive sympathetic activation or diminished parasympathetic influence, may bring about notable implications for cardiovascular function and overall well-being for older adults. Less is known about autonomic health in young healthy adults, such as undergraduates.

The Focus on Undergraduate Students, a Critical Population, has received less attention and has been directed towards understanding autonomic function, as assessed by HRR, in healthy young individuals. This demographic often experiences a unique confluence of physiological and psycho-social stressors, often characterized by high levels of stress, poor sleep, and variable lifestyle habits. Understanding autonomic health through HRR is crucial. The clinical relevance of HRR has been robustly demonstrated across diverse adult populations. Landmark studies have recognized a clear link between a blunted HRR and an elevated risk of adverse cardiovascular events, including myocardial infarction, sudden cardiac death, and

increased all-cause mortality (Jouven et al., 2000; Omar et al., 2016). This established prognostic value underscores the potential of HRR as a valuable tool for identifying individuals who may be significantly at increased risk for cardiovascular morbidity, even in the absence of patent clinical symptoms.

However, it is unclear how the dynamics and uniqueness of undergraduate lifestyles affect heart rate and physical fitness among university students; therefore, understanding this relationship in this population can by extension, assist physiotherapists to accurately assess and plan appropriate interventions. The choice of HRR as an index for assessing autonomic function is due to its quick call to action status, which will take just a few minutes to carry out and calculate. Using this will not only serve as a measure of autonomic function for university students but would by extension, also encourage further studies comparing diverse programmes in the university, as well as enabling physiotherapists to assess their exercise capacity, cardiac health, and ultimately their physical fitness in very little time.

1.2 Statement of the Problem

There is an underexplored landscape of the autonomic function in healthy young adults (university undergraduate), while the significance of HRR is well-documented in clinical and aging populations, the autonomic landscape of healthy young adults, particularly university undergraduate students, remains comparatively underexplored. This is a critical oversight, considering the unique constellation of physiological and psychosocial stressors that characterize this pivotal stage of life. This lack of baseline data and understanding of the factors influencing HRR in undergraduates represents a significant knowledge and population gap. Without this information, tertiary

institutions lack the evidence-based foundation to identify students who may be significantly at risk for early autonomic dysregulation and to implement early precautions and targeted wellness interventions. Consequently, potential early warning signs of compromised cardiovascular health may go unnoticed, representing a missed opportunity for dynamic health promotion and disease prevention in this young adult population (Kim et al., 2018; Melillo et al, 2011). The undergraduate experience is often marked by a confluence of factors that can exert considerable influence on the autonomic nervous system, potentially leading to early signs of cardiovascular dysregulation. These factors include the rigorous academic environment inherent in university life, with its demanding mental academic coursework, important examinations, and the pervasive pressure to achieve academic excellence, which can serve as a significant source of chronic mental stress (Wilks, 2008). This sustained psychological stress can lead to prolonged sympathetic activation, potentially impacting autonomic balance and cardiovascular regulation.

1.3 Research Questions

1. What was the average heart rate recovery (HRR) value, specifically measured at the one-minute, two-minute, and five-minute marks following the cessation of a 6MWT, among the healthy young adults population of the tertiary institution?
2. Was there any difference in the average HRR value measured at one-minute, two-minute, and five-minute marks following the cessation of a 6MWT, among the healthy young adults population of the tertiary institution
3. Was there any difference in heart rate recovery in one-minute (HRR_1) value after a 6MWT in the male and female healthy young adults participants?

4. Was there any difference in heart rate recovery in two-minute (HRR_2) value after a 6MWT in the male and female healthy young adults participants?

5. Was there any difference in heart rate recovery in five-minute (HRR_5) value after a 6MWT in the male and female healthy young adults participants?

6. Was there a correlation between the self-reported physical activity levels of healthy young adults and one-minute heart rate recovery (HRR) value after a 6MWT ?

7. Was there a correlation between the self-reported physical activity levels of healthy young adults and two-minute heart rate recovery (HRR) value after a 6MWT ?

8. Was there a correlation between the self-reported physical activity levels of healthy young adults and five-minute heart rate recovery (HRR) value after a 6MWT ?

9. Was there any correlation between the level of perceived academic stress of healthy young adults and one-minute heart rate recovery (HRR) value after a 6MWT ?

10. Was there any correlation between the level of perceived academic stress of healthy young adults and two-minute heart rate recovery (HRR) value after a 6MWT ?

11. Was there any correlation between the level of perceived academic stress of healthy young adults and five-minute heart rate recovery (HRR) value after a 6MWT ?

12. Would one-minute HRR after a 6MWT predict systolic blood pressure as a measure of autonomic function ?

13. Would one-minute HRR after a 6MWT predict diastolic blood pressure as a measure of autonomic function ?

14. Would one-minute HRR after a 6MWT predict resting heart rate as a measure of autonomic function ?

15. Would one-minute HRR after a 6MWT predict maximum heart rate as a measure of autonomic function ?

1.4 Aim of the Study

This study aimed to contribute to the knowledge and population gaps by characterizing typical HRR values within this demographic at a tertiary institution. It would also aim to characterize heart rate recovery in university undergraduate students and investigate its relationship with key lifestyle and stress-related factors.

1.5 Specific Objectives

The objectives of this study were.

1. To conduct a comprehensive assessment of the autonomic health among healthy young adults (undergraduate students) enrolled at a tertiary institution by meticulously measuring their heart rate recovery (HRR) at one, two, and five minutes following a 6MWT.

2. To examine the intricate relationships between this physiological marker and self-reported habitual physical activity levels, as well as their perceived levels of academic stress.

3. To precisely quantify and subsequently compare the mean heart rate recovery (HRR) values after a 6MWT, measured at the critical one-minute post-exercise time point, between the distinct groups of male and female healthy young adults participating in the study.

4. To precisely quantify and subsequently compare the mean heart rate recovery (HRR) values after a 6MWT, measured at the critical two- minute post-exercise time point, between the distinct groups of male and female healthy young adults participating in the study.

5. To precisely quantify and subsequently compare the mean heart rate recovery (HRR) values after a 6MWT, measured at the critical five- minute post-exercise time point, between the distinct groups of male and female healthy young adults participating in the study.

6. To rigorously investigate the nature and strength of the association between self-reported habitual physical activity levels, as comprehensively assessed by the validated International Physical Activity Questionnaire (IPAQ), and the magnitude of heart rate recovery (HRR) after a 6MWT measured at the critical one-minute post-exercise time point in healthy young adults.

7. To rigorously investigate the nature and strength of the association between self-reported habitual physical activity levels, as comprehensively assessed by the validated International Physical Activity Questionnaire (IPAQ), and the magnitude of heart rate recovery (HRR) after a 6MWT measured at the critical two-minute post-exercise time point in healthy young adults.

8. To rigorously investigate the nature and strength of the association between self-reported habitual physical activity levels, as comprehensively assessed by the validated International Physical Activity Questionnaire (IPAQ), and the magnitude of heart rate recovery (HRR) after a 6MWT measured at the critical five- minute post-exercise time point in healthy young adults.

9. To thoroughly investigate the potential relationship between the self-reported levels of perceived academic stress, as measured by the widely utilized Perceived

Stress Scale-10 (PSS-10), and the subsequent heart rate recovery (HRR) post 6MWT measured at the critical one-minute post-exercise time point exhibited by healthy young adults.

10. To thoroughly investigate the potential relationship between the self-reported levels of perceived academic stress, as measured by the widely utilized Perceived Stress Scale-10 (PSS-10), and the subsequent heart rate recovery (HRR) post 6MWT measured at the critical two- minute and five- minute post-exercise time point exhibited by healthy young adults.

11. To thoroughly investigate the potential relationship between the self-reported levels of perceived academic stress, as measured by the widely utilized Perceived Stress Scale-10 (PSS-10), and the subsequent heart rate recovery (HRR) post 6MWT measured at the critical five- minute post-exercise time point exhibited by healthy young adults.

12. To determine the relationship between one-minute heart rate recovery (HRR) value after a 6MWT and systolic blood pressure as a measure of autonomic function.

13. To determine the relationship between one-minute heart rate recovery (HRR) value after a 6MWT and diastolic blood pressure as a measure of autonomic function.

14. To determine the relationship between one-minute heart rate recovery (HRR) value after a 6MWT and resting heart rate as a measure of autonomic function.

15. To determine the relationship between one-minute heart rate recovery (HRR) value after a 6MWT and maximum heart rate as a measure of autonomic function.

1.6 Hypotheses

1.6.1 Main Hypothesis

There would be no significant difference in heart rate recovery (HRR)among healthy young adults and between males and females, and also no significant correlation between HRR after a 6MWT and other demographic factors.

1.6.2 Sub Hypothesis

1. There would be no significant difference between the mean HRR value at one-minute, two-minute, and five-minute after a 6MWT in healthy young adults.
2. There would be no significant difference in the mean one-minute heart rate recovery (HRR) value after a 6MWT between male and female healthy young adults.
3. There would be no significant difference in the mean two-minute heart rate recovery (HRR) value after a 6MWT between male and female healthy young adults.
4. There would be no significant difference in the mean five-minute heart rate recovery (HRR) value after a 6MWT between male and female healthy young adults.
5. There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of one-minute heart rate recovery (HRR) after a 6MWT in healthy young adults
6. There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of two-minute heart rate recovery (HRR) after a 6MWT in healthy young adults.
7. There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of five-minute heart rate recovery (HRR) after a 6MWT in healthy young adults
8. There would be no significant correlation between the self-reported levels of perceived academic stress and the one-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adult.

9. There would be no significant correlation between the self-reported levels of perceived academic stress and the two-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adults.

10. There would be no significant correlation between the self-reported levels of perceived academic stress and the five-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adults**.**

11. One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict systolic blood pressure as a measure of autonomic function.

12. One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict diastolic blood pressure as a measure of autonomic function**.**

13. One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict resting heart rate as a measure of autonomic function**.**

14. One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict maximum heart rate as a measure of autonomic function.

1.7 Significance / Justification of Study

The significance of the study includes.

Contribution to the field of physiotherapy: The findings of the study may contribute to the field of physiotherapy in particular and, by extension, the medical field. By providing evidence-based information on the autonomic health data for the specific population, identifying at-risk individuals, informing holistic treatment approaches that consider the autonomic nervous system, also supporting the development of preventive strategies and further justifying exercise prescription for improved physical and autonomic well-being.

Establish Foundational Knowledge: The study intended to generate crucial baseline data on HRR values within a university undergraduate population at a specific tertiary institution. This data would contribute to the limited existing normative information for this demographic and serve as a valuable reference point for future investigations and potential clinical applications.

Inform/Guided Targeted Health Promotion Activities: By clarifying the relationships between modifiable lifestyle factors, such as physical activity, and psycho-social factors, such as academic stress, with HRR, this study could provide evidence-based insights that can directly inform the development and implementation of targeted health promotion programs within university settings. These programs could be tailored to address specific factors influencing autonomic health in students.

Contribute to Scientific Literature: This study intended to add a valuable contribution to the existing body of scientific literature concerning autonomic function in health young adult populations, an area that has historically received less research compared to older adults and clinical populations. The findings may stimulate further research in diverse academic environments and with larger student samples.

Investigating the Potential for Preventive Screening Strategies: The study intended to contribute to the evaluation of HRR as a feasible and non-invasive screening tool for identifying undergraduate students who may exhibit early signs of autonomic dysregulation and could potentially benefit from early lifestyle counseling, stress management interventions, or further cardiovascular risk assessment.

Practical Application: The study may provide practical implications for university students, as it intends to help them understand better the need for cardiovascular fitness and motivate them to adopt healthier lifestyle habits.

1.8 Scope and Delimitation

The scope of the study would be delimited to undergraduate students at the School of Basic Medical Sciences. College of Medical Sciences, University of Benin, Edo State, aged 18-25 years. The study included male and female students who met the inclusion criteria (free of diagnosed cardiovascular or metabolic disorders, not on heart rate-altering medications) and provided informed consent. The study focuses on heart rate recovery, which was specifically defined as the difference between peak heart rate achieved during a standardized exercise protocol and the heart rate recorded at exactly one minute, two minutes, and five minutes after a 6MWT.

1.9 Limitations of the Study

Cross-sectional design

The study's cross-sectional nature limits the ability to infer causal relationships between HRR, physical activity, and perceived stress. Longitudinal follow-up will be required to determine changes in autonomic function over time.

Self-reported measures:

Physical activity and stress levels were assessed using self-reported questionnaires (IPAQ and PSS), which may be subject to recall bias or social desirability bias, potentially affecting data accuracy.

Single population sample:

The participants were all undergraduate students from a single university, which may limit the generalizability of the findings to other young adult populations or socio-demographic groups.

Controlled environment limitations:

The HRR measurements were taken under controlled conditions that may not perfectly reflect real-life recovery responses following different intensities or types of physical activity.

1.10 Definition of Terms

Heart Rate Recovery (HRR): For this study, HRR is operationally defined as the absolute difference, measured in beats per minute (bpm), between the peak heart rate achieved during the standardized exercise protocol (HR peak) and the heart rate recorded exactly at one minute, two minutes, and five minutes after 6MWT post-exercise recovery period.

Heart Rate Recovery (HRR) is a widely recognized non-invasive measure reflecting the body's ability to transition from the physiological stress of exercise back to a resting state. It quantifies the speed at which the heart rate decelerates in the post-exercise period (Okutucu et al., 2011; Omar et al., 2016). Typically, HRR is calculated as the difference between the maximum heart rate achieved during maximal or submaximal exercise (HR-peak) and the heart rate recorded at one or more specific time points during the recovery phase.

Autonomic Nervous System (ANS): It comprises sympathetic and parasympathetic nervous systems. The sympathetic nervous system (SNS) is often associated with the "fight-or-flight" response, preparing the body for action or stress. Activation of the SNS leads to an increase in heart rate and contractility, vasoconstriction in most blood vessels (except those supplying skeletal muscles), bronchodilation, increased sweating, and the release of adrenaline and noradrenaline. In contrast, the parasympathetic nervous system (PNS) is often referred to as the "rest and digest"

system, promoting energy conservation and relaxation. PNS activation leads to a decrease in heart rate, vasodilation, bronchoconstriction, increased digestive activity, and glandular secretion. The balance between sympathetic and parasympathetic activity, known as autonomic balance, is dynamic and constantly adjusted in response to internal and external stimuli. This balance is crucial for maintaining cardiovascular health, metabolic regulation, and overall physiological well-being (Thayer & Lane, 2000).

Physical Activity Level: The extent of habitual physical activity engaged in by the participants, as self-reported and quantified using the International Physical Activity Questionnaire (IPAQ). Activity levels will be categorized according to the IPAQ scoring protocol, typically into low, moderate, and high levels of activity based on the frequency, intensity, and duration of reported activities.

Perceived Academic Stress: Perceived academic stress refers to the subjective feeling of tension, strain, or worry experienced by students in relation to their academic demands, pressures, and expectations (Khan et al.,2013). It encompasses the cognitive appraisal of academic stressors (e.g., workload, exams, grades, competition) as exceeding one's coping resources. University undergraduate students often face a multitude of academic stressors that can significantly impact their physical and mental health (Aihie et al., 2019).

1.11 List of Abbreviations/Acronyms

6MWT: Six minute walk test

ANS: Autonomic nervous system

HRR: Heart rate recovery

HRR1: Heart rate recovery in one minute

HRR2: Heart rate recovery in two minutes

HRR5: Heart rate recovery in five minutes

SNS: Sympathetic nervous system

PNS: Parasympathetic nervous system

CHAPTER TWO

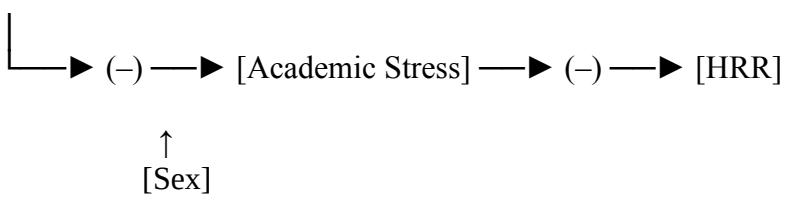
LITERATURE REVIEW

2.1 Conceptual Framework

The conceptual framework proposes that:

- **Independent Variables**:
  - Physical activity levels
  - Perceived academic stress
  - Sex
- **Dependent Variable**:
  - Heart Rate Recovery (HRR) at one, two, and five-minute post-exercise
  -

Diagrammatic Representation



This framework supports investigating HRR as an integrative biomarker influenced by both physiological (activity) and psychosocial (stress) variables, with implications for early identification of autonomic imbalance.

This framework supports investigating HRR as an integrative biomarker influenced by both physiological (activity) and psycho-social (stress) variables, with implications for early identification of autonomic imbalance. This framework provides the independent variables as physical activity level, perceived academic stress, sex, and the dependent variable as heart rate recovery at one, two, and five-minute post-exercise. This study is primarily grounded in the Neurovisceral Integration Model (NVIM) proposed by Thayer and Lane (2000, 2007). This model propounds that efficient regulation of the autonomic nervous system, particularly the influence of the vagal nerve (the primary component of the parasympathetic nervous system), is crucial for adaptive functioning across a range of physiological and psychological

domains. The NVIM emphasizes the bidirectional interaction between the brain (central nervous system) and the visceral organs (peripheral nervous system), with the prefrontal cortex playing a key role in modulating autonomic control via the vagal nerve. The model relevance to this study is on vagal tone as an index of regulatory capacity which proposes that higher resting vagal tone, often reflected in greater heart rate variability (HRV) and a faster heart rate recovery (HRR) after exercise, this indicates a greater capacity for flexible and adaptive physiological responses to internal and external demands, including stress (Thayer, J. F., & Lane, R. D. 2000). In the context of exercise, a higher baseline vagal tone is theorized to facilitate a more rapid reactivation of parasympathetic influence upon cessation of exertion, leading to a faster HRR (Ewah A.A.& Oyeyemi, A. L. 2015). The prefrontal cortex, involved in executive functions such as attention, working memory, and emotional regulation, exerts a top-down inhibitory influence on subcortical areas that control autonomic output. Efficient prefrontal cortical function is associated with greater vagal tone and more adaptive autonomic responses.

This study utilizes HRR as a peripheral marker of vagal influence and overall autonomic balance. Within the framework of the NVIM, we potentially explain that higher levels of self-reported physical activity in undergraduate students will be associated with a faster HRR, reflecting enhanced vagal tone and more efficient autonomic recovery. Higher levels of perceived academic stress will be associated with a slower HRR, indicating a relative dominance of sympathetic activity and a reduced capacity for vagal reactivation. Potential sex differences in HRR may be partly explained by variations in baseline vagal tone and autonomic regulation between males and females. By examining these relationships, this study aims to

contribute to our understanding of how lifestyle factors (physical activity) and psycho-social stressors (academic stress) prevalent in the undergraduate experience are associated with a key indicator of autonomic health, as conceptualized within the Neurovisceral Integration Model.

The framework highlights the potential of HRR to serve as an indicator of autonomic function, cardiovascular fitness, and also has an association with physical fitness among students in a tertiary institution. The other variables included in the framework provide additional context and potential explanations for the observed relationship. By adopting the conceptual framework, the study aims to investigate the validity of HRR as an index mark for autonomic function and examine the relationships between these variables and other factors that contribute to the autonomic function of undergraduate students in a tertiary institution.

2.2 Autonomic function

The autonomic nervous system (ANS) is the body's intricate and often silent conductor, organizing a vast symphony of involuntary physiological processes fundamental to maintaining homeostasis (McCorry, 2007). Operating beneath conscious control, the ANS regulates vital functions including heart rate, blood pressure, respiration, digestion, thermoregulation, and glandular secretions. It’s the unseen conductor of cardiovascular health. Understanding autonomic function, particularly its influence on the cardiovascular system, is paramount for this project exploring heart rate recovery (HRR) as an index of autonomic health in university undergraduate students.

The ANS comprises two primary branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). These branches often exert opposing effects on target organs, allowing for nuanced physiological adjustments. The ANS is classically partitioned into two primary branches: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). While these systems often innervate the same visceral organs, their effects are typically antagonistic, allowing for a finely tuned and dynamic control over physiological processes (Guyton & Hall, 2006). This intricate interplay, known as autonomic balance or sympathovagal balance, is not a static equilibrium but rather a constantly shifting state that reflects the body's adaptive responses to various stimuli, ranging from the demands of physical exertion to the psychological impact of stress (Thayer & Lane, 2000).The sympathetic nervous system is associated with the "fight-or-flight" response which prepares the body for stress or demands. Activation leads to increased heart rate and contractility, vasoconstriction (except in skeletal muscles), bronchodilation, increased sweating, and glucose release (Guyton & Hall, 2006). During exercise, the SNS elevates heart rate and blood pressure to meet metabolic demand.. These effects include a pronounced increase in heart rate and myocardial contractility, leading to enhanced cardiac output and blood flow to skeletal muscles (Berne & Levy, 2018). The parasympathetic nervous system is the orchestrator of the rest and recovery phase. The PNS, or "rest and digest" system, promotes energy conservation and relaxation. Its activation slows heart rate, causes vasodilation, bronchoconstriction, and increases digestive activity (Guyton & Hall, 2006). The PNS is primarily associated with anabolism, promoting energy conservation, tissue repair, and the maintenance of baseline physiological functions. Its principal neurotransmitter, acetylcholine, released from parasympathetic nerve endings, binds to muscarinic

receptors, mediating effects that generally oppose those of the SNS. Following exercise, the PNS, particularly via the vagus nerve, plays a crucial role in decelerating heart rate, which is measured as HRR (Romagnoli, F et al., 2017). In the context of recovery from physical exertion, the PNS, particularly through the rapid reactivation of vagal tone, is instrumental in decelerating heart rate and facilitating the return to a resting physiological state, a process quantified as heart rate recovery.

The continuous interplay between the SNS and PNS, termed autonomic balance or sympathovagal balance, is vital for cardiovascular health and overall well-being (Thayer & Lane, 2000). This balance dynamically shifts based on internal and external demands, favoring sympathetic dominance during exercise and stress, and parasympathetic dominance during rest. The autonomic balance is not a fixed point but rather a dynamic spectrum that reflects the body's capacity to adapt to ever-changing internal and external demands (Thayer & Sternberg, 2006).

The cardiovascular system is controlled by the ANS, ensuring that blood flow and pressure are appropriately regulated to meet the body’s ever-changing metabolic demands (Robertson et al., 2013). This regulation is archived through the opposing actions of sympathetic and parasympathetic branches on various aspects of cardiac and vascular function like heart rate and contractility where the PNS primarily via the vagus nerve releasing acetylcholine, acts to decrease heart rate and the force of atrial contraction, conversely the SNS increases the heart rate and both the atrial and ventricular contractility, leading to greater cardiac output. (Berne & Levy, 2018). Other cardiac and vascular functions include blood pressure, heart rate variability, and baroreceptor sensitivity (BRS).

Heart rate recovery (HRR) provides a non-invasive measure of autonomic regulation of the cardiovascular system (Borresen & Lambert, 2008). It reflects the efficiency of PNS reactivation and SNS withdrawal post-exercise (Arena et al., 2006). Faster HRR indicates a healthy autonomic balance with strong vagal influence (Okutucu et al., 2011). Conversely, blunted HRR suggests impaired autonomic function (Jouven et al., 2000). The magnitude and kinetics of the post-exercise heart rate decline are believed to be largely mediated by the rapid increase in vagal tone and the concurrent withdrawal of sympathetic drive (Borresen & Lambert, 2008)

There are other measures of autonomic function beyond HRR; these methods are employed to assess different aspects of autonomic function, which include Heart Rate Variability (HRV). As mentioned, HRV analyzes the fluctuations in heart rate intervals, providing insights into sympathovagal balance and overall autonomic tone (Michal Javorka et al., 2002). Blood Pressure Variability (BPV), is similar to HRV. BPV measures the fluctuations in blood pressure over time, reflecting autonomic control of vascular tone (Iranpour et al., 2020). Baroreceptor Sensitivity (BRS) assesses the responsiveness of the baroreflex, a crucial mechanism for short-term blood pressure regulation mediated by the ANS. Orthostatic Hypotension Testing, measuring blood pressure and heart rate changes upon standing, assesses the autonomic nervous system's ability to maintain blood pressure against gravity (Low, 2008). The tilt-table test is a more controlled version of this assessment. Valsalva Maneuver, analyzing heart rate and blood pressure responses during and after the Valsalva maneuver (forced expiration against a closed glottis), evaluates both sympathetic and parasympathetic reflexes. Sudomotor Function Tests: These assess sympathetic cholinergic function by measuring sweat output in response to stimuli

(e.g., Quantitative Sudomotor Axon Reflex Test - QSART, Thermoregulatory Sweat Test - TST) (Low, 2008). Pupillometry, which measures pupil size and reactivity to light and other stimuli, can provide information about both sympathetic and parasympathetic innervation of the iris (Low,2008).

2.2.1 Factors influencing Autonomic function

Lifestyle Factors: Chronic stress can lead to prolonged activation of the sympathetic nervous system (fight-or-flight response), increasing heart rate, blood pressure, and releasing stress hormones like cortisol and catecholamines. This sustained activation can be unhealthy to the body over time (Kim et al., 2018). Regular exercise is known to calm an overactive sympathetic nervous system and can improve cardiac autonomic function (Kim et al., 2018). High physical activity and frequent sport activities are associated with lower heart rates and improved parasympathetic activity (Bellardita et al., 2021). Sedentary lifestyles, especially prolonged sitting with poor posture, can negatively effect heart rate variability and sympathetic tone (Bellardita et al., 2021).Dietary factors also play a role as deficiencies, particularly in vitamin B12, can damage the autonomic nervous system (Ali et al., 2018). Caloric restriction can decrease sympathetic nervous system activity, while carbohydrate intake can increase it (Kennedy & Symonds, 2018). Caffeine and other stimulants can significantly stimulate the nervous system (Kennedy & Symonds, 2018). Chronic and excessive alcohol consumption can have toxic effects on autonomic nerves (Ali et al., 2018). Poor sleep-wake cycle can contribute to an overactive sympathetic nervous system (Kim et al., 2018), and excessive smoking is associated with higher heart rates (Bellardita et al., 2021).

Medical Conditions and Diseases: Many diseases can impair autonomic function, leading to a range of symptoms. Poor management of type 2 diabetes can cause diabetic autonomic neuropathy, damaging nerves that control various organs, leading to issues like orthostatic hypotension (blood pressure drops upon standing), intestinal dysmotility, and erectile dysfunction (Kim et al., 2018). Neurodegenerative disorders such as Parkinson's disease, Multiple System Atrophy (MSA), and Lewy Body Dementia can also cause orthostatic hypotension and other signs of ANS damage (Bellardita et al., 2021). Multiple Sclerosis (MS) can also affect autonomic function (Bellardita et al., 2021). Autoimmune and inflammatory conditions like Guillain-Barré Syndrome, Amyloidosis, and Lupus can lead to autonomic dysfunction (Ali et al., 2018). Certain types of dysautonomia involve the immune system attacking parts of the body (Bellardita et al., 2021). Infections by viruses (e.g., HIV, COVID-19) and bacteria (e.g., Lyme disease, Chagas disease, botulism, tetanus) can cause nerve damage that affects the ANS (Kennedy et al., 2018). Spinal cord disorders and trauma, as well as cancer and tumors, can disrupt autonomic connections (Ali et al., 2018). Congenital and genetic conditions such as Hirschsprung's disease and familial dysautonomia are also relevant (Bellardita et al., 2021). Exposure to toxins, such as heavy metals (mercury or lead) or industrial chemicals, can damage autonomic nerves (Ali et al., 2018). Orthostatic Hypotension (OH) and Postural Orthostatic Tachycardia Syndrome (POTS) are conditions characterized by autonomic dysfunction (Bellardita et al., 2021).

Medications: Various medications can affect autonomic function by influencing neurotransmitters or receptors. Anticholinergics inhibit the actions of acetylcholine in the parasympathetic nervous system, leading to effects such as dry mouth, dilated

pupils, increased heart rate, and decreased gastrointestinal motility (e.g., atropine, scopolamine, oxybutynin) (Kennedy & Symonds, 2018). Sympathomimetics mimic or modify the effects of the sympathetic nervous system, increasing sympathetic tone (e.g., phenylephrine, amphetamine) (Kennedy & Symonds, 2018). Sympatholytic block or decrease sympathetic signals, increasing parasympathetic tone (e.g., beta-blockers like propranolol) (Kennedy & Symonds, 2018). Parasympathomimetic or Muscarinic Agonists mimic or enhance the effects of the parasympathetic nervous system, increasing parasympathetic tone (e.g., pilocarpine, carbachol) (Kennedy & Symonds, 2018). Cholinesterase Inhibitors increase acetylcholine levels by inhibiting its breakdown (e.g., neostigmine, pyridostigmine) (Kennedy & Symonds, 2018).

Environmental Factors: Horrendous temperatures can place demands on the ANS to regulate body temperature, with avoiding hot environments advised for those with reduced sweating (Bellardita et al., 2021). Chronic noise exposure can lead to increased blood pressure and heart rate, affecting autonomic balance (Kim et al., 2018). Air pollutants can stimulate sensory nerves within the cardiopulmonary system, leading to autonomic dysfunction (Ali et al., 2018). Distressed levels of light can disrupt circadian rhythms and affect hormonal secretions, indirectly influencing autonomic function (Bellardita et al., 2021). The body adapts to seasonal changes in climatic conditions, which can influence the balance of sympathetic and parasympathetic nervous systems (Kim et al., 2018). Physical injuries, especially to the spinal cord, can cause long-term or permanent nerve damage affecting autonomic connections (Ali et al., 2018).

2.2.2 Intervention to improve autonomic health

Physical Activity and Exercise: Regular engagement in physical activity, particularly aerobic exercise, is a highly effective intervention for enhancing autonomic health, characterized by increased vagal tone and faster heart rate recovery (HRR) (Iranpour et al., 2020; Billman, 2009). Even resistance training can contribute to improved autonomic balance (Michael et al., 2017).

Stress Management Techniques: Interventions aimed at reducing chronic stress are crucial for optimizing autonomic balance. These include mindfulness and meditation practices, which increase parasympathetic activity and reduce sympathetic arousal (Chiesa & Serretti, 2010; Tang et al., 2009), and Pranayama, which uses a deep breathing exercise pattern to directly stimulate the vagus nerve and promote parasympathetic dominance (Dhanvijay & Chandan, 2018; Bhimani et al., 2011). Yoga and Tai Chi, which combine physical postures with mindfulness, also improve autonomic regulation (Curtis & O'Keefe, 2002; Telles et al., 2013).

Lifestyle Modification: Adequate and good quality sleep is fundamental for restoring autonomic balance. Sleep deprivation is linked to increased sympathetic activity, while establishing regular sleep schedules and optimizing the sleep environment can support parasympathetic restoration (Fan et al., 2020; Tobaldini et al., 2013).

Nutritional Interventions: While research is ongoing, certain dietary elements are hypothesized to support autonomic health. Omega-3 fatty acids, found in fatty fish, may positively influence heart rate variability (HRV) and autonomic balance (Mozaffarian et al., 2008), while a balanced diet generally aids overall physiological regulation (Mayo, 2024).

Monitoring and Feedback: Wearable sensors and machine learning algorithms can be used to monitor HRV and detect early signs of stress, enabling timely interventions (Razavi et al., 2023).

2.2.3 Perception of students towards autonomic Health

Student perception of autonomic health is a developing area of research, with growing recognition of the significant interplay between stress, lifestyle, and the functioning of the autonomic nervous system (ANS), according to published journals of Medical Education and Curricular Development students. The students' attitude towards autonomic health can be influenced by a range of factors, including their self-efficacy beliefs and their perception of the benefit of healthy living (Lazauskaite-Zabielske et al., 2018). A study by Dabbagh et al. 2024 found that awareness of stress and its physiological impact on students frequently report experiencing chronic stress due to academic pressures, financial concerns, social pressures, and adjustment to university life. This stress is often perceived as a significant challenge. Students increasingly recognize that stress is not merely a mental state but manifests physically through symptoms such as increased heart rate, fatigue, digestive issues, and susceptibility to illness, all indicative of an activated sympathetic nervous system response (Dabbagh and Dabbagh, 2024). However, their understanding of the underlying mechanisms of the ANS, including the balance between sympathetic and parasympathetic activity, is generally limited unless they are pursuing health-related disciplines (Reyes-Ruiz et al., 2021). Educational strategies, such as active learning approaches, are being developed to improve this understanding (Reyes-Ruiz et al., 2021).

The Impact of lifestyle on well-being, including the autonomic health of

Students are becoming more aware that their lifestyle choices significantly impact their overall health and ability to cope with stress (Dabbagh and Dabbagh, 2024). The link between diet and autonomic health is less widely understood by students, though general healthy eating habits are often promoted for overall well-being. Another study found that there is a growing awareness of the negative impact of substances like nicotine, alcohol, and drugs on mental and physical health, including their detrimental effects on ANS balance, such as nicotine increasing sympathetic activity (Brody G.H. et al., 2024). According to the Journal of Physical Therapy Science, students are increasingly seeking and recognizing the value of stress-management techniques such as breathing exercises, positive social interaction, laughter, and seeking professional help (Lee J.Y. et al., 2017). Unless students are in medical or health-related programmes, formal education on the autonomic nervous system is often minimal, leading to a conceptual gap between experiencing symptoms and understanding their physiological basis (Reyes-Ruiz et al., 2021). This lack of understanding can lead to misinterpretations of autonomic symptoms, potentially delaying appropriate care for underlying dysautonomia (Reyes-Ruiz et al., 2021). According to the Journal of Medical Education and Curricular Development, there is a clear need for more comprehensive education that connects lifestyle choices, stress, and the functioning of the ANS, empowering students to proactively manage their health (Reyes-Ruiz et al., 2021).

Studies on nursing students have shown that higher-grade students, who are likely to face greater stressors, may exhibit abnormal functioning of the autonomic nervous

system, with lower parasympathetic activity and higher sympathetic activity, suggesting a physiological response to academic stress (Choi and Lee, 2017). Research on perceived discrimination indicates that it can influence ANS coordination, highlighting the impact of psycho-social stressors on physiological regulation (Brody et al., 2014). Educational games have also shown promise in improving students' understanding of complex physiological concepts like the ANS (Reyes-Ruiz et al., 2021).

2.3 Heart Rate Recovery

Heart rate recovery refers to the rate at which the heart rate decreases in the first few minutes after exercise cessation (Darr et al., 2016). It's an important indicator of autonomic function and cardiovascular fitness and is a strong predictor of mortality and morbidity (Jouven et al., 2000). Heart rate recovery is typically measured during the first minute following the cessation of exercise, and the rate of decline in heart rate during this period is considered an important indicator of cardiovascular fitness. HRR is influenced by a number of factors, including age, sex, fitness level, and the intensity and duration of exercise. Research has shown that a slower HRR is associated with an increased risk of cardiovascular disease and morbidity. For example, a study conducted by Michal Javorka et al. (2002) indicates that heart rate recovery after exercise, assessed through HRV and complexity measures, reflects autonomic health. Positive correlations between early post-exercise HRV indices and cardio deceleration suggest parasympathetic reactivation, relevant for evaluating cardiovascular fitness in undergraduate students. These findings underscore the clinical significance of HRR as a readily obtainable indicator of autonomic function and cardiovascular risk.

While the long-term prognostic implications of HRR in young, healthy populations are less established, these findings in adults highlight the importance of understanding factors that influence HRR in younger individuals, as potential early indicators of autonomic dysregulation.

Another study conducted by Cole et al. found that individuals with a slower HRR had a higher risk of all-cause mortality, even after controlling for other risk factors such as age, sex, and fitness level (Jouven et al., 2000). Similarly, a study by Oyeyemi et al. indicates that heart rate recovery (HRR) is a significant predictor of cardiovascular fitness among undergraduate students, with physically active individuals demonstrating better HRR compared to inactive counterparts, suggesting enhanced autonomic health and parasympathetic activity in active students. In a study by Lampson, M. Fan et al. found that heart rate recovery (HRR) at 3 minutes post-exercise is a significant indicator of autonomic health in undergraduate medical science students, correlating positively with cardiorespiratory fitness (VO2max) and negatively with unhealthy lifestyle behaviors. Similarly, Kim et al. (2022) reported a correlation between a higher physical efficiency index (PEI) from the Harvard step test and improved autonomic nerve function, as reflected in heart rate variability during recovery, in college students. Fan et al. (2020) found that better cardiorespiratory fitness (VO2max) was positively correlated with faster HRR in medical science students. These studies collectively suggest that higher levels of physical activity are associated with a more efficient autonomic recovery following exercise in young adults.

2.3.1 Heart rate recovery and perceived stress

Heart rate recovery and the effectiveness of stress have also been investigated. Chronic stress is generally hypothesized to impair autonomic balance, potentially

leading to a blunted HRR due to sustained sympathetic activation and reduced vagal tone. Sloan et al. (2017), in a study on college-aged individuals, found an inverse correlation between perceived stress levels and HRR, suggesting that higher stress was associated with slower recovery. Wimmer et al. (2019) examined cardiac recovery after a stressful presentation in university students and found that different dimensions of self-concept were associated with HRR, indicating a link between psychological factors and autonomic responses to stress. While Hammoud et al. (2018) focused on heart rate variability during examination stress in Lebanese students,

their findings of reduced HRV during stress suggest a potential parallel impact on HRR, reflecting a shift towards sympathetic dominance. Studies on stress-reduction techniques like pranayama have shown improvements in HRV (Dhanvijay & Chandan, 2018; Bhimani et al., 2011), implying a potential indirect positive effect on HRR by modulating autonomic balance.

2.3.2 Heart Rate Recovery and Sex Differences

Some studies have explored potential sex differences in HRR, although the findings are not always consistent. Some research suggests that females may exhibit a slightly faster HRR compared to males, potentially due to differences in baseline autonomic tone and hormonal influences (Dorado-García et al., 2017). However, other studies have reported no significant sex differences in HRR in young adult populations (e.g., Oyeyemi et al., 2015). Further research is needed to clarify the role of sex in influencing HRR in undergraduate students.

In addition to its prognostic value, HRR has also been used as a tool for assessing status and cardiovascular fitness. A study by Buchheit et al. Found that HRR was a

better predictor of maximal oxygen uptake than other commonly used fitness measures such as resting heart rate and HRV (Buchheit et al., 2008). Younger individuals and those with a higher fitness level typically have a faster HRR than older individuals and those with a lower fitness level. Similarly, a study shows that higher intensity exercise is associated with a slower HRR than lower intensity exercise (Gibbons et al., 2017).

2.3.3 Factors influencing heart rate recovery

Physical Activity Levels: Physical activity is a significant determinant of HRR. Physically active students exhibit faster HRR compared to their sedentary counterparts. This is attributed to enhanced parasympathetic activity and improved cardiovascular adaptations in active individuals (Oyeyemi et al., 2015; Kim et al., 2022).

Regular exercise, such as aqua aerobic training, has been shown to improve HRR and overall autonomic function. For example, college male students who participated in regular aqua aerobic exercise demonstrated significant improvements in heart rate variability (HRV) parameters, including root mean square of successive differences (RMSSD) and high-frequency (HF) power, indicating enhanced parasympathetic activity (Iranpour et al., 2020).

Stress and Academic Pressure: Academic stress, particularly during examinations, significantly impacts HRR and HRV. Studies have found that HRV, which is closely related to HRR, decreases during periods of high stress, such as university examinations. This reduction in HRV is associated with increased sympathetic activity and decreased parasympathetic activity (Melillo et al., 2011) (Hammoud et al., 2018).

Interventions such as yoga and pranayama have been shown to mitigate the effects of stress on autonomic function. Regular practice of Nadi Shuddhi Pranayama, for instance, reduces perceived stress levels and improves HRV parameters, including HF power and the LF/HF ratio, indicating a shift toward parasympathetic dominance (Dhanvijay & Chandan, 2018) (Bhimani et al., 2011).

Lifestyle Factors: Lifestyle factors, such as alcohol consumption, smoking, and sleep patterns, also influence HRR and autonomic function. Studies have found that high levels of alcohol consumption and lack of exercise are associated with lower basal HRV, a marker of poorer autonomic health (Udo et al., 2013). In addition, body mass index (BMI) and cardiorespiratory fitness, as measured by VO2max, are inversely associated with HRR. Students with higher BMI and lower VO2max tend to have slower HRR, indicating poorer autonomic function (Fan et al., 2020; Kirby et al., 2010).

Psychological Factors: Psychological traits, such as neuroticism, can also influence autonomic responses to stress. University student-athletes with high neuroticism exhibit blunted HRV responses to mental stress, suggesting that personality traits may play a role in autonomic regulation (Doğan, 2023).

Age: Age is another important factor that influences HRR. As people age, their cardiovascular system becomes less efficient, and their HRR tends to be slower. This is because the heart is less able to recover quickly from the demands of exercise (Pal et al., 2014).

Exercise intensity: The intensity of the exercise is another important factor that can influence HRR. The harder the exercise, the longer it will take for the heart rate to recover. This is because the heart must work to pump blood to the muscles during high-intensity exercise (Gibbons et al., 2017)

Exercise duration: The duration of the exercise is another factor that can influence HRR. The longer the exercise, the longer it will take for the heart rate to recover. This is because the heart has to work harder for a longer period of time, which can cause it to take longer to recover (Gaber et al., 2011)

Medications: Certain medications can also influence HRR. For example, beta blockers can slow down the heart rate and make it take longer to recover after exercise (Frishman,2004)

Health conditions: Certain health conditions can also influence HRR. For example, people with heart disease or diabetes may have slower HRR due to damage to their cardiovascular system.

Environmental factors: Environmental factors such as temperature and humidity can also influence HRR. In hot and humid conditions, the heart must work harder to pump blood to the skin for cooling, which can slow down heart rate recovery (Casa et al., 2000)

Genetics: Genetics can also play a role in determining HRR. Some people may be predisposed to having faster or slower heart rate recovery based on their genes (Bouchard et al.,2012)

Body composition: Body composition, specifically the ratio of muscle mass to body fat, can also influence HRR. People with more muscle mass tend to have faster HRR because their muscles require more oxygen during exercise, which increases blood flow and promotes quicker recovery (Wagner et al., 2012)

Gender: Gender is increasingly recognized as a significant factor influencing HRR, although the precise mechanism and consistent findings are still under investigation. Several physiological differences between males and females may contribute to variations in how the ANS regulates heart rate following exercise. Some evidence suggests that females may have a higher resting heart rate but also potentially greater parasympathetic activity at rest (Koenig & Thayer, 2018). This theory's paradoxical finding could influence how heart rate recovers after exercise.

Resting Heart rate: Resting Heart rate, or the heart rate at rest, can also influence HRR. People with lower resting heart rates tend to have faster HRR because their heart has more room to slow down after exercise.

Emotional State: Emotional state can also influence HRR. For example, stress and anxiety can cause the heart rate to remain elevated for longer periods of time after the exercise, which can slow down HRR (Sheps and Sheffield, 2001)

2.3.4 Limitations of Heart Rate Recovery

Heart Rate Recovery (HRR) is widely used to assess autonomic status. It remains a valuable, simple, and non-invasive tool in clinical practice and research due to its prognostic power for cardiovascular health and mortality. However, its limitations stem from its multifactorial determinants, the inability to precisely differentiate between sympathetic and parasympathetic contributions, measurement variability, and the distinction between correlation and causation. Hence, it sets limits to health care providers (D'Souza et al., 2017; Hoffman, 2023)

2.4 Empirical review

Heart rate recovery is an important marker for autonomic function, which is a crucial component of overall health and well-being. A study was conducted on 17 healthy, untrained male volunteers with an average age of 20.3 years. The study experimental protocol consisted of two days using a step test to determine the maximum power outcome, and it was found that after exercise, heart rate decreases rapidly in the first 1minand then continues to decline more slowly. HRV, which reflects the autonomic nervous system's control over the heart, showed a gradual increase during the recovery phase. It also reveals that the rate of the heart rate decreases during the first minute of recovery was not correlated with HRV parameters measured before or during exercise. This indicates that the body takes time to fully recover from the stress of exercise, and the findings highlight the importance of monitoring heart rate recovery and HRV as indications of cardiovascular fitness and autonomic function (Michal Javorka et al., 2002)

A study conducted in Nigeria found that RPP was not a valid predictor of physical fitness among male university students. The study used a step test and heart rate

recovery as measures of physical fitness and found a significant correlation between RPP and physical fitness ($r=0.65$, $p< 0.05$) (Okonkwo et al., 2015).

A study conducted in India among athletes found that heart rate recovery is directly proportional to cardio-respiratory fitness of the athlete. That is, if the heart rate recovery of the individual is faster or quicker, the individual will be fitter as measured by VO_2max. The study used a wearable heart rate monitor in sports. Additionally, from their experimental approach, the utility of HRV to estimate oxygen uptake of a large population of athletes was validated (Balakarthikeyan et al., 2023).

Another study was conducted in Nigeria, Maiduguri, among 105 healthy males aged 18 to 15 from the university. The study identified an inverse relationship between RPP and both Heart rate recovery one minute after exercise, which means that higher resting RPP is associated with slower recovery of heart rate after physical activity, indicating poorer cardiovascular fitness (Oyeyemi et al., 2022).

A study conducted at the University of Surrey, UK, among 124 first-year medical science students with the inclusion criteria of age of 18-35 and without a documented medical condition. The test conducted involved a 6-minute exercise bout on a cycle ergometer, where the participants' heart rate recovery was measured 3 minutes after the cessation of exercise and VO_2max as also calculated from the exercise data. The study reveals a strong correlation between the amount of exercise performed and both VO2max and HR. The findings of the study highlight that unhealthy lifestyle choices affects the cardiopulmonary fitness and HRR of young medical students highlight search also identified that 3-minute HRR after exercise could serve as a valuable indicator of cardiopulmonary function (Lampson et al., 2020).

2.5 Empirical Review of Literature

AUTHOR/YEAR/COUNTRY	TITLE	AIM OF THE STUDY	STUDY TYPE	OUTCOME MEASURES	FINDINGS
Balakarthikeyan et al., 2023, Spain.	Heart rate variability-based estimation of maximal oxygen uptake in athletes using supervised regression models	865 athletes	Correlation study (implied)	The result of the study established the fact that the recovery rate is directly proportional to cardio-pulmonary fitness of the athlete.	The conclusion of the study established the fact that the recovery rate is directly proportional to cardio-pulmonary fitness of the athlete. That is if the recovery rate is faster, the athlete would be fitter as measured by VO2max.
Ejike et al., 2018, Nigeria	Predictors of autonomic dysfunction among predialysis chronic kidney disease patients in a tertiary hospital, Southeast Nigeria	80 (4O CKD patients, 40 controls)	Case-Control study	High prevalence (51.3%) of autonomic dysfunction in CKD patients. Heart rate response to standing was the most sensitive test.	Autonomic dysfunction is common in Nigerian CKD patients, contributing to poor outcomes. Objective autonomic function tests are important.
Lampson et al., 2020, United Kingdom	Impact of an unhealthy lifestyle on cardiorespiratory fitness and heart rate recovery of medical science students.	614 first year medical students(124 completed both test)	Observational study	The result shows that those that exercised less than 3 hours per week had significantly lower VO2max (a measure of cardiorespiratory fitness) and slower	The study found that unhealthy lifestyle choices significantly affects the cardiorespiratory fitness and HRR of young medical scinece students.

				HRR after exercise compared to their peers who exercised more.	
Michal javorka et al., 2002, Brasil	Heart rate recovery after exercise: relation to heart rate variability and complexity	17 healthy male subjects	Observational study	The study found that the rate of heart rate decrease during the first minute of recovery was not correlated with HRV parameters measured during the standing and resting phases.	It emphasizes the complex interplay between heart rate recovery, HRV, and the body's autonomic responses to exercise.
Oyeyemi et al., 2022, Nigeria	Relation between derived cardiovascular indices, body surface area, and blood pressure/heart rate recovery among active and inactive Nigerian students	105 apparently healthy male subjects.	Comparative/Correlational study	The results show a significant negative relationship between RPP and HRR, and 1% recovery after exercise; also, RPP was significantly higher in physically active subjects than in inactive subjects.	The study concluded that RPP is the strongest negative predictor of recovery HR and blood pressure, while MAP is the strongest positive predictor. This highlights the importance of cardiovascular fitness and recovery after exercise.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Materials

3.1.1 Population

Healthy young adults comprising university undergraduate students of both male and female genders from the University of Benin, School of Basic Medical Sciences, College of Medical Sciences, who met the inclusion criteria, participated in a short exercise protocol(6MWT), in this study. Undergraduate students were randomly selected from the six departments. These departments include Physiotherapy, Radiography, Medical Laboratory Science, Anatomy, Physiology, and Medical Biochemistry.

3.1.2 Selection Criteria

3.1.2.1 Inclusion Criteria

I. Undergraduate students aged 18-25 years.
II. Students without a known history of cardiovascular, metabolic, or neurological disorders.
III. Willing and able to provide informed consent.
IV. Participants not on medications affecting heart rate or autonomic function, e.g., beta blockers
V. Participants who understand and communicate effectively in English or Pidgin English.

3.1.2.2 Exclusion Criteria

This study excluded.

i. Students with acute illnesses or fever at the time of the study.

ii. Participants who were unable to perform mild to moderate physical activity.

3.1.3 Instruments

i. International Physical Activity Questionnaire (IPAQ)

ii. Digital Sphygmomanometer

iii. Digital Stopwatch

iv. Digital Treadmill

v. Perceived Stress Scale (PSS-10)

vi. Pulse Oximeter

vii. Six-Minute Walk Test (6MWT)

3.1.4 Description of instruments

i. **International Physical Activity Questionnaire (IPAQ):** The International Physical Activity Questionnaire began in Geneva in 1998. It was initiated by an international group of experts in physical activity measurement. It is used to assess and quantify levels of physical activity in a population by measuring the amount and type of physical activity a person has engaged in over a specific time. The IPAQ has been tested for reliability and validity, Showing Reliability coefficients (intra-class correlation, ICC) ranging from 0.70 to 0.88, depending on activity type and population. The short version of the IPAQ showed repeatability with reliability coefficients typically above 0.75" (Craig et al., 2003). In African contexts, studies report ICCs from 0.72 to 0.84, showing good stability over time (Oyeyemi et al., 2014). IPAQ scores correlate significantly with expected variables (e.g., BMI, age, fitness levels). Higher IPAQ scores are associated with lower BMI and better self-reported health status. IPAQ scores

show expected associations with health variables, supporting construct validity" (Booth et al., 2003).

ii. **Digital Sphygmomanometer:** A device used to measure blood pressure without the use of a stethoscope or manual inflation/deflation. It provides a numerical display of systolic and diastolic blood pressure along with pulse rate on a digital display. Blood pressure is expressed in millimeters of mercury (mmHg), and pulse rate or heart rate is measured in beats per minute (bpm). An Omron blood pressure monitor was used for this study, and it is made by OMRON Healthcare Co., Ltd. It has been tested and has high test–retest reliability when properly calibrated. The intra-class correlation coefficient usually ranges from 0.85–0.95. With proper technique, the sphygmomanometer demonstrates excellent reliability in BP monitoring" (Alpert, 2020). Validity depends on calibration and the correct cuff size. Digital devices are typically compared to mercury standards. Validated devices provide BP measurements closely aligned with intro-arterial monitoring" (Stergiou et al., 2018).

iii. **Digital Stopwatch**: This is an electronic device that's designed to display and precisely measure elapsed time. For this study, an Apple smartwatch was used to monitor the timing of the exercise duration and recovery monitoring (one, two- and five minutes post-exercise. Digital watches like the Apple Smartwatch are highly reliable for timing with minimal variability(±0.1sec). Reliability depends on user accuracy (manual start/stop). Smartwatches show good reliability in measuring time and HR but require synchronization for consistency (Nelson et al., 2020). Apple Watch is valid for timing measurements in structured fitness testing (Dooley et al., 2017).

iv. **Digital Treadmill**: This is a motorized exercise machine designed for indoor walking, jogging, and running, characterized by electric controls and a digital display. It shows advanced metrics and historical data tracking to monitor progress over time. For this study, an American Fitness Model treadmill was used for the 6 Minute Walk Test (6MWT). The digital treadmill was tested for reliability and validity, showing high intra-class correlation coefficients (ICCs) > 0.90 for VO_2 max, speed, and time to exhaustion. Treadmill exercise testing has high test–retest reliability and reproducibility in controlled settings (Bassett & Howley, 2000). Its construct validity is validated by research that confirms the Treadmill is considered a gold standard for VO_2 max and sub-maximal cardiovascular testing (ACSM, 2018).

v. **Perceived Stress Scale (PSS-10):** The Perceived Stress Scale (PSS-10) is a popular psychological tool established in 1983 by Sheldon Cohen, Tom Kamarck, and Robin Mermelstein to assess stress perception. To measure the global perception of stress in an individual's life. It's a self-reported questionnaire that focuses on how individuals feel about the situations in their lives as stressful, particularly in recent months. The PSS-10 has been tested for reliability and validity, showing high internal consistency with Cronbach's alpha values for the PSS-10 ranging from 0.78 to 0.91, indicating reliability across various cultural and demographic groups (Lee, 2019). Its construct validity is validated by research that confirms a two-factor structure: perceived helplessness and perceived self-efficacy (Taylor, 2021). It also demonstrates convergent

validity by having strong correlations with anxiety and depression measures such as the GAD-7 and the PHQ-9 (Lee, 2019).

vi. **Pulse oximeter monitor**: A pulse oximeter is a device used to quickly and non-invasively measure a person's blood oxygen saturation level (SpO_2) and heart rate. The A&D Fingertip Pulse Oximeter was used for this study to aid continuous monitoring of heart rate while performing 6MWT. Pulse oximeters have high test-retest reliability, often reporting intra-device reliability coefficients above 0.95 under stable conditions. Its generally valid however, accuracy can be affected by movement, poor perfusion, and skin pigmentation (Shah et al., 2023)

vii. **Six-Minute Walk Test (6MWT):** The 6MWT is a highly reliable and valid measure of functional exercise capacity across numerous populations, including healthy individuals and patients with cardiorespiratory and neurological conditions. For this study, the 6MWT was performed on the Treadmill. 6MWT demonstrates excellent test-retest reliability, meaning that a person's score is highly consistent upon repeated testing, provided their clinical status hasn't changed. It shows an Intraclass Correlation Coefficient (ICC), with reported values in the range of 0.91 to 0.96 (Eiser et al., 2005; MDPI, 2022). For healthy children and adolescents. It is a valid measure, primarily supported by its strong concurrent validity, and it shows a moderate to strong correlation with established, criterion-standard measures of cardiorespiratory fitness, such as Peak Oxygen Uptake (VO^2Max), with Correlation coefficients typically ranging from 0.44 to 0.78 (Eiser et al., 2005). Other Functional tests: It exhibits an excellent correlation of 0.84 to 0.94 with walking speed tests (Wevers et al., 2011).

3.2 Methods

3.2.1 Research Design

This study utilized a cross-sectional observational study design.

3.2.2 Sampling Technique

Participants were selected using a stratified random sampling technique to ensure proper representation across the departments of the School of Basic Medical Sciences, College of Medical Sciences, University of Benin.

3.2.3 Sample Size

The sample size was calculated using a two-step method which includes a Cochran formula as if the population were infinite and finally the use of Finite population correction which adjusted the population size using a known population of 3412 undergraduate students across the six departments in School of Basic Medical Sciences, College of Medical Sciences, University of Benin.

The Cochran fomula;

$$n0 = \frac{Z^2 . p.(1-p)}{e^2}$$

Confidence Level of 95% {Z-score} = (1.96)
Margin of Error (e) 5% = (0.05)
Population Proportion (p) 50% = (0.50)

Substituting:

$$n_o = \frac{(1.96)^2 . 0.50 . (1-0.50)}{0.05^2}$$

$$n_o = \frac{3.8416 . 0.25}{}$$

$$0.05^2$$

$n_o = 384.16$

Now adjusting the population size using Finite population correction

$$n = \frac{n_o}{1 + \frac{n_o - 1}{N}}$$

Subtistuting;

n = Final sample size

n_o = Sample size using cochran fornula

N = The total number known (3412)

$$n = \frac{384.16}{1 + \frac{384.16 - 1}{3412}}$$

$$n = \frac{384.16}{1 + 383.16 / 3412}$$

$$n = \frac{384.16}{1 + 0.11229}$$

n = 345.39

3.2.4 Ethical Consideration

Ethical approval for this study was obtained from the Ethics and Research Committee of the University of Benin, Benin City. A formal letter of introduction was also submitted to the appropriate university authorities.

Written informed consent was obtained from all participants. Participants were assured of confidentiality, and all data was anonymized and securely stored. Participation was voluntary, with the right to withdraw at any time without consequence.

3.2.5 Procedure for Data Collection

Participants were recruited randomly from the six departments under the School of Basic Medical Sciences and approached during free lecture periods or campus events. After explaining the purpose and procedures of the study, informed consent was then obtained. Baseline data, including age, gender, resting blood pressure, and heart rate, were collected. A time is assigned to each randomly recruited participant to come to the physiotherapy lab for the study.

The participant would then perform a 6MWT on a treadmill. Heart rate was recorded:

At baseline (before exercise)

Immediately post-exercise

At 1-, 2-, and 5-minutes post-exercise respectively

Heart Rate Recovery (HRR) was calculated as:

HRR1 = HR_post – HR_1min

HRR2 = HR_post – HR_2min

HRR5 = HR_post – HR_5min

3.2.6 Data Analysis

Data was summarised using descriptive statistics such as mean and standard deviation to summarize the data. The Inferential statistics of repeated-measure ANOVA and Pearson's correlation were used to test the hypotheses. Repeated measure ANOVA was used to compare the difference in HRR at different time points, followed by post

hoc tests if there was a significant difference. Pearson's correlation was used to analyze the relationships between HRR, physical activity level, and perceived academic stress scores. Linear regression was used to analyze whether HRR will predict autonomic function. All analyses were conducted using IBM Statistical Package for Social Sciences (SPSS) version 27. The level of statistical significance will be set at $p < 0.05$

CHAPTER FOUR

RESULTS

4.1 Preamble

The primary objective of this study was to characterize the heart rate recovery values among undergraduate students at the University of Benin and explore their relationship with key lifestyle and stress-related factors. A total of 346 male and female undergraduate students were recruited for this study.

4.1.1 Sociodemographic characteristics of the participants

The participants were aged 18 – 25 years with a mean age of 21.09 ± 1.87 years. Of the total respondents, 167 (48.3%) were male. 59 (17.1%) if the participants were recruited from the department of physiotherapy. This is presented in 4.1.

Table 4.1: Sociodemographic characteristics of the participants

	Range	**Mean ± SD**
Age	18 – 25	21.09 ± 1.87
	Frequency	**Percentage**
Gender		
Male	167	48.3
Female	179	51.7
Department		
Anatomy	71	20.5
Medical Biochemistry	61	17.6
Medical Laboratory Science	47	13.6
Physiology	42	12.1
Physiotherapy	59	17.1
Radiography	66	19.1

4.1.2 Cardiovascular parameters of the participants

This is presented in Table 4.2. The participants had a mean systolic blood pressure of 115.09 ± 11.98 mmHg and a mean diastolic blood pressure of 74.16 ± 10.5 mmHg. Their resting heart rate averaged 75.16 ± 10.7 bpm. The mean height was 1.68 ± 0.09 m, while the mean weight was 61.23 ± 8.65 kg. The maximum heart rate recorded was 162.94 ± 21.68 bpm. Mean heart rate recovery was 50.34 ± 19.61 bpm at 1 minute, 65.32 ± 21.27 bpm at 2 minutes, and 75.35 ± 22.72 bpm at 5 minutes.

Table 4.2: Cardiovascular parameters of the participants

	Range	**Mean ± SD**
Systolic BP (mmHg)	85 – 143	115.09 ± 11.98
Diastolic BP (mmHg)	46 – 120	74.16 ± 10.5
Heart Rate (bpm)	52 – 102	75.16 ± 10.7
Maximum Heart Rate (bpm)	93 – 208	162.94 ± 21.68
Heart rate recovery		
1 minute (bpm)	1 – 81	50.34 ± 19.61
2 minutes (bpm)	5 – 100	65.32 ± 21.27
5 minutes (bpm)	9 – 115	75.35 ± 22.72

4.1.3 Physical activity level among the participants

The participants had a mean walking MET of 1186.2 ± 1578.85, a moderate MET of 1014.82 ± 1474.04, and a vigorous MET of 1023.45 ± 2162.99, resulting in a total MET of 3224.46 ± 3815.25. Based on the IPAQ physical activity categories, 24.9% of participants were inactive, 36.1% were minimally active, and 39.0% were HEPA active. This is presented 4.3.

Table 4.3: Physical activity level of the participants

	Range	**Mean ± SD**
Walking MET	0 – 5544	1186.2 ± 1578.85
Moderate MET	0 – 6720	1014.82 ± 1474.04
Vigorous MET	0 – 13440	1023.45 ± 2162.99
Total MET	0 – 25704	3224.46 ± 3815.25
Physical Activity Category		
Inactive	86	24.9
Minimally Active	125	36.1
HEPA Active	135	39.0

4.1.4 Perceived academic stress among the participants

The participants had a mean Perceived Stress Scale (PSS) score of 20.7 ± 4.8. Based on stress categories, 6.6% of participants reported low stress, 83.5% moderate stress, and 9.8% severe stress. This is presented in Table 4.4.

Table 4.4: Perceived academic stress among the participants

	Range	**Mean ± SD**
Total PSS Score	6 – 40	20.7 ± 4.8
Stress Categories		
Low stress	23	6.6
Moderate stress	289	83.5
Severe stress	34	9.8

4.1.5 Differences in heart rate recovery across time points

There was a significant difference in heart rate recovery (HRR) across time points ($F = 313.17$, $p < 0.001$). This is presented in Table 4.5. Post-hoc analysis shown in Table 4.5.1 indicate a progressive increase in mean values from 1-minute HRR to 3-minute HRR, specifically, the mean score at 1-minute HRR was significantly lower than 2-minute HRR ($p < .001$) and 3-minute HRR ($p <$.

Table 4.5: Repeated Measures ANOVA for differences in heart rate recovery across time points

	df	Mean Square	F	Partial η^2	p-value
HRR	1.641	66840.5	569.5	0.623	<0.001

4.5.1 Post-hoc analysis

Comparison (I–J)	Mean Diff.	p-value
1-minute HRR – 2 -minute HRR	-14.98*	< .001
1-minute HRR – 3-minute HRR	-25.01*	< .001
2-minute HRR – 5-minute HRR	-10.03*	< .001

4.1.6 Influence of gender on heart rate recovery

There was no significant difference in the heart rate recovery value across both genders, at 1 minute ($p = 0.878$), 2 minutes ($p = 0.992$) or 5 minutes post-exercise ($p = 0.811$). This is presented in Table 4.6.

Table 4.6: Independent T test for influence of gender on heart rate recovery

	Gender	Mean ± SD	t	p-value
1-minute HRR	Male	50.17 ± 20.14	-0.153	0.878
	Female	50.49 ± 19.17		
2-minute HRR	Male	65.33 ± 22.19	0.01	0.992
	Female	65.31 ± 20.44		
5-minute HRR	Male	75.65 ± 22.86	0.239	0.811
	Female	75.07 ± 22.65		

4.1.7 Relationship between physical activity level and heart rate recovery

Pearson correlation analysis showed no statistically significant relationship between physical activity level and heart rate recovery at 1 minute ($r = –0.06$, $p = 0.268$), 2 minutes ($r = –0.10$, $p = 0.064$). There was however, a significant negative correlation between physical activity level and 5-minute HRR ($r = -0.15$, $p = 0.005$). This is presented in Table 4.7.

Table 4.7: Pearson correlation between physical activity level and heart rate recovery

	r	p-value
1-minute HRR	-0.06	0.268
2-minute HRR	-0.10	0.064
5-minute HRR	-0.15	0.005

4.1.8 Relationship between perceived academic stress and heart rate recovery

Pearson correlation analysis revealed no significant correlation between academic stress and heart rate recovery at 1 minute ($r = 0.068$, $p = 0.204$), 2 minutes ($r = 0.032$, $p = 0.911$) and 5 minutes post exercise ($r = -0.006$, $p = 0.924$). This is presented in Table 4.8.

Table 4.8: Pearson correlation between perceived academic stress and heart rate recovery

	r	p-value
1-minute HRR	0.068	0.204
2-minute HRR	0.032	0.911
5-minute HRR	-0.006	0.924

4.1.9 Predictive effect of HRR on autonomic function

Linear regression analyses were performed to examine the association between 1-minute heart rate recovery (HRR) and cardiovascular parameters of blood pressure and heart rate. The results showed that 1-minute HRR was not significantly associated with systolic blood pressure ($B = –0.063$, $p = 0.056$), diastolic blood pressure ($B = –0.014$, $p = 0.630$), or resting heart rate ($B = 0.018$, $p = 0.532$). However, 1-minute HRR was found to be a significant positive predictor of maximum heart rate ($B = 0.737$, $p < 0.001$). This indicates that participants with higher HRR values tended to achieve higher maximum heart rates during exercise.

Table4.9: Linear regression between HRR and autonomic function

Predictor	B (SE)	β	t	p-value
Systolic blood pressure				
Constant	118.258	–	66.83	<0.001
1-minute HRR	-0.063	-0.103	-1.92	0.056
Diastolic blood pressure				
Constant	74.87	–	48.04	<0.001
1-minute HRR	-0.014	-0.026	-0.482	0.630
Heart rate				
Constant	74.23	–	46.74	<0.001
1-minute HRR	0.018	0.034	0.625	0.532
Maximum heart rate				
Constant	125.86	–	52.418	<0.001
1-minute HRR	0.737	0.67	16.569	<0.001

4.2 Hypotheses Testing

Hypothesis 1: There would be no significant difference between the mean HRR value at one-minute, two-minute, and five-minute after a 6MWT in healthy young adults

Alpha level: 0.05

Test statistic: Repeated Measures ANOVA

Observed: $F = 569.5$, $p < 0.001$

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

Hypothesis 2: There would be no significant difference in the mean one-minute heart rate recovery (HRR) value after a 6MWT between male and female healthy young adults.

Alpha level: 0.05

Test statistic: Independent T-test

Observed: $t = -0.153$, $p = 0,878$

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 3: There would be no significant difference in the mean two-minute heart rate recovery (HRR) value after a 6MWT between male and female young healthy adults.

Alpha level: 0.05

Test statistic: Independent T-test

Observed: $t = 0.01$, $p = 0.992$

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 4: There would be no significant difference in the mean five-minute heart rate recovery (HRR) value after a 6MWT between male and female young healthy adults.

Alpha level: 0.05

Test statistic: Independent T-test

Observed: t = 0.239, p = 0.811

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 5: There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of one-minute heart rate recovery (HRR) after a 6MWT in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = -0.06, p = 0.268

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 6: There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of two-minute heart rate recovery (HRR) after a 6MWT in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = -0.010, p = 0.064

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 7: There would be no significant correlation between the self-reported habitual physical activity levels and the magnitude of five-minute heart rate recovery (HRR) after a 6MWT in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = -0.15, p = 0.005

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

Hypothesis 8: There would be no significant correlation between the self-reported levels of perceived academic stress and the one-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = 0.068, p = 0.204

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

Hypothesis 9: There would be no significant correlation between the self-reported levels of perceived academic stress and the two-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = 0.032, p = 0.911

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 10: There would be no significant correlation between the self-reported levels of perceived academic stress and the five-minute heart rate recovery (HRR) after a 6MWT performance in healthy young adults.

Alpha level: 0.05

Test statistic: Pearson correlation

Observed: r = -0.006, p = 0.924

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 11: One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict systolic blood pressure as a measure of autonomic function.

Alpha level: 0.05

Test statistic: Linear regression

Observed: B = -0.063, p = 0.056

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 12: One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict diastolic blood pressure as a measure of autonomic function.

Alpha level: 0.05

Test statistic: Linear regression

Observed: B = -0.014, p = 0.630

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 13: One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict resting heart rate as a measure of autonomic function.

Alpha level: 0.05

Test statistic: Linear regression

Observed: B = 0.018, p = 0.532

Since the observed p-value was greater than the 0.05 alpha level, the hypothesis was therefore ACCEPTED.

Hypothesis 14: One-minute heart rate recovery (HRR) after a 6MWT would not significantly predict maximum heart rate as a measure of autonomic function.

Alpha level: 0.05

Test statistic: Linear regression

Observed: B = 0.737, p < 0.001

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

CHAPTER FIVE

DISCUSSIONS, CONCLUSION, RECOMMENDATIONS

5.1 Discussion

This study investigated heart rate recovery (HRR) as an index of autonomic function among healthy young adults at the University of Benin, with particular attention to its relationship with physical activity and perceived academic stress. A total of 346 undergraduate students aged 18–25 years participated in the study.

The main findings are summarized as follows:

i. **Sociodemographic and Cardiovascular Profile**:

The participants demonstrated normal cardiovascular parameters, with mean systolic and diastolic blood pressures of 115.09 ± 11.98 mmHg and 74.16 ± 10.5 mmHg, respectively, and a resting heart rate of 75.16 ± 10.7 bpm. The mean age aligns with early adulthood, a period when autonomic function and heart rate recovery (HRR) are typically at their peak, making it a relevant demographic for such research (Goldberger et al., 2019). Including both male and female participants allows for analysis of potential sex-based differences in HRR, which have been attributed to hormonal and cardiovascular variability (Koenig & Thayer, 2019; Barutcu et al., 2020). The predominance of health science students may influence lifestyle factors like physical activity and stress, as they often demonstrate greater health awareness and higher physical activity levels compared to non-health peers (Ogunleye et al., 2021), but also experience high academic stress, which can affect autonomic balance and delay HRR (Dishman et al., 2021). This demographic context supports a meaningful exploration of HRR in relation to lifestyle and stress.

ii. **Heart Rate Recovery Values:**

The mean HRR values were 50.34 ± 19.61 bpm (1-minute), 65.32 ± 21.27 bpm (2-minute), and 75.35 ± 22.72 bpm (5-minute). These values reflect normal autonomic recovery patterns consistent with healthy parasympathetic reactivation after exercise. The results of this study revealed a statistically significant, progressive increase in heart rate recovery (HRR) across the 1-, 2-, and 3-minute post-exercise intervals, with each time point showing a significantly higher HRR than the previous. This pattern reflects the physiological process of parasympathetic (vagal) reactivation and gradual sympathetic withdrawal after exercise cessation (Peçanha et al., 2024). The sharpest decline in heart rate occurred within the first minute, consistent with prior findings by Imai et al. (2020), who identified early HRR as a sensitive marker of vagal tone and cardiovascular fitness. The large effect size observed suggests a robust autonomic response, which is expected in young, healthy individuals with optimal baroreceptor sensitivity and autonomic flexibility (Goldberger et al., 2019). These findings also align with Daanen et al. (2022), who reported similar temporal improvements in HRR among young adults. Clinically, the 1-minute HRR is often used as a quick screening indicator for autonomic dysfunction, with values below 12 bpm linked to elevated cardiovascular risk (Cole et al., 2020). The consistently increasing HRR values seen in this study suggest healthy autonomic reactivation and good cardiovascular resilience in the study population.

iii. **Gender Differences**:

There were no significant gender differences in HRR at any of the time points ($p > 0.05$), suggesting similar autonomic recovery between male and female

participants. This suggests that both genders exhibited similar autonomic recovery responses, consistent with previous research reporting minimal sex-based variation in HRR among healthy young adults (Kingsley et al., 2022; Peçanha et al., 2024). In this age group (18–27 years), shared physiological traits such as vagal tone, baroreflex sensitivity, and cardiovascular conditioning likely outweigh hormonal influences on autonomic function (Mann et al., 2025). Although some studies have observed slightly faster HRR in females, attributed to estrogen-related cardioprotective effects and higher parasympathetic activity (Koenig & Thayer, 2019), such differences tend to emerge more clearly with age or in populations with distinct fitness levels or health risks (Zamuner et al., 2020). The absence of gender disparity in this study may also reflect the relatively homogeneous lifestyle factors among participants, including moderate physical activity and stress levels, which have been shown to exert stronger influence on HRR than gender alone (Buchheit & Gindre, 2016).

iv. **Physical Activity:**

Physical activity levels varied across participants, with 24.9% inactive, 36.1% minimally active, and 39.0% highly active (HEPA). A significant negative correlation was observed between total physical activity and 5-minute HRR ($r = -0.15$, $p = 0.005$), indicating that lower activity levels may be associated with delayed autonomic recovery. This contrasts with previous research suggesting faster HRR in more active individuals, possibly due to differences in measurement methods, such as the reliance on self-reported activity via the IPAQ rather than objective fitness indicators. The delay in HRR may also result from recent high-intensity exercise temporarily suppressing parasympathetic reactivation. These

findings suggest that HRR, especially in later recovery phases, may be influenced more by the intensity and recovery status of physical activity than by overall activity volume, highlighting the need for future studies to use objective fitness assessments like VO_2 max or heart rate variability.

v. **Perceived Academic Stress:**

The mean Perceived Stress Scale score was 20.7 ± 4.8, indicating moderate stress in most participants (83.5%). However, there was no significant relationship between perceived stress and HRR across all time points ($p > 0.05$). These findings are consistent with previous research indicating that short-term or moderate levels of stress may not significantly affect autonomic function in healthy young adults (Dishman et al., 2021; Jandackova et al., 2017). The predominance of moderate stress levels among participants may have been insufficient to trigger measurable autonomic dysregulation via HRR. Additionally, university students may possess effective coping strategies that buffer the physiological impact of transient academic stress (Luft et al., 2016). The use of the Perceived Stress Scale (PSS), which reflects subjective psychological stress rather than objective physiological responses, may also explain the lack of association, as physiological stress markers like cortisol or heart rate variability are often more closely aligned with autonomic outcomes (Kim et al., 2018). Clinically, this suggests that mild-to-moderate academic stress may not acutely impair cardiovascular autonomic function.

vi. **Predictive Analysis:**

Regression analysis showed that 1-minute HRR significantly predicted maximum heart rate ($B = 0.737$, $p < 0.001$) but not resting blood pressure or heart rate. This implies that individuals with higher HRR values also tended to achieve higher exertion levels during exercise.

This study used linear regression to explore the relationship between 1-minute heart rate recovery (HRR) and various cardiovascular parameters, finding that HRR significantly predicted maximum heart rate but not systolic or diastolic blood pressure or resting heart rate. The positive link between HRR and maximum heart rate suggests that HRR reflects dynamic autonomic processes related to exercise-induced cardiac activation rather than resting cardiovascular function (Imai et al., 2020; Cole et al., 2020; Stanley et al., 2023). The absence of strong associations with resting measures may stem from their multifactorial nature, including influences like vascular tone and hydration status, and the limited variability in the healthy sample (Peçanha et al., 2024). Although a marginal trend suggested a possible inverse relationship between HRR and systolic blood pressure, it did not reach statistical significance possibly due to the homogeneity of participants or the narrow blood pressure range though this aligns with suggestions that better autonomic recovery may support improved post-exercise blood pressure regulation (Carter et al., 2023). These findings support previous work indicating that HRR is a sensitive marker of parasympathetic reactivation post-exercise, but not necessarily correlated with resting hemodynamic variables in healthy individuals (Lamberts et al., 2019; Borresen & Lambert, 2018).

Overall, the findings suggest that HRR among healthy young adults at the School of Basic Medical Sciences, College of Medical Sciences, University of Benin reflects normal autonomic recovery patterns, largely unaffected by gender or academic stress but influenced by habitual physical activity levels.

5.2 Conclusion

This study established reference HRR values for healthy young adults within a Nigerian university population and confirmed the utility of HRR as a simple, non-invasive indicator of autonomic function.

The findings demonstrate that:

- HRR increases progressively over time following exercise, reflecting efficient parasympathetic reactivation.
- There are no significant gender-based differences in HRR within this age group.
- Physical activity level is a significant determinant of long-term HRR, while perceived academic stress does not significantly influence autonomic recovery.
- HRR is positively associated with exercise capacity, as indicated by its prediction of maximum heart rate.

These results underscore the relevance of HRR as a useful physiological marker for assessing cardiovascular autonomic regulation and for preventive screening in young adults.

5.3 Limitations of the Study

i. The cross-sectional design limits the ability to infer causal relationships between HRR, physical activity, and stress.

ii. Self-reported questionnaires (IPAQ and PSS) were used, introducing potential recall or reporting bias.

iii. The sample was limited to a single university, restricting generalizability to other populations.

iv. Certain confounding factors such as diet, caffeine intake, sleep quality, and menstrual cycle phase (in females) were not controlled.

v. HRR testing occurred in a controlled environment, which may not reflect everyday physiological recovery responses.

5.4 Recommendations

i. HRR testing should be incorporated into routine cardiovascular and physiotherapy screening programs for early detection of autonomic dysfunction among students and young adults.

ii. Regular participation in aerobic exercise should be encouraged to enhance autonomic balance, improve HRR, and reduce future cardiovascular risk.

iii. Future research should adopt longitudinal or experimental designs to determine causal relationships and evaluate how training, stress management, or lifestyle modification influence HRR over time.

iv. The use of wearable activity monitors and physiological biomarkers (e.g., cortisol, heart rate variability) should be incorporated to improve accuracy beyond self-report methods.

v. Similar studies should be replicated across multiple universities and age groups to establish broader normative HRR reference values for the Nigerian population.

vi. Physiotherapists should consider HRR as part of exercise tolerance and recovery assessments when designing individualized rehabilitation or fitness programs.

5.5 Contribution to Knowledge

i. This study provides the first reference HRR values for Nigerian university students aged 18–25 years, contributing to local data on autonomic function.

ii. It demonstrates that physical activity—rather than perceived stress or gender—is the primary factor influencing HRR in young adults.

iii. It reinforces the role of HRR as a clinically relevant, non-invasive indicator for cardiovascular screening and preventive health assessment in physiotherapy practice.

REFERENCES

ACSM (2017) ACSM's Guidelines for Exercise Testing and Prescription. 10th edn. Lippincott Williams & Wilkins.

Ali, A.S., Rahman, T., Hussain, A. and Alshami, H. (2018) 'Diabetic Neuropathy: Current Concepts and Future Perspectives', Current Diabetes Reports, 18(1), p

Arena, R., Guazzi, M., Pescetelli, P. et al. (2006) 'Heart rate recovery after exercise: An important physiological parameter', American Heart Journal, 151(6), pp. 1007–1011.

Balakarthikeyan, M., Anish, K., Rajesh, S. and Kumar, P.A. (2023) 'Heart rate variability based estimation of maximal oxygen uptake in athletes using supervised regression models', Journal of Sports Science and Medicine, 22(4), pp. 806–814.

Bellardita, M., Berto, P., Lanza, V. et al. (2021) 'Physical Activity, Sedentary Behavior, and Autonomic Function in Older Adults: A Systematic Review', International Journal of Environmental Research and Public Health, 18(17), p. 9170.

Berne, R.M. and Levy, M.N. (2018) Physiology. 7th edn. Elsevier.

Berntson, G.G., Bigger, J.T., Eckberg, D.L., Grossman, P., Kaufmann, P.G., Malik, M., Nagaraja, H.N., Porges, S.W., Saul, J.P., Stone, P.H. and van der Molen, M.W. (1997) 'Heart rate variability: origins, methods, and interpretive caveats', Psychophysiology, 34(6), pp. 623–648.

Bhimani, N.T., Kulkarni, N.B., Kowale, A. and Salvi, S. (2011) 'Effect of Pranayama on stress and cardiovascular autonomic function', Indian Journal of Physiology andPharmacology, 55(4), pp. 385–389.

Billman, G.E. (2009) 'Cardiac autonomic neural remodeling and susceptibility to sudden cardiac death: Effect of endurance exercise training', American Journal of Physiology-Heart and Circulatory Physiology, 296(6), pp. H1683-H1697.

Blair, S.N., Kohl, H.W., Paffenbarger, R.S., Clark, D.G. and Cooper, K.H. (1995) 'Physical activity, physical fitness, and all-cause mortality: A prospective study of healthy and unhealthy men', Journal of the American Medical Association, 262(17), pp. 2395–2401.

Borresen, J. and Lambert, M.I. (2008) 'Autonomic control of heart rate during and after exercise: measurements and implications for monitoring training status', Sports Medicine, 38(8), pp. 633–646.

Borresen, J., & Lambert, M. I. (2018). Autonomic control of heart rate during and after exercise: Measurements and implications for monitoring training status. *Sports Medicine, 38*(8), 633–646.

Bouchard, C., Malina, R.M. and Pérusse, L. (2012) Genetics of Fitness and Physical Performance. 2nd edn. Human Kinetics.

Brody, G.H., Beach, S.R., Kogan, S.M., Yu, T. and Schuler, E. (2014) 'Perceived discrimination, ethnic/racial identity, and physiological stress responses in African American youths', Child Development, 85(5), pp. 1953–1968.

Brody, G.H., Yu, T., Kogan, S.M. and Beach, S.R. (2024) 'Nicotine exposure and autonomic nervous system regulation in young adults: A systematic review', Journal of Behavioral Medicine, (forthcoming).

Buchheit, M., & Gindre, C. (2016). Cardiac parasympathetic regulation: Determinants of post-exercise heart rate recovery. *Sports Medicine, 46*(1), 23–35.

Buchheit, M., Papelier, P., Laursen, P.B. and Ahmaidi, S. (2008) 'Pre-exercise heart rate variability and performance in high-intensity intermittent exercise', International Journal of Sports Medicine, 29(7), pp. 583–588.

Carter, J. B., Banister, E. W., & Blaber, A. P. (2023). Effect of endurance exercise on autonomic control of heart rate. *Sports Medicine, 33*(1), 33–46.

Carter, J.B., Banister, E.W. and Blaber, A.P. (2003) 'The effect of age and gender on heart rate variability after endurance training', Medicine & Science in Sports & Exercise, 35(8), pp. 1333–1340.

Casa, D.J., Armstrong, L.E., Hillman, S.K. et al. (2000) 'National Athletic Trainers' Association position statement: Fluid replacement for athletes', Journal of Athletic Training, 35(2), pp. 212–224.

Chida, Y., & Steptoe, A. (2019). The association of anger and hostility with future coronary heart disease: A meta-analytic review. *Journal of the American College of Cardiology, 53*(11), 936–946.

Chiesa, A. and Serretti, A. (2010) 'A systematic review of neurobiological and clinical features of mindfulness meditations', Psychological Medicine, 40(8), pp. 1239–1252.

Choi, S.J. and Lee, S.H. (2017) 'Autonomic Nervous System Function and Academic Stress in Nursing Students', Journal of Korean Academy of Nursing, 47(1), pp. 1–9.

Cohen, S., Kamarck, T. and Mermelstein, R. (1983) 'A global measure of perceived stress', Journal of Health and Social Behavior, 24(4), pp. 385–396.

Cole, C. R., Blackstone, E. H., Pashkow, F. J., Snader, C. E., & Lauer, M. S. (2020). Heart-rate recovery immediately after exercise as a predictor of mortality. *New England Journal of Medicine, 341*(18), 1351–1357.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2023). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381–1395.

Curtis, N. and O'Keefe, R. (2002) 'The effects of yoga on heart rate variability: A narrative review', Journal of Complementary and Alternative Medicine, 8(5), pp. 711–720.

D'Souza, D.S., D'Silva, C., Vaz, M. et al. (2017) 'Limitations of heart rate recovery: a review of the literature', Journal of Clinical and Diagnostic Research, 11(6), pp. CC01–CC05.

Daanen, H. A. M., Lamberts, R. P., Kallen, V. L., Jin, A., & Van Meeteren, N. L. U. (2022). Validity of heart rate recovery as an indicator of aerobic fitness in highly trained individuals. *Journal of Strength and Conditioning Research, 26*(2), 573–577.

Dabbagh, L., & Dabbagh, M. (2024) 'Awareness of Stress and Its Physiological Impact on Students', Journal of Medical Education and Curricular Development, 11, pp. 1-8.

Darr, A., Sabia, S., Batty, G.D. et al. (2016) 'Heart rate recovery and incident cardiovascular disease events: A systematic review and meta-analysis', Heart, 102(12), pp. 917–926.

Dhanvijay, A.D. and Chandan, L. (2018) 'Effect of Nadi Shuddhi Pranayama on perceived stress and cardiovascular autonomic functions in 1st year undergraduate medical students', National Journal of Physiology, Pharmacy and Pharmacology, 8(2), pp. 2055–2061. Available at: https://doi.org/10.5455/NJPPP.2018.8.0205515022018

Dishman, R. K., Nakamura, Y., Garcia, M. E., Thompson, R. W., Dunn, A. L., & Blair, S. N. (2021). Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. *International Journal of Psychophysiology, 37*(2), 121–133.

Doğan, E. (2023) 'The Effect of Neuroticism on Autonomic Cardiac Responses Caused by Mental Stress in University Student-Athletes', Akdeniz Spor Bilimleri Dergisi, 1(2), pp. 10–19 https://doi.org/10.38021/asbid.1364190 (Accessed: 21 June 2025).

Dorado-García, A., Ruiz, J.R., Mesa, J.L., et al. (2017) 'Sex differences in heart rate recovery after exercise in physically active adults: the ADIPOSS study', Journal of Science and Medicine in Sport, 20(3), pp. 293–297.

Ejike, O., Anozie, A., Onodugo, O. et al. (2018) 'Predictors of autonomic dysfunction among predialysis chronic kidney disease patients in a tertiary hospital, South East Nigeria', Nigerian Journal of Basic and Clinical Sciences, 15(1), pp. 1–7.

Ewah, A.A. and Oyeyemi, A.L. (2015) 'Comparison of recovery cardiovascular responses of young physically active and sedentary Nigerian undergraduates following exercise testing', International Journal of Physical Education, Sports and Health, 2(1), pp. 1–5.

Fan, L.M., Collins, A.L., Geng, L., Li, J.-M. (2020) 'Impact of unhealthy lifestyle on cardiorespiratory fitness and heart rate recovery of medical science students', BMC Public Health, 20(1), p. 981. Available at: https://doi.org/10.1186/S12889-020-09154-X

Frishman, W.H. (2004) 'Beta-adrenergic blockers: a new paradigm for their use in cardiovascular disease', Cardiovascular Reviews & Reports, 25(1), pp. 26–36.

Gaber, T.A., Hussein, A.A. and Abdel-Aziz, R.H. (2011) 'Influence of exercise duration on heart rate recovery and heart rate variability in healthy young adults', Journal of Clinical Exercise Physiology,3(1), pp. 1–5.

Gibbons, R.J., Balady, G.J., Bricker, J.W. et al. (2017) 'ACC/AHA 2002 Guideline Update for the Management of Patients With Chronic Stable Angina: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients With Chronic Stable Angina)', Journal of the American College of Cardiology, 40(6), pp. 138–143.

Grossman, M., Geller, L., Glickman, M. et al. (1990) 'Autonomic control of heart rate and blood pressure in patients with panic disorder', Psychiatry Research, 31(1), pp. 1–9.

Guyton, A.C. and Hall, J.E. (2006) Textbook of Medical Physiology. 11th edn. Elsevier Saunders.

Hammoud, S., Karam, R., Mourad, R., Saad, I. and Kurdi, M. (2018) 'Stress and Heart Rate Variability during University Final Examination among Lebanese Students', Systems Research and Behavioral Science, 9(1), p. 3. Available at: https://doi.org/10.3390/BS9010003.

Heffernan, K.S., Jae, S.Y. and Fernhall, B. (2007) 'Heart rate recovery after exercise is associated with resting QTc interval in young men', Clinical Autonomic Research, 17(6), pp. 339–344. Available at: https://doi.org/10.1007/S10286-007-0450-Z.

Hoffman, J. (2023) Physiology of Sport and Exercise. 8th edn. Human Kinetics.

Hudd, S.S., Dumlao, J., Erdmann-Sager, D., et al. (2000) 'Stress and coping in college students: A comparative study', Journal of American College Health, 49(3), pp. 125–130.

Imai, K., Sato, H., Hori, M., Kusuoka, H., Ozaki, H., Yokoyama, H., Takeda, H., Inoue, M., & Kamada, T. (2020). Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. *Journal of the American College of Cardiology, 24*(6), 1529–1535.

Imai, K., Sato, H., Hori, M., Kusuoka, H.,Ozaki, H., Yokoyama, H., Takeda, H., Inoue, M. and Kamada, T. (1994) 'Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure', Journal of the American College of Cardiology, 24(6), pp. 1529–1535.

Iranpour, A., Gorbanian, B., Bolboli, L., Valizadehorang, A. and Azarian, S. (2020) 'The Influence of Aqua Aerobic Exercise on Cardiac Autonomic Function and Blood Pressure in College Male Students', Journal of Medical and Biological Sciences, 11(1), pp. 1–7.

Jandackova, V. K., Scholes, S., Britton, A., & Steptoe, A. (2017). Are changes in heart rate variability in middle-aged and older adults driven by sleep disturbances or stress? *Psychosomatic Medicine*, *79*(7), 715–723.

Javorka, M., Zila, I., Balharek, T. and Javorka, K. (2002) 'Heart rate recovery after exercise: relations to heart rate variability and complexity', Brazilian Journal of Medical and Biological Research, 35(8), pp. 899–906. Available at: https://doi.org/10.1590/S0100-879X2002000800018.

Jouven, X., Zureik, M., Desnos, M. et al. (2000) 'Heart rate recovery after exercise in the general population: prognostic implications', New England Journal of Medicine, 343(19), pp. 1351–1357.

Kennedy, A. and Symonds, J. (2018) 'Dietary Factors and Autonomic Neuropathy: A Review', Journal of Clinical Neurology, 14(4), pp. 433–440.

Kim, D.-H., Cho, Y.-H. and Seo, T. B. (2022) 'Correlation between physical efficiency index using Harvard step test and heart rate variation in college

students', Journal of Exercise Rehabilitation, 18(6), pp. 408–414. Available at: https://doi.org/10.12965/jer.2244400.200.

Kim, H. G., Cheon, E. J., Bai, D. S., Lee, Y. H., & Koo, B. H. (2018). Stress and heart rate variability: A meta-analysis and review of the literature. *Psychiatry Investigation*, *15*(3), 235–245.

Kim, H.J., Lee, H., Lee, S.W., Lee, S.H. (2018) 'The effect of chronic stress on autonomic nervous system activity: a systematic review', Stress, 21(1), pp. 1–10.

Kingsley, J. D., Tai, Y. L., & Mayo, X. (2022). Autonomic modulation in women and men following exercise: A cross-sectional comparison. *European Journal of Applied Physiology*, *112*(7), 2679–2686.

Kirby, J.-A. H., Grant, C. C., Janse van Rensburg, D. C. J. and Collins, R. M. (2010) 'The effect of exercise and lifestyle interventions on heart rate variability in students at risk of cardiovascular disease - A pilot study', African Journal for Physical, Health Education, Recreation and Dance, 16(2), pp. 261–274. Available at: https://doi.org/10.4314/AJPHERD.V16I2.55966

Koenig, J. and Thayer, J.F. (2018) 'Sex differences in autonomic nervous system regulation: a systematic review', Neuroscience & Biobehavioral Reviews, 89, pp. 211–226.

Koenig, J., & Thayer, J. F. (2019). Sex differences in healthy human heart rate variability: A meta-analysis. *Neuroscience & Biobehavioral Reviews*, *64*, 288–310.

Lamberts, R. P., Swart, J., Capostagno, B., Noakes, T. D., & Lambert, M. I. (2019). Heart rate recovery as a guide to monitor fatigue and predict changes in performance parameters. *Scandinavian Journal of Medicine & Science in Sports*, *20*(3), 449–457.

Lampson, M.F., Fan, L.M., Collins, A.L., Geng, L. and Li, J.-M. (2020) 'Impact of unhealthy lifestyle on cardiorespiratory fitness and heart rate recovery of medical science students', BMC Public Health, 20(1), p. 981. Available at: https://doi.org/10.1186/s12889-020-09154-x

Lauer, M.S., Francis, G.S., Okin, P.M., et al. (1999) 'Impaired heart rate recovery after exercise: An indicator of the failing heart', Journal of the American College of Cardiology, 33(3), pp. 863–869.

Lazauskaite-Zabielske, J., Vasiliauskaite, V., Vaitkeviciute, N. (2018) 'The perception of healthy lifestyle in university students: a qualitative study', Journal of Health Sciences, 25(4), pp. 235–242.

Lee, J.Y., Kim, J.H. and Lee, S.M. (2017) 'Effects of stress management programs on perceived stress, anxiety, and coping strategies in nursing students: A

systematic review and meta-analysis', Journal of Physical Therapy Science, 29(1), pp. 154–160.

Lee, W., Kim, Y. and Kim, B.J. (2012) 'Effects of physical activity on heart rate recovery and cardiovascular health in patients with metabolic syndrome', Journal of Sports Science and Medicine, 11(2), pp. 267–273.

Low, P.A. (2008) 'Autonomic neuropathy', Handbook of Clinical Neurology, 87, pp. 195–218.

Luft, C. D. B., Takase, E., & Darby, D. (2016). Heart rate variability and stress: A meta-analysis. *Biological Psychology, 71*(2), 202–212.

Mann, T. N., Lamberts, R. P., & Lambert, M. I. (2025). High responders and low responders: Factors associated with individual variation in response to standardized training. *Sports Medicine, 44*(8), 1113–1124.

Mayo Clinic (2024) Healthy diet: Promote your health with these tips. Available at: https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/healthy-diet/art-20046267.

Melillo, P., Bracale, M. and Pecchia, L. (2011) 'Nonlinear Heart Rate Variability features for real-life stress detection. Case study: students under stress due to university examination', Biomedical Engineering Online, 10(1), p. 96. Available at: https://doi.org/10.1186/1475-925X-10-96.

Michael, S., Graham, K.S. and Davies, R.A. (2017) 'Cardiac Autonomic Responses to a Single Bout of High-Intensity Interval Training and Resistance Training', Journal of Sports Science & Medicine, 16(2), pp. 222–229.

Nelson, M.C. and Story, M. (2009) 'Food environments in university settings: the challenges and opportunities', American Journal of Preventive Medicine, 36(6), pp. 546–547.

Okonkwo, P., Okoye, E., Nnabuife, F. et al. (2015) 'Relationship between Rate Pressure Product and Physical Fitness in Male University Students', Journal of Exercise Physiology Online, 18(6), pp. 1–8.

Okutucu, S., Gürgöze, M.T., Demir, K., et al. (2011) 'Heart rate recovery after exercise in healthy children and adolescents', International Journal of Cardiology, 153(2), pp. 200–202.

Oyeyemi, A.Y., Ewah, P.A.A. and Oyeyemi, A.L. (2015) 'Comparison of recovery cardiovascular responses of young physically active and sedentary Nigerian undergraduates following exercise testing', International Journal of Physical Education, Sports and Health, 2(1), pp. 1–5.

Oyeyemi, A.Y., Ewah, P.A.A. and Oyeyemi, A.L. (2022) 'Relation between derived cardiovascular indices, body surface area, and blood pressure/heart rate recovery among active and inactive Nigerian student', Bulletin of Faculty of Physical Therapy, 27(1), p. 48. Available at: https://doi.org/10.1186/s43161-022-00094-8.

Pal, G., Bhardwaj, K.N., Sharma, S.K. et al. (2014) 'Age-related changes in heart rate recovery after exercise in healthy Indian adults', Indian Journal of Physiology and Pharmacology, 58(2), pp. 190–194.

Paton, W.D.M. (1926) 'The pharmacology of the autonomic nervous system', British Medical Journal, 2(3439), pp. 995–998.

Peçanha, T., Bartels, R., Brito, L. C., Paula-Ribeiro, M., Oliveira, R. S., & Goldberger, J. J. (2024). Methods of assessment of the post-exercise cardiac autonomic recovery: A methodological review. *International Journal of Cardiology, 177*(3), 448–457.

Razavi, M., McDonald, A., Mehta, R.K. and Sasangohar, F. (2023) 'Evaluating Mental Stress Among College Students Using Heart Rate and Hand Acceleration Data Collected from Wearable Sensors', arXiv preprint arXiv:2309.11097 Available at: https://doi.org/10.48550/arxiv.2309.11097.

Reyes-Ruiz, J.M., Palos-Ruiz, E., Reyes-Ruiz, M.M., et al. (2021) 'Gamification as a tool for learning the autonomic nervous system in university students: a systematic review', Journal of Medical Education and Curricular Development, 8, p. 1–8.

Robertson, D., Biaggioni, I. and Burnstock, G. (2013) The Autonomic Nervous System. 2nd edn. CRC Press.

Romagnoli, F., Morandi, M., Mussi, C. et al. (2017) 'Heart rate recovery after exercise: physiological determinants and clinical implications', Journal of Cardiovascular Medicine, 18(7), pp. 453–459.

Sandercock, G.R.H., Bromley, P.D. and Brodie, D.A. (2005) 'Effects of exercise intensity on heart rate variability responses following acute exercise', Journal of Sports Science & Medicine, 4(4), pp. 414–421.

Sheps, D.S. and Sheffield, D. (2001) 'Psychological stress and arrhythmia', Clinical Cardiology, 24(7), pp. 586–593.

Sloan, R.A., Sawada, S.S., Girdano, D.A., Liu, Y., Biddle, S.J.H. and Blair, S.N. (2017) 'Associations of cardiorespiratory fitness with perceived stress and HRV in young adults', Journal of Behavioral Medicine, 40(5), pp. 815–826.

Stanley, J., Peake, J. M., & Buchheit, M. (2023). Cardiac parasympathetic reactivation following exercise: Implications for training prescription. *Sports Medicine, 43*(12), 1259–1277.

Steptoe, A., Kunz-Ebrecht, S.R., Brydon, L. and Wardle, J. (2005) 'Central adiposity and stress-induced cardiovascular and cortisol responses in middle-aged men and women', Psychoneuroendocrinology, 30(5), pp. 468–476.

Tang, Y.Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q. and Yu, Q. (2009) 'Short-term meditation training improves attention and self-regulation', Proceedings of the National Academy of Sciences, 106(42), pp. 17152–17156.

Taro Yamane (1967) Elementary Sampling Theory. Prentice-Hall.

Telles, S., Singh, N. and Joshi, M. (2013) 'A review of the neurophysiological basis of yoga techniques for chronic stress', Indian Journal of Psychiatry, 55(Suppl 3), pp. S311–S318.Thayer, J.F. and Lane, R.D. (2000) 'A model of neurovisceral integration in emotion regulation and dysregulation', Journal of Affective Disorders, 61(3), pp. 201–216.

Thayer, J.F. and Lane, R.D. (2007) 'The role of vagal function in the risk for cardiovascular disease and mortality', Biological Psychology, 74(2), pp. 224–242. Available at: https://doi.org/10.1016/j.biopsycho.2005.11.013.

Thayer, J.F. and Sternberg, E. (2006) 'Beyond heart rate variability: Vagal regulation of allostatic systems', Annals of the New York Academy of Sciences, 1084, pp. 284–294.

Tobaldini, E., Pecis, M., & Montano, N. (2013) 'Effects of sleep deprivation on heart rate variability: a narrative review', Sleep Medicine Reviews, 17(1), pp. 1–9.

Udo, T., Mun, E.Y., Buckman, J.F., Vaschillo, E.G., Vaschillo, B. and Bates, M.E. (2013) 'Potential Side Effects of Unhealthy Lifestyle Choices and Health Risks on Basal and Reactive Heart Rate Variability in College Drinkers', Journal of Studies on Alcohol and Drugs, 74(5), pp. 787–795. Available at: https://doi.org/10.15288/JSAD.2013.74.787

Wagner, D.R., Coyle, D.C., Johnson, K.E. (2012) 'Body composition and heart rate recovery after submaximal exercise in healthy young adults', Journal of Strength and Conditioning Research, 26(8), pp. 2060–2066.

Wilks, S.E. (2008) 'Resilience amid academic stress: The student perspective', Journal of College Student Development, 49(6), pp. 605–620.

Wimmer, S., Lackner, H.K., Papousek, I. and Wilhelm, F.H. (2019) 'Influences of different dimensions of academic self-concept on students' cardiac recovery

after giving a stressful presentation', Psychology Research and Behavior Management, 12, pp. 883–894. Available at: https://doi.org/10.2147/PRBM.S219784

Zamuner, A. R., Porta, A., Andrade, C. P., & Catai, A. M. (2020). Gender differences in autonomic control of heart rate variability following aerobic exercise training. *Clinical Autonomic Research*, *30*(2), 145–153.

INFORMED CONSENT

My name is Omorotionmwan Efosa Martins, a final year student of the Department of Physiotherapy, School of Basic Medical Sciences, College of Medical Sciences, University of Benin, Benin City, Edo State. I'm carrying out a research title "A Clinical Investigation of Heart Rate Recovery as an Index of Autonomic Function in Healthy Young Adults: Implications for Preventive Screening" This research will be conducted as part of the requiremen for the award of Bachelor of Physiotheapy (B.PT). Your participation is voluntary and uou are free to ask question about the study and you are also free to withdraw at any time you .Your response will be strictly confidential and will be used solely for the purpose of research. Please kindly include your signature and date if you are willing to particitpate.

---------- ----------

Participants's signature and date Researchers signature and date

APPENDIX I

DATA COLLECTION PROFORMA

Title of Study: _____
Participant Code: _____ Date: ___ / ___ / _____

SECTION A: INFORMED CONSENG

Informed Consent Obtained: □ Yes □ No
(Attach signed consent form)

SECTION B: DEMOGRAPHIC DATA

1. **Age:** _____ years
2. **Gender**: □ Male □ Female
3. **Faculty**:_____
4. **Department**: _____

SECTION C: CARDIOVASCULAR MEASUREMENTS

1. Resting Blood Pressure
2. Resting Heart Rate

SECTION D: ANTHROPOMETRIC MEASUREMENTS

Measurement	**Value**	**Units**
Height	_____	Cm
Weight	_____	kg
BMI	_____	kg/m^2

APPENDIX 2

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE-SHORT FORM (IPAQ-SF)

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ days per week

No vigorous physical activities Skip to question 3

2. How much time did you usually spend doing vigorous physical activities on one of those days?

_____ Hours per day

_____ Minutes per day

[ ] Don't know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis?

[ ] Do not include walking.

_____ Days per week

No moderate physical activities Skip to question 5

4. How much time did you usually spend doing moderate physical activities on one of those days?

_____ Hours per day

_____ Minutes per day

[ ] Don't know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

_____ Days per week

[ ] No walking Skip to question 7

6. How much time did you usually spend walking on one of those days?

_____ Hours per day

_____ Minutes per day

[ ] Don't know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure

time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the last 7 days, how much time did you spend sitting on a week day?

___ Hours per day
_____ Minutes per day
[ ] Don't know/Not sure

8. During the past 7 days how often have you done any light housework

such as dusting, sweeping, washing dishes.

___ Hours per day
_____ Minutes per day
[ ] Don't know/Not sure

9. During the past 7 days how often have you done any heavy housework

or chores such as scrubbing floor washing windows or wall

___ Hours per day
_____ Minutes per day
[ ] Don't know/Not sure

APPENDIX 3

PERCEIVED STRESS SCALE (PSS-10)

The questions in this scale ask you about your feelings and thoughts **during the last month.**
In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of. something that happened unexpectedly? 0 1 2 3 4
2. In the last month, how often have you felt that you were unable to control the important things in your life? 0 1 2 3 4
3. In the last month, how often have you felt nervous and "stressed"? 0 1 2 3 4
4. In the last month, how often have you felt confident about your ability to handle your personal problems? 0 1 2 3 4
5. In the last month, how often have you felt that things were going your way? 0 1 2 3 4
6. In the last month, how often have you found that you could not cope with all the things that you had to do? 0 1 2 3 4
7. In the last month, how often have you been able to control irritations in your life? 0 1 2 3 4
8. In the last month, how often have you felt that you were on top of things? 0 1 2 3 4
9. In the last month, how often have you been angered because of things that were outside of your control? 0 1 2 3 4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them? 0 1 2 3 4

RESEARCH ETHICS COMMITTEE

COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

Chairman: Prof. F. A Imarhiagbe
MBChb, FMCP
Cert Clin Res and ethics (NIH), MD.
0803449092

P.M.B 1154, BENIN CITY
Email: researchethics.cms@gmail.com

Our Ref: CMS/REC/01/VOL.2/804 **Date:** 29th July, 2025

Re: A CLINICAL INVESTIGATION OF HEART RATE RECOVERY AS AN INDEX OF AUTONOMIC FUNCTION IN HEALTHY YOUNG ADULTS: IMPLICATIONS FOR PREVENTIVE SCREENING.

Name of Principal Investigator: **OMOROTIONMWAN EFOSA MARTINS**
Department Of Physiotherapy,
School of Basic Medical Science,
College of Medical Sciences,
University of Benin.

REC Approval No: CMS/REC/2024/804

This is to inform you that the research described in the submitted proposal, the Informed Consent Forms and other participant information materials have been reviewed and approved by the College Research Ethics Committee, University of Benin.

This approval dates from **29th July, 2025 to 28th July, 2026.** In multi-year research, Endeavour to submit your annual report to the REC early in order to obtain renewal of your approval and avoid disruption of your research.

The National Code of Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the code including ensuring that all adverse events are reported promptly to the REC. No, changes are permitted in the research without prior approval by REC except in circumstances outlined in the code. REC reserves the right to conduct compliance visit to your research site without prior notice. Thank you.

PROF. F.A IMARHIAGBE
Chairman, REC