Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical assessments

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Submitted in fulfilment of the requirements for the
DOCTOR OF PHILOSOPHY IN EMERGENCY MEDICAL CARE
in the
DEPARTMENT OF EMERGENCY MEDICAL CARE AND RESCUE
FACULTY OF HEALTH SCIENCES
DURBAN UNIVERSITY OF TECHNOLOGY

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DECLARATION

I, Erefaan Ismail, do hereby declare that:

- this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary);
- this dissertation has not been submitted for any degree or examination at any other university; and
- this dissertation does not contain another person's data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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ETHICAL CLEARANCE

This is to confirm that full approval to conduct research had been granted by the Institutional Research Ethics Committee (IREC) of the Durban University of Technology (DUT) in KwaZulu-Natal for the purposes of this dissertation.

Institutional Research Ethics Clearance Number: IREC 075/20

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ABSTRACT

Background

This study presents a comprehensive insight into the degree of psychological stress experienced by paramedic students during clinical assessments. Available evidence shows that high anxiety levels may impact performance negatively, which can lead to poor patient safety outcomes. To achieve the objectives of the study, multiple validated psychological and physiological biometric tools were utilised to generate the most accurate and 'complete' stress profiles for this cohort to date.

Methodology

At a specific university, the total undergraduate Bachelor's Emergency Medical Care (BEMC) student population was (n) 83 students, of which (n) 56 enrolled as voluntary participants to form the experimental group. Data collection occurred during this cohort's final-term clinical assessments. Meanwhile for comparison, the control group's data (n 15) was collected during their clinical simulations practice in class (non-assessment conditions). Psychological stress was measured using the validated State-Trait Anxiety Inventory Questionnaire and concurrently, the following stress indicators were utilised to capture the participants' physiological biomarkers, which included saliva samples (for both α-amylase and cortisol assay), heart rate, respiration rate, as well as heart rate variability, as recorded by the Hexoskin smart vest' connected platform. To the author's knowledge, it was the first time in Africa that this biometric online technology was utilised to capture respiration and cardiovascular stress biomarkers in this context.

Results

The State-Trait Anxiety Inventory results showed a strong positive correlation between the Y2 scores before and after assessment ($r = 0.78$). In addition, there was a moderate positive correlation ($r = 0.78$, $p = <0.001$) between the total State-Trait Anxiety Inventory score, before assessment and the total State-Trait Anxiety Inventory score after assessment, meaning the participants experienced elevated anxiety levels at each point in time. The majority who indicated they experienced elevated anxiety levels (87.5%; n = 49), showed a linear relationship between their measured biomarkers and State-Trait Anxiety Inventory anxiety scores. For example, a statistically significant association was observed between the Y2 scores and RR, for the period after the experiment, particularly in the group with a Y2 score of >40. When the data was stratified by year of study, a similar significant association occurred

between the State-Trait Anxiety Inventory scores and observed RR ($p<0.001$). The mean heart rate for the exposed group were significantly higher ($p = 0.026$) for the before and during assessments, but not after the assessments ($p = 0.2$), when compared to the mean HR for the control group. The experimental groups' Heart Rate Variability (only standard deviation of normal-to-normal R-R intervals method) during the assessments were significantly higher than the control group ($p = 0.020$). However, there were also exceptions to this linear relationship 'rule', specifically related to the salivary assay results, where the findings of the α-amylase assay over time (before and after assessment), revealed that the enzyme levels of the enzyme decreased over time, although the change in concentration was not statistically significant ($p = 0.31$). In contrast, there was a significant difference in the cortisol assay results of the first-year group, in comparison to the groups of other years, both their before- ($p = 0.006$) and after-experiment results ($p = 0,003$).

Conclusion

The study findings highlighted that both the control and experimental groups were exposed to clinical simulation-based learning environments which predisposed them to elevated anxiety levels (before, during and after these activities), which may impact learning and performance negatively. Ultimately, students must develop the ability to integrate their cognitive ability, specialised practical knowledge and ethical awareness, including stress management skills into clinical practice to become caring and professional healthcare providers (paramedics).

Key words:

paramedicine; paramedic undergraduate students; psychological anxiety indicator; physiological stress biomarker; clinical assessments; simulations, clinical performance

ACKNOWLEDGEMENTS

This thesis was developed with the support and direction from my supervisor and co-supervisors. Therefore, I would like to acknowledge my supervisor, Prof Champaklal Chhaganlal Jinabhai, for his research expertise which was invaluable from the conception of this academic journey, as well as my co-supervisors, Dr Dorcas Rosaley Prakaschandra and Dr Simpiwe Sobuwa, for contributing their extensive knowledge in health sciences research and expert advice, which were essential to the completion of this body of work.

A special thanks of appreciation to all the students of the DUT BEMC programme (Class of 2020) for their participation, without who this study would not have been possible.

Likewise, I would like to express my sincere gratitude and acknowledgement to the following individuals for their invaluable contributions:

- Dr Suresh Babu Naidu Krishna, Department of Biomedical and Clinical Technology for his mentorship and overseeing the salivary assay procedures
- Derrick Govender, for sharing the “pearls” of lab work;
- Gaositwe Melvin Makolomakwa, for providing access to the specialised equipment his laboratory;
- Catherine Connolly, for her positive engagement and assistance with the data analysis;
- Juanita du Toit, for providing valuable guidance and expert language editing;
- Mrs Avenal Finlayson (Durban University of Technology library), for her guidance and efficient service obtaining full-text articles; and
- The academic staff of Durban University of Technology BEMC programme, who assisted with the information sharing of the study and for being accommodating during the data collection sessions (during classes and examinations).

Lastly, to my family. This journey would not have been possible without their unwavering support and many sacrifices.

SHUKRAN. THANK YOU!

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LIST OF ABBREVIATIONS

ALS: Advanced life support

ANS: Autonomic nervous system

BEMC: Bachelor of Emergency Medical Care

BHSc EMC: Bachelor of Health Sciences Emergency Medical Care

CCC: Concordance correlation coefficient

CLT: Cognitive load theory

CPR: Cardiopulmonary resuscitation

DUT: Durban University of Technology

ECG: Electrocardiogram

ECP: Emergency care practitioner

EMC: Emergency medical care

EMS: Emergency medical service

HOD: Head of Department

HPCSA: Health Professions Council of South Africa

HR: Heart rate

HRV: Heart rate variability

ICC: Intraclass correlation coefficient

IREC: Institutional Research Ethics Committee

JBI: Joanna Briggs Institute

OSCE: Objective structured clinical evaluations

pNN50: Proportion of number of times successive R-R intervals exceed 50 ms

RMSSD: Root mean square of successive differences

PRISMA-ScR: Preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews

RMSSD: Root mean square of successive differences

RR: Respiration rate

SAQA: South African Qualifications Authority

SDNN: Standard deviation of normal-to-normal R-R intervals

SCDC: Student Counselling and Development Centre

WHO: World Health Organisation

WM: Working memory

GLOSSARY OF TERMS

This is a list of the operational definitions used in this text.

- **Paramedic undergraduate students:** students registered for the four-year bachelor's degree Emergency Medical Care programme
- **Clinical:** the reproduction of an effect (such as sound or sensation) that is almost indistinguishable from a similar human-produced effect (for example, a heartbeat or pulse)
- **Emergency care practitioner:** the holder of a four-year degree and a paramedic working in the prehospital environment
- **Medical harm:** causing accidental physical injury to a patient due to medical clinical errors (either by performance or by omission)
- **Patient safety:**- the simplest definition of patient safety is the prevention of errors and adverse effects to patients associated with health care
- **Self-efficacy:** one's belief in one's ability to succeed in specific situations or accomplish a task. One's sense of self-efficacy can play a major role in how one approaches goals, tasks, and challenges (Psychologist, Albert Bandura).

Tools and test measures:

- **Biomarker:** a distinctive biological or biologically derived indicator (such as a metabolite) of a physiological process, event, or condition.
- **Biometrics:** using modern scientific technologies to measure physiological and behavioural characteristics specific to an individual. This data can then be analysed to provide scientific evidence for an individual's physical and mental health status.
- **Stress:** a physical, chemical, or emotional factor that causes bodily or mental tension and may be a factor in disease causation (Merriam Webster)
- **Acute psychological stress:** occurs suddenly when an individual perceives that prevailing circumstances surpass his or her emotional resilience
- **Clinical simulations:** Simulation education in a clinical laboratory which endeavours to enhance theoretical learning and emulate real-life clinical experiences
- **Clinical performance:** executing patient management interventions efficiently, without causing harm
- **Salivary cortisol:** is found throughout the body and produced by the adrenal glands. It is released in stressful situations and actively involved in a multitude of physiological functions (for example, the regulation of calcium absorption, blood pressure

maintenance, anti-inflammatory function, gluconeogenesis, gastric acid, pepsin secretion and immunity)

- **Alpha (α) amylase:** plays an important function in the process of digestion. It has been found to be useful as a biomarker of activity in the autonomic nervous system.
- **Hexoskin Smart Vest:** a ‘smart’ garment embedded with the latest biometric monitoring technology (including continuous monitoring of cardiac, respiratory, sleep and activity tracking). It can record and upload this biographical data to cloud storage for analysis.

CHAPTER ONE: INTRODUCTION AND OVERVIEW OF THE STUDY

1.1 Setting the scene

"Men have different capacities and react differently to stress. But the stronger ones raised up the weaker ones, and both became stronger in the process" (Nelson Mandela)

The literature abounds with the many detrimental effects associated with acute stress on our health, including emotional, social, cognitive and physiological consequences (Konduru, 2012). Stress has been defined as "the bodily expression of the generalized call to arms of the defensive forces of the organism" (Selye, 1984). The acute stress response is experienced as the result of an immediate perceived threat. It is characterised by an activation of the autonomic nervous system (ANS) with an increase in cortisol and adrenalin levels, increased heart rate, quickened breathing (Schuurmans et al., 2021). The higher education environment also presents its own form of psychological and physiological acute stress on students, impacting cognitive function negatively (Saleh et al., 2017). This has been documented prolifically in health professions students who describe learning in the healthcare environment as stressful, thus creating barriers to learning (Khajehei, Ziyadlou, Hadzic and Kashefi, 2011; Rafidah, Azizah, Norzaidi, Chong, Salwani and Noraini, 2009; Sarid, Anson, Yaari and Margalith, 2004; Sobuwa, 2018), as well as contributing to high discontinuation rates (Sobuwa, 2018).

Various pedagogical approaches are incorporated during undergraduate paramedic training, as it involves both academic outcomes (theory components), as well as strenuous physical outcomes related to rescue activities (such as swimming and endurance exercises). Clinical simulation has become an integral component of undergraduate health care education across professional boundaries (Bradley, 2006). Clinical patient care clinical simulation provides learners with an opportunity to engage with real-life clinical scenarios and allows for the cultivation of a patient safety culture in a laboratory setting (Bradley, 2006). Other simulation benefits include better acquisition of knowledge and the promotion of self-directed lifelong learning, as compared to traditional teaching (Scalese et al., 2008). In addition, when a student is successful at performing a simulated clinical scenario, his or her self-efficacy receives a boost, which is an important attribute that can influence an individual's confidence in performing new tasks (Morfoot & Stanley, 2018). However, stressful emotions, which include fear and anxiety, may impact an individual's cognitive function negatively (Russo, Stetz and Thomas, 2005). For example, during aviation simulation training, a mayor safety module such as mechanical failure with extreme case scenarios can be practiced. Although highly stressful,

pilots acquire the ability to manage their negative emotions and to make split-second complicated decisions (Lehrer, 2009).

The World Health Organization (WHO) developed the international patient safety event classification, which defines a patient safety event as “an event which resulted in, or could have resulted in, unintended harm to a patient by an act of commission or omission, not due to the underlying medical condition of the patient” (World Health and Safety, 2010). Acute psychological stress of health care providers may therefore directly contribute to medical harm and poor patient safety, as these stressors can lead to either “therapeutic misadventures or iatrogenic injuries” (World Health and Safety, 2010). It was reported that up to 440 000 patients die due to medical harm in the United States of America. Cancer and heart disease, followed by medical errors, are the leading burdens of disease in America (Makary & Daniel, 2016).

Human error, such as omission, is a major contributing factor which leads to medical errors. Human error can be viewed as a cognitive failure causing a mishap in a physical action, which “cannot be attributed to chance” (Zhang, Patel, Johnson, and Shortliffe, 2004). Furthermore, it was reported that due to the inefficient prehospital EMS systems on the African continent, there has been an increase in prehospital morbidity and mortality (Stein, Mould-Millman, De Vries, and Wallis, 2016).

In South Africa, there is a high number of poor patient-care incidents. The National Health Department has labelled these as patient safety incidents, which can be described as incidents where a patient is harmed or harm could have occurred, unrelated to the patient’s prevailing medical condition (Department of Health National Guideline, 2016). Although international studies have explored the role of psychological stress in healthcare professionals, there is a paucity of evidence specifically related to South African undergraduate paramedic students and whether stress may translate to poor patient care (clinical performance).

1.2 Background and significance

Emergency care practitioners (ECPs, or paramedics) are at the frontline of healthcare in South Africa, providing the initial care of the critically ill or injured patient. The profession can be both exciting and gratifying, especially when a clinical intervention leads to a good prognosis and reduce or limit mortality rates. A four-year professional degree in Emergency Medical Care equips graduates with advanced life support (ALS) and medical rescue skills, allowing for

registration as autonomously practicing clinicians with the Health Professions Council of South Africa (HPCSA – ECP).

Full-time paramedic degree courses are offered at most universities across South Africa. Presently, these universities employ a body of lecturers who have been recruited from the operational prehospital environment. However, not many have a teaching diploma or degree and their exposure and/or understanding of various pedagogical teaching strategies may be limited. Subsequently, learner-centred pedagogy to teaching, learning and assessment may take some time to evolve (Sobuwa, 2018).

Undergraduate paramedic students may find learning about the 'jaws of life' exciting and non-stressful. In contrast, learning about the responsibility of having someone's life in their hands may be very stressful. For this reason, clinical simulation has become an integral component of under-graduate health care education across professional boundaries (Bradley, 2006). Clinical patient care simulation provides learners an opportunity to engage with real-life clinical scenarios and allows for the cultivation of a patient safety culture in a laboratory setting (Bradley, 2006). Other simulation benefits include the acquisition of knowledge and the promotion of self-directed lifelong learning by physicians, compared to traditional teaching (Issenberg et al., 1999). Furthermore, when a student is successful at performing a simulated clinical scenario, his or her self-efficacy receives a boost, which is an important attribute that can influence an individual's confidence to perform new tasks (Morfoot & Stanley, 2018). Self-efficacy implies that for an individual to perform a skill successfully, the individual has to have faith or believe in themselves first (Bandura, 1977). In the nursing profession, evidence suggests that nursing practitioners' perception of their self-efficacy directly influences their patient care abilities (Dunn, Osborne and Link, 2014).

In South Africa, clinical simulation is an inherent component utilised during the training of paramedic students. It forms part of the continuous assessment processes which the undergraduate student must pass in order to be registered as an ECP (HPCSA, 2020). The current literature is inconclusive on the contribution of stress to learning. Studies have shown that performing clinical simulation under stress is linked to enhanced performance and retention of skills (DeMaria Jr et al., 2010). In addition, simulation practice also promotes good interdisciplinary teamwork and that, even if healthcare practitioners experience significant skills decay (possibly due to working as an administrator), by using simulation, they improved their theoretical knowledge, psychomotor skills and self-reported comfort (Bender, Kennally, Shields and Overly, 2014). On the other hand, excessive stress may negatively affect performance and learning outcomes, as students may make clinical judgement errors under

pressure (Bong, Fraser and Oriot, 2016), and the literature suggests that clinical simulation may introduce its own stress and anxiety – areas which are unexplored in emergency medical care students in South Africa.

Stress can be defined as “a physical, chemical or emotional factor that causes bodily or psychological/mental tension and may be a factor in disease causation” (Mariam-Webster, 2019). It is well documented that acute stress can alter numerous biological functions and lead to the release of chemicals which can help cope with the stressor(s) (McEwen et al., 2015). The central nervous system is able to activate various neural pathways as a defence against acute stress, through hormonal, cognitive, emotional and physiological responses (Joëls & Baram, 2009). As Figure 1 demonstrates, stress has a multitude of external influences and corresponding physiological chemical mediators which are activated and/or released due to these factors. The endocrine, immune and central nervous systems are closely connected and stress hormones can easily cross the blood–brain barrier, which can affect learning and memory (Lupien, Mcewen, Gunnar and Heim, 2009). Psychological stress impacts cognition in both positive and negative ways. However, ultimately, psychological stress is perceived as a negative experience (Starcke & Brand, 2012).

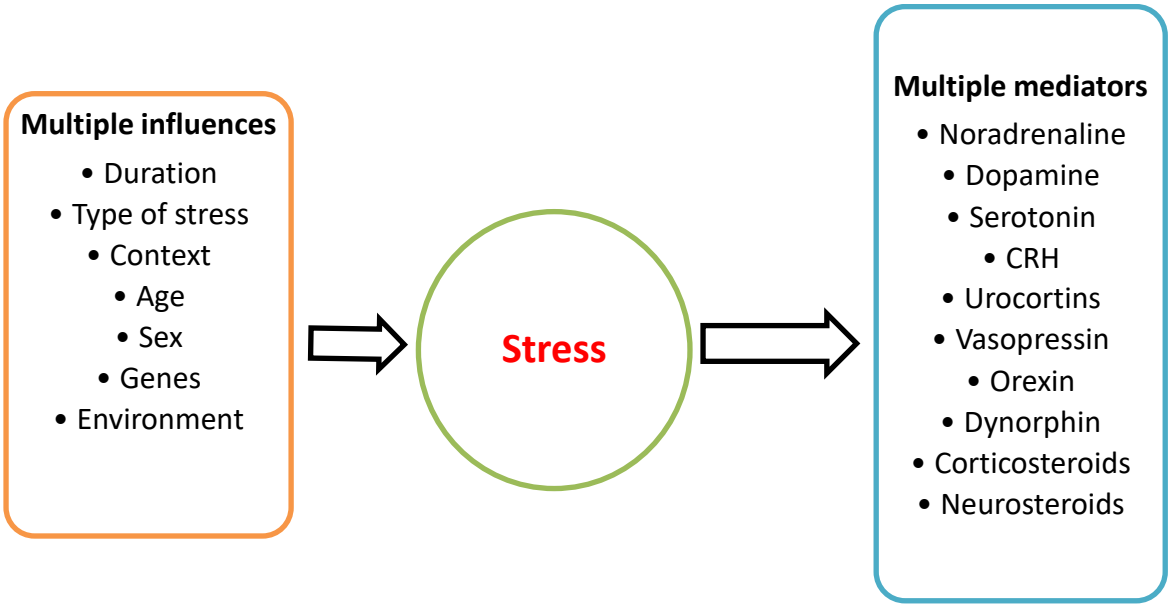

Figure 1: Representation of stress influences and chemical mediators (adapted from Joëls & Baram, 2009)

Studies have highlighted that the stress incorporated during simulation training can have a positive effect on the performance and retention of clinical skills (Clarke et al., 2014; DeMaria Jr et al., 2010). However, in other studies high levels of stress affected the clinical performance of paramedics negatively, which lead to both communication misunderstandings and drug administration miscalculations (LeBlanc et al., 2012). Another study suggests that learning under duress may impair the retention of knowledge and affect the recollection of knowledge negatively (Schwabe & Wolf, 2010).

However, there is a paucity of research exploring the effect of physiological and psychological stress of undergraduate paramedic students, especially during clinical assessments, which can be very stressful activities (Dyrbye, Thomas and Shanafelt, 2005). Technological advances have evolved and created novel solutions which are able to collect physiological stress biomarkers (including cardiac and respiratory vital signs) incorporated in smart wearable clothing (Paradiso, Loriga, and Taccini, 2005; Cherif, Mezghani, Gaudreault, Ouakrim, Mouzoune and Boulay, 2018). The current study utilised both older technologies (a psychological questionnaire and saliva sampling) and incorporated a new 'smart vest' technology (Hexoskin smart vest smart vest, 2019) to use as comparison which will for the first time in Africa, provide a comprehensive understanding of the stress levels experienced by this cohort during clinical assessments.

1.3 Problem statement

The prehospital domain in which paramedics serve the public is a stressful environment, with multiple high-anxiety situations which may lead to elevated stress levels. These situations include resuscitating children with major trauma or treating gunshot victims, where the paramedic's own life may also be in danger on the scene. To prepare undergraduate paramedic students for these stressful events, they are exposed to the management of these types of cases using clinical simulation. Some excel and will perform the clinical tasks and/or management of the 'patient' flawlessly, while others falter and state: "I went blank …" or "I could not remember anything…" A few will even have "tunnel vision" and perform tasks which are not required, becoming unsafe and the simulation will need to be stopped.

Clinical simulations can be designed to evoke high psychological stress, for example when the scenario involves the resuscitation of a child. The researcher's own clinical simulation exposure, from initial undergraduate emergency medical care training to currently as an assessor, examiner and/or moderator of clinical simulation assessments, perceived stress and/or anxiety in students in the laboratory as a culmination of multiple factors. These include:

- the weighting of the assessment (for example, first term assessment versus exit level);

- the learner's theoretical knowledge;
- the assessors present in the exam venue (some are viewed as being more lenient than others);
- the clinical team dynamics (for example, errors and/or omissions of a partner can be distracting or frustrating for the learner being assessed);
- the learner's clinical competencies (which depend on how much preparation and/or practice the learner invested prior to the assessment); and
- the learner's personality and coping style to adapt and/or focus on the task at hand.

Stress may impair memory in certain situations, such as when a person forgets an important appointment due to experiencing a heavy workload (Schwabe et al., 2009). However, the same person might remember the details of a traumatic event from their childhood, vividly remembering minute details decades later, suggesting that stress enhances memory (Schwabe & Wolf, 2010). Others postulate that stress may affect clinical performance negatively (Joëls et al., 2006). Psychological stress during these assessments (which includes Viva Voce – a verbal exam, as well as practical simulation and objective structured clinical examinations – OSCE) was suggested as the key barrier to academic success on the Bachelor of Emergency Medical Care (BEMC) degree. In addition, a recent study by Sobuwa (2018) found that clinical assessments lead to the delayed graduation of undergraduate paramedic students. It is unclear at this stage to what degree this form of psychological stress as a teaching activity promotes or impedes effective learning in undergraduate paramedic students in South Africa.

1.4 Aims and objectives

The study research aim was to assess the psychological and physiological stress which undergraduate paramedic students experienced during clinical assessments.

The following objectives were identified for this study.

1. To describe the trends between different stress biomarkers of paramedic students before, during and after clinical assessments.
2. To explore the associations between different physiological stress biometric data of paramedic students before, during and after clinical assessments and trends among the four different year groups of students.
3. To establish whether there is any association between the physiological stress biomarkers (cardiac and/or respiratory data from the Hexoskin smart vest smart vest 'smart vest', salivary α-amylase versus cortisol levels) and the undergraduate

paramedic students' perceived psychological stress (State-Trait Anxiety Inventory - STAI questionnaire) between the different year groups, before and after clinical assessments.

4. To evaluate the impact of physiological stress biomarkers and their perceived psychological stress before, during, and after their clinical assessment of undergraduate paramedic students on their assessment results.
5. To compare the different biomarker data sets and identify the biomarker which most accurately correlates to the participant's perceived psychological stress.

1.5 Research design

The current research utilised a descriptive exploratory pre-test–post-test study design (quantitative paradigm) to establish the associations between psychological stress (according to the STAI questionnaire) and physiological stress biomarkers (as recorded by the Hexoskin smart vest smart vest 'smart vest' and salivary sampling – cortisol and α-amylase assay) throughout clinical assessments.

1.6 Population or target population

The target population consisted of all undergraduate paramedic students registered with the Department of Emergency Medical Care and Rescue (Durban University of Technology) for the Bachelor's Emergency Medical Care (BEMC) degree programme. After obtaining the necessary gate-keeper permission and access, at the time of data collection (2020 final-term assessments), the total population was (n) 83.

1.7. Sampling method and size

Purposeful sampling (also called judgment sampling) was employed to create a sample, with the intention of generalising from the sample to the overall study population (Patton, 1990). This implies that the sample units (in this case undergraduate paramedic students) share similar attributes and/or characteristics such as similarities in terms of experience, specific skill set, background, age, etc.). Specifically, total population sampling involves examining the entire study population. The advantage of total population sampling is that it incorporates all potential participants within the population of interest, allowing for a wide range of insights. It is a purposive sampling technique and therefore one cannot make statistical generalisations about the sample being studied. However, this method does allow for analytical generalisations of the study population (Etikan, Musa and Alkassim, 2016).

1.8 Data collection

The participants wore their Hexoskin smart vest smart vest ‘smart vests’ for the duration of their assessments. This allowed for continuous (before-, during- and after-assessment) physiological data capture of their biometrics (both respiratory and cardiac biomarkers). They were asked to complete the STAI questionnaire before and after their assessment. The STAI questionnaire focussed on the participants’ demographics and explored their perceived psychological stress experienced before, during and after their clinical assessment (Appendix 8). Lastly, saliva samples for α-amylase and cortisol measurements were collected, also before and after their assessments. It was kept cool using ice packs until data collection for that session was complete, and then frozen to –20 ^{0}C until ready to be thawed for processing.

1.9 Pilot testing

A pilot study was conducted prior to the commencement of the primary study. The necessary information was emailed to the lecturer, with the intention of recruiting voluntary participants. After waiting a week, a total of 6 (n) students had volunteered to participate. On the day, multiple data sets were recorded. However, not all the information was readily available for analysis.

1.10 Ethical considerations

The current study recruited students as the target population and therefore many factors were considered to ensure ethical compliance. The main elements included the right to autonomy and confidentiality, avoiding harm, fair treatment and seeking informed consent (Brink, 2009).

1.11 Overview of chapters

This is a breakdown of the chapters in this work.

Chapter One: Introduction and overview of the study

Chapter One provides a detailed introduction and background to this study. It described the study aim, objectives, problem statement and the significance of the study.

Chapter Two: Literature review

Chapter Two is a critical assessment of the literature regarding psychological and physiological stress affecting healthcare professionals, specifically related to paramedic students, as well as identify any knowledge gaps related to this topic. The search included non-indexed grey literature, clinical trial registries and unpublished thesis sources.

Chapter Three. Research Methodology

This chapter highlights the research design and methodology chosen for this study. It elaborates and justifies the methods used in conducting this research, describing how it relates to the aims and objectives of the study.

Chapter Four: Results

The results represent all the ‘raw’ data from the various data collection tools which was analysed with the help of a biostatistician. The analysis process was guided by the study aims and objectives, specifically seeking answers as reported in the problem statement.

Chapter Five: Discussion

This chapter represents an in-depth discussion to interrogate and highlight the findings in relation to the aims and objectives of the study.

Chapter Six: Conclusions and recommendations

The final chapter provides a comprehensive overview for the conclusions of the study and also proposes recommendations garnished from this endeavour.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Medical training can be a stressful experience for some students, which may affect their mental well-being and academic performance negatively (Rafidah, Azizah, Norzaidi, Chong, Salwani and Noraini, 2009; Sarid, Anson, Yaari and Margalith, 2004; Sobuwa, 2018), as well as contribute to high discontinuation rates (Sobuwa, 2018). Learning to become a paramedic requires various teaching methodologies, as it requires both physical (rescue activities) and mental (theory assessments) pedagogical approaches. Clinical simulation has become an integral component of under-graduate health care education across professional boundaries (Bradley, 2006). Clinical patient care simulation provides learners an opportunity to engage with real-life clinical scenarios and allows for the cultivation of a patient safety culture in a laboratory setting (Bradley, 2006). Other simulation benefits include better acquisition of knowledge and the promotion of self-directed lifelong learning, as compared to traditional teaching (Scalese et al., 2008). Furthermore, when a student is successful in performing during a simulated clinical scenario, his or her self-efficacy receives a boost, which is an important attribute that can influence an individual's confidence to perform new tasks (Morfoot & Stanley, 2018).

2.2 Methods

This research is a thorough and descriptive review, using the JBI methodological guidelines for scoping reviews (Peters et al., 2020), which is drafted according to PRISMA-ScR (preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews) reporting guidelines (Tricco et al., 2018). A scoping review is defined as a type of research synthesis that aims to "map the literature on a particular topic or research area and provide an opportunity to identify key concepts; gaps in the research; and types and sources of evidence to inform practice, policymaking and research" (Daudt, van Mossel and Scott, 2013).

A literature search was conducted using six international indexed databases (namely Cumulative Index to Nursing and Allied Health Literature (CINAHL) Complete, Medline with Full Text, ProQuest Health and Medical Complete, Pubmed, Science Direct and Google Scholar databases). The researcher used the following key search phrases: "impact of stress on paramedic student clinical performance"; "impact of health care practitioners' stress on patient safety"; "stress leading to clinical errors and adverse events"; "physiological and psychological stress impact on performance" and "clinical simulation for learning and teaching".

2.3 Types of evidence sources

Sources which were peer-reviewed and available online were identified to answer the research questions. The search included non-indexed grey literature, clinical trial registries and unpublished thesis sources. The author then expanded the search, by using the reference lists of the selected articles. The sources searched were mostly in English or if initially found in another language, an English version was traced (depending on availability).

2.4 Search strategy

The various databases which were searched, produced a multitude of results, for example using the CINAHL database (Table 1) provided the items listed below.

Table 1: CINAHL database search results

Search phrase	**Results**
impact of stress on paramedic student clinical performance	4,188
impact of health care practitioners' stress on patient safety	134,934
stress leading to clinical errors and adverse events	80,194
physiological and psychological stress impact on performance	2
clinical simulation for learning and teaching	54

Reference management software was utilised to amalgamate search results and remove duplicate records (EndNote). Titles and abstracts of results were independently assessed by a single author to eliminate recognisably irrelevant literature and obtain full text documents of potentially eligible studies. Full-text studies were examined for inclusion or exclusion criteria. Also, no language, date or publication limits were applied to the search strategies, which were conducted up to December 2020. A flow diagram (see Figure 2 below) was created to illustrate the systematic study selection process.

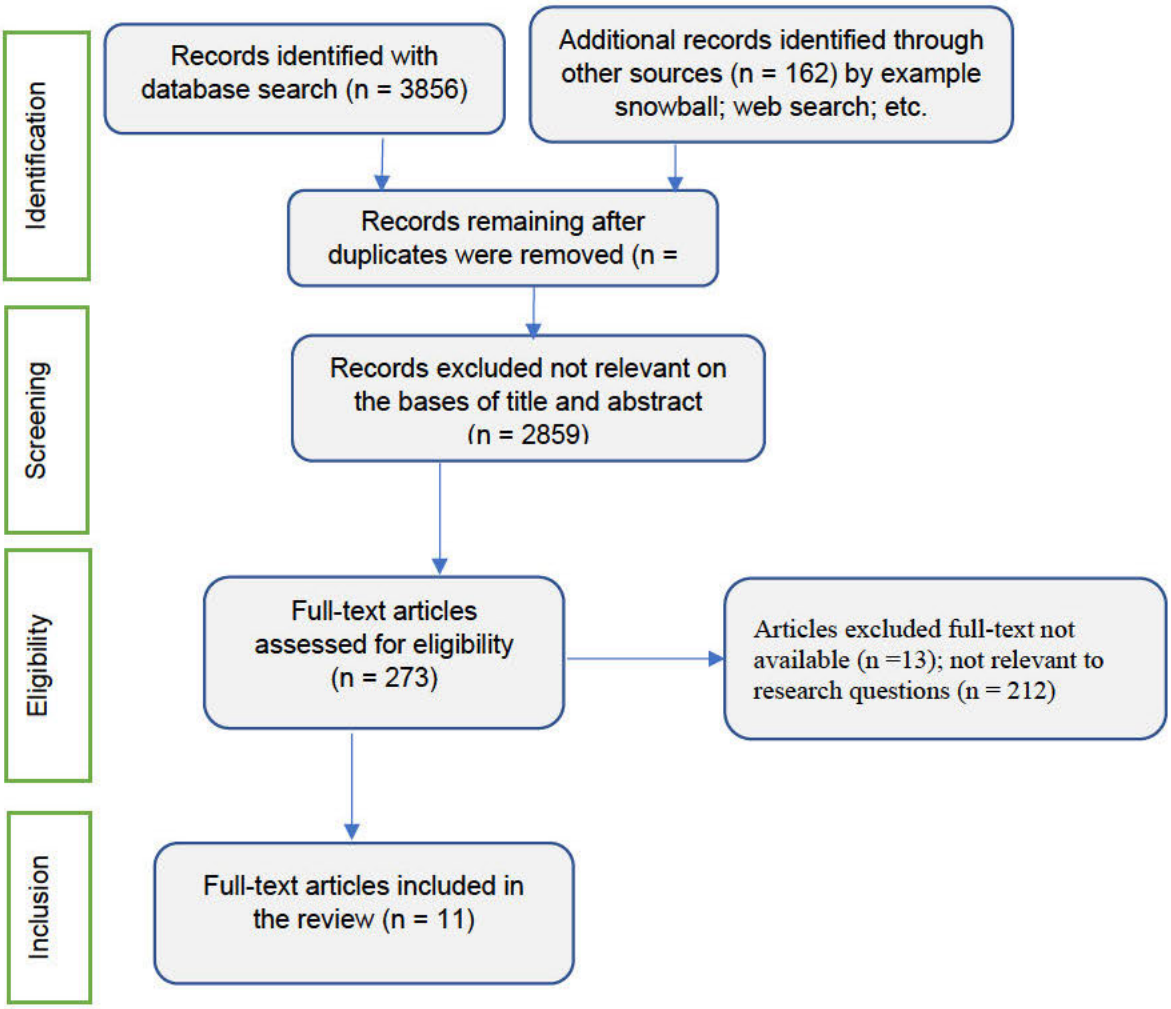

Figure 1: PRISMA flow diagram of study selection process

2.5 Inclusion criteria

Eligible literature for inclusion was independently screened by a single author. Both empirical and non-empirical studies of stress, affecting the clinical performance of prehospital and in-hospital healthcare students were included in this review. There were no exclusion criteria applied to the study design types.

2.6 Population

The population was adult (18 years and older) undergraduate or postgraduate healthcare students enrolled at a tertiary education institution, where clinical simulation is used as a learning and teaching pedagogy. Studies that focussed on qualified healthcare practitioners experiencing stress while performing their patient-care duties, were also included.

2.7 Concept

This scoping review aimed to detect key concepts in the published literature which describes the effect of stress on undergraduate paramedic students' performance during clinical simulation assessments, as well as to identify any knowledge gaps related to this topic. The scope of this enquiry was guided by the following research questions.

1. How does stress affect clinical performance?
2. What are the documented judgement errors or adverse events that occur in the healthcare environment due to stressful situations?
3. How can clinical simulation be used as an effective learning and teaching pedagogy?

2.8 Context

The context of this scoping review will be Emergency Medical Care (paramedic) Degree programmes offered at Higher Education Institutions, where clinical simulation is utilised both as a teaching pedagogy and as a form of assessment. This review includes sources which explore the facilitator's experiences incorporating simulation in the classroom.

2.9 Sources of evidence selection

Selected sources were screened by incorporating the JBI methodology (Peters et al., 2020), which focusses on the population, concept, context and source type of the evidence. Following this filtering process, the sources were scrutinised to see if the full-text article was available.

2.10 Presenting the results

The short-listed sources were evaluated with the intention of providing evidence best to answer the review questions. This review will only be descriptive in nature and will not entail thematic analysis, whereby the researcher interrogated the data to identify common themes or patterns of meaning (Nowell, Norris, White and Moules, 2017). In addition, exploring the validity or quality appraisal of sources were explored, as this did not form part of a scoping review (Tricco et al., 2018). Summarising the evidence related to the review questions, the following conceptual categories emerged: stress effect on clinical performance, measuring psychological stress during clinical simulation, measuring physiological stress during clinical simulation (biometrics) and simulation as an education tool.

2.11 Discussion

Paramedics operate outside of the safety of the hospital environment, with few health care providers to assist on the scene. They are often the first responders to life or death situations which require immediate clinical decisions to affect patient outcomes positively. In contrast, a

physician (in-hospital) may have a team of nursing staff to assist with an emergency case. Therefore, paramedics may be working under high psychological stress, with limited time to make important clinical decisions and then execute their management plan flawlessly. During their undergraduate training, simulation has become a prominent form of assessment to avoid patient harm (Sobuwa, 2018).

The aim of this scoping review was to detect key concepts in the published literature which describes the effect of stress on the undergraduate paramedic student's performance during clinical simulation assessments. However, as indicated by the results, there are gaps in the available evidence which require further research related to this topic. Most studies are international and only one local study featured (see Table 2 below). In addition, further research is required to determine the evidence-based best practice describing the ideal simulation theoretical grounding, as well as facilitator guidelines for the delivery of pedagogical content knowledge, specifically for simulation during paramedic undergraduate training programmes.

Stress impact on clinical performance

Medical training has been recognised as a highly stressful experience for students, affecting both their physical and mental health (Dyrbye et al., 2005). It is for this reason that academic institutions have established student support centres, in order to have resources available to provide students with the necessary skills to cope with these stressors (Campo et al., 2008). Furthermore, a recent study found that simulation assessments lead to the delayed graduation of undergraduate paramedic students, which in turn directly influences the ALS paramedic workforce in South Africa. Psychological stress during these assessments was suggested as the key confounder to academic success on the Bachelor of Emergency Medical Care (BEMC) degree (Sobuwa, 2018).

Furthermore, modern day humans are overwhelmed by daily stressors which can accumulate, affecting the body's normal homeostasis and can sometimes manifest clinically with nausea and vomiting. Other symptoms may include a lack of concentration or lashing out in anger and frustration at minor events (Kowalski-Trakofler & Vaught, 2012). In addition, evidence indicated that physicians experience acute stress during emergency care situations and intensity of this alarm reaction phase may lead to negative effects on their emotional and physical well-being, as well as short-comings in performance and the quality of patient care (Dias & Scalabrini Neto, 2017).

Measuring psychological stress during clinical simulation

The literature describes multiple validated tools to measure levels of anxiety, which can be classified according to general measures of anxiety, severity of anxiety symptoms, self-reported anxiety and psychometric diagnostic assessment (Julian, 2011). The following four self-reported anxiety instruments are regularly cited in research studies:

1. Hamilton anxiety scale – which assesses the emotional state of adults and of family caregivers (Hamilton, 1959);
2. Goldberg anxiety scale – which assesses psychic and somatic anxiety (Magnavita, 2007);
3. State-Trait anxiety inventory – which evaluates anxiety as a personality trait and as an emotional state (Spielberger, 1983); and
4. Beck anxiety inventory (BAI) – which assesses symptoms of anxiety independent of symptoms of depression (Wang & Gorenstein, 2013).

Multiple psychometric studies have utilised the state-trait anxiety inventory as an anxiety measurement tool (Noto, Sato, Kudo, Kurata, and Hirota, 2005; Leblanc, Regehr, Tavares, Scott, Macdonald and King, 2012; Stein, 2020), as it has been assessed for validity and the overwhelming evidence indicates that it has acceptable internal reliability (Hishinuma et al., 2000). This assessment consists of two parts:

- State-anxiety scale (S-anxiety) which is characterised by high-state stress, such as during classroom examinations or military training programmes, where there is activation of the autonomic nervous system (ANS); and
- Trait-anxiety scale (T-anxiety) which evaluates the opposite emotional aspects such as a person's general states of calmness, confidence and security (Spielberger, 1983).

The STAI is used world-wide in research and has been translated into multiple languages, including Greek, Dutch, Japanese, Chinese, and Malaysian. It is suitable to administer in clinical practice and research, because of its "relatively brief self-report scale to assess both state and trait anxiety" (Bee Seok et al., 2018).

Measuring physiological stress during clinical simulation (biometrics)

Biometrics can be described as quantifiable physiological characteristics which are distinctive to a specific individual (Slamon, Penfil, Nadkarni and Parker, 2018). They have gained prominence in research, as the measurement of physiological biomarkers (for example, saliva α-amylase and cortisol, breathing rate and heart rate) which can be related to the health and wellness of an individual, as well as psychobiological markers for stress, anxiety and depression (Levine, Zagoory-Sharon, Feldman, Lewis and Weller, 2007).

One such study used these biomarkers to explore “stress-related output during burdensome work shifts and leisure time” and found acceptable “consistency of salivary α-amylase and cortisol total daily secretion between laboratory and field circumstances” (Karhula et al., 2017). The reason for incorporating multiple psychological stress biomarkers (tests) is due to previous studies highlighting possible discrepancies between the results of salivary biomarkers. For example, in a comparative study, salivary α-amylase sampling was found to be “a better index of stress” (Takai et al., 2004).

Technological improvements of wearable computers have enabled real-time physiologic biometric monitoring, which includes measuring biomarkers such as heart rate, respiration rate, galvanic skin response and movements (Martin, Jovanov and Raskovic, 2000). As highlighted above, physiological elements can be used to indicate an individual’s psychobiological stress level (Martin et al., 2000). According to the Carre Technologies website (Hexoskin smart vest smart vest, 2019), the Hexoskin smart vest smart vest Smart Garment (vest) is an intelligent vest with flexible sensors sewn directly into the fabric and it is perfectly machine washable. Using Bluetooth technology, these signals can be monitored remotely from a smart device (Hexoskin smart vest smart vest, 2019). It is embedded with several sensors (Hexoskin smart vest smart vest, 2019), including:

- Activity sensors, which record the movements (in three dimensions) and the acceleration of the user;
- Respiration sensors, to calculate the number of breaths per minute and the volume of air consumed; and
- Heart sensors in the form of electrodes, which can act as an electrocardiogram and deliver the heart rhythm (beats per minute).
-

The Hexoskin smart vest was initially developed to monitor and track athletes of high-level sport (Cherif et al., 2018). However, its usability and functionality make it suitable for usage in clinical settings. Their study aim was to validate the physiological data recorded by the Hexoskin smart vest smart vest Smart Shirt against data collected using a laboratory standard metabolic system. Statistical analysis for the physiological data validation included the intraclass correlation coefficient (ICC), the concordance correlation coefficient (CCC) and the Bland-Altman method, which validated the data of the Hexoskin smart vest smart vest smart vest (Cherif et al., 2018). Furthermore, another objective physiological stress measurement previously used in research and validated (Järvelin-Pasanen, Sinikallio, S. and Tarvainen, 2018; Thielmann & Boeckelmann, 2015) is heart rate variability (HRV). HRV indicates the periodic variations in the heart rate and can indicated “the relative contributions of the sympathetic and parasympathetic nervous system”, therefore it has been recommended as a

“reliable biomarker of stress and health” (Thayer, Åhs, Fredrikson, Sollers III and Wager, 2012).

Clinical simulation as an education tool

Simulation has become a valuable educational tool in healthcare training. Clinical simulation is designed to allow participants to demonstrate skills and enhance critical thinking in a safe environment to repeatedly reproduce prehospital patient situations (Jeffries, 2005). Moreover, paramedic student error rates were reduced when simulation was used to instruct specific programme components (Wyatt, Fallows and Archer, 2004). Another study looked at the effect simulation had on recent graduates as they transitioned from novices to confident professionals (Thomas & Mraz, 2017). While many factors affected this process (from novice to expert), many indicated that they were able to improve both communication and clinical decision-making skills, by recalling their initial exposure to simulation (Thomas & Mraz, 2017).

However, simulation-based training can be expensive (both for the initial purchase and ongoing maintenance), resource-intensive, time-consuming (to set up) and require additional rooms and/or space (ideally outside the classroom), which may be difficult in lower-income countries (Morfoot & Stanley, 2018). In addition, students may experience cognitive overload, as the outcomes for the clinical simulation may be too overwhelming, especially if there has been a lack of knowledge scaffolding or poor practicum exposure (Khan, 2015). Lastly, to use clinical simulation effectively as a teaching tool, the assumption is that the facilitators have the necessary skills and technological knowledge to convey specific outcomes (Mishra & Koehler, 2006).

2.12 Conclusion

Although this review found multiple studies related to stress, there is a paucity of literature related to the prehospital emergency care environment, and even less concerning the training of undergraduate emergency care students at South African tertiary institutions. To reduce medical errors or patient harm, further research is required using psychological and physiological stress markers, to assess if this cohort of students can navigate the stressors evoked during clinical assessments.

Table 2: Summary of evidence

Author(s), year	Country	Design and purpose	Sample	Findings	Limitations
Bender et al., 2014	United States of America	Randomised, controlled educational intervention to assess individual resident's resuscitation performance, procedural skill and teamwork behaviour	Medical school graduates (n = 50) from two Brown University affiliated residency programmes	● The intervention group demonstrated better procedural skills and teamwork behaviours ● Deliberate practice with simulation enhances teamwork The results caution against relying on cognitive measures to project clinical performance or patient outcomes ● Customising scenarios to the practitioners' clinical practices may optimise learning	Study limited to one scenario – resuscitation of a critically ill neonate
Clarke et al., 2014	United States of America	Prospective observational cohort study to assess medical residents' performance during simulations	Medical residents (n = 34) from the Department of Emergency Medicine at UC Davis Medical Centre	● Simulation is associated with physiologic stress, and heart rate elevation alone correlates poorly with both perceived stress and performance. ● Non-technical performance in the simulation setting may be more closely tied to one's level of clinical experience than to perceived or actual stress.	● Due to clinical time obligations of the residents, in depth psychometric testing pre- and post-simulation was not assessed ● Faculty members assess resident performance and may have been influenced by prior shared experience in the clinical environment
DeMaria et al., 2010	United States of America	Prospective observational study to determine whether a high-fidelity simulation with added emotional stress could provoke anxiety and, if so,	Medical students (n = 25)	● Simulation with added emotional stressors led to greater anxiety ● Emotional stress, may represent an important variable that affects the	● Participants were junior medical students with no appreciable clinical experience, which may have had an effect on their

		whether or not participants learning ACLS would demonstrate better written and applied knowledge retention six months after their initial course.		outcomes of simulation-based medical education	ability to perform during the mega code and to rate the realism of the scenario ● The voluntary nature of the study may have introduced selection bias ● The absence of more experienced practitioners and the small sample size are also limiting factors, despite the fact that statistical significance was achieved for several key outcomes
Dias and Scalabrini Neto, 2017	Brazil	Cross-sectional observational study to assess acute stress responses in residents during real emergency care and investigate the related personal and situational factors	Second-year internal medicine residents at the University of Sao Paulo Medical School (n = 48)	● Emergency care provoked substantial acute stress in residents ● Resident experience, trait anxiety and number of emergency procedures were independently associated with an acute stress response	The study was carried out in a single centre and included only second-year internal medicine residents, the findings may not necessarily generalize to other settings
Herrmann-Werner, Nikendei, Keifenheim,, Bosse, Lund, Wagner,, Celebi, Zipfel, and Weyrich, 2013.	Portugal	Randomised controlled trial to investigate the long-term retention of 'best practice' skills laboratory training (BPSL) versus a traditional 'see one, do one' bedside teaching (TRAD) in a simulated setting of two different procedural skills (nasogastric tube insertion, NGT, and IV cannulation (IVC) at	First-year medical students (n = 94)	The importance of skills laboratory training being an integral part of teaching students with respect to long-term performance	● Recruitment was voluntary, which may have lead to selection bias with only the very motivated students signing up ● We cannot exclude that some students practised the tasks on their own ● All teaching took place in a simulated environment

		undergraduate medical educational level			and therefore the generalisability of our findings with regard to clinical context
Khajehei et al., 2011	Iran	Cross-sectional study was undertaken to investigate various sources of stress among students and also explored the effect of stress on the students' performance, physical and mental health	Senior and junior full-time undergraduate midwifery students enrolled in a four-year full-time course at the Faculty of Nursing and Midwifery, Shiraz University of Medical Sciences (n = 90)	● Relationships with the clinical preceptors and the learning environment were identified as the two main sources of stress in the students ● Having performed under stress, students rarely experience personal satisfaction and their learning is more likely to be negatively affected	Inclusion criteria: The participants must have attended at least one clinical practice session ● This may imply that the data may be skewed, as a participant(s) may have limited clinical exposure to provide an accurate subjective assessment
Leblanc et al., 2012.	Canada	Prospective crossover study to examine paramedics' acute stress responses and performance during simulated high-stress scenarios	Advanced care paramedics from regional ambulance services (n = 22)	● The participants showed impairments on some aspects of clinical performance and in their ability to subsequently report information from the scenarios ● Clinical performance and documentation are vulnerable to stress	The effects of acute stress during a simulated clinical event were examined, which could raise concerns as to whether the findings are generalisable to clinical events with real patients
Morfoot. and Stanley, 2018	United Kingdom	Literature review using Kirkpatrick's training evaluation model to evaluate the evidence to explore whether a simulation-based approach to neonatal skills	Total articles (n = 18)	● Increased self-efficacy could influence ability to perform a skill ● Studies within this review reveal a positive correlation between neonatal simulation experiences, improved confidence and self-efficacy	● Small sample size meant that no measure of statistical significance was made and results were presented as mean scores or percentages

		training impacts self-efficacy in post-registration nurses		● There is a paucity of robust quantitative data relating to the impact of neonatal simulation for post-registration nurses ● Further research is required fully to evaluate the impact of neonatal simulation on clinical performance, team behaviours, service delivery and patient outcome	● Many of the papers contain expert opinion, pilot studies and case reports, which might impact on the validity and generalizability of results ● An inherent gender bias is not uncommon in research involving nurses since females frequently dominate the study population
Rafidah et al., 2009	Malaysia	Survey using a structured, self-administered questionnaire to examine the relationship between stress factors (health, social, and academic) and the level of perceived stress at three different periods of a semester (beginning, middle and end), and their effect on students	Pre-Diploma Science students at the University of Technology MARA (n = 154)	● Overall, the students experienced moderate level of stress and none of the stress factors significantly affected the academic performance of students ● There was a significant difference in the level of perceived stress between the beginning and middle of the semester ● With regard to academic performance, there was no significant correlation in the level of perceived stress at both the beginning and middle of the semester ● However, a significant correlation was found between the level of perceived stress at the end of the semester with academic performance ● Majority of students reported that they do not get enough sleep and face nutritional problems throughout the semester	● The small sample size might have contributed to the weak correlation and the absence of evidence on the effects of the stress factors on academic performance ● Since culture may play a key role in adaptation to stress, a larger sample size from different institutions and geographical locations might yield different yet interesting result

Slamon et al., 2018	United States of America	Prospective observational pilot study to measure the biometrics (heart rate, heart rate variability) of critical care physicians during live clinical patient scenarios	Physicians (n = 5)	● Study of the biometrics of physicians as they deliver real-time critical patient care is feasible using wearable technology ● Critical care activities requiring not only thought, focus, and planning, but also the physical execution of technical skills, resulted in higher levels of sympathetic activation	● Small number of subjects and inability to compare between training levels ● A limitation that enhanced the study involved the Hexoskin smart vest smart vest 14-h battery life. Rather than record for an entire 15 to 24 h shift, the project focused on shorter discreet activities. This prevented sifting through many hours of data, much of which was non-stressful. ● While this study demonstrates it is possible to quantitate physician biometrics, the true practice implications are unclear
Stein, 2020	South Africa	Prospective, repeated measures experimental design to assess the effect of participation by students in an emergency care simulation	Bachelor of Health Sciences in Emergency Medical Care undergraduate students of the Department of Emergency Medical Care at the University of Johannesburg (n = 36)	● Heart rate in the simulation assessment group increased significantly ● State anxiety scores increased significantly both before and after the simulation assessment ● No linear relationship was found between any HRV variables and anxiety scores ● The high levels of anxiety documented before and after simulation assessments may have a negative effect on	● Without control data for comparison, no inferences can be made about the effect of the simulation assessment ● A smaller sample and fairly large dispersion of data, as observed in the interquartile range of many of the HRV variables, raises the possibility of a Type II error

				performance and require further investigation	in the HRV simulation assessment and control comparisons. Many HRV variables are known to be affected by changes in posture and resulting baroreceptor reflexes ● It is possible that a non-linear relationship may exist between HRV and STAI data that was not detected by correlation analysis

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The previous chapters gave an overview, as well as a critical review of the available literature which guided the approach of this study. The research methodology serves to find answers to the research questions through the application of scientific procedures (Kothari, 2004). The purpose of this research endeavour was to assess the effect of stress during the clinical assessments of undergraduate paramedic students, by monitoring their physiological and psychological stress indicators (biometric and biomarkers). This chapter describes the study design, procedures used for conducting the research enquiry, research instruments used, data collection and/or analysis techniques, including the research setting, sampling process and the data analysis plan. Also note that the following methodological adaptation was incorporated. The experimental group was exposed to: pre-test ➞ intervention or term assessment ➞ post-test. However, the control group was exposed to pre-test ➞ intervention or mock assessment ➞ post-test, which is a deviation as the control group was meant to be exposed to 'placebo' or 'normal practice' (Bloomfield & Fisher, 2019).The reason for this was to illicit a measurable stress response in the control group, as this study explored the levels of stress and anxiety which paramedic undergraduate students (BEMC degree programme), experience during clinical assessments by measuring validated stress biomarkers. The research paradigm for the study is discussed first, followed by elaborating on the research design. The chapter concludes with the ethical considerations and limitations of the research.

3.2 Research paradigm or design

Research is about gathering facts and presenting the information after interpretation (Walliman, 2005). Moreover, research follows a process of intense preparation and planning, followed by the execution of the selected research activities "to find solutions to research problems" (Sekaran & Bougie, 2016). This research endeavour aligns with a positivist paradigm, as positivism aims to incorporate quantitative approaches to identifying explanatory associations or causal relationships (Park, Konge and Artino, 2020). The core methodological goals of positivism include measurement, generalisability, replication of findings and controlled experimentation (Tavakol & Sandars, 2014). Accordingly, a pre-test–post-test quantitative research design was used to establish the association between psychological stress, physiological stress biomarkers and the clinical performance of undergraduate paramedic students, throughout clinical simulation assessments. In addition, some argue that quantitative research has a very important role in healthcare, as "quantitative researchers adopt an objective perspective and strive to minimise bias" (Bloomfield & Fisher, 2019). The resultant quantitative data captured can then be measured or interpreted

in multiple applications including “mathematical, statistical, and computer techniques” (Cohen, Manion, Morrison and Wyse, 2010).

Undergraduate paramedic students (first-, second-, third- and fourth-year groups) from a particular South African university were included in the study. Data was collected during each year group’s particular clinical assessments, as specified in their curriculum. This implies that the degree of difficulty (assessments), incorporating knowledge scaffolding, was different between the groups. However, all participants utilised the same stress biometric research tools.

As highlighted, there were two phases of data collection for the study. The first phase (control group) involved obtaining base-line data during ‘mock’ clinical assessments practice in the classroom-setting (pre-test ➞ intervention or mock assessment ➞ post-test). Thereafter, the primary data was captured, using the experimental group by collecting ‘real-time’ data during their final term clinical assessments (pre-test ➞ intervention or term assessment ➞ post-test).

A fellow researcher based at the university, collected the control group data, which was captured during clinical practice sessions within the classroom. This was mainly recorded during preparation for the final-term assessments. Each year-group had the opportunity to practice clinical patient care scenarios, with a clinical facilitator present and included peer review feedback. Although, these sessions were not for formal marks capturing, it is often still highly stressful as the students experience the urgency and the need to ‘treat’ the patient or manikin appropriately, especially in light of their upcoming assessments.

The experimental group’s data was collected during their final-term assessments. This is where the participants of the different year-groups combine their theoretical and practical knowledge gained during the academic syllabus to ‘treat’ a patient in a clinically simulated setting. These assessments are video recorded and had two or more assessors present to evaluate the participants objectively according to the examiners’ specified clinical outcomes.

Research method

The data was collected in a three-phased approach, which included:

- Phase 1: Pilot study;
- Phase 2: Control group; and
- Phase 3: Main study.

It incorporated multiple validated tools to measure levels of anxiety, both for physiological and psychological stress. These included a questionnaire (the state-trait anxiety inventory [STAI]), a biometric ‘smart vest’ (the Hexoskin smart vest smart vest smart vest – allowing for online recording of activity, respiration and heart rate capture) and salivary assay (IBL α-amylase assay and IBL ELISA salivary

cortisol enzyme immunoassay [see Appendix 14]). The data was then collated to determine an accurate psychological and physiological stress profile for each participant.

3.3 Identification and selection of target population

The target population consisted of all undergraduate paramedic students registered with the Department of Emergency Medical Care and Rescue at Durban University of Technology (DUT) for the Bachelor of Health Sciences Emergency Medical Care (BHSc EMC) degree programme. This cohort of students would be similar to other undergraduate paramedic students across South Africa, as all higher education institutions need to comply with the HPCSA education policies for their emergency care programmes, including conforming to the respective clinical practice standards set for their students to become registered professionals (HPCSA, 2022). Presently, all emergency care programmes incorporate clinical simulation practice and assessments, thus allowing for the study results of this undertaking to be generalised (Whitley Jr & Kite, 2012). During the protocol development phase for this study, the total BEMC student population was (n) 120 students. However, after obtaining the necessary gate-keeper permission and access, at the time of data collection (final assessments of 2020), the final sample population was (n) 83. Multiple factors contributed to this attrition, such as drop out and/or poor performance, absenteeism and prolonged illnesses.

3.4. Sampling method and size

Purposeful sampling (also called judgement sampling) was employed to create a sample, with the intention of generalising from this sample to the overall study population (Patton, 1990, Whitley & Kite, 2012). This implies that the sample units (in this case undergraduate paramedic students) share similar attributes and/or characteristics such as similarities in terms of experience, specific skill set, background, age, etc. Specifically, total population sampling was used which involves examining the entire study population (Etikan et al., 2016). The advantage of total population sampling is that it incorporates all potential participants within the population of interest, allowing for a wide range of insights (Etikan et al., 2016). The use of a purposive sampling technique may not allow statistical generalisations about the sample being studied. However, this method does allow for analytical generalisations of the study population (Etikan et al., 2016).

The main disadvantages of total population sampling include that it may be a challenge to create a sample list “if the population is geographically dispersed or requires the permission of a gatekeeper not only to get the list, but also to contact members on the list. If the list of the population is incomplete or a large (or even small) proportion of members choose not to take part in the research, the ability of the total population sample to allow the researcher to make analytical generalisations can be severely compromised” (Etikan

et al., 2016). Fortunately, the chosen population for this study was not “geographically dispersed” as they were attending classes at the same university programme on the same campus. Also, student lists were well documented.

3.5 Inclusion criteria

All undergraduate paramedic students who were registered on the BHSc EMC programme at the DUT Emergency Medical Care and Rescue, Faculty of Health Sciences, during the data collection phase (November 2020 to January 2021).

3.6 Exclusion criteria

Any undergraduate paramedic students who had de-registered or suspended their studies for medical and/or personal reasons, as well as those who declined to participate. Those who participated in the pilot study were also excluded to avoid bias. There were no participants excluded for specific medical or health reasons, however if they were absent on their respective assessments (due to ill health), they were excluded due to time-constraints.

3.7 Data collection tools and data elements

As highlighted, data was collected using multiple anxiety biometric and biomarker collection tools, which measured both physiological and psychological stress biomarkers, with the intention of creating an accurate ‘stress profile’ for each participant. Previous stress studies (Valentin, Grottke, Skorning, Bergrath, Fischermann, Rörtgen, Mennig, Fitzner, Müller, Kirschbaum, Rossaint and Beckers, 2015; González-Cabrera, Fernández-Prada, Iribar, Molina-Ruano, Salinero-Bachiller and Peinado, 2018; Stein, 2020) have highlighted possible discrepancies between the results of stress biomarkers and therefore this study incorporated various stress biomarkers for comparison and to “create an accurate picture” of the stress levels for this cohort. For example, in a comparative study (Takai et al., 2004), salivary α-amylase was “a better index of stress” when compared to the salivary cortisol assay. In addition, the Hexoskin smart vest smart vest smart vest is a relatively new technology being used in research and this study may highlight its sensitivity and specificity, by comparing the Hexoskin smart vest smart vest data versus the salivary data to identify physiological stress accurately.

Study data collection tools incorporated included:

A. Hardcopies of the STAI Questionnaire;
B. Smart vest data capture tool (Hexoskin smart vest smart vest); and
C. Laboratory saliva assay.

D.

Table 3 below is a representation of the various data tools, with the elements recorded for this study.

Table 3: Study data collection tools

Data collection tool	Elements explored	Collection method
STAI Questionnaire	Trait and state anxiety	Before and after a clinical assessment activity
Hexoskin smart vest smart vest smart vest	Heart rate (HR), respiratory rate (RR) and heart rate variability (HRV)	Continuous recording: before, during and after a clinical simulation activity
Salivary assay	α-amylase and cortisol enzymes	Passive drool Salicap specimen collection: before and after a clinical assessment activity

A. Hardcopies of the STAI questionnaire

This questionnaire explored the participants' perceived psychological stress experienced before and after their clinical assessments (Appendix 9). It is used world-wide in research and has been translated into multiple languages, including "Greek, Dutch, Japanese, Chinese, and Malaysian" (Bee Seok et al., 2018). The analysis guidelines specific to this tool was developed and validated using different adult and adolescent population groups, including working adults, high school students, college students and military recruits (as described by Spielberger et al., 1983). "The STAI is widely used and suitable to administer in clinical practice and research, because of its relatively brief self-report scale to assess both state and trait anxiety" (Bee Seok et al., 2018). The participants were asked to complete the STAI questionnaire as truthfully as possible by reading each statement and then indicating "how you feel right now, that is, at this moment". It was highlighted that there are no right or wrong answers for this activity, but rather the aim is to explore the participant's present emotional state. The questionnaire also required the participants to indicate their general emotional state, outside of the assessment environment. This process only took a few minutes at a time (average questionnaire completion time: 5 to 10 minutes).

B. Smart vest data capture tool (Hexoskin smart vest)

The Hexoskin smart vest is a non-invasive and comfortable tech smart vest. Each participant was measured (correct size) and given a smart vest to fit their physique. This wearable smart vest has various built – in sensors to measure physiological data in real time, validated in multiple studies (Cherif, Mezghani, Gaudreault, Ouakrim, Mouzoune and Boulay, 2018; Al Sayed, Vinches and Hallé, 2017).The data was synchronised via Bluetooth with a phone application and uploaded to cloud storage for later analysis

through a secure website (Hexoskin, 2019). Recorded data can be measured in real time (maximum 14 hours continuously), with shared Bluetooth capability and online cloud storage (Hexoskin smart vestt, 2019). The Hexoskin smart vest technology has multiple parameters it can measure, including physical activity monitoring (step count), minute ventilation, rate of oxygen consumption, inactivity and sleep parameters. It also has an electrocardiographic sensor, which is a one-channel, 256 Hz detector with variability rates from 30 to 220 beats per minute, allowing for heart rate variability (HRV) analysis (Hexoskin smart vest smart vest, 2019).

The research focus is related to the physiological measurement of stress and therefore the following Hexoskin smart vest online data was explored:

- Breathing or respiration rate (RR);
- Heart or pulse rate (HR); and
- Heart rate variability (HRV).

However, as data analysis was completed using the Stata v15 statistical software, the Hexoskin smart vest captured online information first needed to be downloaded in Excel format or CVS file format (text delimited format) to enable processing the results. The participants' CSV files contained more than 5 000 observations on average and as they would have felt stressed at different times on the data collection days, the focus was placed on their assessment times, specifically before, during and after 'treating' the patient. The researcher had recorded the exact time of the participant's assessment, as there were prepared student lists (randomised) with time slots allocated for each group on their respective assessment days.

Breathing or respiration rate (RR)

The function of respiration is to ensure that the body receives adequate oxygen at cellular level, which is vital to maintain the body's normal internal homeostasis (Dougherty & Lister, 2015). During respiration, ventilation and gaseous exchange occurs, ensuring that the normal range of oxygen saturation of the blood is 94–98% (SpO2), which is achieved by maintaining a normal respiratory rate (RR) of 12–20 breaths per minute (bpm) (Hartley, 2018).

Pulse or heart rate (HR)

As your heart muscle contracts (heartbeat), blood is circulated throughout your body, allowing one to palpate a pulse either on your wrist or neck (Heart Foundation, 2022). By measuring your pulse, determined by "counting the number of times your heart beats in one minute", you will calculate your heart rate (Heart Foundation, 2022). "A normal heart rate, when you're not being active, is generally between

60 to 100 beats per minute (Heart Foundation, 2022). With physical activity, your heart beats faster. However, using certain substances such “caffeine, nicotine and recreational drugs” can also increase your pulse rate (Heart Foundation, 2022). In addition, “your heart will also beat faster when you feel strong emotions, like anxiety, fear or excitement” (Heart Foundation, 2022).

Heart rate variability (HRV)

As mentioned, the Hexoskin smart vest online data can also be used to explore HRV (both for individual participants and within the groups). During the scoping review process for this study, it became evident that complex links exist between stress and autonomic control, as well as behavioural and cardiovascular systems (Kim, Cheon, Bai, Lee, and Koo, 2018). It was determined that the results from multiple studies indicated that due to “stress-associated variation in HRV and existing neurobiological evidence, HRV may be used as an objective assessment of stress and mental health” (Kim et al., 2018). However, to explain HRV, the researcher now first elaborate on how it was recorded.

Electrocardiography or an electrocardiogram (ECG), records and captures the miniscule differences in electrical potential generated by the heart through the placement of electrodes on the patient’s chest surface (Hlaing, Dimino, Kowey, and Yan, 2005). In the case of the Hexoskin smart vest, these cardiac sensors are embedded in the chest straps. By carefully scrutinizing and correlation of an ECG pattern (Figure 3 below), a large amount of anatomical, pathological and physiological information of the patient’s heart can be observed (Romdhane, Alhichri, Ouni and Atri, 2020).

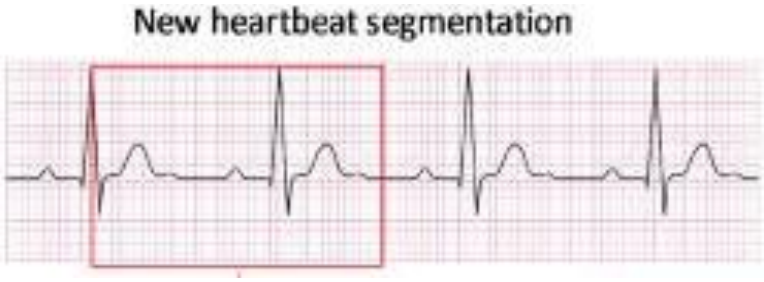

Figure 3: ECG heartbeat pattern (Romdhane *et al*., 2020)

The ventricular depolarisation is represented by the QRS complex (Figure 4 below), with each letter corresponding to a different part of the action of the heart (Noble, Hillis and Rothbaum, 1990).

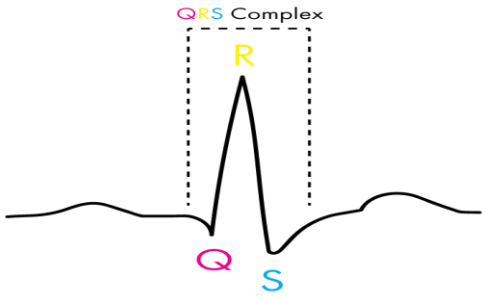

Figure 4: QRS complex (Noble et al., 1990)

The point ‘R’ of the complex is the area of interest from which the values for HRV analysis are notated (Kim et al., 2018). As illustrated by Figure 5 below, the RR interval (which is determined by recording several heartbeats next to each other, with the distance (in milliseconds) between each point ‘R’ is defined as the ‘RR interval’ (Noble et al., 1990).

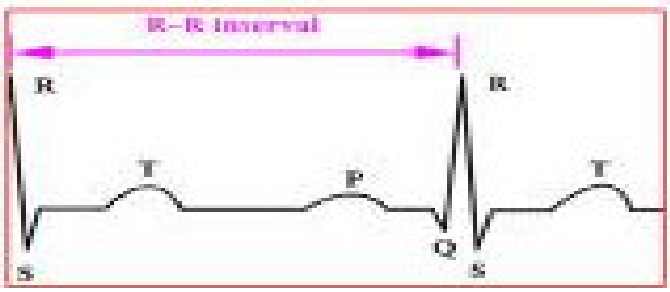

Figure 5: RR interval (Romdhane et al., 2020)

The captured data is accessible online (electronically encrypted and password protected, and only the researcher and supervisor team have access) via the Hexoskin smart vest smart vest Connected Health Platform (http://my.Hexoskin smart vest smart vest.com/). Before the start of their assessments, the participants were separated and taken to secluded classrooms, where they were able to put on their smart vest in privacy (worn against their skin, under their own clothing). The smart vest was then activated and worn for the duration of their respective assessments. On completion of their assessment, but before taking off the smart vest, they completed their post-assessment STAI questionnaire. This allowed for continuous (before, during and after assessment) physiological data capture of their biometrics (both respiratory and cardiac biomarkers).

C. Laboratory salivary α-amylase and cortisol assay

The participants' salivary samples were collected and coded with an identification label applied to the Salicap tubes (sputum collection tubes), one for before and another tube for after their assessments (for example labelled as "P1 B" (for before the exam) and "P1 A" (for after the exam) for "Participant One". The label also indicating the collection time and date of the particular saliva sample. The samples were collected for the assay of both α-amylase and cortisol measurements. It was kept cool using ice packs until data collection for that session was complete, then frozen to –20 ^{0}C, until ready to be thawed for processing. After the assay or calculations, measured values were captured and presented in an Excel sheet.

As highlighted, the IBL International test kits for salivary α-amylase and cortisol enzymes was used for the before- and after-assessment samples assay process (Appendix 14). The use of their product is specifically intended for the quantitative enzymatic determination of these enzymes or activity in human saliva. Each test assay kit comes complete with an instruction booklet which includes notes for:

- Warnings and precautions;
- Storage and stability;
- Specimen collection and storage;
- All equipment requirements for the assay process (not supplied);
- Procedure notes;
- Quality control; and
- Calculation of the results.

3.8 Phase 1: Pilot testing

A pilot study was conducted prior to the commencement of the primary study. Pilot or vanguard studies provide a good opportunity to assess feasibility of large full-scale studies (Doody & Doody, 2015). It can contribute valuable information by providing the researcher with "the opportunity to develop and enhance the skills necessary before commencing the larger study" (Doody & Doody, 2015). The following is a comprehensive overview of conducting a pilot study for this research undertaking. The results of the pilot study were excluded from the final data analysis.

The researcher was already familiar with some of the data collection tools, namely the Hexoskin smart vest smart vest smart vest and the STAI questionnaire. However, it was the first time the researcher worked with salivary samples using the α-amylase and cortisol IBL assay kits. Therefore, arrangements were made (by the co-supervisors) for the researcher to attend training and practice sessions at the laboratories of the DUT Department of Biomedical and Clinical Technology, prior to the commencement of the pilot study. This laboratory was also used as the venue for the primary salivary assay processing.

3.9 Pilot testing preparation

After the necessary institutional permission was granted (APPENDIX 1), the researcher made arrangements to do a pilot study using the research tools.

Salivary assay at the Department of Biomedical and Clinical Technology at Durban University of Technology

A laboratory technician was tasked to orientate, as well as train the researcher in the skills required to perform salivary specimen collection successfully, storage and the actual test procedures in accordance with the manufacturer of the salivary assay kits. The technician has a wealth of experience in the laboratory work, having worked in the industry for 16 years as chief medical technologist, and at the time, 20 years training exposure at a university. His formal qualifications include: Dip Clinical Pathology, NHDip Clinical Pathology and MHSc Medical Laboratory Science. He focussed on the practicing of multiple skills which included pipetting, using the specific equipment required for the assay such as a Voltex mixer and an automatic electronic gravimeter. The researcher made notes, especially concerning the pitfalls of the assay processes. These included accuracy and precision in pipetting, calibration of the machines and the importance of time management for certain procedures. The researcher actively sought to avoid these variables which could impact the assay results by, for example:

- ensuring the pipettes which were used, were calibrated and certified by the manufacturer before use;
- all equipment which was used (such as the Voltex mixer and an automatic electronic gravimeter) were calibrated and set to the manufacture's standardisation requirements; and
- the researcher had an assistant who was given the task of time management for all the procedures during the assay.

A record was created with the assay steps to follow and the specific time at each section. The timer of a cell phone was used and alarms set accordingly, which ensured meticulous time management at each sequential procedural step.

Recruitment of participants: Department of Emergency Medical Care and Rescue

This study proposal underwent vigorous scrutiny and only after ethical approval by the Institutional Research Ethics Committee (IREC - Ethical clearance number IREC 075/20 – see Appendix 1), as well as obtaining the necessary gatekeeper permission, could the research process commence with a pilot study. The researcher approached the HOD of the DUT – Department of Emergency Care and Rescue, to enquire which student group might be available for this pilot study (information and permission letters had already been provided – see Appendices 4 to 6). The HOD indicated, based on the various study year

groups' programme activities, that the third-year group was available on the 13 August 2020 (clinical simulation practice activity). The HOD then introduced the researcher to the relevant lecturer, with the view of recruiting participants for this pilot study. The following documents were emailed for the lecturer to share with the class:

- Participant information letter (Appendix 5);
- Consent form (Appendix 6); and
- Covid-19 screening guideline (Appendix 7).

After waiting a week, a total of 5 (n) students had volunteered to participate. Logistical arrangements were confirmed (including the date, venue and time).

Pilot study process

The following is a synopsis of the processes which guided the pilot study:

a) A briefing was held in the classroom of the group (examination holding venue), prior to the commencement of the assessment to confirm the research procedures and to respond to any participant concerns.
b) The participants' signed consent forms were collected (see Appendix 6).
c) The participants were then given their individual Hexoskin smart vest smart vest smart vests to don in private (in the bathrooms), as their body measurements in terms of weight and height had already been captured. Errors in the recording of data from Hexoskin smart vest smart vest smart shirt has been highlighted, due to poor sensor skin contact or the incorrect shirt size (MacQuarrie, 2018). After donning their vests, the participants' straps around the chest (for females) and the abdomen (for males) were secured, as well as ensuring the recording unit (smart device) was activated to ensure data capture had commenced.
d) The participants completed the pre-assessment psychological STAI questionnaire.
e) Thereafter, their pre-assessment salivary sample was requested (after a short specimen collection demonstration, which entailed showing the participants how to fill a Salicap container with 0.5 ml to 1 ml of their saliva by passive drool. These samples were immediately placed on ice packs (within a cooler box) and subsequently taken to the laboratory to be frozen at –20 ^{0}C until ready to be thawed for processing.
f) The participants then commenced their clinical assessment in an adjacent venue. During this stage of the study, their vital signs were recorded by the smart shirt and activated smart device. As the participants completed their assessment, before departure, the smart device was deactivated and removed from the vest. The participants were given privacy in a separate room to remove the vest, which was then collected for washing purposes. Subsequently, their recorded data was uploaded to the Hexoskin smart vest smart vest Connected Health Platforms, which already had profiles created

for each participant according to their participant number. No identifiable information such as names or date of birth was captured to maintain anonymity.

g) Once their assessment was completed, the second, post-assessment salivary samples were requested from the participants.

h) Finally, the data collection concluded with the completion of their post-assessment STAI questionnaire.

i) There was a short debriefing session. The participants were thanked for their time and effort to participate in the study. They were asked for their input based on their experience with the data tools and/or research proceedings. The researcher made notes, with a view to ensure that 'smooth' main study data Covid-19 screening tool was completed upon entry to the venue (Appendix 7).

Results of the pilot study

Multiple data sets were recorded on the day. However, not all the information was readily available for analysis. Table 4 below highlights the different recorded data sets and timelines for analysis, followed by a summary of the results for the different data tools.

Table 4: Pilot data for analysis

Data type	**STAI Questionnaire**	**Hexoskin smart vest smart vest smart vest**	**Salivary assay**
Availability of the results for interpretation	Immediately	Immediately	2 days
Data format	Hard copies	Online server	Tables and Excel sheet

3.10 Phase 2: Control Group

The same pilot process described above, was followed to conduct and obtain data for the control phase of this study. This group consisted of 15 participants and data was collected during their clinical simulations practice (non-assessment conditions). The group consisted of six fourth-year participants and nine third-year participants. The control data collection sessions were held in class, during preparation for their final assessments. Lessons learned from the pilot study, was compensated for to ensure accurate data capture (both for the control and main study groups). These included:

- Allowing adequate time for the collection of sputum samples (passive drool);

- Checking that the recording unit of each smart vest was plugged in correctly;
- Ensuring the respective chest and abdomen vest straps were secured correctly; and
- Ensuring that the firmware of the Hexoskin smart vest device was updated and it was in sync with the Hexoskin Connected Health Platform dashboard.

These baseline levels (non-assessment conditions), together with the pilot study (assessment conditions) provided realistic stress biomarker data and gave an indication of the effectiveness of the data tools. Furthermore, the above "Saliva sampling collection guideline" was developed to limit any potential confounders which may skew results.

The following criteria were used for selection of the control group:

- All undergraduate paramedic students registered on the Bachelor's Emergency Medical Care programme at the DUT Emergency Medical Care and Rescue, Faculty of Health Sciences;
- Age of participants: more than 18 years old; and
- Gender: both males and females.

3.11 Phase 3: Main study

Arrangements were made to be present during the final-term clinical assessments for the main study's data collection.

Research process

An information sharing session (in class) was arranged by their lecturer to inform all potential participants of the proposed study and highlight the possible benefits (see Appendix 5). The data collection tools were presented, so that participants were fully aware of what was required of them. Participants were then asked for voluntary participation and to sign the necessary consent form (see Appendix 6). The data collection was scheduled to coincide with their clinical assessment. As data collection occurred during the Covid-19 pandemic and even though the university had its own Covid-19 pre-entry screening and/or surveillance in place, the participants had temperature checks as well as a Covid screening tool to complete (prior to commencing and issuing them with the data tools [see Appendix 7]) As highlighted, the participants first completed a pre-assessment STAI questionnaire, then completed their clinical simulation assessment and lastly, completed a post-assessment STAI questionnaire. Similarly, the acquisition of samples for saliva assay was obtained before and after clinical assessments. Throughout this process, the participants were wearing their Hexoskin smart vest smart vest smart vests which continuously

measured their physiological data in real time. This data was recorded and uploaded to cloud storage for later analysis through a secure website.

State-trait anxiety inventory questionnaire

This questionnaire focussed on the participants' demographics and explored their perceived psychological stress experienced before, during and after the clinical assessment (Appendices 8 to 10). The participants were asked to complete a hardcopy of the STAI questionnaire before and after their assessment.

The Hexoskin smart vest smart vest smart vest

As stated, on the data collection day, the participants were wearing their smart vests under their own clothing for the duration of the assessments. In the morning, before the start of the assessments, the students were issued their smart vests (which had already been fitted previously), to put on in the bathroom (for privacy). The smart vest was then worn for the duration of the assessment.

Salivary α-amylase and cortisol assay

Salivary samples were taken before the commencement of the participants' clinical assessments and again afterwards, including completing their post-assessment questionnaire. The above, allowed for continuous (before, during and after assessment) physiological online data capture of their biometrics (both respiratory and cardiac biomarkers). As highlighted, these salivary assay samples were then frozen and assayed with equipment provided by the Biomedical and Clinical Technology, and Biotechnology and Food Science Research Laboratory at DUT.

Figure 6 below is a representation of the data collection processes before, during and after the participants' clinical assessments, incorporating the following data instruments:

- State-trait anxiety inventory questionnaire;
- Hexoskin smart vest smart vest smart vest; and
- Salivary α-amylase and cortisol assay.

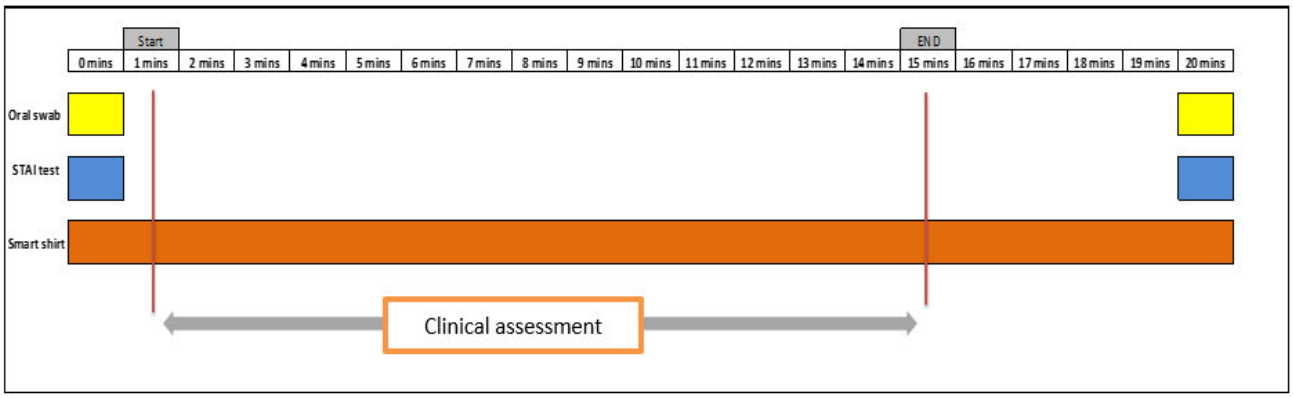

Figure 6: Representation of the data collection processes

The researcher was on site before the commencement of assessments on all the data collection days of the various groups. The reason for this was to set up a research station and prepare the necessary data collection tools, both to make available to the participants, as well as to be able to be ready for collection, after they completed their assessments.

As highlighted, participants were provided their unique coded Salicap tubes (for both salivary samples) which contributed to maintaining their confidentiality. Saliva samples for α-amylase and cortisol measurement was collected using a 'straw' technique before and after assessments. Participants had to 'fill' their tubes with 0.5 ml to 1 ml of their saliva. Thereafter the samples were kept cool using ice packs until the data collection session was completed for that day. The cooler box was taken to the Department of Biomedical and Clinical Technology, where the samples were placed in a specialised laboratory fridge (set at –20 ^{0}C), until ready to be thawed for processing. Before the assay process commenced, the samples were thawed to room temperature and then centrifuged for 15 minutes. All saliva samples were then assayed according to the instructions provided by the commercially available kinetic reaction kits (respectively IBL α-Amylase Assay and IBL ELISA salivary cortisol enzyme immunoassay).

Saliva sampling collection guideline

The following guidelines were implemented to limit any confounders, which may have impacted the saliva sampling:

- The assessments started at 08:00 and finished no later than 15:00 daily. Participants were randomised in groups for their clinical assessment by their respective lecturers. Thus, the time of sample collections (both in the morning and the afternoon) eliminated any potential confounding fluctuations related to the circadian rhythm.
- Participants were asked to avoid eating, drinking (including alcohol or caffeine) and smoking (nicotine) within an hour before their allocated assessment times, as these may affect salivary pH

or composition. For those who ate breakfast within an hour before their allocated assessment times, the researcher asked them to rinse their mouth with a small amount of water prior to providing a specimen. Due to the rinsing process which may dilute saliva and lead to lowered estimates of measured analytes, their specimens were only taken 10 minutes after rinsing (Harmon, Hibel, Rumyantseva and Granger, 2007).

- No participants took any medication on the morning of the assessment.

As highlighted above, many physiological and pathological processes may impact the participants' analyte levels on the sample testing days, producing either abnormally high or low readings (as compared to the median ranges). These were highlighted and warranted further medical investigation, as it may have been that the participant has an undiagnosed illness.

Data analysis

Descriptive statistics was employed to summarise the data at three time points: before, during and after clinical assessments. The aim was to describe the research data and interrogate the distribution of each variable by "determining whether the scores on different variables are related to each other" (Lind, MarchaL and Wathen, 2017). Categorial data was analysed using descriptive statistics such as proportion and percentages, as well as inferential statistics (with the assistance of a biostatistician) to make comparisons regarding the frequencies found in the groups. For data recorded continuously such as from the Hexoskin smart vest smart vest smart vest, a summary measure before, during and after was calculated. The frequency distribution of numeric data was then examined for normality and means (Schubert et al., 2009) or medians (IQR).

Numeric data captured included vital signs or biomarkers (for example, respiration rate and heart rate) which were subjected to repeated measures (Analysis of Variance or ANOVA), to compare measurements at different time points. The association of demographic factors such as year of study and gender differences of the recorded biomarkers were assessed, using a repeated mixed model with an interaction between independent variables and time. For analysis of the STAI questionnaire scores, Cronbach's alpha was used to assess the reliability of the questionnaire. Scores were also categorised into stressed and non-stressed using the recommended cut-off points.

Correlation was used to compare biomarker measurements such as Hexoskin smart vest smart vest (heart rate or respiratory rate) and salivary assay recordings with the STAI results. Comparisons of biomarker data between stress and non-stressed students were determined using t test or Wilcoxon rank sum test. Multiple logistic regression was then used to adjust for any confounders.

Lastly, graphical representations were constructed to convey the data collected, which includes Poincaré plots to determine any similar patterns of physiologic activation. Both the independent t-test (parametric

test for a comparison of the means) and the Pearson's chi-square test (for nominal data) were utilised to determine statistical significance. Statistical significance was set at < 0.05 and Stata v15 statistical software was used for data analysis.

3.12 Internal validity

Research validity describes the degree to which the research findings accurately represent what they intended to measure (Leedy & Ormrod, 2005). The study design, implementation, analysis and interpretation processes have been incorporated to maximise the internal validity of the study. In addition, as described previously, all data collection instrument tools have been validated (Haddad, Dalansi, Kharbach, Mohamed and Aganovic, 2019; Mannée, De Jongh and Helvoort, 2021; Karhula, Härmä, Sallinen, Lindholm, Hirvonen, Elovainio, Kivimäki, Vahtera and Puttonen, 2017; González-Cabrera, Fernández-Prada, Iribar, Molina-Ruano, Salinero-Bachiller and Peinado, 2018; Julian, 2011). Furthermore, all paramedic undergraduate students at DUT were included, thus avoiding any potential biases related to selection which may have compromised the study results.

3.13 External validity

The selected study population at the University (DUT) can be generalised or compared to other undergraduate student paramedics in other provinces. This is due to the common academic assessment stressors most paramedic students are exposed to across all provinces. In addition, all training institutions have to comply with and are regulated by the Health Professions Council of South Africa (HPCSA) in terms of curriculum and/or assessments for undergraduate paramedic students, meaning all undergraduate paramedics have received similar training across the provinces

.

3.14 Reliability

Reliability can be defined as the consistency (performance) of a measuring instrument (Welman, Kruger, and Mitchell, 2005). This implies that the measuring tools (instruments) should provide similar results consistently. Studies have explored the reliability of the Hexoskin smart vest smart vest Smart Vest. One such study, measured the cardiorespiratory function of healthy individuals during physical exercise, which concluded that the Hexoskin smart vest presented good agreement for heart rate and breathing rate (Cherif et al., 2018). As this smart shirt will be used for the first time in Africa, the researcher conducted a pilot study to become comfortable with the technology, and the process and application for its use.

The salivary biomarkers which were used in this study (namely, salivary α-amylase and cortisol) have also been investigated. One such study used these biomarkers to explore "stress-related output during

burdensome work shifts and leisure time" and found acceptable "consistency of salivary cortisol and alpha-amylase (Bhavee, Rachel and Pramodh, 2018) total daily secretion between laboratory and field circumstances" (Karhula et al., 2017). Therefore, these salivary instruments have been validated as psychological stress biomarkers.

3.15 Ethical considerations

Ethical clearance was obtained from the Institutional Research Ethics Committee of the Durban University of Technology (Appendix 3). Secondly, gatekeeper permission was granted by the Director: Research and Postgraduate support directorate and the Head of Department: Emergency Medical Care and Rescue, Faculty of Health Sciences at DUT (Appendices 2 and 4). Thereafter, further engagement with the lecturing staff followed to inform them of the purpose of the study. The staff then in turn informed their students as a letter of information was provided (Appendices 5, both for the pilot study and the main study). All the participants signed informed consent forms before participating in the study (Appendix 6). As indicated on the information letter, the potential participants were assured that their participation was entirely voluntary. In addition, potential participants were informed that they could withdraw from the study at any time, with no questions asked and no penalties or demerits.

This study recruited undergraduate students as the target population and therefore many factors were considered to ensure ethical compliance. The main elements included the right to autonomy and confidentiality, avoiding harm, fair treatment and seeking informed consent (Brink, 2009, Polit & Beck, 2012). Firstly, as students, they were informed that they had the right to agree freely to either participate or not in the study (autonomous individuals), with no punitive consequences. The participants completed a questionnaire, therefore it was important also to highlight that there is a risk to the professional reputation of participants, as well as the risk of participant identification based on the research data collected. However, these risks were mitigated by ensuring anonymity (allocating numerical numbers to participants), as well as no personal data was collected (upholding their right to anonymity and confidentiality).

Beneficence or the right to freedom from harm and discomfort was maintained as participants were not subjected to any risk of physical harm (Polit & Beck, 2012), since only salivary samples were requested from participants. In addition, as the data collection was during an assessment, students were made aware of the Student Counselling and Development Centre (SCDC) for any psychological and/or emotional support if needed.

Participants were also wearing the Hexoskin smart vest smart vest vest, which was purchased in their size to fit comfortably. The participants were informed that their entire group were eligible for this study, with everyone having an equal chance to be participants (ensuring fair treatment). Each study participant was requested to sign a consent form (Appendix 6), which contained a full description of the purpose of the

study, data collection and intended use (informed consent). The participants were made cognisant of the fact that the research information letters provided to them, contained the contact information of the research supervisors if they felt aggrieved in any way during the data collection proceedings. Finally, the participants were also made aware that a copy of their research results would be sent to them, if they wished to receive feedback of their measured psycho-physiological stress data.

3.16 Conclusion

A synopsis of the research methodology and procedures used to conduct the research enquiry were discussed in this chapter, which included the researcher's insights, having gone through the research steps. The next chapter presents the data collected using the research instruments.

CHAPTER FOUR: ANALYSIS OF RESULTS

4.1 Introduction

The preceding chapter outlined the methodology incorporated for this study and why a quantitative approach was identified as the most appropriate to meet the aim and objectives of this study. This chapter presents an analysis and interpretation of the data collected for all the research objectives and their respective instruments. As this study entailed multiple different data sets, analysis and interpretation will be displayed in the following sections:

- Section One: Biographical data of the sample;
- Section Two: Comparison of the trends between different stress indicators (biomarkers) of the participants before, during and after clinical assessments;
- Section Three: Exploring the associations between the different stress biomarkers (psychological and physiological indicators) of the participants before, during and after clinical assessments;
- Section Four: Evaluating the impact of psychological and/or physiological stress indicators on the participants' assessment results (clinical performance); and
- Section Five: Evaluating the different physiological stress indicators to identify which most accurately correlate to the participants' perceived psychological stress level.

4.2 Section One: Biographical data of the sample

Reviewing the participants' biographical data, the following was highlighted:

The participants (P)

The total undergraduate BEMC student population was (n) 83 students. As participation was voluntary, the study sample was (n) 56 or a 68% recruitment rate. However, not all participant data streams recorded were valid. The study incorporated both a control group (data captured during in-class practice) and an experimental group, where data was collected during final term clinical assessments. In the experimental group, one participant's assessment time was moved forward and therefore the participant was unable to provide a sputum specimen (the captured STAI questionnaire results and the recorded heart rate and/or heart rate variability data was not included in analysis), resulting in n = 55 (66%). Additionally, three participants who were excluded were those that completed the entire data collection process, but due to possible poor sensor contact and/or movement, the Hexoskin smart vest smart vest online platform recorded no heart rate (HR) or heart rate variability (HRV) data for these participants, only their respiration rates. Nevertheless, the STAI questionnaire and sputum results of these participants were still valid (included in analysis), but not their HR/HRV data. This resulted then in n = 53 (63.85%). Table 5 below depicts the final sample enrolled for this study, highlighting those with validated or invalid data capture.

Table 5: Research participants with validated/invalid data capture

Control group	Participants	Invalid (Hexoskin smart vest smart vest data)	Incomplete (sputum collection)
Third Year	9	0	0
Fourth Year	6	0	0
Total	**15**		
Experimental group			
First year	19	0	0
Second year	13	0	0
Third year	15	3	0
Fourth year	9	0	1
Total validated data (n)	**56**	**53**	**55**

0 indicates invalid Hexoskin smart vest smart vest data points and incomplete sputum data points

Age and gender of the participants

In the experimental group, the mean age of the participants was 25.68 ± 7.35 years old (range: 18–40 years). In both the experimental and control group, the males participants outnumbered the females participants (see Table 6 below).

Table 6: Participants' demographic data

	Gender	Frequency (n)	Mean age	T test
Experimental	Male	39	27.10 ± 7.50	P= 0.03
	Female	17	22.41 ± 5.99	
	Total	56	25.68 ± 7.35	
Control	Male	12	28.42 ± 5.60	P= 0.9
	Female	3	28.33 ± 9.45	
	Total	15	28.40 ± 6.12	

Mean ± Standard deviation

4.3 Section Two: Comparison of the trends between different stress indicators (biomarkers) of the participants before, during and after clinical assessments

Before exploring the trends between different stress indicators, the following is a representation of the psychological and physiological biomarker data collection streams captured for this study.

Psychological anxiety results: State-trait anxiety inventory questionnaire

Normality distribution of the data was verified using the Shapiro-Wilk W test (see Table 7 below). The results indicate that all the p values were > 0.05, so assumption of normality is met and subsequently parametric measures of central tendency (mean) and deviation (Schubert et al., 2009) could be used.

Table 7: Shapiro-Wilk W test for normal data

Shapiro-Wilk W test					
Variable	**Obs**	**W**	**V**	**z**	**Prob>z**
Score Y1 before	56	0,98318	0,865	-0,311	0,62212
Score Y2 before	56	0,99142	0,442	-1,755	0,96034
Total before score	56	0,98351	0,848	-0,353	0,63805
Score Y1 after	56	0,98242	0,904	-0,216	0,58543
Score Y2 after	56	0,98057	1	-0,001	0,50026
Total after score	**56**	**0,96741**	**1,676**	**1,109**	**0,13367**

Scoring interpretation for the STAI questionnaire

As highlighted in Chapter Three, scores for both the S-Anxiety (Short Form Y-2) and the T-Anxiety (Short Form Y-1) scales can vary from a minimum of 20 to a maximum of 80, with the “higher score indicating greater anxiety” (Spielberger, 1983). Table 8 below illustrates that the Y1 scores were similar across the year groups before the assessment, with Y1 and Y2 scores similar after the assessment.

Table 8: STAI before- and after-assessment scores

STAI Questionnaire	Assessment (20 items)	Examples (statements to choose)
Short Form Y-1	Trait anxiety	"I am tense; I am worried"
Short Form Y-2	State anxiety	"I am content; I am a steady person."

Year	Frequency (n)	Y1 Mean Scores	Y2 Mean Scores	Total Mean Scores
STAI before assessment				
1	19	47.79 ± 12.98	42.63 ± 11.12	90.42 ± 22.29
2	13	50.31 ± 13.92	46.62 ± 8.99	96.92 ± 21.15
3	15	48.07 ± 10.31	45.57 ± 8.30	93.53 ± 15.94
4	9	48.11 ± 8.81	44.33 ± 6.22	92.44 ± 13.12
STAI after assessment				
1	19	42.00 ± 12.58	40.84 ± 13.18	82.84 ± 23.36
2	13	45.38 ± 11.40	44.15 ± 7.80	89.54 ± 18.06
3	15	49.47 ± 12.14	45.80 ± 8.87	95.27 ± 19.00
4	9	47.22 ± 15.83	47.00 ± 8.87	94.22 ± 23.07

Mean ± Standard deviation

A frequently used method to "quantifying the reliability of a score to summarize the information of several items in questionnaires" is called the Cronbach's alpha score (Christmann & Van Aelst, 2006). A reliability coefficient of 0.60 or higher is considered as acceptable for a newly developed construct (Bryman, 2016). Table 9 below highlights an alpha score >0.8 which is considered as a good score (Tavakol & Dennick, 2011).

Table 9: Making sense of Cronbach's alpha (Tavakol & Dennick, 2011)

Cronbach's Alpha	Internal consistency
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor

The Cronbach's alpha score for all the items of which this study's questionnaire for the before assessment and after assessments were good. Following the scoring of the results, further comparisons were investigated. Table 10 below highlights that there was no difference in the mean before assessment Y1, Y2 and total score by year-group. Similarly, there was no difference (p = 0,8) in the mean after assessment Y1, Y2 and total score by year-group.

Table 10: Comparison of STAI before- and after-assessment scores

Comparisons of STAI before assessment scores by year-groups			
		p value	**R^2**
ANOVA	Score Y1	0,9	0,8%
	Score Y2	0,7	3,0%
	Overall score	0,8	1,7%
Comparisons of STAI after assessment scores by year groups			
	Score Y1	0,4	5,5%
	Score Y2	0,4	5,4%
	Overall score	0,3	6,3%

To analyse the associations between the participants' cognitive function measures baseline physiological activity and stress reactivity, correlation or linear regression models were applied (Figures 7 and 8 below). "Correlation depends on the range of the true quantity in the sample. If this is wide, the correlation will be greater than if it is narrow" (Bland & Altman, 2010).

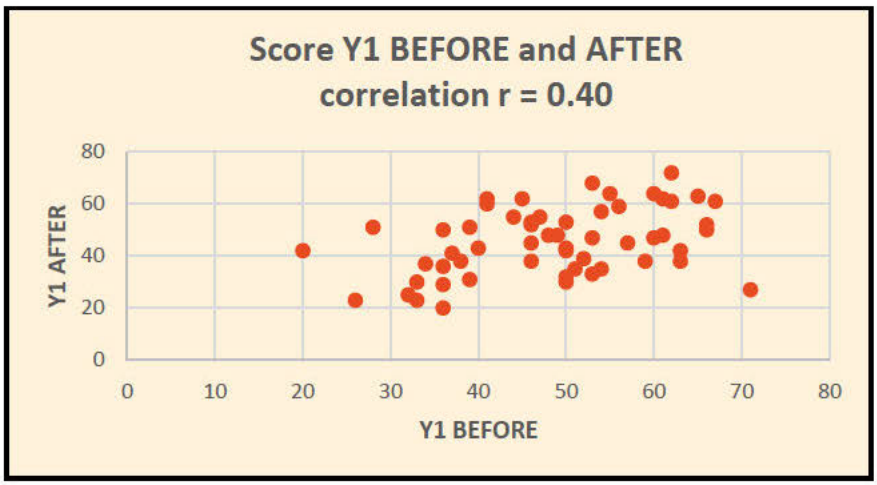

Figure 7: Y1 scores before- and after-assessment correlation

Figure 7 depicts a moderate positive correlation between the Y1 scores before assessment and the Y1 score, after assessment (r = 0.4 p = 0.002).

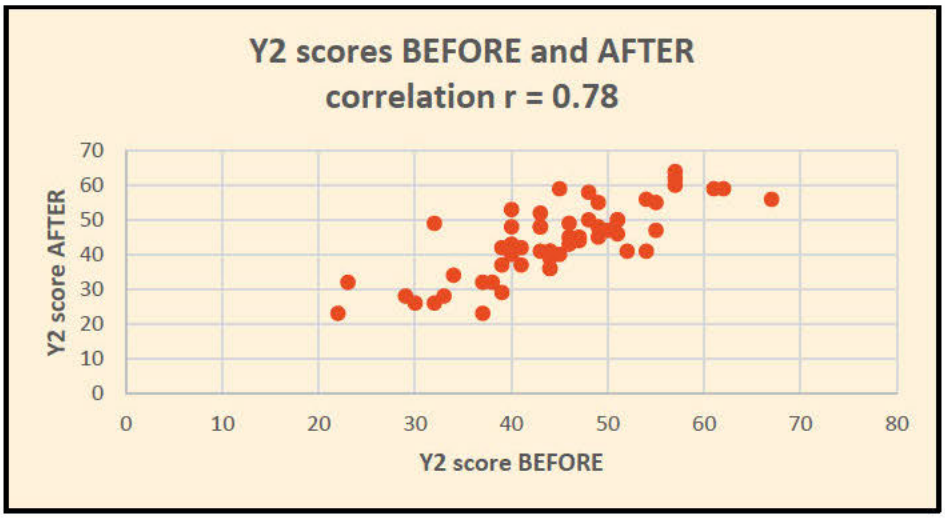

Figure 8: Y2 scores before and after correlation

A strong positive correlation (r = 0.78) can be seen between the Y2 score before and after assessment (Figure 8 above). Furthermore, the total STAI score (Y1 + Y2) score shows a moderate positive correlation (r = 0.60 p =<0.001) between the total STAI score, before assessment and the total STAI score after assessment (Figure 9 below).

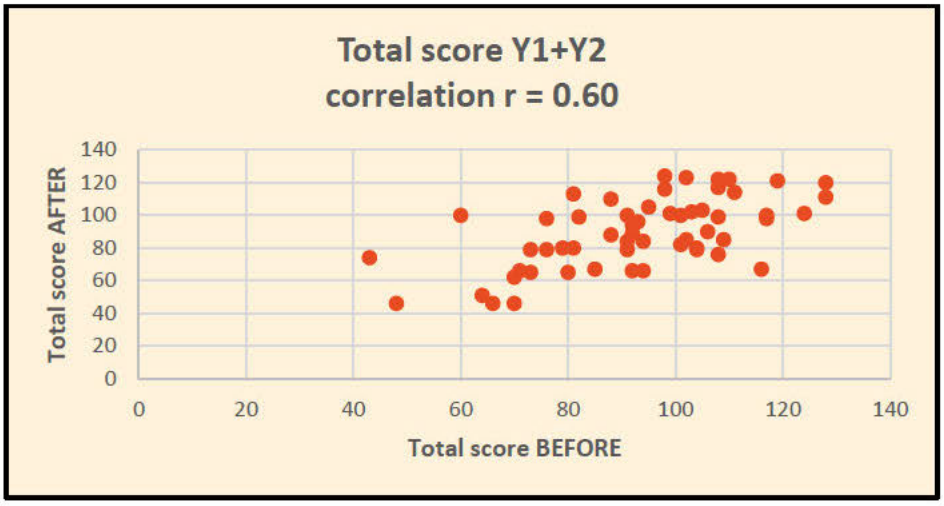

Figure 9: Total score Y1 and Y2 before and after correlation

Thereafter, an Anova model was used to compare the STAI Y1 scores (before and after assessments) to ascertain the significance between the year groups' scoring results (Table 11 below).

Table 11: ANOVA model Y1 scores

ANOVA model					
N = 56		R-squared = 0.7738			
Root MSE = 10.6162		Adj R-squared = 0.3089			
Source	**Partial SS**	**df**	**MS**	**F**	**Prob> F**
Model	6940.47	37	187.58	1.66	0.12
scoreY1_bef	6445.71	34	189.58	1.68	0.12
year_new	346.26	3	115.42	1.02	0.41
Residual	2028.65	18	112.70		
Total	**8969.13**	**55**	**163.08**		

The model explains 77% of variance (R^2 = 77.38%). Neither score Y1 before assessment or year-group was significantly associated with score Y1 after assessment (p = 0.120). In addition, an Anova model was also used to compare the STAI Y2 scores (Table 12 below). The model explains a significant amount of the variance in the data (R^2= 85.83%) (p<0.001). The year-group had no statistically significant effect on the Y2 score, after assessment (p = 0.14).

Table 12: ANOVA model Y2 scores

ANOVA model					
Number of obs = 56	R-squared = 0.8583				
Root MSE = 5.7869	Adj R-squared = 0.6883				
Source Partial SS	**Partuak SS**	**df**	**MS**	**F**	**Prob>F**
Model	5072.509	30	169.0836	5.05	<0.001
scoreY2_bef	4753.413	27	176.0523	5.26	<0.001
year_new	199.7444	3	66.58145	1.99	0.14
Residual	837.2057	25	33.48823		
Total	**5909.714**	**55**	**107.4494**		

The results of the STAI scoring were grouped according to the participants' various percentiles (Table 13 below) to determine if the anxiety levels were similar or different amongst the groups, for before and after their respective clinical assessments.

Table 13: Y1 S anxiety and Y2 anxiety categorical data

Y1 S Anxiety												
		Before - assessment					After - assessment					
			< 40		>=40			< 40		>=40		McNemars paired chi square
Year	N	n	%	n	%	Fisher's p value	n	%	n	%	Fisher's p value	
1	19	6	31,6%	13	68,4%		9	47,4%	10	52,6%		0.38
2	13	3	23,1%	10	76,9%	0.9	4	30,8%	9	69,2%	0.6	0.65
3	15	4	26,7%	11	73,3%		4	26,7%	11	73,3%		0.9
4	9	2	22.2%	7	77.8%		3	33,3%	6	66,7%		0.56
All	**56**	**15**	**26.8%**	**41**	**73.2%**		**20**	**35,7%**	**36**	**64,3%**		0.30
Y2 T Anxiety												
		Before - assessment					**After - assessment**					
			< 40		**>=40**			**< 40**		**>=40**		
Year	**N**	**n**	**%**	**n**	**%**		**n**	**%**	**n**	**%**		
1	19	10	52,6%	9	47,4%		9	47,4%	10	52,6%		0.32
2	13	1	7,7%	12	92,3%	0.01	3	23,1%	10	76,9%	0.02	0.16
3	15	2	13,3%	13	86,7%		3	20,0%	12	80,0%		0.56
4	9	1	11,1%	8	88,9%		1	11,1%	8	88,9%		0.90
All	**56**	**14**	**25,0%**	**42**	**75,0%**		**16**	**28,6%**	**40**	**71,4%**		0.69

It has been recommended that a cut-off point of 39–40 be used to identify clinically significant symptoms Spielberger, C., Goruch, R., Lushene, R., Vagg, P. and Jacobs, G. 1983; Julian, 2011). Accordingly, the data was classified into <40 and >40 and the Fisher's exact test was done to assess the significance of the association of the STAI scores (Table 13 above). The associations between Y1 Anxiety scores before and after assessments were not statistically significant (p = 0.9 and p = 0.6 respectively), confirmed by the McNemars paired chi square (a test for pairwise significance). However, there was a statistically significant association between the Y2 Anxiety scores before and after assessments (p = 0.01 and p = 0.02). The McNemars paired chi square test, though, revealed that the proportional difference was not statistically significant.

4.4 Physiological data: Hexoskin smart vest

Breathing and/or respiration rate (RR)

The Hexoskin smart vest smart vest RR data of the participants were recorded in real-time (online) and captured as respirations per minute (rpm). Figure 10 below is a representation of a participants' RR trace monitored before, during and after the assessment period. Note the 'peaks' in RR at and above 40 rpm, as recorded during the assessment.

Figure 2: Participant's RR trace monitored before, during and after the assessment period

After reviewing individual RR (experimental cohort), all the participant groups' RR were analysed for comparisons and/or significance. Table 14 below represents the overall RR for all the participants. The table illustrates that the mean respiration rate for the fourth-year group was significantly lower than that of the first-year group ($p < 0.001$), which showed the highest RR.

Table 14: Overall RR for the experimental participants

Respiratory rate						
Year	**n**	**mean (0verall)**	**sd**	**min**	**max**	**p value**
1	19	19,06	3,58	12,27	26,30	<0.001
2	13	21,74	3,17	15,26	25,58	
3	12	19,08	3,52	14,54	28,24	
4	9	12,71	4,56	6,83	21,58	
Total	**53**	**18,67**	**4,55**	**6,83**	**28,24**	

This pattern was confirmed with the mean RR for all the participants (Table 15 below), where the fourth-year group's mean (max) was significantly lower than all the other groups.

Table 15: Comparison of the mean maximum RR for all the participants

Year	n	mean (max)	min	max	p value
1	19	44,74 ± 8,69	29,00	65,00	0,004
2	13	43,92 ± 7,17	27,00	54,00	
3	12	44,53 ± 13,25	31,00	82,00	
4	9	30,44 ± 9,32	13,00	44,00	
Total	**53**	**42,20**	**13,00**	**82,00**	

Mean ± Standard deviation

Pulse or heart rate (HR)

For ease of reference, the following time points was analysed for their assessment period:

- Before - TPB
- During - TPD
- After - TPA

Furthermore, a mixed method ANOVA was applied to this data to determine if there was a significant interaction between the groups and time on HR variables.

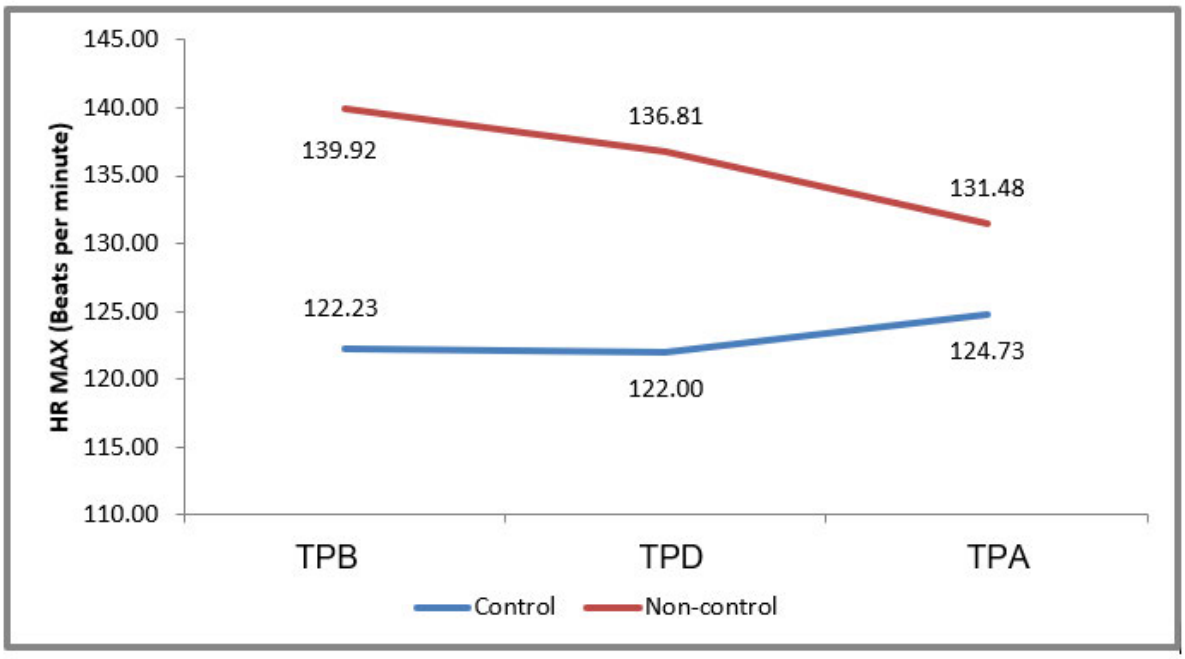

Figure 11: The mean HR for the control and experimental groups

The mean HR before, during and after the assessment, for both the experimental and the control group is shown in Figure 11 above. The figure shows that the mean HR for the exposed group are significantly higher (p = 0.026) than for the TPB and TPD, but not the TPA (p = 0.2), when compared to the mean HR for the control group. Interestingly, the mean HR for the control group was higher at the 'after' time point compared to the 'before' and 'during' TP (Table 16 below).

Table 16: Comparison of HR data (Two-sample t test with equal variances)

		Before	p value
	n	**mean**	
Control	113	122.23 ± 16.7	0.0
Experimental	53	139.92 ± 20.3	
		During	
	n	**mean**	
Control	115	122.00 ± 22.7	0.0
Experimental	53	136.81 ± 19.8	
		After	
	n	**mean**	
Control	115	124.73 ± 18.8	0.2
Experimental	40	131.48 ± 19.1	

Mean ± Standard deviation

All the participant groups' HRs were analysed for comparisons and/or significance. Table 17 below represents the overall HR for all the participants. The mean (overall) HR of the first-year group is lower than that of the other groups, however it is not statistically significant (p = 0,37), while the mean (overall) HR of the rest of the groups are similar. Of note, the HR (max) indicates an increased HR, and specifically, a tachycardia (Heart Foundation, 2022) for the second- and third-year groups.

Table 17: Overall HR for all the participants (Experimental cohort)

Year	n	mean (0verall)	min	max	p value
1	19	95,57 ± 11,46	79,68	116,27	0,37
2	13	104,71 ± 16,91	81,99	133,43	
3	12	100,52 ± 19,14	69,09	141,27	
4	9	102,57 ± 9,45	89,08	116,67	
Total	**53**	**100,14 ± 14,99**	**69,09**	**141,27**	

Mean ± Standard deviation

When comparing the mean HR (min and max-min difference) for all the groups (Table 18 below), firstly, the fourth-year group's minimum is significantly greater than the first-year group (p = 0.001) and the third-year group (p = 0.006). The fourth-year group's minimum is also greater than the second-year group, however it was not significant (p = 0.11), with an overall significance of p= 0.006. Secondly, the year 4 mean difference (max-min) is also significantly greater than that of the first-year group (p = 0.001) and third-year group (p= 0.009). Similarly, the fourth-year group's mean difference (max-min) versus the second-year group was not significant (p = 0.16), with an overall significance of p= 0.004.

Table 18: Comparing the mean HR (min/max-min) for all the year groups

Year	n	mean (min)	min	max	p value	mean diff (max-min)	min	max	p value
1	19	58,11 ± 14,23	30	83	0.001	90,53 ± 28,24	45	147	0.001
2	13	69,08 ± 17,14	45	103	0.11	69,62 ± 24,47	39	115	0.16
3	12	61,07 ± 16,04	30	104	0.006	83,07± 20,47	58	132	0.009
4	9	80,33 ± 16,59	40	95		54,00 ± 26,97	31	123	
Total	53	65,02 ± 17,29	30	104		77,80 ± 27,86	31	147	
Overall					0,006				0,004

Mean ± Standard deviation

Heart rate variability (HRV)

HRV is an accurate method to assess autonomic nervous system (ANS) function, which plays a role to regulate the heart rate (Kubios, 2022). As highlighted, raw data collected online from the Hexoskin smart vest was converted (Microsoft Excel) and analysed using the Kubios HRV standard software. The following measures which exhibit different autonomic modulations (Kleiger, Stein, Bosner and Rottman, 1992; Pittig, Arch, Lam and Craske, 2013) were investigated:

- standard deviation of normal-to-normal R-R intervals (SDNN) – sympathetic modulation;
- the root mean square of successive differences (RMSSD) – parasympathetic modulation: and
- the proportion the number of times the successive R-R intervals exceed 50 ms (pNN50) – parasympathetic modulation.

For this cohort, three variables of HRV were applied, however there was only significant interaction as shown by the SDNN method. Both the RMSSD and pNN50 analysis displayed no significant interaction (see Table 19 below) between the control or experimental groups (either before, during and after assessments). The findings of the current study provide more evidence that HRV is a good indicator of physiological stress, showing that a clinical decline in HRV corresponds to an increase in sympathetic activity.

Table 19: HRV – SDNN, RMSSD and pNN50 (the control or experimental groups)

Heart Rate Variability			
	Control (n=13)	**Non-control (n=40)**	**Total (n=53)**
***RMSSD (mean, sd)**			
TPB (before)	222.,508 (138.2905)	224,293 (222.3129)	223,855 (203.6693)
TPD (during)	206,469 (154.9456)	258,138 (253.0836)	245,464 (232.5565)
TPA (after)	242,723 (215.2415)	330,703 (328.8741)	309,123 (305.4020)
****SDNN (mean, sd)**			
TPB (before)	169.308 (93.5071)	180.810 (179.3901)	177.989 (161.7972)
TPD (during)	156.592 (105.1739)	198.150 (195.8283)	187.957 (177.8766)
TPA (after)	213.977 (228.6378)	287.500 (293.2751)	269.466 (278.5519)
#pNN (mean, sd)			
TPB (before)	46.969 (28.8225)	32.335 (28.5778)	35.925 (29.0626)
TPD (during)	40.992 (33.6988)	35.465 (31.0413)	36.821 (31.4722)
TPA (after)	43.962 (26.0430)	31.455 (28.0687)	34.523 (27.8732)

**Measure in milliseconds; ** Measure in milliseconds; #Measure in %*

Furthermore, only the SDNN of the experimental group (Figure 12 below) during the assessments was significantly higher than the control group ($p = 0.020$), while the SDNN values after the experimental group's assessments, were significantly higher than before assessments ($p = .041$).

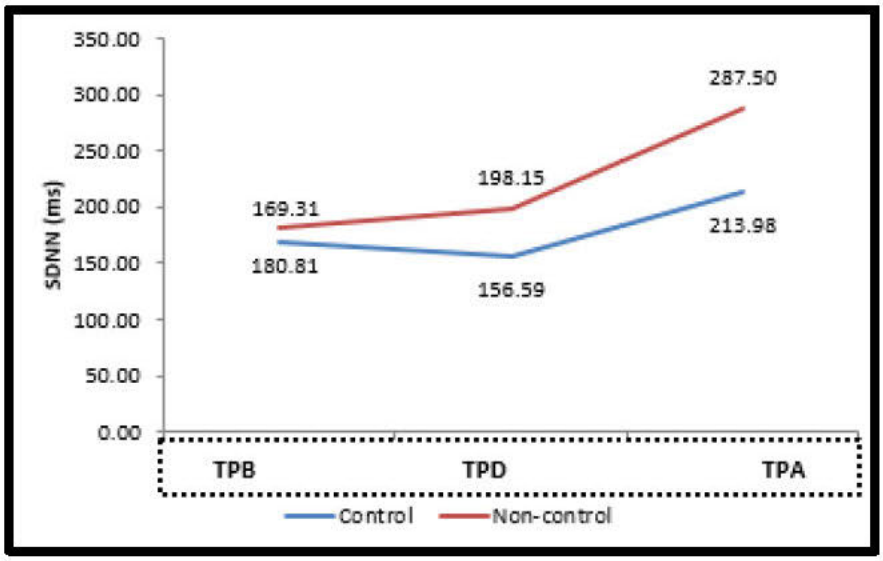

Figure 12: SDNN

4.5 Physiological anxiety indicators: Saliva α-amylase and cortisol assay

As highlighted, the salivary assay of the participants' samples included two validated stress enzymes, namely α-amylase and cortisol. By investigating the individual results of each enzyme, a comparison can be made in terms of the responsiveness and accuracy to record individual anxiety levels.

Saliva α-amylase assay results

The results of the α-amylase samples were determined directly by using the standard curve, after precisely following the enzymatic assay protocols to measure the participants' enzyme activity before and after assessments (experimental group). Both the before- and after-assessment α-amylase results were highly skewed. In the before-assessment sample 26/55 (47%) had the value of 400 (U/ml) and 24/55 (43%) in the after-assessment sample. Of those below 400 (U/ml), the majority were less than 200 (U/ml): 22/55 (40% in the before and 25/55 - 45% in the after samples). Figure 13 below represents the α-amylase assay for all participants (experimental group).

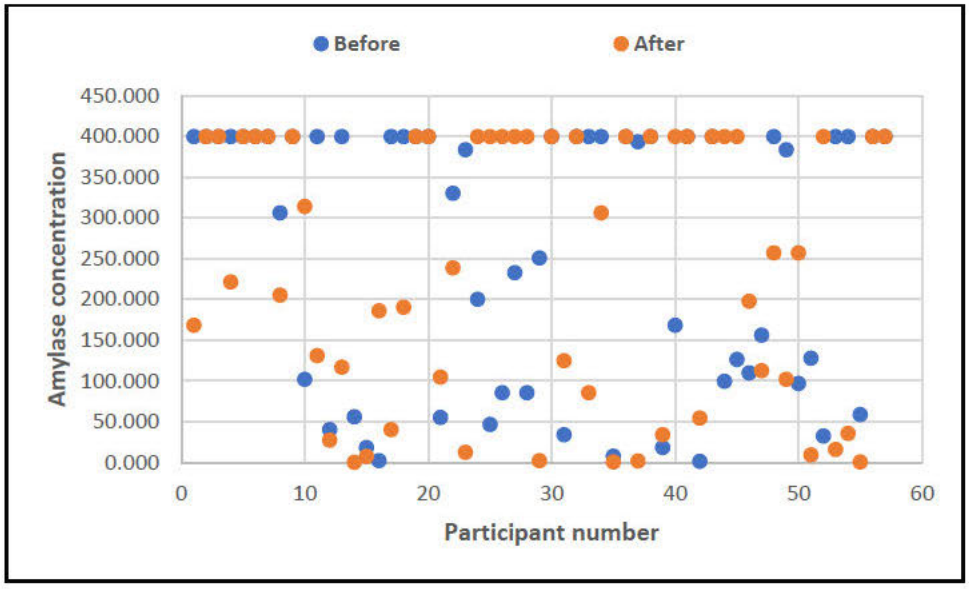

Figure 13: α-amylase assay results

Applying the Wilcoxon signed-rank test (Table 20) to the α-amylase assay results over time (before and after the assessments), indicates that α-amylase enzymes decreased over time, however the change in α-amylase concentration was not statistically significant (p = 0.31).

Table 20: Wilcoxon signed-rank test

Variable α-amylase	n	median	IQR		min	max	p value
amylase_before	55	383,75	97,03	400	1,45	400	
amylase_after	55	257,24	85,63	400	0,06	400	
amylase_change	55	0	-118,6	53,14	-391,56	367,7	0,31

A comparison between the different year groups using the Kruskal-Wallis equality-of-populations rank test (Table 21 below), found that there were no major differences in α-amylase levels before assessments (p = 0.18). Subjecting the α-amylase assay after-assessments results to the same rank test, showed that there was a borderline difference in amylase levels after the experiment (p = 0.07). As the Kruskal Wallis test was borderline significant, the Dunn Test was used for pair wise comparisons, which showed that the fourth-year group was significantly higher than the first-year group (p = 0.02), the second-year group (p = 0.04) and third-year group (p = 0.04). The differences between the first-, second- and third-year groups were not significant. Lastly, the second-year group was significantly lower than both the third- (p = 0.02) and fourth-year groups (p = 0.007), but not from the first-year group (p = 0.08).

Table 21: Kruskal-Wallis equality-of-populations rank test

α-amylase_before							
α-amylase	**n**	**Median**	**IQR**		**Min**	**Max**	**p value**
Year 1	19	156,02	97,03	400	1,45	400	
Year 2	13	383,75	55,28	400	2,23	400	
Year 3	15	250,89	85,63	400	7,58	400	
Year 4	8	400,0	400,0	400	102	400	0,18
α-amylase_after							
α-amylase	**n**	**Median**	**IQR**		**Min**	**Max**	**p value**
Year 1	19	257,24	35,69	400	0,77	400	
Year 2	13	117,04	27,11	190,57	0,06	400	
Year 3	15	400	85,63	400	0,51	400	
Year 4	8	400	221,41	400	168,17	400	0,07

Saliva cortisol assay results

Similarly, having strictly adhered to the protocol for the cortisol assay, it yielded the following results (Figure 14 below). This distribution is odd, as the values 'clump' together at both the lower level and for a few participants (43–51) at higher values.

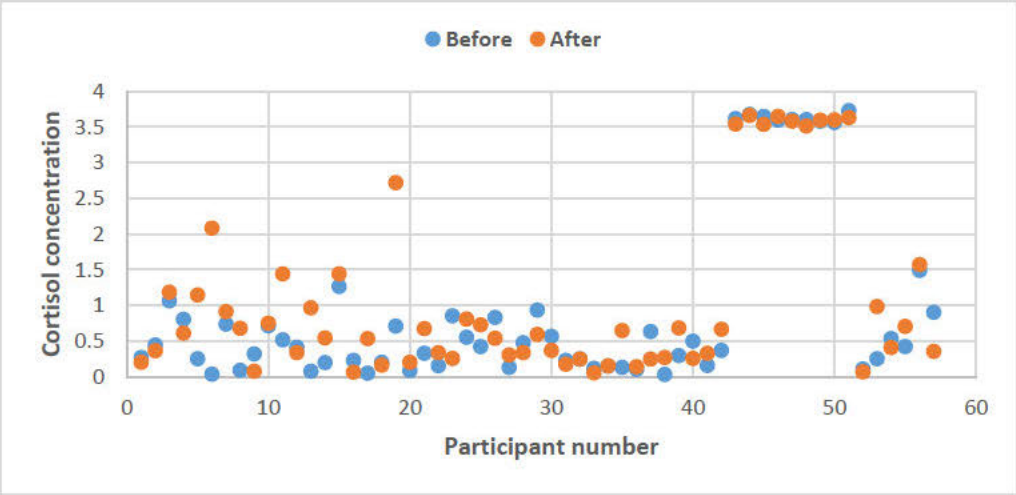

Figure 14: Cortisol assay results

Subjecting the participants' cortisol assay results to the same statistical tests as mentioned above, the Wilcoxon signed-rank test (Table 22 below) indicated an increase in measured cortisol enzyme levels between the before- and the after- assessment results (borderline significant, p = 0.09).

Table 22: Wilcoxon signed-rank test

Cortisol	n	median	IQR		min	max	p value
cortisol_before	55	0,42	0,2	0,86	0,04	3,73	
cortisol_after	55	0,61	0,27	1,19	0,06	3,66	
cortisol_change	55	0,03	-0,09	0,28	-0,6	2,05	0,09
change = after-before							

However, conducting the Kruskal-Wallis equality-of-populations rank test (Table 23 below) found that there was no difference in the cortisol change between year groups (p = 0.27).

Table 23: Changes in cortisol before and after assessments

		Before		
Year	**n**	**median**	**IQR**	
1	191	1.49	0.37	3.60
2	31	0.23	0.15	0.52
3	51	0.25	0.13	0.57
4	81	0.45	0.27	0.74
Total	**555**	**0.44**	**0.18**	**0.88**
		After		
Year	**n**	**median**	**IQR**	
1	191	1.57	0.41	3.60
2	31	0.54	0.26	0.97
3	51	0.31	0.18	0.60
4	81	0.68	0.36	0.91
Total	**555**	**0.606**	**0.267**	**1.314**
		change in cortisol (after-before)		
	n	**median**	**IQR**	
1	191	-0.01	-0.10	0.17
2	31	0.18	-0.04	0.48
3	51	0.00	-0.20	0.24
4	81	0.04	-0.08	0.17
Total	**555**	**0.024**	**-0.093**	**0.27**

4.6 Section Three: Exploring the associations between the different stress biomarkers (psychological and physiological indicators) of the participants before, during and after clinical assessments

After all the 'raw' data was compiled and scrutinised in terms of statistical significance (for the experimental group), it was combined to form a 'stress profile' for each participant (see Figure 14 below). This included all the physiological data (Hexoskin smart vest smart vest smart vest and salivary assay results), as well as the psychological markers (STAI questionnaire results). The combined data sheet was then further explored both for individual's and the different groups' overall stress levels (first, second, third and fourth years). Only 13% of the participants recorded an elevated physiological response, however their psychological stress levels were within normal parameters (Spielberger, C., Goruch, R., Lushene, R., Vagg, P. and Jacobs, G. 1983; Julian, 2011).

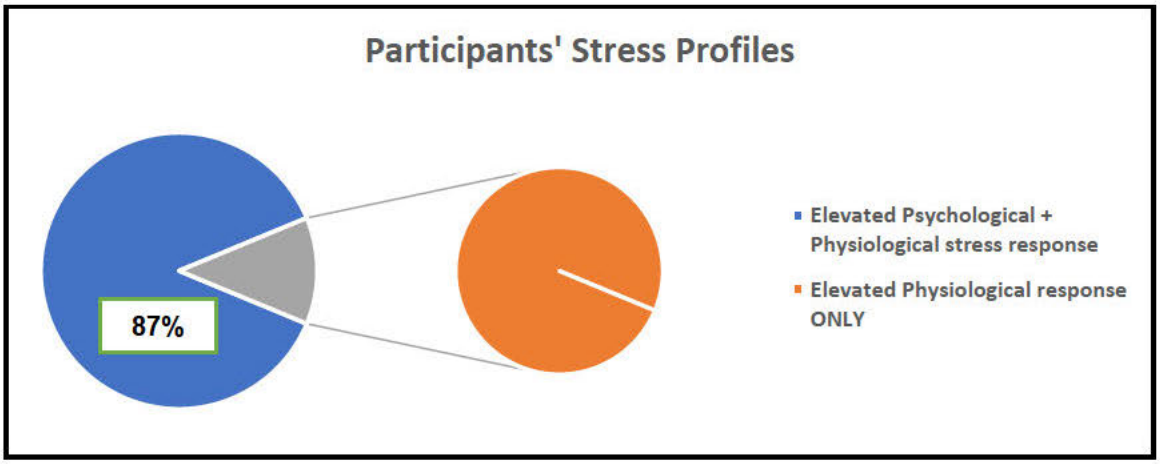

Figure 15: Percentage distribution of the participants who only recorded a psychological stress response

Furthermore, taking a closer look at the participants' perceived psychological stress response (Figure 15 below), revealed that the majority (> 80%) of the participants experienced an elevated anxiety level, while only 16% reportedly experienced 'normal anxiety' levels, as described in the Methodology Chapter (Spielberger, C., Goruch, R., Lushene, R., Vagg, P. and Jacobs, G. 1983; Julian, 2011).

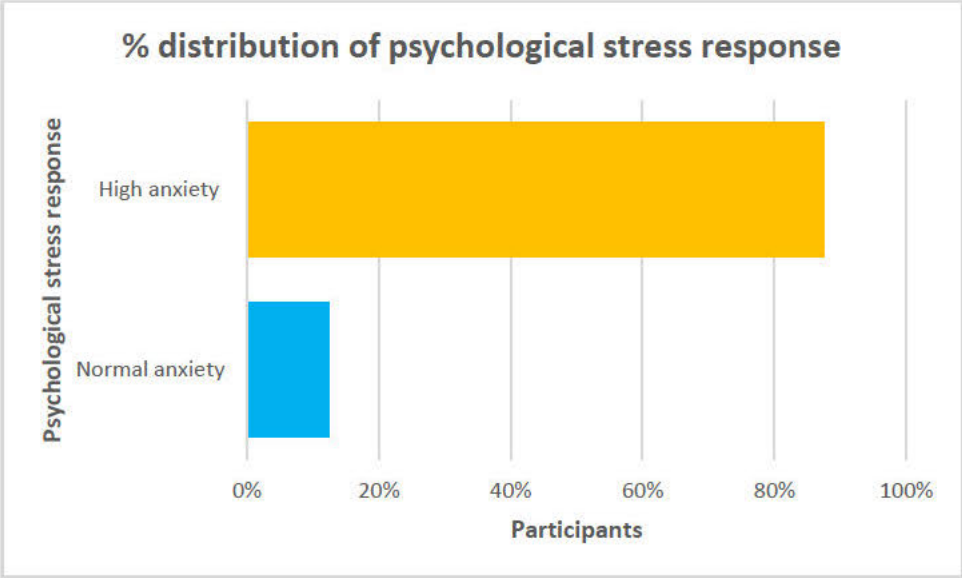

Figure 16: Participants' perceived psychological stress response (experimental group)

However, when comparing the stress indicator trends, even those who experienced 'normal anxiety' recorded saliva assay results and/or Hexoskin smart vest smart vest vest data which were indicative of elevated physiological stress levels. Table 24 below is a comparison of all the data streams as recorded for the experimental group. As highlighted initially, complete validated records of all the data tools were captured for n = 56, however only n = 53 had valid Hexoskin smart vest smart vest data (HR, RR, HRV) and n = 55 valid sputum assay results. During the data analysis this was managed by firstly processing each data stream individually and then compiling a spreadsheet, ensuring the relative participant (s), with invalid data were isolated and not included as per their affected data tool.

Table 24 : Comparison of all the data streams indicating anxiety levels (experimental group)

Experimental Group	Data stream	Normal anxiety (n)	Elevated anxiety (n)
First years	STAI	6	13
	HR	0	19
	RR	0	19
	HRV	0	0
	α-amylase assay	11	8
	Cortisol assay	14	5
Second years	STAI	1	12
	HR	0	13
	RR	0	13
	HRV	0	0
	α-amylase assay	11	2
	Cortisol assay	5	8
Third years	STAI	0	15
	HR	0	13
	RR	0	13
	HRV	0	0
	α-amylase assay	9	6
	Cortisol assay	9	6
Fourth years	STAI	1	8
	HR	0	9
	RR	0	9
	HRV	0	0
	α-amylase assay	7	1
	Cortisol assay	5	3

Additionally, Table 25 below compares the mean RR with their STAI Scores. Before the experiment, for participants with a Y1 score ≤ 40 and > 40, the mean RR measure was not statistically significant (p = 0.37). For the Y2 score measured before the experiment, a similar trend emerged in the observed mean RR (Y2 ≤ 40: mean of 19.89; Y2 > 40: mean of 18.09). Similarly, this association was also not statistically significant (p = 0.17). However, we did observe a statistically significant association between the Y2 score and RR, after the experiment, particularly in the group with a Y2 score > 40. When the data was stratified by year, we also observed a significant association between the STAI score and observed RR (p ≤ 0.001).

Table 25: Experimental group: comparison between the mean RR with the STAI Scores (before and after assessments)

	n	Mean	P value
Before			
Y1 score			
≤ 40	16	19.53 ± 3.81	0.37
>40	14	18.32 ± 4.81	
Y2 score			
≤ 40	18	19.89 ± 3.82	0.17
>40	13	18.09 ± 4.79	
After			
Y1 score			
≤ 40	20	19.98 ± 4.22	0.11
>40	13	17.94 ± 4.62	
Y2 score			
≤ 40	18	20.40 ± 3.48	0.049
>40	13	17.85 ± 4.80	
Year			
1	19	19.06 ± 3.58	<0.001
2	13	21.74 ± 3.17	
3	12	19.08 ± 3.52	
4	9	12.71 ± 4.56	

Mean ± Standard deviation

4.7 Section Four: Evaluating the impact of psychological and/or physiological stress indicators on the participant's assessment results (clinical performance)

The biometric 'stress profile' recorded for each participant was evaluated in comparison to their individual assessment results. A pass was recorded as equal to or more than 50% and a fail less than 50%, highlighted for all groups in red (Table 26 below represents the overall clinical assessment marks) The mean results indicated that overall, the third-year group obtained the lowest marks (mean 41.33), while the first years scored the highest overall marks (mean 69.67). However the fourth years had the largest mark variance (39.93 - 86.32, 95% CI).

Table 26: Overall clinical assessment marks

Clinical Assessment Results (overall)					
Year	n	Mean	sd	95% CI	
1	18	69.67	10.92	64.24	75.10
2	13	53.31	13.12	45.38	61.23
3	15	41.33	13.19	34.03	48.64
4	8	63.13	27.74	39.93	86.32
Total	54	56.89	18.91	51.73	62.05

In addition, a further breakdown of each group's marks (in order of the assessment dates – data collection days), will follow, starting with the fourth-year group's individual marks (Figure 16 below).

Code	P1	Red bars	Orange bars
Explanation	Participant number	Failed assessment	Passed assessment

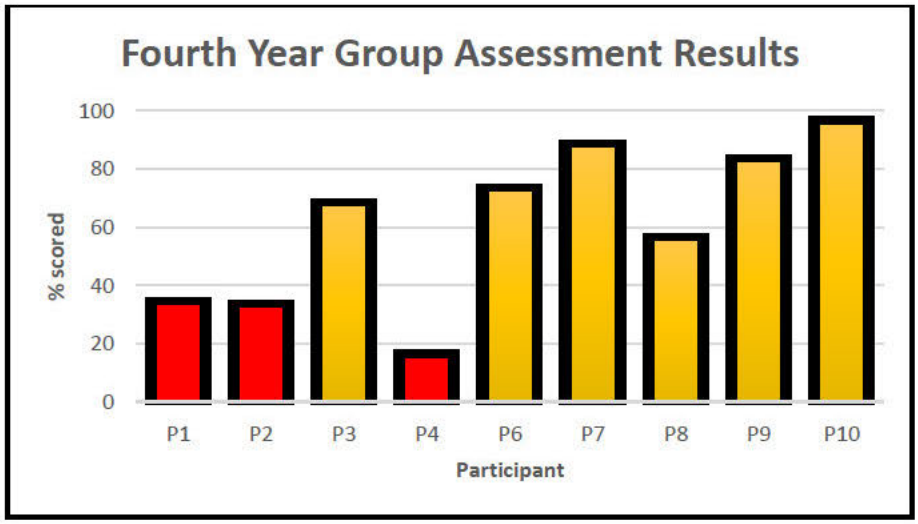

Figure 17: Fourth-year group assessment results (note: P5 excluded due to incomplete data collection)

For this group, the psychological stress scores of the majority (n = 8) indicated they experienced elevated anxiety, both before and after their assessment (n = 8) and only one participant scored 'normal anxiety'. This participant's salivary assay results (for both α-amylase and cortisol enzymes) also indicated "no change", before and after the assessment. However, this participant (P3), recorded HR of 116,67 – 148 (mean - max) and RR of 11,61 – 27 (mean - max). P1, P2 and P4 who were unsuccessful, all indicated elevated anxiety levels for their STAI scores, meaning they felt very anxious both before and after their assessments, which was confirmed physiologically by elevated HR and RR for all of them. The results of their salivary assay (see Table 26 below) do not, however, show a similar stress response.

Table 27: Saliva assay results

Participant	α-amylase	Cortisol
P1	Decreased	Decreased
P2	No change	Decreased
P4	Decreased	Decreased

The group's top performer (P10) for this assessment, experienced psychological stress (elevated anxiety on the STAI scoring) both before and after assessment, however the stress biomarkers for this individual produced mix saliva assay results, namely increased α-amylase levels, with "no change" recorded for the before- and after-assessment cortisol levels. This participant recorded HR of 89,08 - 163 (mean - max) and RR of 21,57 - 44 (mean - max).

The second-year group was the next final term assessment where data was collected and Figure 17 below represents their individual results.

Code	P1	Red bars	Blue bars
Explanation	Participant number	Failed assessment	Passed assessment

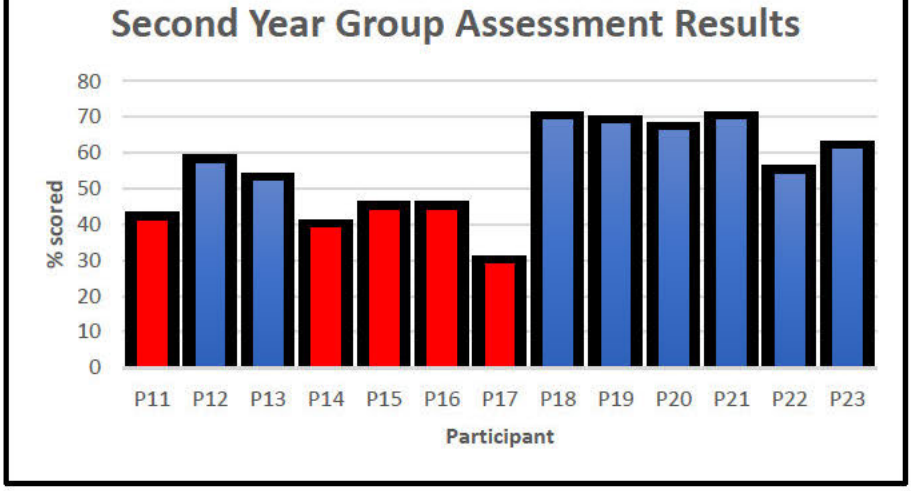

Figure 18: Second-year assessment results

The majority of the participants in this group had indicated 'elevated anxiety' for both their before and after STAI scoring. Furthermore, as a group they experienced increased physiological stress levels (elevated stress biomarkers), except for one individual (P13) whose total scores equated to "normal anxiety" (before and after STAI results). However, the physiological stress biomarker results for this individual, mostly painted a different picture – one of 'elevated anxiety' (Table 27 below).

Table 28: Saliva assay and Hexoskin smart vest smart vest data

Participant	α-amylase	Cortisol	HR (MEAN - MAX)	RR (MEAN - MAX)
P13	Decreased	Increased	89,74- 128	22,54 - 50

Next was the third-year group's data collection during their final term assessments, with results represented in Figure 19 below.

Code	P1	Red bars	Grey bars
Explanation	Participant number	Failed assessment	Passed assessment

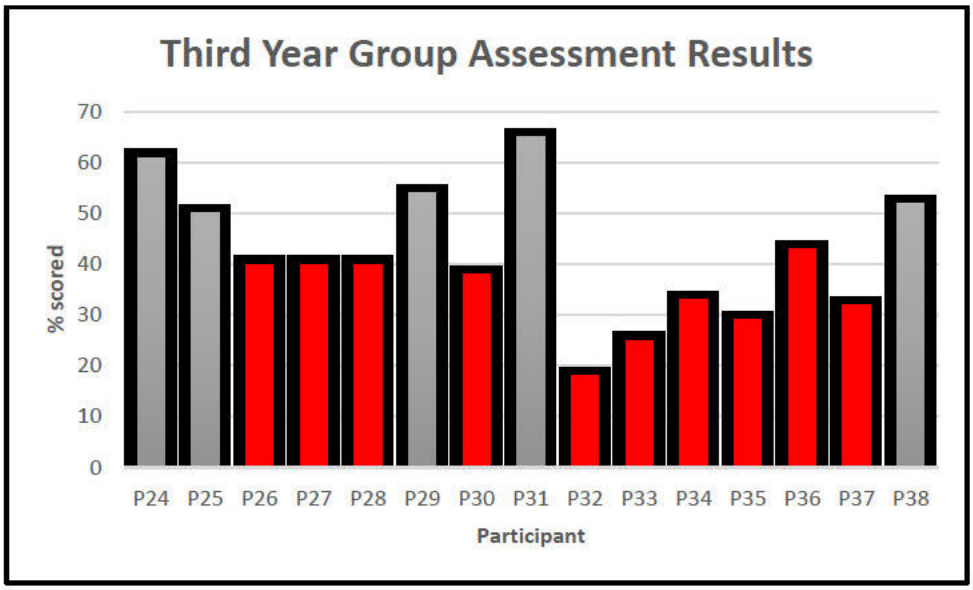

Figure 19: Third-year assessment results

Overall, their results indicated a 66.6% failure rate for the assessment and only five participants managing to pass (two participants scored above 60%, while the other three just passed with 50%, 52%, and 54% respectively). Similar to previous groups, their before and after STAI scores indicated they experienced elevated anxiety levels. This was mostly confirmed by their elevated physiological biomarker results both in terms of saliva assay (α-amylase and cortisol levels), as well as their Hexoskin smart vest smart vest data (HR and RR). Interestingly, one participant (P37) indicated 'normal anxiety' (before and after STAI results). Although this individual's salivary assay results showed a decrease for both α-amylase and cortisol levels (before and after assessment). Once again, as Table 28 below demonstrates, the Hexoskin smart vest smart vest data showed elevated HR and RR.

Table 29: Saliva assay and Hexoskin smart vest data

Participant	α-amylase	Cortisol	HR (MEAN - MAX)	RR (MEAN - MAX)
P37	Decreased	Decreased	89,98 -133	28,23 - 42

The last group (first- years), where data was collected during their final assessment, also had the most participants (n = 18). Figure 19 below represents their assessment results.

Code	P1	Red bar	Green bars
Explanation	Participant number	Failed assessment	Passed assessment

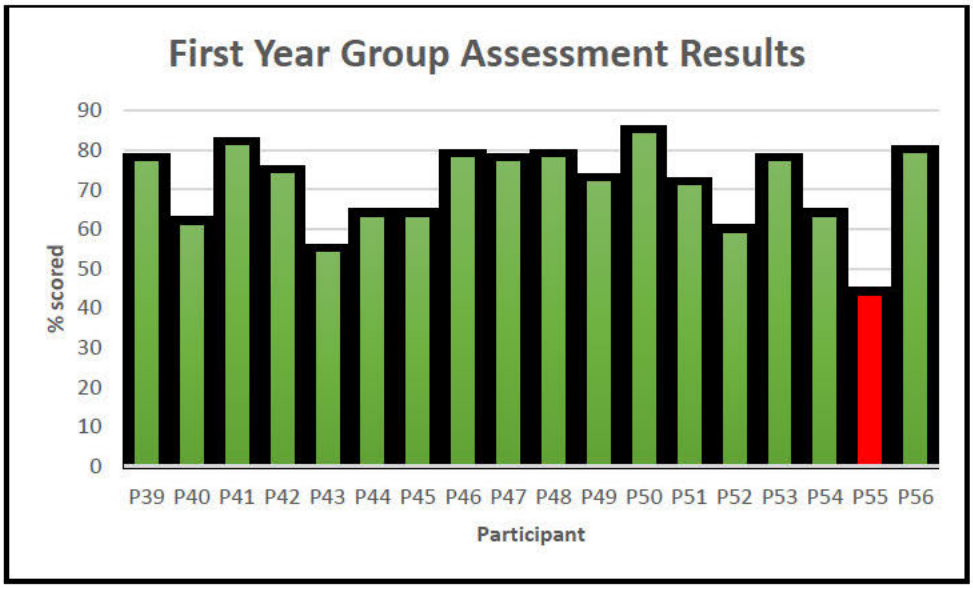

Figure 20: First-year assessment results

In this group, only one participant failed (P55: 43%), while the majority (83%) scored above 60%. In addition, five participants indicated 'normal anxiety' scores (before and after STAI results), whereas the remainder of the group's scoring indicated they experienced elevated anxiety levels, which was mostly corroborated by their physiological biomarker data. As for the five participants, their physiological data varied for their saliva assay results, however once again their Hexoskin smart vest data (HR and RR) indicated elevated anxiety levels (Table 29 below).

Table 30: First-year group participants with ‘normal anxiety’ STAI scores

Participant	α-amylase	Cortisol	HR (MEAN - MAX)	RR (MEAN - MAX)
P40	Increased	Decreased	88,84 - 163	9,59 - 49
P44	Increased	No change	85,46 – 148	16,51 - 37
P50	Increased	No change	96,97 – 130	20,96 - 49
P52	Increased	Decreased	97,58 - 131	23,87 - 52
P56	No change	No change	107,07 – 138	21,60- 42

Lastly, a logistics regression (numeric variables) was performed to predict the outcome of passing or failing, given the predictors α-amylase and cortisol levels, HR, RR and STAI scores (see Table 31 below). Based on the results, it can be concluded that the odds of passing the final assessment was significantly predicted by both the Y1 and Y2 after scores. The odds of passing given the Y1 score after-assessments, were 0.89 times the odds or statistically significant ($p = 0.001$), when holding other covariates constant. Similarly, the odds of passing given the Y2 after-assessment score was 0.93 times the odds or statistically significant ($p = 0.02$), when holding other covariates constant.

Table 31: A logistics regression model

	Assessment result									Odds of passing		
	Fail				Pass				p value	OR	95% CI	
	n	media n	IQR		n	media n	IQR					
Amylase												
Before	1 9	400	58. 9	400	3 5	330.3	99.4 8	400	0.84	1.0 0	1.00	1.00
After	1 9	185.86	7.2 1	400	3 5	257.24	102	400	0.41	1.0 0	1.00	1.00
Ratio	1 9	0.55	0.1	1	3 5	1.0	0.64	2.38	0.49	0.9 8	0.94	1.03
Cortisol												
Before	1 9	0.27	0.1 3	0.5 7	3 5	0.54	0.23	3.56	0.06	2.8 6	0.95	8.57
After	1 9	0.36	0.2	0.6 1	3 5	0.75	0.33	3.51	0.03	3.3 4	1.12	10.0 1
Ratio	1 9	1	0.6 5	2.3 4	3 5	1.02	0.82	2.05	0.54	1.0 5	0.90	1.21
Heart rate												
Heart rate	1 9	98.8	85. 6	112	3 5	100	88.8 4	107. 5	0.84	1.0 0	0.96	1.03
change HR	1 9	73	55	97	3 5	74	58	99	0.93	1.0 0	0.98	1.02
Ratio												
Respiratory rate												
Resp rate	1 9	18.13	15. 3	21. 3	3 5	19.16	15.6 1	21.9	0.44	1.0 5	0.92	1.20
change rr	1 9	36	27	45	3 5	36	31	45	0.78	1.0 5	0.92	1.20
STAI												
Score Y1 before	1 9	47	38	60	3 5	50	39	59	0.9	1.0 0	0.95	1.05
Score Y2 before	1 9	45	40	48	3 5	44	37	51	0.58	0.9 8	0.92	1.04
Score Y1 after	1 9	55	48	63	3 5	42	31	50	0.001	0.8 9	0.83	0.95
Score Y2 after	1 9	48	42	58	3 5	41	32	49	0.02	0.9 3	0.87	0.99

4.8 Section Five: Evaluating the different physiological stress indicators to identify which most accurately correlate to the participant's perceived psychological stress level

Psychological stress level

The participants STAI questionnaire results were consistent in terms of their before- and after-assessment scores, meaning they experienced elevated anxiety levels at each time point (87.5%; n = 49) and this was confirmed with the moderate positive correlation reported for the before and after STAI scores. Some indicated higher anxiety levels before the assessment, while others experienced greater anxiety after their assessments. In contrast, those who indicated that they only experienced normal anxiety levels (12.5%; n = 7), showed similar before- and after-assessment STAI results (see Table 32 below).

Table 32: STAI Questionnaire scoring

STAI Questionnaire Before and after assessments	**Participants**
Elevated anxiety	49
Normal anxiety	7
Total	56

In Table 33 below, the summary statistics are shown for the before and after STAI questionnaire scores, for the participants in the experimental group. In the fourth-year group, the lowest degree of variability between the before and after STAI score (mean difference = -0.89) was observed, which correlates with strong agreement for the pairwise measurement. In contrast, the first-year group had the largest degree of variability between their before- and after-STAI scores (mean difference = -5.79). On average, the total STAI scores, was a mean difference of –2.9 in the before- and after-STAI scores.

Table 33: Comparison of the before- and after-STAI questionnaire

Year	Before		After		Difference	
	n	Mean	n	Mean	Mean	p value
1	19	47,79 ± 12,98	19	42,00 ± 12,58	-5,79 ± 10,55	0,03
2	13	50,31 ± 13,92	13	45,38 ± 11,40	-4,92 ± 16,55	0,30
3	15	48,07 ± 10,31	15	49,47 ± 12,14	1,40 ± 13,05	0,68
4	9	48,11 ± 8,81	9	47,22 ± 15,83	-0,89 ± 14,20	0,86
All years	**56**	**48,50 ± 11,69**	**56**	**45,63 ± 12,77**	**-2,9 ± 13,4**	**0,1**

Mean ± Standard deviation

Physiological stress biomarkers

By focussing on the larger group who experienced the most anxiety (n = 49) and extracting their measured physiological stress biomarker data (both saliva assay and Hexoskin smart vest smart vest smart vest), allowed for comparisons to determine which physiological stress indicator most accurately and consistently correlates to their STAI scores (psychological stress level).

The saliva α-amylase and cortisol assay results were a 'mixed bag' (Table 32 below). For a few participants the different enzymes mirrored each other as it showed increased values for both enzymes (only n = 6). However, for the majority (n = 43; 87%) the saliva assay results were asymmetrical as it either showed increased, decreased or no change (before- and after-assessment samples).

Table 34: α-amylase and cortisol assay results

Assay results	α-amylase	cortisol
Increased	17	25
Decreased	24	22
No change	14	8
Total	**55**	**55**

There is a significant association between time and cortisol. Cortisol levels are significantly higher in the 'after' period compared to the 'before' (Table 33 below). In addition, cortisol levels also differed by year group. The first-year group seemed to be significantly higher (p <0.001) than the other year groups (second, third and fourth).

Table 35: Comparison between cortisol assay and the STAI results (before and after assessments)

Y1 score	n	geo-mean	95% CI		p	mixed model
<=40	36	0.64	0.41	0.99	0.30	0.60
>40	76	0.47	0.36	0.61		
Y2 score						
<=40	36	0.67	0.43	1.05	0.55	0.75
>40	76	0.46	0.35	0.59		
Time						
Before	57	0.45	0.32	0.62	0.02	0.04
After	57	0.60	0.45	0.81		
Year						
1	38	1.17	0.78	1.75	<0.001	0.00
2	26	0.36	0.24	0.54		
3	30	0.28	0.21	0.39		
4	20	0.44	0.27	0.71		

A similar comparison between α-amylase assay and the STAI results (before and after assessments), showed there was no difference in α-amylase levels by time, as well as no association with year of study. Interestingly, the fourth-year group levels were much higher than the other year-groups (Table 34 below).

Table 36: Comparison between α-amylase assay and the STAI results (before and after assessments)

Y1 score	n	geo-mean	95% CI		p	mixed model
<=40	36	133.89	76.44	234.52	0.90	0.57
>40	76	129.23	86.98	192.00		
Y2 score						
<=40	36	106.40	54.97	205.92	0.40	0.50
>40	76	144.09	100.58	206.43		
Time						
Before	57	163.04	114.61	231.92	0.13	0.12
After	57	108.99	64.39	184.45		
Year						
1	38	120.07	71.92	200.45	0.07	0.16
2	26	80.00	34.54	185.26		
3	30	130.09	65.14	259.82		
4	20	327.51	274.17	391.24		

The following are some of the vital sign highlights as recorded by the Hexoskin smart vest smart vest smart vest data (HR, RR and HRV), which focusses on the majority who experienced elevated anxiety levels (n = 49), for the time points (Ghazali et al., 2016) before, during and after assessments. It includes a breath-to-breath analysis represented by a histogram of one such participant's RR, captured for the TP during the assessment activity (Figure 20 below).

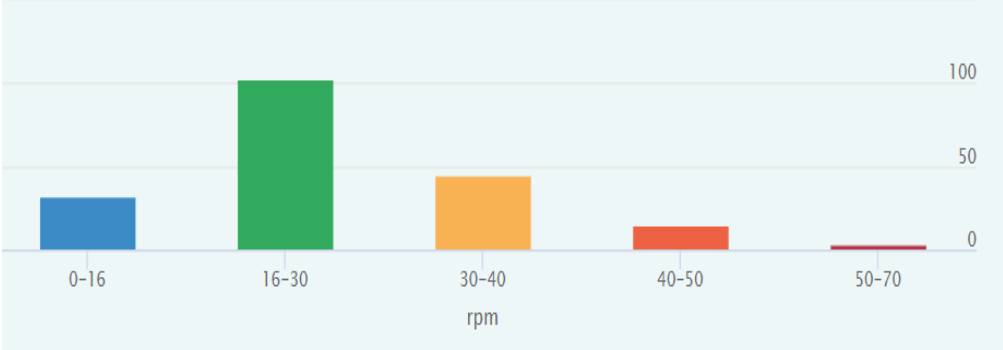

Figure 21: Histogram of a participant's RR during the assessment activity

In addition, an ECG of the corresponding HR increase (for the same participant), also 'peaking' during the actual assessment period is represented in Figure 21 below. However, for this cohort (elevated anxiety levels), there was only a significant difference in the SDNN values of the experimental group, which were significantly higher than the control group. There was no matching significant interaction of their HRV outcomes.

Figure 22: Graphical representation of the recorded HR for a participant before, during and after the assessment period (11:40–12:10)

Furthermore, a corresponding spike (max) in the participants' RR was observed for all the groups. Interestingly, the fourth-year group had the lowest mean (max) = 30.44 rpm, with the rest mean (max) all above >40 rpm (see Table 37 below).

Table 37: RR (mean/min/max)

Year	n	mean (max)	min	max	p value
1	19	44.74 ± 8.69	29.00	65.00	0.004
2	13	43.92 ± 7.17	27.00	54.00	
3	12	44.53 ± 13.25	31.00	82.00	
4	9	30.44 ± 9.32	13.00	44.00	
Total	**53**	**42.20 ± 10.97**	**13.00**	**82.00**	

Mean ± Standard deviation

Therefore, for this study, the Hexoskin smart vest smart vest smart vest HR and RR data (biomarkers) was the more accurate and consistent indicators which correlated to the participants' psychological stress level.

4.9 Conclusion

The evidence provided in this chapter had been recorded by the various research tools. It highlighted the key findings explored to 'construct' an accurate stress profile for undergraduate emergency care students before, during and after clinical assessments. Therefore, the findings were consistent with the objectives of the study.

The following chapter presents a discussion of the results of the study. It will focus on the important findings and describe its significance in relation to the aim of the study, incorporating available literature to substantiate or dispel the results.

CHAPTER 5 - DISCUSSION

5.1 Introduction

The findings of Chapter 4 represent the total data captured for this study, including the statistical analysis of each data collection tool. The significance of these results will be discussed in relation to the aims and objectives of the study. The research aim was to assess the impact of psychological stress on the clinical performance of undergraduate paramedic students during clinical assessments. The study objectives included comparing and exploring the trends between different stress indicators (biomarkers) for the different year groups, evaluating the impact of psychological and/or physiological stress indicators on the participant's assessment results (clinical performance) and lastly, evaluating the different physiological stress indicators to identify which most accurately correlate to the participant's perceived psychological stress level. Furthermore, the key data collection timepoints were before, during and after the intervention (clinical assessments).

This chapter therefore represents an in-depth exploration to interrogate and highlight the study results, while also including insights from relevant published sources related to this body of evidence.

5.2 Biographical data of the sample

Although there is an almost equal gender split in the first-year group, for the rest of the groups, the males outnumber the female participants in both the control and experimental groups. These findings are corroborated by a recent study (Tiwari, Naidoo, English and Chikte, 2021) who investigated the existing human resources in emergency care and concluded that the majority emergency care providers were males. Furthermore, the total active emergency care practitioners registered with the Health Professions Council of South Africa (HPCSA) as at October 2022 was n = 991, of which 66% were male (HPCSA, 2022).

There could be multiple reasons why female numbers in the paramedic field are low and may be attributed to the high levels of contact and violent crime in South Africa (Bezuidenhout & Kempen, 2022). As emergency care frontline responders, EMS personnel often encounter verbal and/or physical abuse due to their interactions with patients, their family members and/or bystanders (Holgate, 2015). Reportedly, 66% of the EMS staff surveyed in a study, indicated that they had experienced assault while on duty in South Africa (Holgate, 2015). Another deterring factor might be the physically taxing requirements for undergraduate emergency care students, especially during rescue learning activities which can be very strenuous and demanding (Muhlbauer, Vincent-Lambert and Coopoo, 2021).

Although the mean age of the study population was 25 years old, there exists a large age gap between the oldest and youngest participants, namely 40 and 18 years old respectively. A further breakdown of the participants' ages indicated that 23% of participants were 34 years old and older. To increase access to and participation in higher education (HE), there has been a movement throughout the South African

educational system, to grant those who do not necessarily have the prerequisite requirements, a chance to do so by means of Recognition of Prior Learning (RPL) programmes (Brenner, 2021). This may also reflect the ongoing developments regarding paramedic training moving from short-courses to tertiary programmes, as these older participants feel the need to up-skill themselves (Sobuwa & Christopher, 2019).

5.3 Comparison of the trends and associations between the different stress biomarkers (psychological and physiological indicators) - before, during and after clinical assessments

Previous anxiety studies (Vincent, Semmer, Becker, Beck, Tschan, Bobst, Schuetz, Marsch and Hunziker, 2021; Hardenberg, Rana and Tori, 2020; Tramer, Becker, Hochstrasser, Marsch and Hunziker, 2018; Dias and Scalabrini Neto, 2017) which related to the practitioner's performance during clinical simulation, have focussed on the individual's psychological characteristics by using one or more surrogate indicators of acute stress. Examples of these were the physiological biomarkers such as heart rate (HR), heart rate variability (HRV), systolic and diastolic blood pressure, salivary α-amylase, salivary interleukin-1β, etc.). In order to ascertain the most accurate stress profiles, the current research endeavour included psychological and several physiological biomarkers (including the α-amylase/cortisol assay, RR, HR and HRV). Similar studies on anxiety have revealed contradictory findings, using different "combinations" of these stress biomarkers. The stress response was either measured against only one set of physiological indicators, for example α-amylase versus cortisol assay (Takai, Yamaguchi, Aragaki, Eto, Uchihashi and Nishikawa, 2004; Ali & Pruessner, 2012), only cardiac stress biomarkers (Schubert, Lambertz, Nelesen, Bardwell, Choi, and Dimsdale, 2009; Lin, Lin, Lin, and Huang, 2011) or incorporating one psychological indicator versus one physiological stress biomarker (Stein, 2020, Piquette, Tarshis, Sinuff, Fowler, Pinto and Leblanc, 2014).

The participant's self-reported anxiety levels were assessed using a validated psychological tool, the State-Trait Anxiety Inventory questionnaire (Zsido, A. N., Arato, N., Lang, A., Labadi, B., Stecina, D. and Bandi, S. A. 2021; Thomas & Cassady, 2021). Respiration and cardiovascular stress biomarkers were measured using the Hexoskin smart vest for the first time in Africa, to assess their levels of anxiety during both classroom training clinical simulations (control group) and final term clinical assessments (experimental group). As both markers were recorded simultaneously and their correlations were investigated, this enabled comparisons between the participants' psychological and physiological status.

Data in respect of each individual marker is presented and the key findings discussed for each category: first the psychological tool, then the physiological markers, which is followed by a description of the relationship between the two sets of stress indicators.

5.4 Psychological tool: state-trait anxiety inventory

The participants' STAI results revealed that the majority (87.5%; n = 49) of the participants experienced elevated anxiety levels, while only 16% reportedly experienced 'normal anxiety' levels using the guidelines specific to this tool as described by Spielberger et al. (1983). A cohort of working adults (highlighted in Chapter 3) who validated the STAI questionnaire, scored a mean baseline of 35. However, when asked to simulate taking a high-stakes exam, participants' STAI scores averaged 42 (Spielberger, 1983). In addition, previous studies which measured stress responses during 'emergency care' simulation activities and/or under clinical assessment conditions, identified similar elevated anxiety levels among both adolescents and adults (LeBlanc, 2009, Piquette et al., 2014, Stein, 2020, Harvey, NathenS, Bandiera and Leblanc, 2010).

A person's sensitivity to perceived stressors or threats and propensity to react to them are measured by their trait anxiety (Endler & Kocovski, 2001). Anxiety is a feeling that is marked by apprehension and physical signs of tension that is experienced when one "anticipates impending danger, catastrophe, or misfortune" (American Psychiatric Association, 2022). The body frequently gets ready to respond with the perceived threat by tensing up muscles, increasing the breathing and heart rate (American Psychiatric Association, 2022). In addition, the hypothalamus-pituitary-adrenal axis and the sympatho-adrenal-medullary axis are two of the body's regulatory systems that become active in response to stress, maintaining homeostasis and causing changes in immunological and cardiovascular markers (Mayor & Gamaiunova, 2014). In this study cohort, these effects were observed as corresponding elevations in heart rate and respiratory rate. In retrospect, these findings are similar to a polygraph test, where an individual may not be entirely truthful initially when providing an answer, however the polygraph sensitivity allows for the recording of different bodily responses (vital signs), which may then be used to determine whether someone is telling the truth or not.

Exploring the STAI results of the different groups highlighted that different year groups 'stressed' at different stages of their assessments. For instance, the first-year group experienced a significant elevation ($p = 0.03$) after, compared to before the assessment. This may have been due to the fact that as first-year students, it was their first summative clinical assessment, so they may not have been fully prepared for what to expect. After their assessment, some may have thought that they did not perform as they had hoped, fearing failure. Nonetheless, their results indicated that only one participant failed, while the rest passed. There was a sizable difference in the anxiety scores (before and after assessments) in the second-year group (mean ± standard deviation: 50,31 ± 13,92 (before); 45,38 ± 11,40 (after); difference: -4,92 ± 16,55; $p = 0,30$). While the third- and fourth-year groups' scoring indicated they experienced significant levels of anxiety, both before and after assessments (third-years' mean ± standard deviation 48,07 ± 10,31 (before); 49,47 ± 12,14 (after); $p = 0,68$; and fourth-years' mean ± standard deviation 48,11 ± 8,81 (before); 47,22 ± 15,83 (after); $p = 0,86$, respectively).

A possible explanation of the above-mentioned data is that each group's assessment had specific objectives, where the students were expected to perform basic to advanced interventions, due to knowledge and skill scaffolding. As highlighted, the third- and fourth-year groups had a similar distribution of anxiety scores (> 80% in each group were at > 40), and these procedures included drug administration and synchronized cardioversion. These findings were similar to previous studies which found that during trauma resuscitation simulations, the participants' subjective appraisals of the situation produced high stress responses, which "have previously been shown to impair performance" (Harvey et al., 2010), while the anticipatory stressful response during simulated resuscitation scenarios may negatively impact "learning and performance" (Piquette et al., 2014). Moreover, stress among medical students is a significant factor which contributes to clinical errors in acute care settings, based on mean STAI scores of 40 and higher (Piquette et al., 2014). Lastly, the mean STAI scores for all participants (n = 56), indicated elevated anxiety levels at both the before- and after-assessments periods, which is comparable to previous studies (LeBlanc, 2009), while others have reported even higher STAI scores where mean post-simulation STAI scores increased substantially from 33.5 to 60 (Stein, 2020).

According to Dickerson and Kemeny (2004), social-evaluative stress implies task performance which could be negatively judged by others, such as during assessments. They suggest that it has been proven "as the most powerful way to induce stress" (Dickerson & Kemeny, 2004). Therefore, formal clinical assessments may elicit an elevated anxiety response resulting in higher STAI scores (LeBlanc, 2009). In addition, multiple variables such as the presence of numerous assessors and video camera recording (for routine moderation purposes) may add to the students' anxiety levels during these clinical assessments (Sobuwa, 2018, Stein, 2020). Moreover, the sample's age range was wide (18–40 years old). Recent studies reveal that negative interactions can be nuanced and associated with increased or decreased physiological stress (Birditt, Tighe, Nevitt and Zarit, 2017). The strength and vulnerability integration (SAVI) theoretical model, which describes how processes of emotion regulation varies across the adult life-span, explains that age-related increases in physical vulnerabilities pose greater challenges for older adults when managing high levels of emotional arousal (Birditt et al., 2018). For example, under circumstances in which older adults experience increased and sustained negative emotions, they have reduced physiological ability to recover and thus decreased well-being (Charles, 2010).

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1. Short Form Y-1; Trait anxiety; "I am tense; I am worried"
2. Short Form Y-2; State anxiety; "I am content; I am a steady person"

5.5 Stress Indicators – Respiration rate, Heart Rate, Heart Rate Variability (Hexoskin smart vest results)

Breathing/respiration rate (RR)

Respiratory psychophysiologists have been interested in the psychobiology of anxiety, as there are clear connections between respiratory distress and subjective anxiety (Abelson, Khan and Giardino, 2010). Despite extensive stress neuroendocrinology and respiratory psychophysiology research, studies of their interactions are rare and the impact of psychological stress on respiration in simulated circumstances is not well understood (Abelson et al., 2010, Herman et al., 2003, Herman et al., 2016). However, the distinct set of emotions associated with prolonged stress is frequently subjectively characterized by anticipation of impending disaster in the absence of any ability to control, shape, or cope with the anticipated negative outcome (Evans & Schamberg, 2009, Abelson, Khan and Giardino, 2010). The RR recordings for the groups indicated elevated breathing rates or tachypnoea/hyperventilation. Tachypnoea is rapid breathing (>20 rpm) and hyperventilation can be described as an increase in ventilation that is greater than that required by metabolic needs or arterial blood gas tensions (Tipton et al., 2017). These findings are similar to physiological responses which have been recorded when levels of anxiety increase (Van Duinen, NiccolaI and Griez, 2009, Jayasankar, Sreeraj, Chhabra, Kumar, Manjunatha, Venkatasubramanian and Reddy, 2022). These findings are not altogether surprising given the high STAI scores and HR that were found in this study. The RR results suggest that the participants were stressed which led to an increase in sympathetic activity, resulting in increased respiration.

Heart rate (HR)

During psychological stressful events, activation of the sympathetic nervous system leads to a state of arousal through beta-adrenergic stimulation of peripheral and central target tissues, such as the heart and amygdala (Chrousos & Gold, 1998, Ziegler, 2012). Concerning the heart, stress increases the HR by withdrawal of parasympathetic input and increased sympathetic stimulation (Ziegler, 2012). These mechanisms were apparent in the findings of this study, as manifested by the increased HR (tachycardia) recorded for most participants in both the control and experimental groups. The mean HR for the experimental group was significantly high ($p = 0.026$) at all three time points (TPB = 139 bpm; TPD = 136 bmp; TPA = 131), compared to the mean HR for the control group (TPB = 122 bpm; TPD = 122 bmp; TPA = 124 bpm). This could be due to the socio-evaluative stress caused by the assessment (Dickerson & Kemeny, 2004), as opposed to the control groups' in-class practice sessions. Interestingly, the mean HR for the control group was higher at the 'after' time point, compared to the 'before' and 'during' time points. A possible reason could have been that these students realised their mistake and/or clinical decision errors which negatively impacted on their performance, causing increased consternation and/or self-doubt,

especially when their peers were spectators. Anxiety linked to poor performance is one of the elements that could lead to higher stress levels (Brasil, Lima, Cunha, Cruz and Ribeiro, 2021).

A study which measured participants' physiological stress in terms of HR during cardio-pulmonary resuscitation (CPR) performance (Hunziker et al., 2011), found a significant increase in HR during resuscitation ($p < 0.001$). While there was a significant increase in HR in their study, the mean HR remained within the normal range of 60-100 bpm. The increase in HR during CPR is to be expected, as it is a physically demanding clinical intervention for any practitioner (Slamon et al., 2018). Although physical exertion could have been a confounder and therefore skewed the results, in the current study, the participants' degree of physical activity was restricted and maintained consistently throughout all of the clinical simulations (both control and experimental groups) and none of the participants performed CPR.

When comparing the mean HR for all the groups, the fourth-year group's minimum was significantly higher than the first- and third-year groups (for example, $p = 0.001/0.009$). These final-year students were completing their 'exit' level-clinical assessments and most would have taken an average of four academic teaching years to get to this point. However, some may have repeated prior subjects over the years, so it may have taken them even longer. This may explain why this group felt even more pressure (stress) compared to the rest, as they were being assessed and expected to perform as 'qualified' paramedics. The practical clinical subject incorporated on the Bachelor of Emergency Medical Care (BEMC) degree programme, often leads to the delayed graduation of undergraduate paramedic students (Sobuwa, 2018), as these students may not pass all components of the practicum. In addition, psychological stress during these assessments was suggested as one of the key barriers to academic success on the BEMC degree (Sobuwa, 2018). These HR findings are also aligned with the evidence reported by Stein (2020), who concluded that undergraduate students who took part in emergency care simulation assessments showed noticeably heightened levels of anxiety and increased heart rates.

Heart rate variability (HRV)

HRV is an accurate method to assess autonomic nervous system function and it predominantly controls unconscious biological processes like heart rate, vasoconstriction, and respiration rate (Kleiger et al., 1992). This study used the Kubios HRV standard software for HRV analysis. This software produced three variables (SDNN, RMSSD and pNN50) based on the data collected using the Hexoskin smart vest. The experimental group's HRV (SDNN only) was substantially higher than those of the control group ($p = 0.020$). SDNN was also significantly higher after the experimental group's assessment than it was before the assessment ($p = 0.041$). Therefore, an increase in sympathetic activity was found to be associated with a clinical decrease in HRV. The typical response to a cognitive stressor is parasympathetic withdrawal, followed by sympathetic nervous system activation (Shaffer & Ginsberg, 2017). Therefore,

alterations in HRV suggestive of a stress reaction include a decrease in parasympathetic activity and an overall HRV decrease (SDNN), which suggests that the experimental group had experienced elevated psychological stress levels. Available literature regarding HRV analysis in similar clinical contexts has shown greater fluctuations in HRV than observed in the current study (Hunziker et al., 2011, Nakayama, Arakawa, Ejiri, Matsuda and Makino, 2018; Stein, 2020). However, in these studies, other variables were also at play, such as introducing physical exertion (participants performing CPR) during data collection (Hunziker et al., 2011). As data suggests that physical activity has an impact on the autonomic nervous system's function and how it regulates heart rate, this may have had an impact on their HRV results (Kwon et al., 2021).

Despite the aforementioned factors, HRV remains a valid indicator of physiological stress and showed a clinical decrease in HRV throughout a simulated scenario (Rieber et al., 2009). Stein (2020), on the other hand, say that the utility of SDNN as a physiological stress marker is of limited value. The results of two HRV analysis methods (RMSSD and pNN50) revealed that neither the control group nor the experimental group's HRV significantly interacted with one another (either before, during or after assessments). However, only the third method (SDNN), showed a significant interaction. The experimental group's SDNN values during assessments were considerably higher than those of the control group ($p = 0.020$). Moreover, the experimental group's SDNN values following assessments were significantly higher than those prior to assessments ($p = 0.041$). These results add to the body of evidence supporting the notion that HRV is a reliable predictor of physiological stress by demonstrating that a clinical fall in HRV is accompanied by an increase in sympathetic activity.

Earlier published literature (Romanowicz, Schmidt, Bostwick, Mrazek and Karpyak, 2011; Altuncu, Baspinar and Keskin, 2012) highlights multiple factors which can affect HRV results, including physiological factors (such as breathing, circadian rhythms and posture), non-modifiable factors (such as age, gender and genetic factors), modifiable lifestyle factors (for example obesity, metabolic syndrome, physical activity, smoking and drinking), as well as other factors such as certain medications (for example, anticholinergics, stimulants and beta-blockers). Therefore, further research is required to determine whether HRV among undergraduate emergency care students can be endorsed as a reliable predictor of psychological stress.

Saliva α-amylase assay

The findings of the α-amylase assay over time (before and after assessment), revealed that the enzyme levels of the enzyme decreased over time (Wilcoxon signed-rank test), although the change in concentration was not statistically significant ($p = 0.31$). In addition, a comparison between the various year-groups, indicated there were no significant differences in the α-amylase levels before and after the

assessments. Previous studies have investigated the association of stress and performance (Bjørshol et al., 2011b, Hunziker et al., 2011, Valentin et al., 2015). Socioemotional stress enhanced the participants' perceived workload, frustration and sense of realism using a high-fidelity simulation, without altering performance (Bjørshol et al., 2011). Furthermore, a study using emergency healthcare professionals, only α-amylase activity increase was observed and no corresponding increases in salivary cortisol levels. Also, stress levels were not significantly influenced by either gender or age, however, performance was not measured and/or assessed (Valentin et al., 2015b). In contrast, a study to investigate whether mental stress negatively impacts team performance during cardio-pulmonary resuscitation (CPR) compared self-reported, biochemical and physiological stress measures with regard to CPR performance (Hunziker et al., 2011). The results revealed that self-reported stress (stress or overload) was the only factor linked to poor CPR performance, whereas biochemical measures (plasma cortisol) showed no association. Heart rate, on the other hand, showed an inverse association, probably as a result of physical activity, which limited its usefulness as a mental stress marker in this acute setting (Hunziker et al., 2011). A German study (Müller et al., 2009), which enrolled intensivists to participate in a simulator training course, found a similar reduction in salivatory α-amylase, as the current study results. They concluded that repeated practice in a realistic simulation environment can lower salivary α-amylase activity, but not salivary cortisol levels during simulated crisis scenarios (Müller et al., 2009).

Another variable which may have contributed to the α-amylase findings of the current study is the time factor. Salivary enzymes are biomarkers which react fast to stress (Takai et al., 2004). An increase in saliva α-amylase activity was observed within 3 minutes of participants seeing a movie regarding corneal transplantation, with a return to baseline levels, shortly after the conclusion of the video (Takai et al., 2004). For the current study, the before -intervention sputum samples were taken before the commencement of the assessments and about 15 to 20 minutes after assessments (after-intervention sputum samples). An ‘exam-day schedule’ was used to record the sequence and progression of the assessment days, so that each participant was aware of his or her allocated time slot. In addition, as mentioned, both sample sets were then frozen until the assay process. The results of another study (meta-analysis) highlighted that α-amylase activity in saliva also shows diurnal changes, but within a smaller range and with a peak in the early evening time (Nater, Rohleder, Schlotz, Ehlert and Kirschbaum, 2007).

Saliva cortisol assay

In contrast, there was a significant difference in the cortisol assay results of the first-year group, in comparison to the other year-groups, both their before (p = 0.006) and after experiment results (p = 0,003). Notably, there was no discernible difference in the fourth-year group's change in cortisol enzymes. The findings for the first-year group are in keeping with previous literature which shows that cortisol is a biochemical measure that reliably responds to acute psychological and physiological stress (Dickerson & Kemeny, 2004, Sapolsky, Romero and Munck, 2000; Lovallo, Dickensheets, Myers, Thomas and Nixon,

2000; Lizotte, Janvier, Latraverse, Lachance, Walker, Barrington and Moussa, 2017). As alluded to previously, a possible reason for the higher cortisol levels of the first-year group may have been that it was their first summative clinical assessment.

The same saliva sample collected from the participants was used for both the α-amylase and cortisol assay, therefore as highlighted, the timing of the collection of the saliva samples for the before- and after-assessment may have had an impact on these findings. Available literature has made comparisons between the stress-related changes in saliva α-amylase and salivary cortisol levels (Dickerson & Kemeny, 2004). In stressful situations, both salivary analytes increased in response to the challenging task at hand, however, salivary α-amylase reaches its peak response faster than salivary cortisol (Granger, D. A., Kivlighan, K. T., El-Sheikh, M., Gordis, E. B. and Stroud, L. R. 2007). The adrenal gland, which is located above the kidneys, releases cortisol into the bloodstream which must then passively diffuse into oral fluids. The hypothalamus-pituitary-adrenal axis is activated and the cortisol content in saliva changes, up to 15 to 20 minutes after the stressor or event (Granger et al., 2007), peaking between 20 to 40 minutes later (Dickerson & Kemeny, 2004). On the other hand, salivary glands immediately release α-amylase into the mouth (Granger et al., 2007).

Additionally, the cortisol level tested 15 minutes after the event may not accurately reflect the highest value (Takai et al., 2004). Consequently, checking cortisol levels at a later time may have revealed higher levels. However, for logistical reasons, this was not possible for the current study, due to the fact that the students had to vacate the exam venue as soon as their assessments were completed. Lastly, an evaluation of emergency healthcare professionals' stress levels by measuring salivary cortisol and α-amylase (before, during and after high-fidelity simulation scenarios), found an increase in salivary α-amylase activity, but no corresponding increase in salivary cortisol levels were observed (Valentin et al., 2015b).

5.6 The relationship between the psychological and physiological stress indicators

Using a logistics regression model, where the independent variables were the physiological measurements (saliva α-amylase and cortisol assay, HR and RR) versus the STAI scores as the dependent variable (categorical), highlighted the odds of passing the final-term assessment was significantly predicted by both the Y1 and Y2 after scores (Y1 score after assessments ($p = 0.001$) and Y2 after assessment score ($p = 0.02$), when holding other covariates constant.

This implies that those with elevated stress levels after their final assessments, may have been extremely anxious about failing, possibly due poor performance during their assessment or throughout the academic year and some may have been at risk of failing the clinical subject, leading to greater anxiety.

5.7 Evaluating the impact of psychological and/or physiological stress indicators on the participants' assessment results (clinical performance)

The majority (> 80%) of the participants experienced clinically significant anxiety levels, while only 16% reportedly experienced "normal anxiety" levels (college student - STAI scoring, Spielberger, 1983). This finding is supported by previous research which highlighted that a high psychological fidelity of the simulator setting is intended to create realistic emotional challenges and thus mimic similar difficulties for clinical performance, as experienced in real-life environments (Al-Ghareeb, Cooper and Mckenna, 2017; Flanagan, Nestel and Joseph, 2004; Stein, 2020, Piquette et al., 2014).

Comparing the overall performance of the participants for the final term assessment, revealed that 33% were unsuccessful, with the third-year group having the highest failure rate (66.6% - with only five participants managing to pass), while the first-year group only had one failure. The reason for these findings may be that as students advance through academic years of study, the clinical cases utilized for evaluations become more complicated, incorporating knowledge scaffolding, as well as progressing from basic to more advanced clinical skills. Paramedic students need to acquire the expertise necessary to ensure patient safety, both for low acuity and critically ill/injured patients (Lynch, Barr and Oprescu, 2012). Additionally, social and behavioural sciences (psychology, communication skills, law, ethics, and research methodology) are taught simultaneously enabling paramedic students to acquire a deeper understanding of the profession (Willis, Pointon, O'Meara, McCarthy, and Jensen, 2009).

According to a constructivist worldview, knowledge is dynamically produced and co-created through relationships and human interactions (Watling & Lingard, 2012). According to this perspective, healthcare simulation is a social activity in which participants engage in goal-oriented interaction with setting characteristics to elicit a behavioural response (Dieckmann, Gaba and Rall, 2007). Simulation has been shown to enhance students' clinical reasoning and critical thinking in complex care situations, as well as to support the growth of students' self-efficacy and confidence in their own clinical abilities, in a safe and controlled environment (Lewis, Strachan and Smith, 2012). A theoretical review of the literature regarding clinical simulation found that it was considered an effective learning and teaching pedagogy, as it serves as a means for bridging the theory-practice gap and allows for the standardization of learning experiences and exposure to rare clinical events (Lavoie et al., 2018).

For undergraduate and graduate medical education, patient simulation is being employed more frequently (Müller et al., 2009). In order to help participants handle critical situations with less stress, simulator training seeks to enhance medical performance (Müller et al., 2009). However, simulation as a training technique can be a significant source of stress for aspiring health professionals (Müller et al., 2009). In contrast, study using medical students as participants, showed that they performed better in a simulator scenario

after only 15 minutes of training (Steadman et al., 2006). Additionally, simulation-based learning can help to advance the knowledge, abilities and attitudes of healthcare providers while safeguarding patients from unwarranted risks (Lateef, 2010). It is a platform that offers a useful tool for learning to reduce ethical tensions and handle practical difficulties frequently encountered in practice (Lateef, 2010). This is supported by evidence showing that, through enhancing the consolidation processes, stressful conditions frequently result in the formation of long-lasting memories (Roozendaal, 2002). However, as previously mentioned, very high levels of stress can overwhelm individuals and impair learning (LeBlanc, 2009). It has been widely demonstrated that when stress levels rise, psychomotor function suffers (Arora et al., 2010).

Healthcare simulation is widely used for performance competency assessment, particularly when using simulated participants in a simulation environment (Yauger, Konopasky and Battista, 2020). Nevertheless, a concern with healthcare simulation is its susceptibility to error stemming from its implementation flexibility and the impact of context-related factors, including availability of diagnostic tools, simulator delay or troubleshooting when participants interact and engage in a simulation setting (Downing & Yudkowsky, 2009). For this study, the assessment performance of the participants included both cognitive (deciding on a treatment plan and/or drug selection, dosage, etc.) and psychomotor function (for example obtaining intra-venous access). Even though simulation-based assessments provided reliable and valid measures of clinical performance (Burns et al., 2013), limited studies have focussed on simulation assessments results (pass or fail percentages) and performance. A recent study (Stein, 2022) who only used the STAI questionnaire and no physiological stress biomarkers, compared anxiety levels and performance, recorded simulation assessment marks which were distributed fairly evenly across different year-groups, highlighted by a mean (95% confidence interval) 37.88–47.71. However, very few achieved the required 50% threshold (competency), which is in contrast to the results of this study, where 67% of the sample passed, despite their elevated psychological and physiological biomarker evidence. The third-year group had the highest failure rate (66.6%), suggesting that for some, stress may have been a confounder that contributed to their poor performance. Furthermore, this may indicate that some undergraduate paramedic students have achieved a level of stress management and coping skills, while others (33%) may require additional support.

Although there are different explanations for stress, one model explains it as a divergence between perceived demands and capabilities (Lazarus, 1966) of the individual. In addition, stress is a psychological concept and as such is not concrete, it cannot be touched or perceived directly (Driskell & Salas, 2016). The factors leading to stress and the reactions of the individual can vary broadly; however, previous research suggests that stress modifies human performance (Bjørshol, Myklebust, Nilsen, Hoff, Bjørkli, Illguth, Søreide and Sunde, 2011; Müller, Hänsel, Fichtner, Hardt, Weber, Kirschbaum, Rüder, Walcher, Koch and Eich, 2009, Hunziker et al., 2011, Valentin et al., 2015). Both the prevalence and severity of

anxiety among healthcare students is on the rise, which may decrease students' academic performance, professionalism and compromise patient care (Macauley, Plummer, Bemis, Brock, Larson, and Spangler, 2018).

A review of cognitive architecture literature suggests that working memory (WM) has a limited capacity (Sweller, 1988). One such theory, the Cognitive Load Theory (CLT), is predicated on the idea that the WM capacity of the human brain can only hold a finite amount of information at any given moment (Van Merrienboer & Sweller, 2005). Therefore, any provided information that exceeds this capacity may reach WM, but will not be processed or encoded into long-term memory (Vogel-Walcutt, Gebrim, Bowers, Carper and Nicholson, 2011). Furthermore, a component of CLT - intrinsic cognitive burden, is determined by the type of learning material, the learner's background, the amount or complexity of the knowledge being taught (Paas, Renkl and Sweller, 2004; Van Merrienboer & Sweller, 2005). Although it was previously believed that intrinsic cognitive burden or load was resistant to external manipulation, mitigating tactics for reducing it have been proposed, such as scaffolding the material or tailoring the quantity of instructional guidance to the learner's level of knowledge (Kalyuga, 2003, Kalyuga, 2007, Van Merrienboer & Sweller, 2005). This might not always be achievable given the crammed undergraduate schedule of the paramedic degree programme, which includes weekly academic lectures, early morning physical training practice sessions, strenuous rescue activities, followed by experiential learning (weekend-rostered clinical practice of 12-hour shifts). This limits the amount of time students have to assimilate and consolidate their own learning and/or finish any assignments or prepare for tests, especially considering that some may live on campus and have additional personal chores to complete over weekends which are unrelated to the formal curriculum. In addition, the instructional design determines how the learning material is presented to the learner and how the learner interprets the information (Vogel-Walcutt et al., 2011). Poor designs have a number of unnecessary or distracting components, whereas information delivered in pertinent and useful ways, encourages effective knowledge acquisition (Vogel-Walcutt et al., 2011).

Paramedic training is divided into theoretical and practical components in South Africa (HPCSA, 2020). The theoretical component includes readings from both medical (Anatomy, Physiology, and Pathology topics) and non-medical literature and/or textbooks (Physics and Chemistry subjects). As part of summative evaluations, the practical component (which includes, among other things, clinical simulations) is used to gauge the proficiency of undergraduate students. Transparency, fairness, validity, and reliability are specific assessment principles that apply to these examinations and are presumed to apply to integrated clinical simulation for summative assessment as mandated by the South African Qualifications Authority (SAQA, 2022). Clinical simulation evaluations mimic real-world clinical situations and unintentionally, the competence displayed during the simulation implies competency in practice (Bommer et al., 2018). Therefore, in order to maximise students' learning capacity, it is imperative to examine the impacts of stress during simulation-based learning thoroughly (LeBlanc, 2009). A recent study exploring

anxiety and performance related to prehospital emergency care simulation assessments (Stein, 2022), highlighted that the elevated stress levels experienced by students during these activities “may impede their learning and performance”. The social-evaluative aspect of simulation assessments may amplify this effect (Stein, 2022). Despite these reservations, clinical simulations play a crucial part in the instruction of medical students, residents, and practicing physicians (Boulet, Murray and Warner, 2010). In addition, simulation as a teaching and learning pedagogical approach is increasingly being used in medical education “as an opportunity for competency assessment” (Weersink, Hall, Rich, Szulewski. and Dagnone, 2019). The results of acute care physicians' high-fidelity simulation assessments and workplace evaluations of their resuscitation competencies, showed a moderate positive correlation, indicating that proficiency in resuscitation in simulation settings may be a marker of proficiency in actual clinical situations (Weersink et al., 2019).

The degree to which simulation elicits an acute psychological and/or physiological stress response, impacting clinical performance during simulations, remain areas of active exploration. A significant association was reported between the participant’s self-efficacy scores and simulation performance (Mauriz, Caloca-Amber, Córdoba-Murga and Vázquez-Casares, 2021). In addition, studies which evaluated nursing students' self-efficacy with regard to their performance of academic or simulation tasks have produced similar results (Expósito, Costa, Agea, Izquierdo and Rodríguez, 2018; Khalaila, 2015). The current study findings showed that most of the participants (control and experimental groups) recorded elevated psychological and physiological stress responses which may have negatively impacted their performance (clinical assessment results - pass or fail), however, a multitude of cognitive and psycho-motor factors could also have contributed to individual performances/or lack thereof.

These include theoretical knowledge gaps, lack of ‘hands-on’ practice, poor stress management or coping skills, etc. Moreover, as mentioned previously, data collection occurred during an unprecedented event (the Covid-19 pandemic), which brought its own level of anxiety for students and healthcare providers alike (Babore et al., 2020). Many were inadequately prepared and the additional anxiety, worrying not just about their own health, but that of their immediate families, may have been a contributing factor. As mentioned, prior to their final term assessments, the participants still had to complete experiential learning shifts (prehospital and in-hospital environments), which exposed them to Covid-19 patients.

5.8 Evaluating the different physiological stress indicators to identify which most accurately correlate to the participant's perceived psychological stress level

The participants' before- and after-assessment STAI questionnaire responses were consistent, indicating that they had high levels of anxiety at both time points, and this was supported by the moderate positive correlation between the before- and after-assessment STAI scores ($r = 0.78$ $p = <0.001$). Some reported higher levels of anxiety prior to the examination, whereas others reported higher levels of anxiety following their assessments. However, individuals who stated that their anxiety levels were 'normal' displayed identical findings in the pre- and post-assessment STAI scores. Similar STAI outcomes were found in earlier investigations which included a clinical simulation intervention (LeBlanc, 2009, Harvey et al., 2010, Piquette et al., 2014, Stein, 2020).

Saliva assay

Both salivary α-amylase and/or salivary cortisol have been used in previous studies to examine the relationship between stress and performance, by correlating acute psychological and physiological stress (Müller, Hänsel, Fichtner, Hardt, Weber, Kirschbaum, Rüder, Walcher, Koch and Eich, 2009; Bjørshol et al., 2011; Hunziker et al., 2011; Valentin et al., 2015; Dickerson & Kemeny, 2004; Sapolsky, R. M., Romero, L. M. & Munck, A. U. 2000; Lovallo et al., 2000; Lizotte et al., 2017). The evidence is not clear as to which particular enzyme consistently and accurately reflects acute psychological and/or physiological stress, due to multiple dynamics and variables which needs to be considered, such as the ideal time of the sputum specimen collection (before and after the intervention), the type of intervention environment (assessment versus non-assessment), as well as the inclusion/exclusion of physical activity (Takai, Yamaguchi, Aragaki, Eto, Uchihashi and Nishikawa, 2004; Nater et al., 2007; Dickerson & Kemeny, 2004; Valentin et al., 2015).

The findings of the current study showed a significant association between cortisol levels and time (saliva samples taken before and after assessments). Cortisol levels were significantly higher in the after-assessment period compared to the before-assessment period. In addition, cortisol levels also differed by year-group, as the first-year group results were significantly higher ($p <0.001$) than the other year-groups. As highlighted, it was their first summative clinical assessment and many may have felt anxious for 'fear of the unknown'. Their emotional state (subjective appraisal of the situation) may have been affected by a lack of preparation and/or a lack of confidence (both before and after the assessments). In contrast, a similar comparison between α-amylase assay and the STAI results (before and after assessments), showed there was no difference in α-amylase levels by time, as well as no association with year of study.

However, as highlighted, the fourth-year group's α-amylase levels were much higher (IQR = 400; p = 0,18) than the other year groups.

Hexoskin smart vest data (HR, RR and HRV)

The 'Hexoskin Smart Garments' have been used in more than 100 scientific publications to date (Hexoskin.com, 2022). However the current study is the first (to the author's knowledge) to have imported and used this comparatively new technology into Africa, including the unique study population (undergraduate emergency care students) and data collection context (in-class simulation practice and final assessments). It allowed for continuous individual cardiac and pulmonary vital signs recordings (before, during, and after the assessment). A significant relationship was identified in average HR between the control and experimental groups among undergraduate emergency care students before, during and after clinical assessments. This included a corresponding RR increase, frequently 'peaking' during the actual assessment period. These findings were true for the majority who felt the most anxiety. However, elevated HR and RR rates were also recorded for those who reported 'normal' anxiety levels.

For this cohort who reported high anxiety levels, there was only a significant difference (p = 0.041) in the SDNN values of the experimental group, which were noticeably greater than the control group during their assessments. There was no comparable significant interaction of their HRV outcomes. These findings are in keeping with similar stress studies, using multiple biomarkers which reported a positive correlation between cortisol and HR (r = 0.44, p = 0.03). However, HRV was negatively correlated with all parameters (Hunziker et al., 2011). Furthermore, studies of HRV in psychological stress situations have produced contradictory results, including both increases and decreases in parasympathetic and sympathetic tone (Kaegi, Halamek, Van Hare, Howard and Dubin, 1999). These results contradict a meta-analysis (Kim et al., 2018), which recommended that the neurobiological data available at the time, supported the use of HRV for the objective evaluation of psychological health and stress.

Psychological stress measures versus physiological stress indicators

As highlighted previously, similar published literature regarding stress measurement during simulation exposure, have incorporated different methodological approaches, varied research tools, as well as different populations (both students and qualified healthcare providers). To date, only two studies have explored this relationship, using prehospital emergency care healthcare providers (LeBlanc et al., 2012, Stein, 2020), of which only the latter, included a student population. Focusing on the majority who felt the most anxiety (n = 49) and extracting their measured physiological stress biomarker data (both saliva assay

and Hexoskin smart vest) allowed for comparisons to identify which physiological stress indicator most accurately and consistently correlated to their STAI scores (perceived psychological stress level).

The majority of the participants seemingly were exposed to elevated anxiety levels and most experienced a corresponding elevation of their physiological stress indicators. These results support previous findings that clinical simulation assessments are associated with higher physiological anxiety (Clarke et al., 2014; Stein, 2022). In addition, Clarke et al. (2014) highlighted that a single biomarker - heart rate "correlates poorly with both perceived stress and performance". For this reason, the current study incorporated both 'traditional' stress indicators (such as a saliva assay) and novel technology to accurately measure vital signs affected by emotional anxiety (Hexoskin smart vest).

The assay of the participants' saliva samples before and after assessments, showed that the cortisol enzymes were more responsive than the α-amylase assay, while the findings of this study related to the validity of using heart rate variability (more specifically, which variable: SDNN, RMSSD or HF) requires further research to identify which variable correlates to perceived psychological stress among undergraduate emergency care students. As highlighted, only the SDNN result showed a statistically significant interaction. In contrast with the above, the HR and RR data of the Hexoskin smart vest (stress biomarkers) were the more accurate and consistent indicators which correlated to the participants' perceived psychological stress levels.

The nature of paramedic work often exposes both professionals and students to acutely stressful environments. As mentioned, multiple factors affect how an individual responds under stress including the individual's perception of the demands and available resources in a situation and coping styles, which in turn may affect performance. A recent study found that "psychophysiological stress can affect the cognitive response and effective learning of students during medical simulation practices" (Mauriz et al., 2021a). Given the potential negative implications of stress on performance, both for academic success and in the interest of improving patient safety, further research is required fully to understand the relationship between these variables.

5.9 Conclusion

This chapter described the recorded stress biomarkers of undergraduate emergency medical care students, as well as exploring the context in which data was collected: in-class practice sessions and during final term clinical assessments. The current research endeavour included psychological and several physiological biomarkers (such as the α-amylase assay, cortisol assay, RR, HR, and HRV), captured in real time, which allowed for comparisons between the participants' psychological and physiological status in order to ascertain the most accurate stress profiles. In addition, the participants' self-reported anxiety levels were assessed using the state-trait anxiety inventory questionnaire. To the author's knowledge, it was the first time in Africa that the Hexoskin smart vest was utilised to capture respiration and cardiovascular stress biomarkers in this context.

The participants' STAI results revealed that the majority of the participants experienced elevated anxiety levels. Furthermore, the participants' stress biomarker salivary assay findings indicated that the cortisol enzymes were more reactive than the α-amylase assay. However, for the majority the saliva assay results were asymmetrical, as it either showed increased, decreased or no change (before- and after- assessment samples). The HR and RR biomarkers were the most reliable and consistent indicators that were associated with the participants' perceived psychological stress levels, however neither the control group nor the experimental group's HRV analyses (RMSSD, and/or pNN50) showed much interaction, except for the SDNN method which reflected a statistical significance in this study.

The study findings highlighted that both the control and experimental groups were exposed to clinical simulation-based learning environments which predisposed them to elevated anxiety levels (before, during and after these activities).

The next chapter concludes this study by presenting a summary of this research endeavour, along with suggestions for additional research.

CHAPTER SIX: SUMMARY, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

To date, limited research has been undertaken in the paramedicine sciences, related to clinical simulation and performance, which often predisposes undergraduate paramedic students to elevated anxiety levels due to the nature of emergency critical care caseloads in South Africa. The challenges this cohort of students face are unique, as to become successful BEMC programme graduates (paramedics), students need to master both theoretical and clinical practicum competencies, including strenuous rescue capabilities (on land, sea, river and mountainous environments), while at the same time developing professional attributes to deal with an often unsympathetic and violent-prone patient and/or environment to perform their duties. Consequently, in order to prepare students adequately for assessment and for the profession, their undergraduate training often exposes them to high-anxiety situations. The research aim of this study was “to assess the psychological and physiological stress which undergraduate paramedic students experienced during clinical assessments” and to achieve the research goal of this study, five objectives were identified (see Summary 6.1 – 6.5 below).

The preceding chapter described the findings of this study in relation to earlier published literature on psychological and physiological stress during clinical practice and assessments, including clinical simulations. This chapter summarises the research findings, offers some recommendations based on the findings, proposes areas for additional study and highlights the shortcomings of the study.

6.2 Summary

Both the psychological and physiological indicators overwhelmingly point to the fact that undergraduate paramedic students experienced elevated levels of stress and anxiety throughout their clinical assessments. Additionally, this holds true even for non-assessment conditions (class practice sessions), when participants' vital signs were recorded as having a mean maximum HR of 122–139 bpm and a mean maximum RR of 42 rpm (Hexoskin smart vest data). These results imply that the targeted psychological clinical activity anxiety is highly effective, as indicated by a corresponding elevation of physiological biomarkers for most participants. However, as the current literature is ambiguous as to whether effective learning takes place under these stressful conditions, it is warranted to keep exploring this relationship to find the ideal balance between achieving the learning outcomes and incorporating a level of subjective anxiety, which would not negatively impact performance. The following objectives will be summarised and its results presented according to the study overview below (Table 36 below):

Table 38: Study “roadmap”:

Stress indicator	Measurement tool	Characteristic
Psychological	STAI questionnaire	Subjective anxiety level
Physiological	Hexoskin smart vest	Heart Rate, Respiration Rate, Heart Rate Variability
Physiological	Saliva assay	α-amylase and cortisol enzymes

To describe the trends between different stress biomarkers of paramedic students before, during and after clinical assessments.

Each biomarker was described individually, with its own statistical analysis performed. The STAI psychological questionnaire data stream (recorded before- and after - assessments) was the first data stream analysed. The assumption of normality was tested (Shapiro-Wilk W test), which revealed that all p values were > 0.05. As a consequence, the assumption of normality was met, allowing for the use of parametric measures of central tendency (mean) and deviation (Schubert et al., 2009). The Cronbach’s alpha score for all the STAI items were good and consistently reflected the high level of subjective stress the undergraduate students were exposed before- and after - assessments.

Similar elevated trends were reflected in the group’s vital signs, specifically HR and RR. However, although three variables of HRV were applied, there was only significant interaction with one method: SDNN. Nonetheless, the findings provide additional evidence that HRV is a good indicator of physiological stress. The final set of biomarkers measured was the salivary assay, which included both α-amylase and cortisol enzymes. Although, for some it revealed an increase in both enzymes, the results were ‘mixed’, with varying degrees of enzyme activity: increases and/or decreases, as well as no changes in the before- and after-assessments saliva samples. For this cohort, the trend for the cortisol assay appeared to mimic the participants’ anxiety levels, while their α-amylase enzymes were less reactive.

To explore the associations between different physiological stress biometric data of paramedic students before, during and after clinical assessments and trends among the four different year groups of students.

A deeper exploration of the associations between different physiological stress biometric data of paramedic students before, during and after clinical assessments revealed that the participants 'stressed' at different times. Some participants experienced greater levels of anxiety prior to their assessments, while others experienced higher levels of stress during assessments, while there were those who experienced their highest levels of stress following assessments. Interesting comparisons also evolved in the trends among the four different year groups of students. However, a closer look at the individual year-groups, found that, for example, when comparing the mean HR (all groups), the fourth-year group's minimum was significantly greater than the first- and third-year groups ($p = 0.001/0.009$). As previously indicated, these final-year students were completing their clinical evaluations at the 'exit' level and the majority of them would have needed an average of four academic teaching years to get there (or more years, if they had any failed subjects, to redo). This may help to explain why this group had even greater pressure (stress) than the others, as they were being evaluated and held to a higher standard of performance as 'qualified' paramedics.

To establish the association between the physiological stress biomarkers (cardiac/respiratory data - Hexoskin smart vest smart vest smart vest, salivary α-amylase versus cortisol levels) and the undergraduate paramedic student's perceived psychological stress (STAI Questionnaire scores) between the different year groups, before and after clinical assessments.

The majority (> 80%) of the participants experienced an elevated anxiety level, while only 16% reportedly experienced 'normal anxiety' levels. The comparison between all the physiological stress biomarkers (cardiac, respiratory, salivary α- amylase and cortisol) to the participants' STAI perceived psychological data (questionnaire scores) produced interesting results. For example, the first-year group indicated they experienced a significant elevation in stress levels 'after' the assessments, while there was a sizable difference in the anxiety scores before and after assessments in the second-year group. As for the third- and fourth-year groups' scoring, they indicated they experienced significant levels of anxiety, both before and after assessments. Subsequently, by creating a 'stress profile" for each participant, these subjective psychological responses were corroborated by corresponding physiological responses or elevation recorded by the various biomarkers (to varying degrees of success). However, surprisingly, when comparing the stress indicator profiles, even those who experienced 'normal anxiety' recorded increased saliva assay results and/or Hexoskin smart vest data which were indicative of elevated physiological stress levels.

To evaluate the impact of physiological stress biomarkers and their perceived psychological stress before, during, and after their clinical assessment of undergraduate paramedic students on their assessment results.

This study results in terms of the psychological and physiological stress indicators allowed for comparisons with their clinical assessment marks, even though the various year-groups completed their individual final-term clinical assessments, which included different outcomes, levels of complexity and knowledge scaffolding. A comparison of the overall performance of the participants for these final-term assessments, revealed that 33% were unsuccessful, with the third-year group having the highest failure rate (66.6%), while the first-year group only had one failure. Second-years had five failures, and lastly the fourth-year group had three unsuccessful participants.

The current study findings showed that most of the participants (the control and experimental groups) recorded elevated psychological and physiological stress responses which may have negatively impacted their performance (clinical assessment results: pass or fail). However, a multitude of cognitive and psychomotor factors could also have contributed to individual performances or lack thereof. Some of these confounders were mentioned with supporting evidence, including socio-evaluative anxiety, theoretical knowledge gaps, lack of preparation due to other academic demands, poor stress management or coping skills, as well as the prevailing Covid-19 pandemic environment at the time.

As highlighted, the degree to which an acute psychological and/or physiological stress response, impacts clinical performance, remain areas of active exploration.

To compare the different biomarker data sets and identifying the biomarker which most accurately correlate to the participant's perceived psychological stress.

The moderate positive correlation between the participants' STAI scores (before and after assessments) showed that they experienced elevated levels of anxiety at both time points. Some participants expressed greater levels of anxiety before the assessment, while others expressed greater levels of anxiety after the assessments. Interestingly, the STAI scores for participants who indicated that their anxiety levels were 'normal', mirrored those results for their before- and after-assessment scores. Furthermore, the results of this study highlighted a significant association between time and cortisol. Cortisol levels were significantly higher in the after-assessment period compared to the before-assessment period. In addition, cortisol levels also differed by year group, as the first-year group results were significantly higher ($p < 0.001$) than the other year groups. In contrast, a similar comparison between α-amylase assay and the STAI results

(before and after assessments), showed there was no difference in α-amylase levels by time, as well as no association with year of study. However, as highlighted, the fourth-year group's α-amylase levels were much higher than the other year groups.

The current study is the first to use the Hexoskin smart vest in Africa, including recruiting the unique study population of undergraduate emergency care students and data collection context (both in-class simulation practice and final-term assessments). It allowed for continuous individual cardiac and pulmonary vital signs recordings (before, during, and after the assessment). A significant relationship was identified in average HR between the control and experimental groups among participants before, during and after clinical assessments. The average HR during the experimental groups' assessments were significantly higher than that of the control group HR ($p < .001$). In addition, the maximum HR during the experimental group's clinical assessments were significantly higher compared to the control group's HR ($p = 0.16$). Noticeably, the maximum HR before the start of the experimental group's clinical assessments, were significantly higher than the control group's practice sessions ($p = .005$). This included a corresponding RR increase, frequently 'peaking' during the actual assessment period. These findings were true for the majority who felt the most anxiety. However, elevated HR and RR increases were also recorded for those who reported normal anxiety levels.

However, for this cohort (high anxiety levels), there was only a significant difference in the SDNN values of the experimental group, which were noticeably greater than the control group during their assessments. Furthermore, studies of HRV in psychological stress situations have produced contradictory results, including both increases and decreases in parasympathetic and sympathetic tone. Additionally, research on HRV under psychological stress has yielded conflicting results, including both increases and decreases in sympathetic and parasympathetic tone.

Lastly, the biomarker(s) which most accurately correlated to the participants' perceived psychological stress was the cardiac and respiration indicators, as measured by the Hexoskin smart vest.

6.3 Contributions to the body of knowledge

This study evaluated older methods and one of the latest stress biometric technologies (Hexoskin smart vest) to explore the levels of anxiety experienced by undergraduate emergency care students in South Africa. In addition, both psychological and physiological stress indicators were quantitatively measured before, during and after clinical simulations, creating the first comprehensive stress profile for this cohort. Subsequently, this new evidence highlighted the elevated levels of anxiety undergraduates are exposed to during clinical simulation training or assessments, which may negatively impact their clinical judgment, self-efficacy, clinical abilities and self-confidence. Prior studies showed that these attributes (or a lack thereof) can contribute to poor patient safety and quality of care.

6.4 Recommendations

Improvement

Clinical evaluations are intended to ascertain an undergraduate's level of competency. However, by default it also periodically instils significant anxiety levels.

This study recommends that educators to be mindful of the possibility that high levels of anxiety may interfere with the learning process and reduce the effectiveness of these simulation-based activities (both for class practice and/or assessments). The ideal situation would be to assess the intended learning objectives, while avoiding cognitive overload, in order to build self-confidence and ultimately improve clinical performance.

Among students, the prevalence and severity of anxiety is increasing, which can hinder academic achievement, professionalism and the capacity for managing aspects of patient care (Macauley et al., 2018).

In order to strengthen students' emotional resilience in terms of managing their anxiety levels, it is also recommended that greater emphasis be placed on teaching stress coping strategies (within the Emergency Medical Care curriculum) and possibly implement targeted awareness, prevention and intervention programmes by qualified psychologists. These tools will also prepare the students for their chosen paramedic career, which can be demanding, with high burnout rates (Reardon et al., 2020).

The novel technology data tool incorporated in this study (Hexoskin smart vest), proved to be accurate in terms of continuous cardiac, respiratory and ECG monitoring. In addition, the Hexoskin Connected Health Platform was user-friendly, providing detailed reports and graphics. Other useful features include up to 36 hours of battery life, as well as up to 100+ days of online recording capacity.

It is recommended that this technology be used in the prehospital environment with paramedics in the field, not only to determine real-life anxiety levels (prevent burnout), but also explore, for example, monitoring sleep patterns and resting heart rates, which may highlight underlying cardiac and/or respiratory pathologies, as breathing volumes can also be monitored.

Development

Post-event debriefing, which is a component of simulation-based education, gives students the chance to evaluate critically the simulated experience with the aim of finding areas that need reinforcing and improvement. This can be achieved by giving them constructive feedback through the development of a departmental structured debriefing guide in order to build self-confidence and therefore, decrease anxiety

levels during training and assessments. PEARLS (Promoting Excellence And Reflective Learning in Simulation) is a model of a structured debriefing guide, which promotes “learner self-assessment, fostering focused dialogue, and offering information in the form of directive feedback and/or training” (Eppich & Cheng, 2015).

Therefore, it is further recommended that reflective debriefing practices be encouraged so that students can actively evaluate their cognitive, affective and psychomotor performance during clinical simulation activities.

Change

Although the evidence has shown that students value clinical simulation training as a learning method, it has limitations and cannot be viewed as the perfect teaching tool to infer effective learning has taken place.

Thus, it is recommended that Emergency Medical Care educators should endeavour to design and implement relevant simulation training and/or assessment content, incorporating clinical, environmental and social-professional elements of paramedic practice, which ultimately can develop reflective practitioners who will be life-long learners.

6.5 Limitations of the study

Only one higher education institution offering the BHSc EMC degree was enrolled in this study, due to time and financial constraints. Consequently, the findings might not be typical of all undergraduate emergency care students. However, as highlighted, clinical assessments are conducted by all institutions that offer emergency care programmes.

The participants of this study may have benefited from a longitudinal study (over three to four years of their degree), to measure their stress or anxiety over a longer period. The available sample at the selected university was relatively small and it would have been useful to draw comparisons from a broader population across all higher education institutions offering the BHSc EMC degree in South Africa. Moreover, the research findings may have been impacted by several variables which affect academic success and may not have accounted for in this study, for example the students theoretical knowledge and/or preparedness and their socio-economic circumstances, which are all contributors to student life stressors.

Furthermore, as mentioned, the data collection occurred on specified final term clinical assessment dates and subsequently only the available students (voluntary consent) on those days were included, meaning no data was recorded for any ‘missed’ assessment candidates.

As highlighted previously, data collection occurred during the Covid-19 pandemic, which presented many daily challenges, both socio-economically and academically (move to online teaching etc.). Most students experienced additional concerns regarding staying healthy and coping with a new 'reality' during a national lockdown. For some, this may have been a confounding factor which impacting their general well-being.

The current study did not evaluate other factors that may affect the neurophysiological systems connected to anxiety in response to increased psychological stress levels, such as physical fitness, the effects of aging or gender differences.

Lastly, although the Hexoskin platform required the participants to declare any pertinent health issues upfront, some may have had unknown co-morbidities such as undiagnosed illnesses or cardiovascular disease.

6.6 Possibilities for future research

The study found that students were anxious during clinical practice and assessments, but this may have been caused by a number of factors. Therefore, more research is needed to determine the causes of students' high levels of anxiety, in order to mitigate the negative impact on learning and recommend appropriate intervention strategies. Another avenue requiring research, is to replicate these results with a larger population and clarify the relationship between different stress markers and performance when treating real patients in the field (operational settings). As highlighted, prior evidence related to the physiological stress indicators are inconclusive and additional research is warranted as to which is the ideal marker to use in the prehospital care setting.

Furthermore, a deeper exploration of the association between psychological stress markers and socio-emotional skills such as personal motivation, cognitive load and self-efficacy in undergraduate emergency care students is needed. Another avenue to research is to determine the optimal integration of simulated learning experiences, as well as to identify which clinical components are better suited for effective learning through other educational pedagogies.

Additionally, to mitigate against the final-term assessments' high anxiety levels, a longitudinal study (with similar objectives as the current study), can be undertaken measuring students' stress levels throughout the academic year (for all clinical assessments). This may highlight findings related to knowledge scaffolding and improve students' confidence and clinical performance by early recognition of poor stress management. A further aspect to explore, would be an experimental study (using the same data collection tools), where the one group is assessed with assessor(s) present in the examination venue versus another group with no assessors present (remote camera viewing). This may indicate what impact (if any), the presence or absence of the assessors have on anxiety levels during clinical assessments.

6.7 Concluding remarks

The real benefit of high levels of stress evoked during simulated scenarios is uncertain, with many diverse factors affecting academic success, including the intended learning objectives, the preparedness of learners, individual demographics such as age and gender, as well as the knowledge and skills of the educator to deliver an effective learning activity. Ultimately, students must develop the abilities to integrate their cognitive ability, specialised practical knowledge and ethical awareness into clinical practice to become caring and professional healthcare providers.

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APPENDICES

APPENDIX 1: PROVISIONAL APPROVAL - PILOT STUDY

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavitshad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

10 September 2020

Mr E Ismail
54 Olifant Road
Primrose Park
Cape Town
7764

Dear Mr Ismail

Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical simulations

I am pleased to inform you that **PROVISIONAL APPROVAL** has been granted to your proposal subject to:

- Piloting of the data collection tool. *Please note that should there be any changes to the data collection tool, in a letter signed by the researcher and supervisor, list the changes to the documents and submit to IREC with the final data collection tool. Even when there are no changes to the data collection tool, IREC has to be notified.*
- Obtaining and submitting the necessary gatekeeper permission/s to Institutional Research Ethics Committee (IREC).

PLEASE NOTE THAT THIS IS NOT A FINAL APPROVAL LETTER. KINDLY SUBMIT THE ABOVE MENTIONED DOCUMENTS WITHIN THREE MONTHS TO THE IREC OFFICE. DATA COLLECTION CAN ONLY COMMENCE WHEN IREC ISSUES FULL APPROVAL

The Proposal has been allocated the following Ethical Clearance number **IREC 075/20**. Please use this number in all communication with this office.

Approval has been granted for a period of **ONE YEAR**, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Yours Sincerely

Dr M A Sathar
Deputy Chairperson: IREC

APPENDIX 2: GATEKEEPER APPROVAL TO CONDUCT RESEARCH

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946

26th October 2020
Mr Ismail Erefaan
c/o Department of Emergency Medical Care and Rescue
Faculty of Health Sciences
Durban University of Technology

Dear Mr Erefaan

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted **Full Permission** for you to conduct your research "Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical simulations" at the Durban University of Technology.

The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings would be submitted to the IRIC on completion of your studies.

Kindest regards.
Yours sincerely

DR LINDA ZIKHONA LINGANISO
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT DIRECTORATE

APPENDIX 3: ETHICAL CLEARANCE LETTER

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
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www.dut.ac.za

4 November 2020

Mr E Ismail
54 Olifant Road
Primrose Park
Cape Town
7764

Dear Mr Ismail

Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical simulations
Ethical Clearance number IREC 075/20

The Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of the data collection tools.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letters.

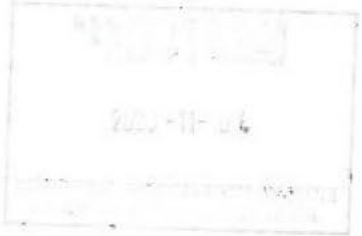
Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Professor J K Adam
Chairperson: IREC



APPENDIX 4: HOD PERMISSION LETTER

Date: 22 October 2020
To: Mr Sageshin Naguran
Department of Emergency Care and Rescue
Faculty of Health Sciences
Durban University of Technology

SUBJECT: REQUEST FOR APPROVAL TO UNDERTAKE RESEARCH

I am currently registered at Durban University of Technology, through the Department of Emergency Care and Rescue with the aim of completing a Doctoral Degree: Emergency Medical Care. I wish to undertake a research project within your department recruiting the undergraduate paramedic students.

Student Name: Erefaan Ismail (MHSc EMC)
Student no: 21447856 (Ethical clearance number: IREC 075/20)
Supervisor: Prof Champaklal Chhaganlal Jinabhai (MD) Contact no: 031 3735160
Co-Supervisor: Dr S. Sobuwa (PhD) Contact no: 031 3735203
Co-Supervisor: Dr D R Prakaschandra (PhD) Contact no: 031 3736885

Title of Research: Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical simulations

Aim of Research:

According to Schwabe, L. and Wolf, O. L., (2009) their study findings "show a memory impairing effect of learning under stress in humans and challenge some assumptions of current theories about the impact of stress around the time of learning on memory formation". It is unclear at this stage to what degree this form of psychological stress as a teaching activity promotes or impedes effective learning in undergraduate paramedic students in South Africa. The aim of the study, therefore, to assess the impact of psychological stress on the clinical performance of undergraduate paramedic students during clinical simulation.

Benefits of Research:

The potential benefits of the proposed study could include:

• This study will, for the first time in Africa, illuminate the role psychological stress play on a paramedic's clinical performance lapses due to the highly stressful environment they operate in, as compared to other medical professions, ultimate leading to improved patient outcomes.

• This study will be the first self-awareness opportunity most undergraduate paramedic students are exposed to become cognisant of their psychological stress and may lead to improvement in future clinical performance by using psychological stress management tools.
• It will be the first time in Africa the perceived psychological stress of undergraduate paramedic students will be compared between the different years of study, which may highlight any deficiencies in the scaffolding of knowledge building. For the first time in South Africa, this study will contribute to the understanding of the impact of clinical simulation training as a teaching activity and whether or not it promotes or impedes effective learning among undergraduate paramedic students for the first time in South Africa.
• Author: The completed study will be submitted by institution for publication in a recommended journal.

All data will be handled with the strictest confidentiality. All participants will remain anonymous and only the researcher/supervisors will have access to the data. All research findings will be made available to you, in an encrypted report. The entire data collection process will occur on scheduled assessment days only, therefore no impact on lecture class sessions.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me (Office: 0219386731; Cell: 0835106459; Erefaan.Ismail@westerncape.gov.za).

Thank you for your time and consideration in this matter.

Yours sincerely,

Erefaan Ismail
Durban University of Technology

DUT DURBAN UNIVERSITY OF TECHNOLOGY
FACULTY OF HEALTH SCIENCES
DEPARTMENT OF EMERGENCY MEDICAL CARE & RESCUE
Corner of Ritson and St Thomas Roads
PO Box 1334, Durban, 4000
Tel: 031-373 5203 • Fax: 031-373 5201

Approved ☑ Disapproved ☐

Emergency Medical Sciences

Signature: **Date:** 29/10/2020

APPENDIX 5: PARTICIPANT INFORMATION LETTER

LETTER OF INFORMATION

Dear participant

My name is Erefaan Ismail, a paramedic from Cape Town, undertaking a PhD study at your EMCR Department. I would like to invite you to participate in my research study. For me research is about exploring new ideas and it allows us to take our EMS profession to new levels, instead of remaining stagnant. For those of you considering pursuing any future research studies, it will be useful to experience being part of a study within your department.

Title of the Research Study: Assessment of psychological stress on the clinical performance experienced by paramedic students during clinical simulations

Principal Investigator/s/researcher: Mr Erefaan Ismail (MHSc EMC)

Co-Investigator/s/supervisor/s:

Supervisor: Prof Champaklal Chhaganlal Jinabhai (MD)	Contact no: 031 3735160
Co-Supervisor: Dr S. Sobuwa (PhD)	Contact no: 031 3735203
Co-Supervisor: Dr D R Prakaschandra (PhD)	Contact no: 031 3736885

Brief Introduction and Purpose of the Study:

According to Schwabe, L. and Wolf, O. L., (2009) their study findings "show a memory impairing effect of learning under stress in humans and challenge some assumptions of current theories about the impact of stress around the time of learning on memory formation". It is unclear at this stage to what degree this form of stress as a teaching activity promotes or impedes effective learning in undergraduate paramedic students in South Africa. The aim of the study, therefore, is to assess the impact of psychological stress on the clinical performance of undergraduate paramedic students during clinical simulation.

Outline of the Procedures:

All undergraduate paramedic students registered on the Bachelor's Emergency Medical Care programme will be eligible to participate. The study will involve the recording your vital signs for the duration of your simulation assessment, recorded remotely using the latest biotechnology embedded in a smart shirt in real-time (Hexoskin). In addition, your saliva samples will be required, as it is a stress biomarker (PPE for Covid-19 precautions will be in

place) and lastly you will be asked to complete a pre- and post- assessment stress questionnaire (takes 5 minutes to complete).

Precautionary Covid-19 protocol and screening:

As part of the data collection involves obtaining a salivary specimen from the participant, the following Covid 19 measures will be adhered to:

- Covid 19 screening (which will include temperature checks) will be recorded for all involved with data collection, as well as all participants
- Hand sanitiser and paper towels will be available for use by both the researcher/assistant (s), especially for use after every individual specimen collected, as well as for the participants - on entering the room and departure, although personal contact will be minimized
- Researcher and assistant (s) – Personal protective equipment (PPE) donning of a N95 respirator; goggles or visor; A 40 suits or apron; gloves
- Wearing of a clean set of gloves for each participant
- Removal/ discarding of used PPE at a site certified to dispose of infectious waste
- If the participants is not already wearing a mask, a surgical mask will be on hand to provide to them
- Salivary specimen collection will occur in a separate venue, away from the assessment venue, with only one participant allowed at a time into the room

Confidentiality:

If you agree to participate in the study, you will be asked to complete a consent form. You will then be allocated a numerical number and remain anonymous. The same numerical number, example "Participant 12" will be used on all the data formats and biological specimens, meaning no demographic or personal information will be collected for the purpose of data analysis or the final report. Confidentiality will be ensured, as all study data will be stored on password protected on data base and only the researcher/supervisor/co-supervisor will have access.

Risks or Discomforts to the Participant: there will be no risk to you, especially in relation to the spread of Covid-19 as, according to the World Health Organization (WHO), the wearing of the correct PPE has been proven to prevent the spread of Covid-19 (https://www.who.int/medical_devices/priority/COVID_19_PPE/en/)

Benefits:

The potential benefits of the proposed study could include:

- This study will, for the first time in Africa, illuminate the role psychological stress play on a paramedic's clinical performance lapses due to the highly stressful environment they operate in, as compared to other medical professions, ultimate leading to improved patient outcomes.

- It will be the first time in Africa the perceived psychological stress of undergraduate paramedic students will be compared between the different years of study, which may highlight any deficiencies in the scaffolding of knowledge building. For the first time in South Africa, this study will contribute to understanding the impact of clinical simulation training as a teaching activity and whether or not it promotes or impedes effective learning among undergraduate paramedic students.

• Participant: This study will be the first self-awareness opportunity most undergraduate paramedic students are exposed to become cognisant of their psychological stress and may lead to improvement in future clinical performance by using psychological stress management tools.

• Author: The completed study will be submitted by institution for publication in a recommended journal.

Reason/s why the Participant May Be Withdrawn from the Study: Your participation is voluntary and there is no obligation. If you decide to take part you will be given this information sheet to keep and you will be asked to sign a consent form. If you decide to take part and then withdraw, you are free to withdraw, at any time without giving a reason. A decision to withdraw at any time or a decision not to take part, will not affect you in any way.

Remuneration: No remuneration will be offered for participation in the study

Costs of the Study: You will not be asked to cover any costs associated with the study
Research-related Injury: Not applicable as there is no risk of injury due to the study

Persons to Contact in the Event of Any Problems or Queries:

Supervisor: Prof Champaklal Chhaganlal Jinabhai (MD) Contact no: 031 3735160

Please contact the researcher Mr. E. Ismail (Contact no. 0835106459), my Supervisor:

Prof Champaklal Chhaganlal Jinabhai (Contact no: 031 3735160) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or dvcrie@dut.ac.za.

Best regards

E. Ismail

APPENDIX 6: PARTICIPANT CONSEND FORM

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Mr Erefaan Ismail, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: **IREC 075/20**
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials ad surname will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____	_____	_____	_____
Full Name of Participant	**Date**	**Time**	**Signature/Right thumbprint**

I, Mr Erefaan Ismail herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Erefaan Ismail	_____	_____
Full Name of Researcher	**Date**	**Signature**
_____	_____	_____
Full Name of Witness (If applicable)	**Date**	**Signature**
_____	_____	_____
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

APPENDIX 7: PARTICIPANT COVID - 19 SCREENING CHECK LIST

COVID 19 SCREENING CHECK LIST

PARTICIPANT	TEMPERATURE °C	FEVER/FLUCTUATING TEMPERATURE?	DRY COUGH?	SORE THROAT?	REDNESS OF EYES?	SHORTNESS OF BREATH?	BODY ACHES/PAINS?	LOSS OF SMELL/TASTE?	NAUSEA/VOMITING?	DIARRHEA?	STOMACH PAINS?	FATIGUE/PHYSICAL WEAKNESS?	DATE
1.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
2.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
3.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
4.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
5.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
6.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
7.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
8.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
9.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
10.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	

PARTICIPANT	TEMPERATURE °C	FEVER/FLUCTUATING TEMPERATURE?	DRY COUGH?	SORE THROAT?	REDNESS OF EYES?	SHORTNESS OF BREATH?	BODY ACHES/PAINS?	LOSS OF SMELL/TASTE?	NAUSEA/VOMITING?	DIARRHEA?	STOMACH PAINS?	FATIGUE/PHYSICAL WEAKNESS?	DATE
11.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
12.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
13.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
14.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
15.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
16.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
17.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
18.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
19.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	
20.		YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	

APPENDIX 8: STAI PERMISSION LETTER

State-Trait Anxiety Inventory for Adults™

Instrument and Scoring Key

Developed by Charles D. Spielberger
in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

Published by Mind Garden, Inc.

info@mindgarden.com
www.mindgarden.com

APPENDIX 9: STAI SELF - EVALUATION QUESTIONNAIRE

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1
Please provide the following information:

Name_____Date_____S_____
Age_____ Gender (*Circle*) M F T_____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name_____ Date_____

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you *generally* feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

APPENDIX 10: STAI SCORING KEY

State-Trait Anxiety Inventory for Adults™

Scoring Key

Developed by Charles D. Spielberger
in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

Published by Mind Garden, Inc.

info@mindgarden.com
www.mindgarden.com

State-Trait Anxiety Inventory for Adults Scoring Key (Form Y-1, Y-2)

Developed by Charles D. Spielberger in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

To use this stencil, fold this sheet in half and line up with the appropriate test side, either Form Y-1 or Form Y-2. Simply total the scoring **weights** shown on the stencil for each response category. For example, for question # 1, if the respondent marked 3, then the **weight** would be **2**. Refer to the manual for appropriate normative data.

Form Y-1	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1.	4	3	2	1
2.	4	3	2	1
3.	1	2	3	4
4.	1	2	3	4
5.	4	3	2	1
6.	1	2	3	4
7.	1	2	3	4
8.	4	3	2	1
9.	1	2	3	4
10.	4	3	2	1
11.	4	3	2	1
12.	1	2	3	4
13.	1	2	3	4
14.	1	2	3	4
15.	4	3	2	1
16.	4	3	2	1
17.	1	2	3	4
18.	1	2	3	4
19.	4	3	2	1
20.	4	3	2	1

Form Y-2	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21.	4	3	2	1
22.	1	2	3	4
23.	4	3	2	1
24.	1	2	3	4
25.	1	2	3	4
26.	4	3	2	1
27.	4	3	2	1
28.	1	2	3	4
29.	1	2	3	4
30.	4	3	2	1
31.	1	2	3	4
32.	1	2	3	4
33.	4	3	2	1
34.	4	3	2	1
35.	1	2	3	4
36.	4	3	2	1
37.	1	2	3	4
38.	1	2	3	4
39.	4	3	2	1
40.	1	2	3	4

State-Trait Anxiety Inventory for Adults™ (Short Form)

Instrument and Scoring Key

Developed by Charles D. Spielberger
in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

Published by Mind Garden, Inc.

info@mindgarden.com
www.mindgarden.com

Important Note to Licensee

Self-Evaluation Questionnaire
STAIAD Short Form Y-1

Please provide the following information:

Name_____ Date_____ S____

Age_____ Gender (*Circle*) **M** **F** T____

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel ***right*** now, that is, ***at this moment***. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best. Use the following scale:

NOT AT ALL – SOMEWHAT – MODERATELY SO – VERY MUCH SO

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel at ease	1	2	3	4
4. I am presently worrying over possible misfortunes	1	2	3	4
5. I feel frightened	1	2	3	4
6. I feel nervous	1	2	3	4
7. I am jittery	1	2	3	4
8. I am relaxed	1	2	3	4
9. I am worried	1	2	3	4
10. I feel steady	1	2	3	4

SELF-EVALUATION QUESTIONNAIRE

STAIAD Short Form Y-2

Name_____ Date_____

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you ***generally*** feel.

Use the following scale:

ALMOST NEVER – SOMETIMES – OFTEN – ALMOST ALWAYS

		ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
11.	I feel nervous and restless	1	2	3	4
12.	I feel satisfied with myself	1	2	3	4
13.	I wish I could be as happy as others seem to be	1	2	3	4
14.	I feel like a failure	1	2	3	4
15.	I worry too much over something that really doesn't matter	1	2	3	4
16.	I lack self-confidence	1	2	3	4
17.	I feel secure	1	2	3	4
18.	I feel inadequate	1	2	3	4
19.	I am a steady person	1	2	3	4
20.	I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

State-Trait Anxiety Inventory for Adults Short Form Scoring Key (Short Form Y-1, Short Form Y-2)

Developed by Charles D. Spielberger in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

To use this stencil, line up with the appropriate test side, either Short Form Y-1 or Short Form Y-2. Simply total the scoring **weights** shown on the stencil for each response category. For example, for question # 1, if the respondent marked 3, then the **weight** would be **2**. Refer to the State Trait Anxiety Inventory for Adults manual for appropriate normative data.

Short Form Y-1

		NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1.	**I feel calm**	**4**	**3**	**2**	**1**
2.	I am tense	1	2	3	4
3.	**I feel at ease**	**4**	**3**	**2**	**1**
4.	I am presently worrying over possible misfortunes	1	2	3	4
5.	I feel frightened	1	2	3	4
6.	I feel nervous	1	2	3	4
7.	I am jittery	1	2	3	4
8.	**I am relaxed**	**4**	**3**	**2**	**1**
9.	I am worried	1	2	3	4
10.	**I feel steady**	**4**	**3**	**2**	**1**

Short Form Y-2

		ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
11.	I feel nervous and restless	1	2	3	4
12.	**I feel satisfied with myself**	**4**	**3**	**2**	**1**
13.	I wish I could be as happy as others seem to be	1	2	3	4
14.	I feel like a failure	1	2	3	4
15.	I worry too much over something that really doesn't matter	1	2	3	4
16.	I lack self-confidence	1	2	3	4
17.	**I feel secure**	**4**	**3**	**2**	**1**
18.	I feel inadequate	1	2	3	4
19.	**I am a steady person**	**4**	**3**	**2**	**1**
20.	I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

APPENDIX 11: HEXOSKIN SMART VEST SIZING CHART

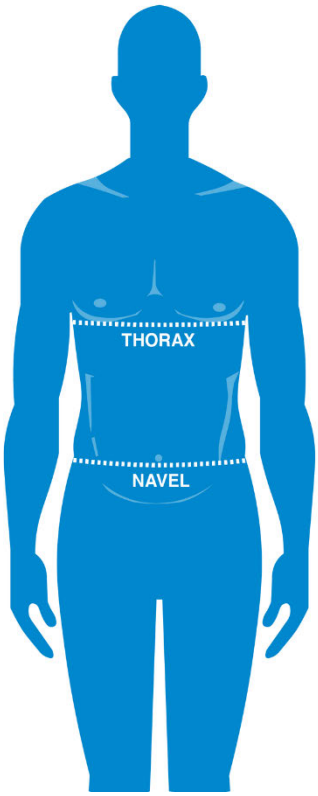
Hexoskin Smart Clothing - Males

Tip: *Stand up straight, preferably in front of a full-length mirror, and take all measurements by applying the measuring tape directly against your body. Make sure the tape is parallel to the ground and keep your arms along your body as much as possible.*

1. Position a measuring tape around your rib cage, under your pectoral muscles
2. Breathe out and note your Thorax measurement
3. Repeat steps 1-2 at the level of your Navel
4. Locate your corresponding shirt size in the chart below based on your measurements.

If you are unsure, please contact us at support@hexoskin.com or by phone at 1-888-887-2044.

	THORAX		NAVEL	
	INCHES	CENTIMETRES	INCHES	CENTIMETRES
2 EXTRA SMALL (2XS)	27.5 - 30	70 - 76	27.5 - 30	70 - 76
EXTRA SMALL (XS)	29.5 - 32.5	75.5 - 82	29.5 - 32.5	75.5 - 82
SMALL (S)	32 - 35	81 - 88.5	32 - 35	81 - 88.5
MEDIUM (M)	34 - 37	86.5 - 94.5	34 - 37	86.5 - 94.5
LARGE (L)	36.5 - 39.5	92 - 100.5	36.5 - 39.5	92 - 100.5
EXTRA LARGE (XL)	38.5 - 42	98 - 106.5	38.5 - 42	98 - 106.5
2 EXTRA LARGE (XXL)	40.5 - 44.5	103.5 - 112.5	40.5 - 44.5	103.5 - 112.5
3 EXTRA LARGE (XXXL)	44 - 48	111.5 - 122	44 - 48	111.5 - 122
4 EXTRA LARGE (XXXXL)	47.5 - 51.5	120 - 131	47.5 - 51.5	120 - 131



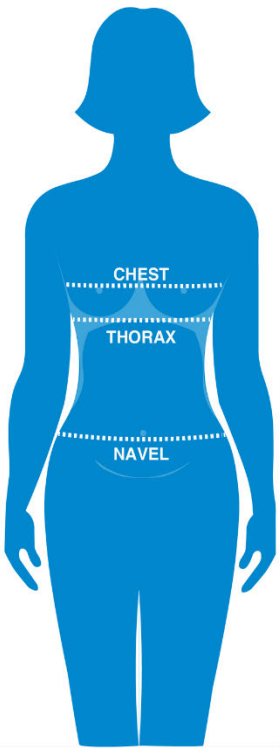
Hexoskin smart vest smart vest Smart Clothing - Females

Tip: *Stand up straight, preferably in front of a full-length mirror, and take all measurements by applying the measuring tape directly against your body. Make sure the tape is parallel to the ground and keep your arms along your body as much as possible.*

1. Position a measuring tape around your rib cage, under your breasts
2. Breathe out and note your Thorax measurement
3. Repeat steps 1-2 at the level of your Navel and the fullest part of your Chest (optional)
4. Locate your corresponding shirt size in the chart below based on your measurements.

If you are unsure, please contact us at support@hexoskin.com or by phone at 1-888-887-2044.

	THORAX		NAVEL		CHEST (Optional)	
	INCHES	CENTIMETRES	INCHES	CENTIMETRES	INCHES	CENTIMETRES
2 EXTRA SMALL (2XS)	26.5 - 29	67 - 73	26.5 - 29	67 - 73	28.5 - 34	72 - 86.5
EXTRA SMALL (XS)	28.5 - 31	72.5 - 79	28.5 - 31	72.5 - 79	30.5 - 36.5	77 - 92.5
SMALL (S)	31 - 33.5	78 - 85.5	31 - 33.5	78 - 85.5	32.5 - 39	82 - 98.5
MEDIUM (M)	33 - 36	84 - 91.5	33 - 36	84 - 91.5	34.5 - 41.5	87.5 - 105
LARGE (L)	35 - 38.5	89.5 - 97.5	35 - 38.5	89.5 - 97.5	36.5 - 43.5	92.5 - 111
EXTRA LARGE (XL)	37.5 - 41	95 - 103.5	37.5 - 41	95 - 103.5	38.5 - 46	97.5 - 117
2 EXTRA LARGE (XXL)	39.5 - 43	100.5 - 109.5	39.5 - 43	100.5 - 109.5	40.5 - 48.5	102.5 - 123
Sizes 3XL & 4XL are available with the Hexoskin ProShirt						
3 EXTRA LARGE (XXXL)	43 - 47	109 - 119	43 - 47	109 - 119	43.5 - 52	110 - 132
4 EXTRA LARGE (XXXXL)	46 - 50.5	117.5 - 128	46 - 50.5	117.5 -128	46.5 - 55.5	118 -141.5



APPENDIX 12: HEXOSKIN SMART VEST ONLINE ANALYSIS HEALTH PLATFORM

Compatible with kubios

Kubios HRV Analysis

Compatible with VivoSense

VivoSense Analysis Platform

APPENDIX 13: KUBIOS HRV USER'S GUIDE

kubios

Kubios HRV Software

USER'S GUIDE

Kubios HRV Standard
Kubios HRV Premium

(version 3.5)

November 3, 2021

Mika P. Tarvainen, Ph.D.
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Juha-Pekka Niskanen, PhLic
Perttu O. Ranta-aho, MSc

IBL INTERNATIONAL

Instructions for Use

alpha-Amylase Saliva Assay

Enzymatic assay for the determination of alpha amylase activity in human saliva.

REF **RE80111**

Σ **96**

2-8°C

EU: IVD CE

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IBL@IBL-International.com
www.IBL-International.com

Instructions for Use

Cortisol Saliva ELISA

Enzyme Immunoassay for the quantitative determination of free cortisol in human saliva.

REF **RE52611**

Σ **96**

2-8°C

EU: IVD CE

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APPENDIX 15: CLINICAL SIMULATION SETTINGS

Control Group Simulation Settings

Data collection for the control group took place in the following clinical training simulation-based emergency scenario environments under non-assessment conditions:

Scenario 1: A 28-year-old male patient was found unresponsive after being pulled out of a local swimming pool by a bystander. Year group: third-year hybrid students. Duration: 20–30 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

Scenario 2: A 35-year-old male patient was found unresponsive with a pathological bradycardia. Year group: third-year hybrid students. Duration: 20–30 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

Scenario 3: A 48-year-old male patient was involved in a motor vehicle collision and presented with a decreased level of consciousness after sustaining a traumatic brain injury. Year group: third-year hybrid students. Duration: 20–30 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

Scenario 4: An interfacility transfer of an adult male patient lying supine in a critical care unit intubated and being mechanically ventilated. Year group: fourth-year students. Duration: 15–30 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

The Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator is capable of simulating a multitude of high-fidelity clinical presentations and appropriate responses for the pre-hospital and ICU settings. Some of the versatile capabilities of the Gaumard® HAL® S3201 patient simulator includes reactive eyes; seizures; advanced airway management;

auscultation; defibrillation, cardioversion and pacing; real mechanical ventilator responses and monitoring, 12-lead electrocardiogram, automated external defibrillation, oxygen saturation, capnography and automatic blood pressure monitoring (HAL S3201 - Advanced Multipurpose Patient Simulator - Gaumard, 2021).

Experimental Group Simulation Settings

Data collection for the experimental group took place in the following simulation-based emergency scenario environments under assessment conditions:

Scenario A: A 35-year-old male patient sustained an open fracture to his right tibia and/or fibula after being tackled by his opponent during a soccer match. The patient presented with a +/- 5 cm laceration and an exposed bone projecting from his right distal tibia and/or fibula region with active haemorrhage, obvious deformity and oedema. The expected management outcomes included haemorrhage control, oxygen administration, splinting of injured extremity and transport decision. Analgesia was not available as a management option in this scenario. Year group: first-year students. Duration: 15 minutes. Patient simulation manikin used: LAERDAL.

Scenario B: A 23-year-old female patient 38 weeks pregnant in labour. The patient presented with post-partum haemorrhage due to uterine atony and tears to the cervical opening after going into labour and delivering her baby prior to the emergency medical services arrival. The expected management outcomes included clamping and cutting the umbilical cord, assessing the newborn's Apgar score, oxygen administration and the management of the post-partum haemorrhage, which included fundal massage initiation, encouragement of breastfeeding, intravenous access and the administration of oxytocin. Year group: second-year students. Duration: 20 minutes. Patient simulation manikin used: LAERDAL.

Scenario C: A +/- 30-year-old male patient in status epilepticus. The patient presented with active seizures, blood-stained sputum as a result of a 0.5 mm laceration to the tip of the patient's tongue and urinary incontinence. The expected management outcomes included oxygen administration, basic airway management, anticonvulsant medication administration, intravenous access, as well as identifying that the patient is hypoglycaemic and requires the administration of dextrose 50%. Year group: third-year students. Duration: 20 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

Scenario D: A 45-year-old male patient experienced palpitations and syncope. The patient presented with light-headedness, palpitations and a pathological atrial tachycardia. The expected management outcomes included ensuring adequate oxygenation and ventilation, intravenous access, vagal manoeuvres, administration of adenosine and synchronised cardioversion. Year group: third-year hybrid students. Duration: 20 minutes. Patient simulation manikin used: Gaumard® HAL® S3201 Advanced Multipurpose Patient Simulator.

Scenario E: A verbal clinical case handover of the patient and management plan for a two-hour interfacility transfer by road of an intensive care unit patient. The expected assessment outcomes included the students' ability to demonstrate their understanding of the patient's presenting clinical illness or injury and relevant in-hospital management, to base clinical decisions on correctly interpreted clinical information, to effectively package and move the patient, and to identify the risks associated with the management of the patient during the interfacility transfer. Year group: fourth-year students. Duration: 30 minutes. Real patient interaction.