Effect of gender & lifestyle on

Cardio Stress Index & Heart Rate Variability

By

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'Now to Him who is able to do immeasurably more than all we ask or imagine, according to His power that is at work within us'

(Ephesians 3:20)

Research Outputs

PUBLICATIONS IN PEER-REVIEWED OR REFEREED JOURNALS

1. The influence of an intense training program on cardio stress index among armed services recruits. Du Toit, P., St Clair Gibson, A., Wood, P., Grant, CC., Grimes, KR., Tope, AM., Janse Van Rensburg, DC., van Rooyen, JM., Mckune, A., **Nortje, E**., Fletcher, L., Ferreira, R., Joubert, AM., Stander, A. Journal Of Strength and Conditioning Research (submitted 7 March 2014)

2. Comparing the influence of sedentary and active work environments on wellness (Translated). Naicker, L-A., Du Toit, P., **Nortje, E**., Kleynhans, M., Ferreira, R. & Gericke, G. (2013). Suid-Afrikaanse Tydksrif vir Natuurwetenskap en Tegnologie 32(1), Art #768, 6 pages. http://dx.doi.org/ 10.4102/satnt.v32i1.768

3. A comparison between the cardio-stress indices of active and sedentary populations (Translated). Du Toit, P., Wood, P., Grant, CC., **Nortje, E**., Kleynhans, M., Fletcher, L., Krüger, PE., Joubert, AM., Kennedy, JJ., Ferreira, R., Van Schoor, A., Joubert, F. & Gericke, G. (2013). Suid-Afrikaanse Tydksrif vir Natuurwetenskap en Tegnologie 32(1), Art#769, 7 pages. http://dx.doi.org/10.4102/satnt.v32i1.769

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8. Die korrelasie tussen kardio-stres en visuele vaardighede: referaatopsomming. N Mthembu, HC Terblance, AF Mahomed, **E Henning**, M Kleynhans, C Govender, R Grant, P Wood, PJ du Toit. Suid-Afrikaanse Tydskrif vir Natuurwetenskappe en Tegnologie, Vol. 31, Issue 1, 2012

9. Die belangrikheid van antropometrie, fisiese en motoriese vaardighede, sport spesifieke toetsing en sport visie tegnieke in die evaluering van rugbyspelers: referaatopsomming. S Gray, **E Henning**, M kleynhans, C Grobbelaar, HC Terblanche, D Crafford, PJ du Toit. Suid-Afrikaanse Tydskrif vir Natuurwetenskappe en Tegnologie, Vol. 31, Issue 1, 2012

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12. The effect of sport specific exercises on the visual skills of rugby players. PJ du Toit, P Janse van Vuuren, S le Roux, **E Henning**, M Kleynhans, HC Terblanche, D Crafford, C Grobbelaar, PS Wood, CC Grant, L Fletcher. World Academy of Science, Engineering and Technology, 71, 2012

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3. Die belangrikheid van liggaamskomposisie , fiksheid en visuele vaardighede in die evaluasie van swemmers; J Hudson (poster presentation), J Lawson, PJ du Toit, **E Nortje**, M Kleynhans

4. Die effek van sport spesifieke oefeninge op die visuele vaardighede van rugby spelers; S Raman (poster presentation), PJ du Toit, **E Nortje**, M Kleynhans

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9. Visual skill performance of university students
   H Gwenhure, **E Henning**, HC Terblanche, M Kleynhans, N Coetzee, P du Toit (Poster Presentation)

10. A retrospective case-study to determine the efficacy of Zolpidem in neurologically impaired patients to improve brain functioning and mental cognition
    P Jansen van Vuuren, N Soupen, K Khuzwayo, M Venter, C Fourie, PJ du Toit, Y Hlophe, C Grobbelaar, **E Henning**, M Kleynhans, HW Nel, RP Clauss, NE Nyakale, MM Sathekge (Poster Presentation)

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12. *Vergelyking van die kardiostress-indeks tussen sedentere en aktiewe populasies.* **E Henning**; HC Terblanche; M Kleynhans; D Crafford; P Wood; R Grant; PJ du Toit **[Oral Presentation by E Henning]**

13. *Die effek van sport-spesifieke oefening of die visuele vaardighede van rugbyspelers.* P Jansen van Vuuren; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; C Grobbelaar; S Gray; PS Wood; CC Grant; DC Janse van Rensburg; PE Kruger; PJ du Toit [Presentation by P Jansen van Vuuren]

14. *Die samestelling van 'n rugbyspeler-indeks vir suksesvolle evaluasie van rugbyspelers.* S le Roux; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; C Grobbelaar; PS Wood; CC Grant; DC Janse van Rensburg; PE Kruger; PJ du Toit [Presentation by S le Roux]

15. *Die verhouding tussen uitbranding, werkbevrediging, sosiale ondersteuning en bewustheid.* HC Terblanche; N Coetzee; KL Hussain Abdool; **E Henning**; M Kleynhans; D Crafford; C Van Wyk; PJ du Toit [Presentation by HC Terblanche]

16. *Die effek van sportvisie-oefening op die visuele vaardighede van universiteitstudente.* J Armstrong; AF Mahomed; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; N Coetzee; PS Wood; CC Grant; PJ du Toit [Presentation by J Armstrong]

17. *Die belangrikheid van fisiese-en motorvaardigheidstoetsing in die evaluasie van manlike rugbyspelers.* J Malyon; S Gray; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; C Grobbelaar; PS Wood; CC Grant; DC Janse van Rensburg; PE Kruger; P du Toit [Presentation by J Malyon]

18. *Visuele vaardighede van universiteitstudente.* M Kleynhans; D Crafford; **E Henning**; H Terblanche; N Coetzee; PJ du Toit [Presentation by M Kleynhans]

2012: Faculty Day (University of Pretoria – Faculty Health Sciences)

19. *Anxiety experienced by a group of first team high school rugby players.* M Kleynhans; M Jooste; N Coetzee; **E Henning**; HC Terblanche; PJ du Toit [Poster]

20. *The measurement of a physiological stress response in beginner scuba divers.* M Kleynhans; N Coetzee; **E Henning**; HC Terblanche; PJ du Toit [Poster]

2012: Institute for Food, Nutrition and Well-being (IFNuW) official launch

21. *Various Posters*

2012: Neuroscience day (UP – May 2012)

22. *The importance of physical and motor skills testing in the evaluation of male rugby players.* J Malyon; R Fourie; C Roberts; A Mckune; S Gray; **E Henning**; M Kleynhans; HC Terblanche; C Grobbelaar; P Wood; C Grant; P du Toit [Poster]

23. *The effect of Sports Vision Exercises on the visual skills of university students.* J Armstrong; AF Mahomed; **E Henning**; M Kleynhans; HC Terblanche; N Coetzee; P Wood; C Grant; P du Toit [Poster]

24. *The measurement of a physiological stress response in beginner scuba divers.* N Coetzee; **E Henning**; M Kleynhans; HC Terblanche; P du Toit [Poster]

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28. *The correlation between cardio stress and visual skills.* C Grobbelaar; HC Terblanche; **E Henning**; M Kleynhans; C Govender; PJ du Toit.

2011: Neuroscience day (UP – May 2011)

29. *Heart health amongst two groups of students.* **E Henning**; C Govender; A Tsotetsi; M Kleynhans; P Wood; R Grant; N De Villiers; JM Van Rooyen; L Fletcher; PJ du Toit **[Student presentation by E Henning]**

30. *The influence of an intense training programme on the visual skills of males and females, aged between 18 and 22.* T Broodryk; **E Henning**; M Kleynhans; HC Terblanche; L Naicker; F Mahomed; D Crafford; P Wood; PJ du Toit [Poster]

31. *The influence of an intense training program of Cardio Stress Index.* T Claassen; **E Henning**; M Kleynhans; HC Terblanche; L Naicker; F Mahomed; R Grant; P Wood; PJ du Toit [Poster]

32. *The importance of visual skills index, body composition and fitness in the evaluation of adult male rugby players.* S Gray; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; PJ du Toit [Poster]

33. *Comparing visual skills in sedentary and active work environments.* L Naicker; **E Henning**; M Kleynhans; HC Terblanche; D Crafford; F Mahomed; C Govender; R Grant; P Wood; PJ du Toit [Poster]

34. *The correlation between cardio stress and visual skills.* HC Terblanche; F Mahomed; L Naicker; **E Henning**; M Kleynhans; N Mthembu; R Grant; P Wood; PJ du Toit [Poster]

2010: Neuroscience day (UP – May 2010)

35. *Wellness testing on recruits to determine current state of wellbeing.* L Naicker; **E Henning**; J Lawson; PJ du Toit; MJ Kleynhans; PE Kruger

2010: Faculty Day (University of Pretoria – Faculty Health Sciences)

36. *Comparison of Cardio Stress Index between university students and a physically more active population.* **E Henning**; M Kleynhans; N de Villiers; PJ du Toit **[Poster presentation by E Henning**]

2010: Suid Afrikaans Akademie vir Wetenskap en Kuns (Pretoria – October 2010)

37. *Vergelyking van Kardio Stres Indeks tussen universiteit studente en 'n fisies, meer aktiewe populasie*. **E Henning**; MJ Kleynhans; N de Villiers; PJ du Toit **[Presentation by E Henning]**

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Abstract

Title: Effect of gender & lifestyle on Cardio Stress Index & Heart Rate Variability

Candidate: Ms E Henning
Supervisor: Prof PJ du Toit
Department: Physiology
Degree: MSc: Human Physiology

The importance of physical exercise tends to be neglected in today's modern lifestyle. This increased passive way of life conveys a notable increase in the prevalence of lifestyle disorders such as hypertension and vascular pathology which lead to cardiovascular strain. Taking this into account, the aim of this investigation was to explore the empirical association between the heart health status of an active and sedentary South African lifestyle, thus intending to provide insight into impact of the significant changes that are associated with the modernised society.

With the aforementioned objective in mind, four separate studies were completed:
Study 1 sought to investigate the cardiovascular status of 162 undergraduate university students in order to determine whether, despite their youth, students remained at risk of cardiovascular complications. Astonishingly, results indicate that a number of students between the ages of 18 and 25 in a university setting present with preeminent cardiovascular risk. This data highlights some serious concerns regarding the cardiovascular health among the youth.

In sequel to study 1, study 2 permitted the comparison of a sedentary and active South African population, however some discrepancies originated due to the notable age difference between the groups. Nevertheless, results gained from this cross-sectional comparison between the populations indicate significantly higher cardiac risk amongst the sedentary population.

Study 3 was conducted on 202 infantry service recruits between the ages of 18 and 24 years. A pre- post intervention study design was incorporated in pursuit of determining the influence of an intense training programme on cardiovascular

variables of a population over a 20 week time-frame. Results yielded from this study indicate a significant decrease in overall cardiovascular risk, as tested over three intervals (week 1, week 12, and week 20) during the 20 week training period.

Study 4 was designed as a longitudinal study with self-controls for within group comparisons, as well as a comparative study between the two contrasting populations. Thus, affording the opportunity to determine the impact of physical activity on cardiovascular risk by comparing two divergent South African lifestyles over a 20-week time frame. The 202 infantry service recruits of study 3 served as the intervention group, while the control group comprised of 126 sedentary university students. Findings from this study conveyed strong association between the active population and decreased cardio-stress index and related heart health measurements in comparison to results of the sedentary population.

This research validates the positive correlation between a physically active lifestyle and improved heart health, thereby implying reduced cardiovascular risk. In the combat against cardiovascular disease it is clear that focus should be shifted from pharmacological treatment to behavioural prevention.

As a principle component of this preventative approach it is vital that individuals are equipped with screening technology that enables early detection and monitoring of probable cardiovascular complications. Several novel ideas were introduced in this research, including the endorsement of the cardio-stress index method as an efficient non-invasive technique to directly observe cardiovascular stress.

Key terms: cardio stress index, sedentary lifestyle, active lifestyle, physical activity, exercise, cardiovascular health, heart rate variability, cardioprotection

Abstrak

Titel: Uitwerking van geslag en lewenstyl op Kardio Stres-Indeks & Hartklop Veranderlikheid

Kandidaat: Me E Henning

Promotor: Prof PJ du Toit

Departement: Fisiologie

Graad: MSc: Menslike Fisiologie

Die moderne leefstyl bring dikwels ‘n toenemende passiewe leefwyse na vore wat lei tot aansienlike styging in die voorkoms van lewenstylsiektes soos hipertensie en verskeie vorme van vaskulêre patologie. Met inagneming hiervan is die doel van hierdie ondersoek om die empiriese verband tussen die hart gesondheid status van 'n aktiewe en sedentêre Suid-Afrikaanse leefstyl te verken, dus van voorneme om insig te verkry rondom die impak van die noemenswaardige veranderinge wat verband hou met die gemoderniseerde samelewing.

Met voorgenoemde doel in gedagte, is vier afsonderlike studies voltooi:
Studie 1 het die kardiovaskulêre status van 162 voorgraadse universiteitstudente geondersoek om ten einde te bepaal of, ten spyte van hul jeug, studente steeds aan die risiko van kardiovaskulêre komplikasies blootgestel word. Verbasend dui resultate daarop dat verskeie studente tussen die ouderdomme van 18 en 25 in 'n universiteit omgewing met kardiovaskulêre risiko na vore gekom het. Hierdie data beklemtoon ernstige kommer oor die kardiovaskulêre gesondheid onder die jeug.

In opvolg tot studie 1 was studie 2 ontwerp om ‘n vergelyking te tref tussen 'n passiewe en aktiewe Suid-Afrikaanse bevolking. Ongelukking het sommige ongerymdhede ontstaan weens die noemenswaardige ouderdom verskil tussen die twee groepe. Nietemin, die resultate verkry uit die dwarsdeursnit vergelyking tussen die bevolkings dui beduidend hoër hart risiko onder die onaktiewe bevolking.

Studie 3 is uitgevoer op 202 weermagrekrute tussen die ouderdomme van 18 en 24 jaar. 'n Kontrole-studieontwerp is gebruik in nastrewing tot vasstelling van die invloed van 'n intensiewe opleiding program op kardiovaskulêre veranderlikes soos opgeneem oor 'n tydperk van 20 weke. Resultate opgelewer uit hierdie studie dui op 'n beduidende afname in die totale kardiovaskulêre risiko, soos getoets oor drie intervalle (week 1, week 12 en week 20) in die 20 week tydperk van opleiding.

Studie 4 is ontwerp as 'n studie met self- kontroles vir binne -groep vergelykings, sowel as 'n vergelykende studie tussen die twee kontrasterende bevolkings. Dus word die geleentheid gebied om die impak van fisiese aktiwiteit op kardiovaskulêre risiko te bepaal deur die vergelyking van twee uiteenlopende Suid-Afrikaanse lewenstyle oor 'n 20-week tydraam. Die 202 weermagrekrute van studie 3 het gedien as die intervensie groep, terwyl die kontrole groep bestaan het uit 126 passiewe universiteit studente. Bevindinge vanuit die studie bewys sterk assosiasie tussen die aktiewe bevolking en beduidende afgename in kardio stres-indeks, sowel as verwante hart gesondheid mates, in vergelyking met resultate van die passiewe bevolking.

Hierdie navorsing bekragtig die positiewe korrelasie tussen 'n fisies aktiewe leefstyl en verbeterde hart gesondheid en sodoende ook verlaagde kardiovaskulêre risiko. In die stryd teen kardiovaskulêre siekte is dit duidelik dat die fokus verskuif moet word vanaf farmakologiese behandeling na voorkomende gedragsverandering.

As 'n belangrike komponent van hierdie voorkomende benadering is dit noodsaaklik dat individue ook toegerus is met tegnologie wat die vroeë opsporing en bewaking van moontlike kardiovaskulêre komplikasies moontlik maak. Verskeie nuwe idees is in hierdie navorsing bekendgestel, insluitend die onderskrywing van die kardio stres-indeks metode as 'n doeltreffende, nie-indringende tegniek om kardiovaskulêre stres direk waar te neem.

Sleutelterme: kardio stres-indeks, sedentêre leefstyl, aktiewe lewenstyl, fisiese aktiwiteit, oefening, kardiovaskulêre gesondheid, harttempo variasie, kardio beskerming

Chapter 1

Introduction

1.1 Background

Cardiovascular disease is a chronic health problem and remains the leading cause of death in modern society [1]. Cardiac risk factors are characteristics that predict a person's chances of developing cardiovascular disease [2]. Risk factors include advanced age, a history of high blood pressure, hypercholesterolemia and diabetes mellitus, as well as adverse risk behaviours such as smoking, stress and physical inactivity [1,2]. Amid the lifestyle risk factors identified, increased psychosocial stress and physical inactivity have been established to play a key role in the development of cardiovascular disease [1,3,4].

Stress is a subjective and commonly used term that refers to a state of threatened or altered internal homeostasis which results from exposure to various stressors or stimuli [5]. Stressors can be of internal or external origin and they undertake a variety of forms [6]. Some stressors are of biological or physical nature, whereas stressors induced by stressful life events and the social environment are of psychological or psychosocial nature [6]. These stressors act as input signals and are received and integrated by means of the stress system, ultimately triggering a stress response leading to physical and behavioural changes [7]. The stress system consists of both the central nervous system (CNS) and peripheral divisions [6,7]. CNS components include the hypothalamus and the brainstem, whilst peripheral components refer to the efferent sympathetic-adrenomedullary (SAM) axis; the peripheral branches of the hypothalamic-pituitary-adrenal (HPA) axis; and components of the parasympathetic system [7].

The brain plays a key role in setting the stress response in motion by evaluating the perceived stressor and determining the threat it holds, so as to convey appropriate messages to various parts of the body [8,9]. The intricate interaction amongst the central and peripheral divisions of the stress system provides means to restore homeostasis by orchestrating the necessary adaptation responses upon exposure to physical and behavioural stressors [8]. The extent of the stress response is reliant on the intensity and controllability of the stressor, for example, an increase in psychological distress usually occurs when the demands of the task or situation at hand outweigh the persons assessment of their ability to meet these demands [10,11]. Research also provides evidence that different individuals elicit different stress response patterns to stressors [11]. It has been found that genetic inheritance undoubtedly contributes to these individualized stress-related outcomes, though responses may also be determined by personal, developmental and environmental factors [6,8,11].

Perception of an acute stressor results in the activation of a complex neuroendocrine system, consisting of the HPA-axis and the sympathetic nervous system (SNS) in order to induce an adaptive stress response [6,11]. The rapid reaction to acute stress entails the activation of the SAM-axis, which leads to the subsequent release of catecholamines (epinephrine and norepinephrine) from the adrenal medulla [6,7,11]. The core function of this response is to increase cardiovascular tone and respiratory rate, thus increasing blood flow and oxygen delivery to vital organs and the required skeletal muscle in order to give rise to the fight-or-flight response [6,7] . A stressor evoking stimulation of the HPA-axis consequently results in elevated plasma glucocorticoid concentrations [6,7]. Glucocorticoids carry out various peripheral effects by means of their ubiquitous receptors and also play a role in adaptation to repetitive stress, as well as termination of the stress response by means of negative feedback mechanisms [6,7]. Adrenal cortisol is considered a key glucocorticoid in the physiology of stress and serves as a vital neuroendocrine effector that regulates metabolism during the stress response [6,7]. Due to their dominant involvement in the stress response, cortisol and epinephrine are often collectively referred to as the stress hormones and are considered the principle peripheral mediators [5,9].

Short-term responses to everyday stressors are essential in initiating a series of physical and behavioural changes which enable individuals to respond and adapt to the stressful event at hand [6,7]. The physiological changes evoked by this adaptive response are short lived and homeostasis is restored soon after the stressor has passed [7]. Chronic or continual stress, however, causes a prolonged or excessive stress response resulting in a persistent state of dyshomeostasis, which has maladaptive consequences on various physiologic functions, such as: inflammation, haemostasis, metabolism and cardiac autonomic control [7,8]. These altered biological processes result in the attrition of fundamental physiological systems, such as the cardiovascular system, subsequently leading to medical complications and ill health [9].

The demands of today's modern lifestyle bring about stressors of a psychological and social nature that have been linked to the increased occurrence of cardiovascular disease [3,4]. Studies also claim that people suffer an increased level of stress in the period before myocardial infarction [12]. This confirms the notion that chronic stress has a particularly precarious impact on the cardiovascular system and can be seen as one of the major risk factors contributing to the multifactorial aetiology of cardiovascular disease [12].

Although there is a clear association between psychological stress and cardiovascular disease, the precise mechanisms involved in the intermediary pathways require elaboration [3]. However, the hyperactivation of the two stress axes mentioned previously (HPA and SAM axes), with resultant over secretion of their respective stress hormones has proven to adversely affect the cardiovascular system in various ways [3,5,7]. For instance, increased plasma concentrations of epinephrine and norepinephrine excessively stimulate various adrenoreceptors, resulting in increased cardiac output, hypertension and vascular hypertrophy [5,11]. Furthermore, chronically elevated blood pressure increases the workload of the heart, resulting in myocardial hypertrophy and thickening of the ventricular wall [5,11]. Frequent surges of adrenaline, particularly those trailed by physical inactivity, has also been implicated in raised total cholesterol levels [5]. On the other hand, chronically elevated cortisol levels have adverse metabolic effects which result in the centripetal redistribution of fat [5,7]. Central obesity has also been linked to the development of cardiovascular disease [5].

Physical activity is considered one of the most important interventions for decreasing various cardiovascular complications and risks [13]. Evidence shows that increased physical activity corresponds with reductions in cardiovascular disease mortality and morbidity, whereas sedentary lifestyles exhibit a robust association with deteriorated heart health [1,13]. In an international case control study of risk factors for cardiovascular conditions, physical inactivity was found to be one of the major behavioural contributors to heart disease, with data indicating that physical inactivity is attributable to 12% of myocardial infarctions [1].

The extensive range of beneficial effects induced by regular exercise, on both physical and psychological health are brought about by an array of direct and indirect mechanisms [13,14]. Cardioprotective biological mechanisms triggered by regular physical activity can be classified under the following headings [13,14]:

Antiatherosclerotic effects:

- Improved artery endothelial function;
- Increased vasodilatation;
- Increased repair of damaged endothelium;
- Decreased blood pressure;
- Reduced inflammatory response; and
- Decreased plasma low density lipoprotein and total cholesterol.

Antithrombotic effects:

- Reduced platelet aggregation;
- Reduced blood clotting (due to decreased fibrinogen);
- Increased activity of endothelial plasminogen activator; and
- Increased fibrinolysis.

Anti-ischemic effects:

- Improved oxygen uptake ($VO_{2\ max}$);
- Reduced myocardial oxygen demands;
- Increased myocardial oxygen supply;
- Improved contractility of myocardium;

- Improved arterial compliance and elasticity;
- Arteriogenesis; and
- Improved circulation.

Antiarrhythmic effects:

- Cardiomyocyte adaptations;
- Improved electrical stability;
- Reduced heart rate;
- Improved autonomic nervous control;
- Reduced sympathetic tone;
- Increased vagal stimulation;
- Increased heart rate variability; and
- Improved baroreflex sensitivity.

In addition to the wide scope of cardioprotective benefits, physical activity also has favourable indirect mechanisms for reducing cardiovascular risk. Regular participation in physical activity has been found to augment the mind-body relationship, thus implying improved physiological responses to psychological demands, such as attenuated blood pressure responses to mental stress [8,13]. Possible mechanisms may involve increased neurogenesis and neurotrophin expression in the brain [8]. Furthermore, studies have found that aerobic exercise reduces anxiety, promotes relaxation and decreases tension, thus promoting an overall improvement in subjective well-being [13,15].

Due to the persistent prevalence of cardiovascular disease it has become essential to establish methods which enable individuals to recognise and respond to the crucial warning signs. A non-invasive diagnostic method commonly used to assess heart functionality and current health status of the heart is by means of heart rate variability (HRV) analysis [16]. This detailed analysis of beat-to-beat fluctuation provides unobtrusive information about the dual modulation of the heart, by means of the autonomic nervous system, in response to a variety of dynamic circumstances [16, 17].

As the human heart is constantly influenced by external and internal stimuli it requires dynamic innervation by both sympathetic and parasympathetic divisions in order to react appropriately to the constant change [16]. Alterations in the HRV pattern or more specifically, the standard deviation of intervals between successive R waves (SDRR) of the cardiac cycle provide early and perceptive indications of compromised heart health [16, 17]. This implies that a healthy individual, with an adequately functioning autonomic control mechanism, should display high variability between consecutive heart beats [16]. Conversely, a reduced HRV pattern implies a possible underlying pathological condition, causing maladaptive responses of the autonomic nervous system to stimuli [16]. For instance, during times of psychosocial distress the heart undergoes adjustment reactions such as increased heart rate and reduction of the variation range of cardiac cycles, suggesting changes in the co-ordinated sympathovagal balance and implying a sympathetic dominant control mechanism (**Figure 1.1**) [16, 18].

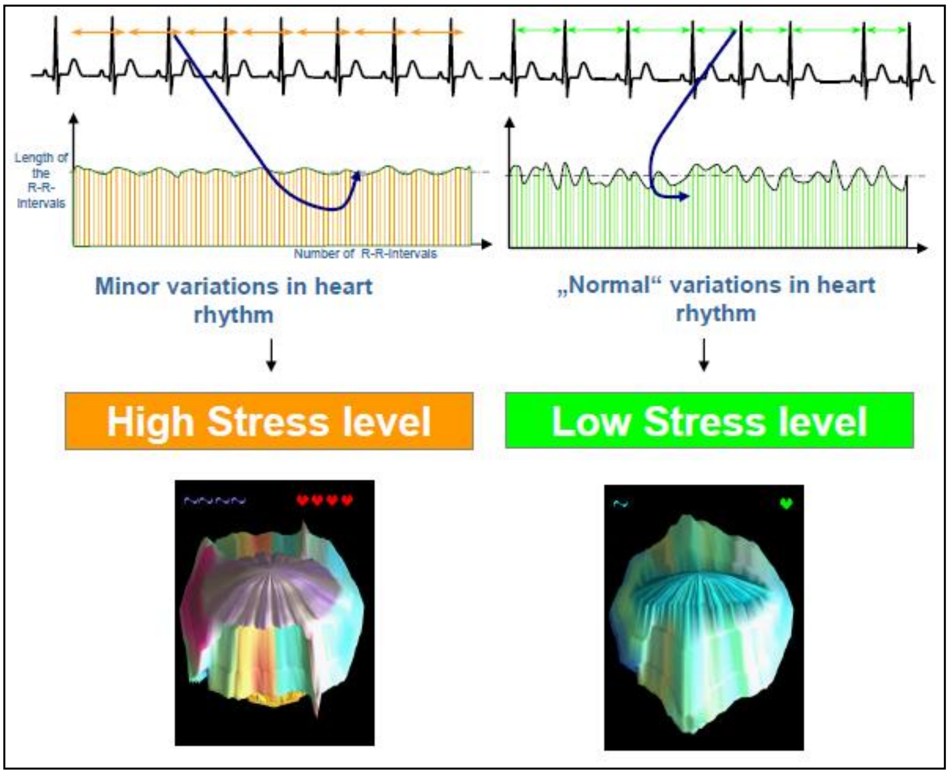

Figure 1.1: R-R interval variation and stress levels [18]

The link between stress and HRV, as well as the vital role of a balanced autonomic nervous system in promoting and maintaining cardiovascular health, has called for the development of intelligent life science technologies which facilitate early prediction and prevention of cardiovascular conditions [16, 17]. Innovative heart and stress screening technologies such as the Viport^{TM} allows for quick and efficient electrocardiograph (ECG) based assessment of heart health [18]. The ECG measurement is then transformed into a three dimensional electrocardioportrait (ECP), which uses a "*traffic light principle*" to indicate the heart health of the tested person (**Figure 1.2**) [18].

This modern technology also allows for various HRV parameters to be transferred via algorithms into the cardio stress index (CSI), which provides an indication of the current stress loading of the heart [18]. Normal HRV translates into a low CSI percentage of between 0-25%, thus implying a low stress level and healthy condition [18]. Alternatively, minor heart rate variation measurements transform into high CSI readings, ranging from 26-100%, indicating a high cardiac stress load and associated cardiovascular risk [18].

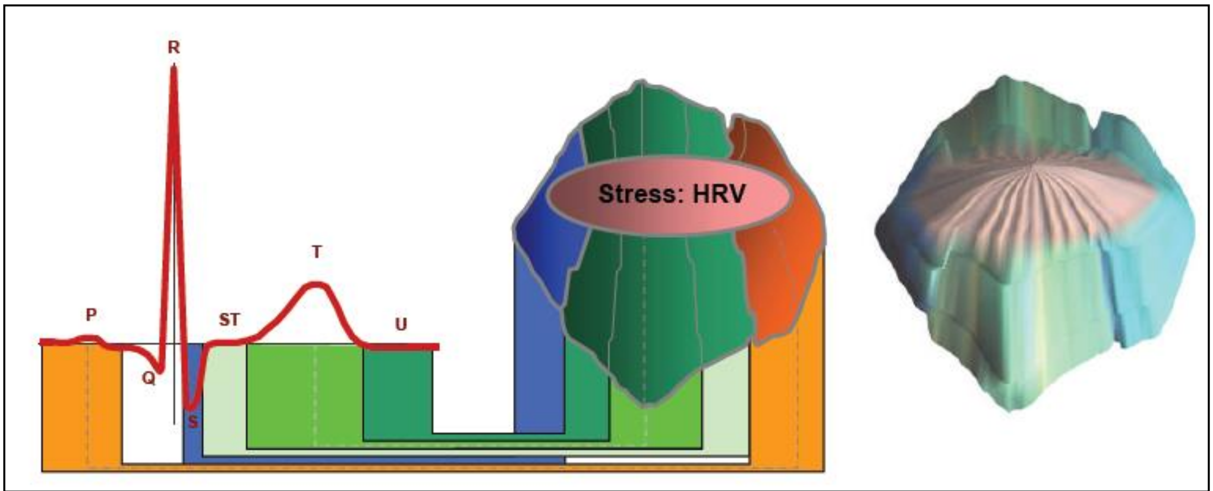

Figure 1.2: ECG transformed into a three dimensional electrocardioportrait [18]

After converting the calculated data, the Viport^{TM} displays the CSI as a percentage along with additional information about the current heart rate, ventricular contraction and any heart rhythm irregularities. Due to the efficiency, simplicity and easy interpretation of this ECG-based heart and stress measurement device, it may prove to be the ideal tool for physicians, patients and everyone wishing to look after their health and take preventative action against heart disease [18].

The present study was designed with the purpose of comparing CSI measurements of university students with a training population in order to determine stress levels and heart health risks provoked by the two different environments. Research proves that lifestyle is one of the most important factors affecting health [15,16]. In light of this, the study is further aimed to link behavioural/modifiable risk factors such as stress and physical inactivity to specific lifestyles.

Although literature refers to an ample number of studies on HRV, stress and physical activity, these topics are usually investigated either individually or in association with one other factor, with little or no research referring to all three simultaneously. More importantly, the novelty of this study is attributed to the methodology and equipment used. The Viport™ is a relatively new medical device providing direct CSI measurements and directly calculating individuals' stress levels and current cardiovascular state.

It is hypothesized that the sedentary or less active population will have elevated CSI readings, reflected by decreased HRV measures, thus resulting in a consequently increased population risk factor and the need for intervention or lifestyle-related modification.

1.2 Research Approach

A combination of qualitative and quantitative research methods were used in this research. With more than one study included in the overall research in order to make concluding remarks about the research question the combined approach is considered advantageous.

The first phase in this research comprised of assessing the cardiovascular risk among the sedentary and active populations. During this phase the qualitative approach was the best in order to gain information regarding the heart health status of the populations involved in the study. During the second phase of the research the quantitative approach was used to measure the impact of the training program on the active population in comparison to the sedentary controls.

1.2.1 Aim:

The overall aim of the research is to compare various heart health measurements between two populations (sedentary and active) in order to determine the effect of activity levels on cardiovascular condition. The non-exercising population serves as the control group, whilst the second population underwent a supervised and guided 20-week training program as part of the interventional design of the study. A wide range of variables were included in the study, in order to cover the overall lifestyle and mental and physical state of the participants from both populations. These variables include: psychological variables (perceived stress); physiological variables (HRV, heart rate, blood pressure, heart rhythm, QRS duration, CSI); anthropometric variables (body mass index); lifestyle variables (nutritional index, fitness index).

1.2.2 Specific objectives:

1.2.2.1 Within group comparisons of training population:

(i) Within group comparison of CSI measurements during three intervals (week 1, 12 & 20) of a 20 week basic training program, to determine the influence of an intense training program on overall cardiovascular health;

(ii) within group comparison of CSI measurements between males and females during the 20 week basic training program, to determine gender differences with respect to the influence of intense training on overall cardiovascular health;

(iii) within group comparison between physiological measurements such as heart rate and blood pressure with the CSI measurements during the three intervals of the basic training program, to determine correlation between other physiological factors and cardiovascular health; and

(iv) within group comparison of the results from the perceived stress inventory questionnaire and the CSI measurements, to determine the correlation between subjective stress and physiological cardiovascular stress.

1.2.2.2 *Within group comparisons of sedentary population:*

(i) Within group comparison of CSI measurements, during a once-off measurement as well as over a longer period of time (20 weeks);

(ii) within group comparison of CSI measurements between males and females during three intervals;

(iii) within group comparison between physiological measurements such as heart rate and blood pressure with the CSI measurements during the three intervals; and

(iv) within group comparison of the results from the perceived stress inventory questionnaire and the CSI measurements, to determine the correlation between subjective stress and physiological cardiovascular stress.

1.2.2.3 *Inter-group comparisons between sedentary and training populations:*

(i) Inter-group comparison of CSI measurements, to compare these variables between active and more sedentary environments;

(ii) inter-group comparison between CSI measurements of males and females between the two populations, to determine gender differences (within the two environments) regarding cardiovascular health;

(iii) inter-group comparison between physiological measurements such as blood pressure and heart rate, to determine differences between the two populations; and

(iv) inter-group comparison between body composition measurements such as Body Mass Index (BMI) to correlate these values with the sedentary and more active environments, as well as the cardiovascular measurements.

(v) inter-group comparison between fitness test results and CSI readings of the two populations, to correlate fitness and cardiovascular health.

1.3 Type of Research

At first glance one would undertake this type of research to be classified as applied research. This is due to the obvious objective of elucidating a practical problem of the modern world [19]. However, upon closer inspection it is clear that the type of research used for this study is basic research. Basic research, also referred to as fundamental research, is defined as "research undertaken with the primary goal of advancing knowledge and theoretical understanding rather than solving practical problems" [20]. This is contrasted with applied research which is described as "research undertaken with the intention of applying the results to some specific problem" [20]. A further contrast between these two research types lies within the purpose or intention of the study. Basic research aims at determining statistically significant relationships or effects, whilst applied research intends to discover practically significant relationships [19].

For this study intervention research in the context of basic research was implemented as part of the experimental study design. This intervention design aims to establish a causal relationship between the tested variables, thereby proving the effect of the implemented intervention [21]. Various types of intervention research designs were employed during this study in order to gain the required information, these include: the within-participant design and the between-group design (including both cross-sectional and longitudinal methods).

With the aforementioned objectives in mind, various studies were conducted in order to thoroughly compare the difference in cardiac risk amongst sedentary and active populations. The studies are discussed as separate chapters of the dissertation.

The first study was conducted in order to determine whether sedentary student populations indicated signs of possible cardiovascular risk. A descriptive cross-sectional study design was implemented. Unpredictably, results indicated that despite the young age the majority of the students presented with elevated CSI.

The second study followed a case-control design and aimed at comparing a sedentary student population with an active population in order to determine possible differences induced by the variation in physical activity levels. The results obtained from this cross-sectional comparison between the populations indicated significantly higher cardiac risk amongst the sedentary student population.

In the subsequent study (study 3) a pre- post intervention study design was incorporated with the aim to determine the influence of an intense training programme on cardiovascular variables of a population over a period of 20 weeks. The results indicated a significant decrease in overall cardiovascular risk, as tested over three intervals during the 20 week training period.

Aforementioned discoveries led to the planning and execution of the final study (study 4), which aimed at comparing a sedentary population with an active population undergoing a 20-week training programme. This study was able to determine the impact of physical activity on cardiovascular risk by comparing a control and intervention group over a 20 week time frame. Thus, serving as a longitudinal study with self-controls for within group comparisons; as well as a comparative study between the two populations.

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Chapter 2

Literature Review

2.1 Physical activity and health

Systemic research regarding the influence of physical activity on health began to intensify from the middle of the 20th century [1]. By 2009 an estimate of 50 000 articles relating to the topic of physical activity or physical fitness and health had been published in scientific journals [1]. The amplification in such research serves as proof of the interest that has developed around this field of study. With the increase in knowledge gained from this body of research attention is drawn to the significant role of physical activity in maintaining health and well-being, whilst the hazards of modern day sedentary lifestyles are highlighted [1,2].

2.1.1 Benefits of physical activity: the history

Suggestions of the importance of physical activity for health date back to as early as 3000 BC, as described in the oldest known medical book from China: *Nei Ching* [3]. Similar theories also exist in other cultures - for example, Susruta (600 BC) was a physician from the ancient civilisations of India who prescribed physical activity as medicine in aim of prevention and treatment of diseases [4]. He advocated daily exercise of moderate intensity in order to reduce illness and the consequence thereof [4]. Historical teachings of this belief continued with that of Hippocrates who is considered "…*the most influential physician from Greek antiquity*" and "…*the founder of Western scientific medicine*" [5]. Hippocrates taught that ''*Eating alone will not keep a man well; he must also take exercise. For food and exercise, while possessing opposite qualities, yet work together to produce health*'' [6]. In his book *Regimen for Health* he further wrote the following with regards to exercise: "*And it is necessary…to discern the power of various exercises, both natural exercises and artificial, to know which of them tends to increase flesh and which to lessen it; and not only this, but to proportion exercise to bulk of food, to the constitution of the patient, to the age of the individual… Exercise should be many and of all kinds, running on the double track increased gradually…sharp walks after exercises, short* *walks in the sun after dinner, many walks in the early morning, quiet to begin with, increasing till they are violent and then gently finishing*" [7]. Galen, another prominent physician of the ancient era, built on the teachings of Hippocrates to conclude his own theory in support of moderation, preservation and balance in order to emphasise health promotion and disease prevention [8]. The writings and philosophies of these great physicians, even though they are based on theories and inspirations rather than scientific evidence, serve as an indication that physical activity has been seen to play an essential part in the endeavour for good health since the ancient times.

It was only until the dawn of the era known as the Industrial Revolution, a period from the 18th to the 19th century, that investigations into the beneficial relationship between exercise and health were conducted in a more unbiased manner with the introduction of mathematical quantification [9]. During this period Dr WA Guy (1843) and Edward Smith (1863) compared and contrasted health and mortality rates of sedentary workers relative to physically active workers [9]. Their findings disclosed favourable health and decreased mortality among the more active counterparts [9]. Upon delving into the more modern history of physical activity and health it appears that it is the work of Professor Jeremy Morris and Professor Ralph Paffenbarger which made a substantial impact during the mid-1900s [7,9].

2.1.1.1 Professor Jeremy Morris' contributions

The ground-breaking research of Professor Morris and colleagues endorsed the notion that increased physical activity correlates to reduce risk of chronic diseases [7,10]. This hypothesis was formulated based on his work on the epidemiology of coronary heart disease (CHD) [9,10]. It was Professor Morris who acknowledged the steep rise in the occurrence of CHD by the late 1940s and set forth to discover the social factors related to the epidemic [10]. The research strategy rooted from the intuition that the augmented occurrence of CHD may be occupation related [1,9,10]. Pursuing this hunch, a series of studies was initiated to determine the incidence of CHD among workers across a varied range of occupations [1,9,10]. The initial study included the morbidity/mortality data sets of about 31 000 men employed in Britain's transport sector and found that the physically active conductors exhibited favourable health relationships relative to the inactive bus drivers [1,10]. This discovery was supported by a subsequent study which found corresponding patterns pertaining to the level of physical activity and health when comparing the CHD incidence among Britain's inescapably active postmen versus the desk-bound sedentary telephonists [1,9]. These findings supported the initial hypothesis that serious health conditions such as CHD can be correlated to the level of physical activity implemented and led to several more studies. In 1958 Professor Morris and colleagues conducted a national necropsy survey on the hearts of men in order to further test the hypothesis that physical activity of work is a protection against heart disease [1,11]. They found the hearts of the deceased sedentary workers to present pathology, with regards to main coronary occlusion and ischaemic myocardial fibrosis, as much as 10-15 years before that of the physically active workers [11]. Succeeding this work on occupational physical activity and CHD followed more than three decades worth of study regarding the association between leisure-time physical activity and heart health [1,9,12]. The conclusion of this research was published in 1990, with robust evidence for cardiovascular protection among individuals who deliberately partake in enduring, vigorous aerobic exercise in leisure-time [1,9,12]. One of the key messages to be taken from the substantial epidemiological research of Professor Morris is that the benefits of physical activity is not confined to certain populations, ages or races but rather that positive association can be enjoyed by everyone [9].

2.1.1.2 Professor Ralph Paffenbarger's contributions

Professor Paffenbarger is recognized as one of the epidemiologists who conducted what is considered to be the most insistent and convincing studies of physical activity and health [7,8]. His most recognized work comprised two large epidemiological cohort studies conducted in the United States [1,7]. The 16-year follow-up study of the occupational activity in San Francisco Bay Longshoreman reported that the physically active cargo holders expended an average of 925 more kilocalories per work day than that of the sedentary administrators and supervisors [1,13]. Upon correlating kilocalorie consumption in relation to coronary mortality rates it was found that the sedentary workers showed fatality rates one third higher than that of the active counterparts [13,14]. In the Harvard College alumni study a composite index was compiled and used to estimate the weekly energy expenditure of the 16 936 male graduates during leisure-time physical activity [1,15]. Results proved an inverse relationship between kilocalorie expenditure and cardiovascular protection; with a strong decline in heart attack risk among the men with an estimated energy expenditure of 2000 kilocalories per week [1,15]. These seminal findings paved the way for proposed expenditure targets in aim of gaining healthful benefits and improving longevity whilst spawning scientific interest in the concept of physical activity as preventative medicine [1,7,15].

2.1.2 Benefits of physical activity on health: the evidence

With ancient and modern history laying the foundation for the topic of physical activity and health, it is not surprising that interest in this regard has grown exponentially up to the present time. Modern research has provided incontrovertible evidence relating to the importance of physical activity as a vital component in the battle against a pre-mature mortality and a number of chronic diseases [16-18]. Research has evolved from pilot studies aiming to prove the concept to studies in aim of proving efficacy and effectiveness and have now progressed toward interpretation and propagation because of the irrefutable proof of physical activity's role in primary and secondary prevention of cardiovascular disease as well as several other major public health problems [16,18-20]. **Table 2.1** refers to some of the health conditions that have been identified to be related to physical activity or inactivity on the basis of published scientific evidence [20].

When reviewing evidence pertaining to the relationship between routine physical activity and all-cause mortality a strong dose response association has been established [17]. This association is such that increased volumes of physical activity and energy expenditure are inversely related to incidence and prevalence of various states of ill health in a graded linear relation [18]. Bauman [17] reports an estimated increased risk of 30% among inactive individuals, compared to individuals achieving the recommended levels of physical activity. A closer look at cause-specific mortality and habitual physical activity reveals comparable evidence for a growing number of chronic conditions such as cardiovascular disease, diabetes, cancer, hypertension, obesity, osteoporosis and even neurological and mental conditions [2,16-20]. With regards to the latter, there is robust emerging evidence that besides broadly benefiting the physiological functionality of the body, physical activity contributes to brain health and delays cognitive deterioration [2,21,22].

Table 2.1: Health conditions related to physical activity (PA) or physical inactivity (PIA) on the basis of published scientific evidence [20]

Musculoskeletal conditions
Sarcopenia: p, m Osteoporosis, falls, and related fractures: p, m, r Osteoarthritis: m, p? Rheumatoid arthritis: m Low back pain: m, p Neck pain: m Injuries and posttraumatic/operative states: r
Cardiorespiratory conditions
Coronary heart disease: p. m, r Congestive heart failure: m Stroke: p, r Peripheral arterial disease: m, p Hypertension: m, p Hyperlipidemia: p, m Bronchial asthma: m Chronic obstructive pulmonary disease: m
Metabolic conditions
Overweight and obesity: p, m Type 1 diabetes mellitus: m Type 2 diabetes mellitus: p, m Metabolic syndrome: p, m Gallstone disease: p? (PIA increases risk)
Cancer
Colon cancer: p, r Breast cancer: p, r Most other cancer´s: r
Neurological and mental conditions
Cognitive decline (with ageing): m, p? Alzheimer disease: m, p? (PIA may increase risk) Several neurological diseases: m, r Depression (mild, moderate): m, p? Anxiety: m, p?
Other conditions
Fibromyalgia: m Upper respiratory infections: p? Duodenal ulcer: PIA may increase risk Urinary incontinence: m Chronic fatigue syndrome: m Menopausal symptoms: m Acute and chronic pain: m Erectile dysfunction: PIA may increase risk Smoking (addiction): PA may help in cessation Sleep disturbances: m

Explanations: p = prevention; m = management; r = rehabilitation; ? = insufficient evidence

2.1.2.1 Physical activity and cardiovascular disease

Research promulgates the irrefutable, profoundly positive effects that physical activity has on cardiovascular health. Most of the evidence in support of this beneficial relationship comes from large epidemiological studies [9-15,23,24]. The significant findings from the various studies generally unify in a general consensus that a strong inverse relationship exists between physical activity and cardiovascular risk, including incidence of adverse cardiovascular events. This implies that through the practice of regular physical activity, individuals can improve their cardiorespiratory fitness and dramatically decrease their risk of cardiovascular-related mortality and morbidity.

Research suggests numerous probable cardioprotective biological mechanisms which are kindled by the act of physical activity [20,25]. Mechanisms include a variety of direct cardioprotective effects such as reduced inflammation and improved cardiac antioxidant capacity and artery endothelial function [25,26]. However, it is clear that the benefits of regular physical activity are also conveyed indirectly via synergistic improvement and modification of other risk factors associated with cardiovascular disease and the metabolic syndrome [25,26].

Although many factors contribute to the development and progression of cardiovascular disease, physical activity is considered to be one of the most influential modifiable determinants of cardiovascular disease risk [27]. Wessel et al [28] tested the individual contributions of obesity and physical fitness to risk of coronary heart disease and adverse cardiovascular outcomes. Results indicate that lower physical activity levels were more significantly associated with angiographic stenosis and adverse cardiovascular events (all-cause death or hospitalization for nonfatal myocardial infarction, stroke, congestive heart failure, unstable angina, or other vascular events), suggesting that fitness may be more important than obesity when weighing the risk for cardiovascular disease [28]. These findings further highlight the notion that although habitual physical activity supports weight management, health benefits are gained irrespective of weight loss [2]. In an investigation of attributable fractions of various population risk factors Blair [2] reports that low cardiorespiratory fitness is the most confounding cause of mortality when compared to obesity, smoking, hypertension, high cholesterol and diabetes. Results showed that an estimated 16% of all deaths in both men and women within this population could have been avoided if this risk factor had been absent [2].

With regards to the type of physical activity, studies have shown that the benefits reaped and the reduction in relative risk of adverse cardiovascular events seems to be similar for leisure-time exertion and occupational physical activity [27]. This indicates that it is overall physical activity, physical fitness and energy expenditure scores which contribute to conveyance of desired health outcomes. Epidemiological studies providing the landmark for these associations are rooted in the works of Professor Jeremy Morris [10-12,29] and Professor Ralph Paffenbarger [9,13-15,23] as previously described under heading 2.1.1.

Epidemiological studies which compare physical activity and health across age indicate that the inverse relation persists in both younger and older populations [30]. This is despite the fact that age in itself serves as a risk factor for cardiovascular disease, with increased risk associated with advanced age [31]. However, it should be noted that further research on populations older than 80 years is required due to limited availability of data to this regard [30]. As for gender, coronary heart disease has been reported to be more common in men than in women [1,31]. Most of the earlier studies focused mainly on the relationship between physical activity and cardiovascular disease among men [13,15,23] however, recent years have delivered more studies relating to women [28,32-34] and both genders [24,35,36]. Upon testing the gender-based association of physical activity and cardiovascular risk, substantial evidence supports similar inverse relation in both males and females [30]. Some studies suggest that the magnitude of the association is more pronounced in women, indicating an average risk reduction of 40% in active women as compared to their inactive counterparts, while men showed 30% risk reduction [30]. Studies pertaining to the relationship of physical activity and cardiovascular disease risk among different races or ethnicity are relatively sparse. Manson et al [37] conducted a study on 73 743 women who were enrolled in the Women's Health Initiative Observational Study, thus providing a racially and ethnically diverse study population. Results concluded substantial reductions in the incidence of cardiovascular events among physically active women, irrespective of race or ethnic group. Gregg et al [38] reported similar findings in their prospective cohort study on a representative sample of the US population, proposing no statistically significant associations among race. These reports differ to that of Folsom et al [39] who examined this association in a biracial cohort by comparing physical activity to adverse cardiovascular incidence in the Atherosclerosis Risk in Communities study. Results suggest that the inverse association was not observed among the non-white participants, thereby limiting the conveyed benefits of physical activity with regards to cardiovascular risk reduction to the white population.

2.1.3 Benefits of physical activity on physiological parameters

Physical activity results in numerous beneficial physiological adaptive responses which will be briefly mentioned in the following section.

2.1.3.1 Biochemical changes

2.1.3.1.1 Aerobic

I. Myoglobin content: Myoglobin has shown to be directly correlated with oxygen consumption in exercising muscle [40]. The association can be clarified by examining myoglobin's function within the muscle. Myoglobin supports oxidative capacity of the muscle which is one of the three major biochemical characteristics essential to muscle function [41]. Myoglobin delivers oxygen to the mitochondria therefore aiding oxidative phosphorylation and increasing aerobic capability and fatigue resistance during submaximal exercise [41].

II. Oxidation of fat: During rest the rate of lipolysis is approximately twice the rate of fat oxidation [42]. This implies that the quantity of fatty acids released from adipose tissue into the plasma typically surpasses the amount oxidized; resulting in re-esterification back into triacylglycerols [42]. When engaging in physical activity the rate of fatty acid oxidation escalates progressively, while the rate of re-esterification is halved [42]. Fat oxidation is influenced by exercise intensity; with moderate exercise intensity resulting in greater fat oxidation rates as compared to high intensity exercise - implying that fat serves as the primary fuel supply during lower intensities [41,42]. Studies indicate that endurance training alters mitochondrial enzymes which enhances fat oxidation capabilities and results in increased performance [43].

III. Oxidation of carbohydrates: When engaging in physical activity of increasing intensity there is a shift in fuel selection resulting in decreased fat metabolism and increased preference of carbohydrate as the primary fuel source [41]. This is attributed to the increased recruitment of fast muscle fibres which are better equipped for carbohydrate metabolism than fat oxidation [41]. Research demonstrates that the overall capacity for oxidative formation of ATP, or aerobic metabolism, is enhanced by endurance training [44].

2.1.3.1.2 Anaerobic

I. Capacity of the Adenosine Triphosphate Phosphocreatine (ATP-PC) system: At the onset of physical activity the contracting muscles require an immediate and rapid supply of energy which is provided by phosphocreatine breakdown [41]. However, because of the limited portion of phosphocreatine stored in the muscle cells the energy supplied by the ATP-PC system is only sufficient for short duration, high intensity exercise [41]. Research provides evidence that strength training exercises produce increased muscle concentrations of ATP as well as the creatine kinase enzyme which catalyzes the ATP-PC anaerobic system [44].

II. Glycolytic capacity: Physical activity exceeding approximately 5-10 seconds in duration result in the recruitment of the second anaerobic pathway for ATP production, namely glycolysis [41]. A study by Costil and colleagues [44] found that short, high intensity exercise bouts performed twice a day for 4 times a week were sufficient to increase the phosphofructokinase activity within the muscle cells. This implies that certain training programmes are able increase the activity of the rate limiting enzyme of glycolysis [41,44].

2.1.3.2 Cardiorespiratory changes

The measurement of VO_2 max (or maximal oxygen consumption) is seen as the gold standard of measuring cardiorespiratory fitness. This value essentially provides information regarding the ability of one's body to utilize oxygen in order to generate energy in the form of ATP [41]. Research indicates that exercise training has the ability to increase the overall mean maximum oxygen consumption, thereby implying increased cardiorespiratory fitness [45]. Furthermore, the improve oxygen uptake is considered a cardioprotective anti-ischemic effect [25].

2.1.3.3 Heart size

Various reports suggest the occurrence of exercise-induced cardiac hypertrophy as an adaptation to participation in regular exercise, thus implying that athletes have larger hearts than sedentary individuals [46].

2.1.3.4 Heart rate

At the onset of physical activity heart rate increases due to parasympathetic withdrawal and is maintained at high rates during increased workloads by augmented sympathetic stimulation [41]. However, regular participation in physical activity results in decreased heart rate at rest and during effort, thus implying a cardioprotection [20].

2.1.3.5 Stroke volume

Stroke volume increases during exercise in response to increased end diastolic volume and cardiac contractility [41]. Endurance training results in an increased maximal stroke volume which is attributed to an increased end diastolic ventricular volume, along with the associated increase in plasma volume (see *2.1.3.7*) [41]. Increased maximal stroke volume is further attributed to increased maximal muscle blood flow with no change in mean arterial blood pressure, thereby resulting in decreased afterload [41].

2.1.3.6 Cardiac output

Cardiac output represents the product of heart rate and stroke volume. Exercising muscle has higher oxygen demands which are partly met by increasing cardiac output and partly met by redistribution of blood flow (discussed in 2.1.3.10). This implies that cardiac output increases during exercise in direct proportion to the required metabolic rate [41].

2.1.3.7 Blood volume and haemoglobin

Alterations in haemoglobin are mediated through changes in arterial oxygen content, with research indicating that the level of arterial desaturation is inversely related to VO_2max [47]. Alterations in blood volume are mediated through changes in cardiac output [48]. Research suggests that a major percentage of the difference in the enhanced cardiovascular function of endurance athletes can be attributed to their increased blood volume and the consequent improvement of diastolic function [48].

2.1.3.8 Skeletal muscles - capillary density and hypertrophy

Long term resistance exercise has been associated with increased muscle cross-sectional area as a result of hypertrophy of individual muscle fibres [49]. Furthermore, it was found that there is a greater increase in the area of fast twitch muscle fibres as compared to slow twitch fibres [49]. Research further indicates that capillary density increases proportional to muscle fibre growth [50].

2.1.3.9 Lactic acid production

Blood and muscle lactate accumulation is estimated to occur at around 50 – 70% of VO_2max [51]. This point is described as the anaerobic threshold and differs between trained and untrained individuals; with the threshold being reached at higher work rates in trained individuals [41]. The lactate threshold is used as a marker of training intensity and is also considered useful in predicting endurance performance [41].

2.1.3.10 Muscle blood flow

Blood flow redistribution needs to occur in order to comply with the increased oxygen commands of the exercising skeletal muscle, thus implying that muscle blood flow is increased while reducing the splanchnic circulation [41]. The redistribution of blood flow during exercise occurs as a linear function of VO_2 max [41]. The changes which occur during exercise with regards to the shunting of blood away from the viscera to the muscles is synchronised by autoregulation [41]. The increased metabolic rate of the contracting skeletal muscle result in vasodilation of the arterioles delivering blood to the muscles [41]. During intense exercise the blood flow to muscles is further aided by recruitment of an increased percentage of the capillaries within the contracting muscle [41].

2.1.4 Quantifying health related physical activity

Although a large body of evidence has agreed on the beneficial influence of an active way of life on health and longevity, consensus is yet to be reached on the exact dose required to elicit optimal benefits. There has been continued deliberation as to the type, mode, duration and frequency of physical activity necessary to convey health related benefits to individuals [52]. Debates have led to the promulgation of numerous different public health and clinical recommendations with discrepancies relating to the components of physical fitness [52]. Initial exercise training studies delivered results which supported recommendations that vigorous, high intensity physical activity is necessary in order to gain beneficial physiological adaptations [52]. By the 1990s these physical activity prescriptions were argued as evidence was mounting that vigorous training may not necessarily be a prerequisite for healthy living [52,53]. These findings advocated that moderate intensities and moderate amounts of physical activity best delivered health benefits [52,53]. Furthermore, this public health prescription seemed to be more realistic to adhere to in the hope that a larger number of the population would heed to the recommended lifestyle changes if the target seemed more attainable [53]. This view was supported by the US Centers for Disease Control and Prevention and the American College of Sports Medicine who concluded that physical activity performed at a moderate intensity of 3-6 METs (metabolic equivalents) for 30 minutes on most days of the week would result in substantial health benefits [53]. This set forth the formulation of an estimated dose-response curve (**Figure 2.1**) which aims to explain the relationship of different volumes and intensities of physical activity relative to achieved health benefits [53].

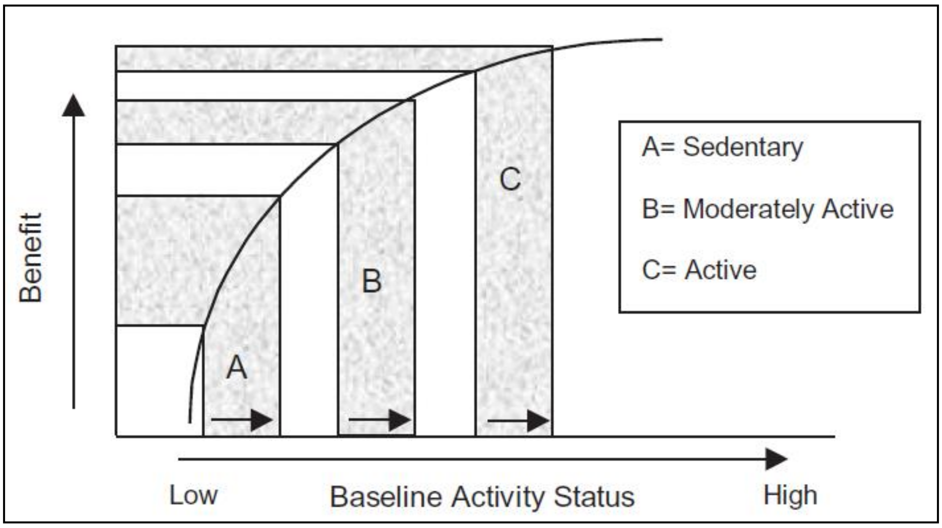

Figure 2.1: Estimated 'dose–response' curve of health benefits from physical activity. The dose–response curve represents the best estimate of the relationship between physical activity (dose) and health benefit (response). The lower the baseline physical activity status the greater will be the health benefit associated with the given increase in physical activity (arrows A, B and C) [53].

The Institute of Medicine Recommendation (IOM) released a report which argued that the prescribed guideline of physical activity for 30 minutes a day is inadequate [52]. Their report suggests engagement in 60 minutes of daily moderate intensity physical activity in aim of preventing weight gain as well as to accrue further health benefits [52]. The discrepancies related to the individual components of physical activity, that is, frequency, duration volume and intensity, are owed to the fact that different health outcomes were pursued, thus resulting in what seems to be disparate recommendations [52]. It is apparent that exercise training prescriptions will differ when aiming to prevent adverse health consequences or unhealthful weight gain in comparison to building muscular strength or gaining performance-related fitness, thus recommendations should clearly state the objective at hand [52]. Current physical activity recommendations are predominantly derived from analyses of the influence and effect of physical activity on cardiovascular health [53].

2.1.5 Classifying physical activity and physical fitness

The question at stake is whether increased physical activity is enough or whether a certain level of fitness needs to be obtained before substantial health benefits can be reaped. Although the words physical activity, exercise and physical fitness are used interchangeably, they actually have distinct definitions [54,55]. Physical activity is described as "any bodily movement produced by skeletal muscles that results in energy expenditure" [54]. Physical fitness has many definitions and has been described in various ways in the literature, however the following standard definition was set forth the by the US Centers for Disease Control and Prevention: "a set of attributes or characteristics that people have or achieve that relates to the ability to perform physical activity" [55,56]. In order to achieve physical fitness one has to engage in exercise, which is defined as "a subcategory of physical activity that is planned, structured, repetitive and purposive in the sense that improvement or maintenance of one or more components of physical fitness is the objective" [55]. Adding to the confusion the President's Council on Physical Fitness devised an additional, more specific term known as 'health related physical fitness', described as "those specific components of physical fitness that have a relationship with good health" [55].

Sassen et al [57] conducted a cross-sectional study on 1298 participants to determine whether physical fitness or physical activity matters more when controlling cardiovascular disease risk factors. The researchers adjusted data for age and sex, after which they related physical fitness as well as each of the individual physical activity components (intensity, duration and volume) with cardiovascular risk scores. Results show that both physical activity and physical fitness hold inverse relationships with cardiovascular disease risk factors. Of the physical activity components it seems that intensity, specifically high intensity, holds the strongest relation to reduced risk. However, it is physical fitness which proved to exert the maximum effect on overall cardiovascular disease risk reduction. These findings suggest the importance of daily physical activity, especially at high intensity, as the cornerstone of achieving improved physical fitness with the ultimate goal of reducing cardiovascular disease risk [57].

2.2 Evolution of lifestyle promotes physical inactivity

The importance of physical activity and physical fitness to health and longevity have been continuously propagated [9]. Modern research has even delivered necessary prescriptions in order to guide individuals with regards to the quantity and mode of physical activity required to reap health-related rewards. However, it is clear that irrespective of the aforementioned - the trend of sedentary living remains imminent [2]. The shift in eras from hunter-gatherer to agrarian, and then to industrialisation resulted in a parallel alteration in physical exertion and energy expenditure; with each transition diminishing the demands on the cardiovascular and musculoskeletal systems [27].

By the dawn of the late 20th century the labours and exertions which were obligated by the earlier eras were replaced with increased sedentarism and concurrent initiation of the morbidities that the modern man now faces [27]. The synchronised decrease in physical exertion and rise in morbidity and mortality caused by cardiovascular and other chronic diseases demonstrates the hazards of societal progression [27]. The success of advancement has ultimately resulted in a population manifestly becoming less active in its occupations and throughout life [1,9]. This implies that if society pursues the previously advocated benefits of physical activity in the prevention and treatment of cardiovascular and related diseases, it would necessitate deliberate exercise and conscious changes in lifestyle behaviours [27].

The fact remains that even though man has obtained unrivalled success in shaping the environment through the evolution of eras to increase efficiency and decrease exertion, we remain genetically programmed to move and physical activity persists to be a vital biological stimulus for optimal physiological functioning [20].

2.2.1 Hazards of the modern-day inactive lifestyle

When investigating the relationship between physical activity and health it may appear that the benefits of activity or exercise and the harms of inactivity are one and the same, however it seems apparent that both sides of the comparison should be emphasised in order to accrue public health [58].

Despite the accumulation of robust scientific evidence promoting the necessity for physical activity, physical inactivity has markedly declined over the last half a century [59]. For instance, over the past 40 years physical activity in the US has declined by 32%, while physical activity in China decreased by 45% from 1991 to 2009 alone [59]. The decline in energy expenditure and physical activity has triggered a synergistic rise in morbidity and mortality related to non-communicable diseases [59]. The World Health Organisation reported that non-communicable diseases are the leading cause of morbidity and mortality, accounting for 60% of all deaths and 44% of premature deaths [60].

A study by Lee et al [61] aimed to quantify the effect of physical inactivity on major non-communicable diseases by estimating how much disease could be avoided if physical inactivity were absent or decreased. They concluded that an estimated 6-10% of major non-communicable diseases (specifically, coronary heart disease, type 2 diabetes, and breast and colon cancers) are caused by physical inactivity. Furthermore, it was found that insufficient physical activity accounts for 9% of premature deaths [61] and is the fourth leading cause of death worldwide [62] . Lee et al [61] suggest that a 10% decrease in physical inactivity could forestall more than 533 000 annual deaths; while elimination of physical inactivity would increase life expectancy of the world's population by 0.68 years. However, Wen et al [58] suggest a 3 year gap in life expectancy when comparing the least active population in relation to the most active.

Regardless of augmented publication of position statements, exercise prescriptions and physical activity guidelines, the rise in physical inactivity and concomitant chronic diseases has not been mitigated [59]. This points out that the mere existence of these recommendations and physical activity policies does not necessarily guarantee adherence and implementation [59]. Statistics show that merely 20% of Norwegian, 8.2% of American and 5% of British adults meet the recommended physical activity dosage [59]. Worldwide an estimated 31% of the population is not engaging in sufficient physical activity to meet present recommendations [62].

Wen et al [58] propose that the prevalence of inactivity could be substantially underestimated, especially in Asian countries where up to 80% of the population is considered to be inactive. It is reports and figures like these which have steered the pandemic of physical inactivity to be considered the biggest public health problem of the 21st century [2,62].

2.2.1.1 Sedentary behaviour: a risk in addition to physical inactivity

A recent study by Owen et al [63] set the foundation for research addressing social and environmental attributes to sedentary behaviour. Upon inspecting how different age groups allocate their time to varying intensities of physical activity, they found sedentary time to be ubiquitous (**Figure 2.2**). The three age-groups spend an average of 46-59% of their day in a sedentary state, described as "any waking behaviour characterised by an energy expenditure of ≤1.5 METs, while in a sitting or reclining posture" [63]. The authors argue that sedentary time, or too much sitting, significantly adds to the risks associated with insufficient physical activity and that the factors concurrently pose a threat to attaining optimal health. This implies that sedentary behaviour should be seen as an additional, measurable element in the prevention of chronic diseases [63]. The 2011 American College of Sports Medicine (ACSM) Position Stand [64] promotes the notion of decreasing the total time spent sedentary by interspersing regular, short sessions of standing and physical activity between sedentary periods. The ASCM suggests that reduction of sedentary pursuits in this manner confers health benefits even in physically active adults [64].

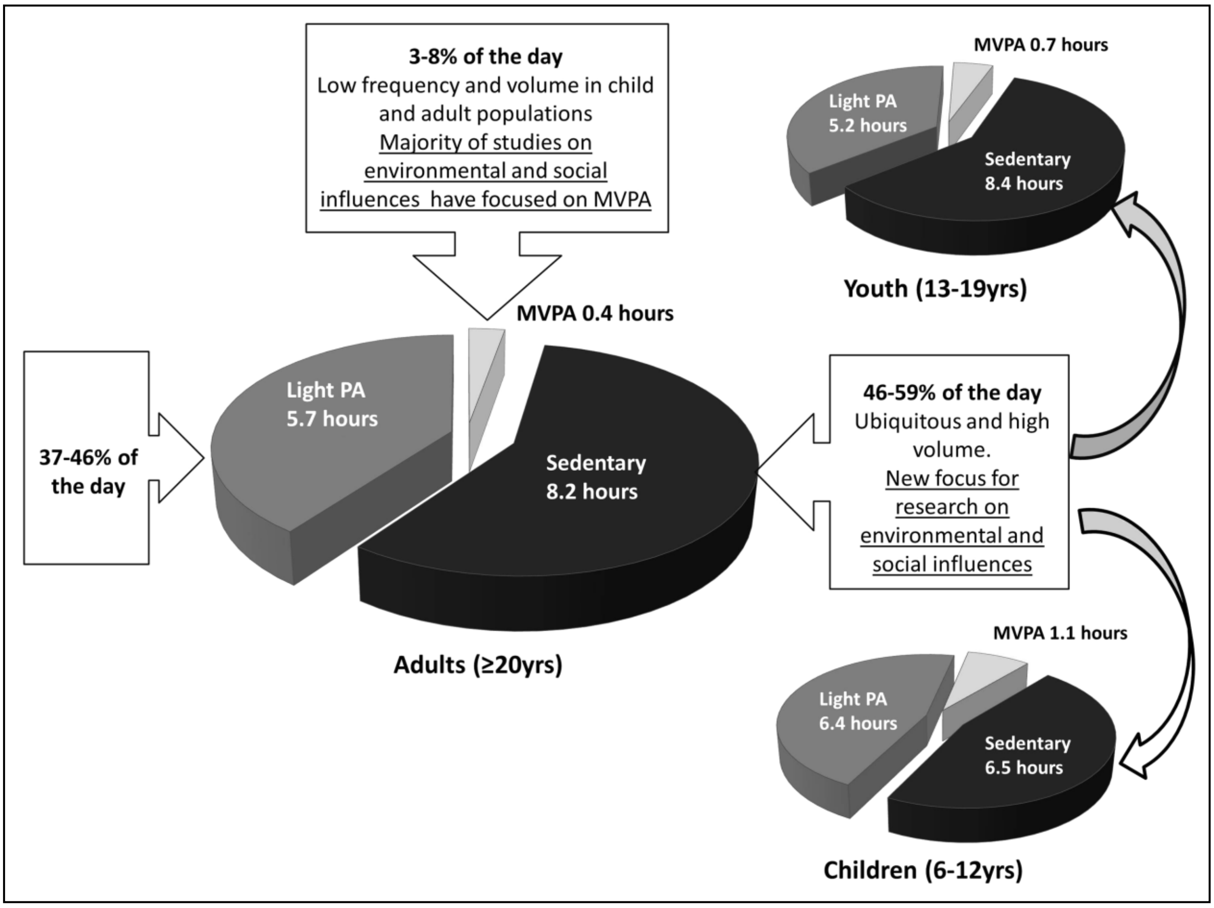

Figure 2.2: How adults and children typically allocate their time spent sedentary, in light-intensity physical activity (PA) and moderate-to-vigorous intensity physical activity (MVPA) [63].

2.3 Measuring heart health

Following the review of literature related to the benefits of physical activity and the hazards of present-day sedentarism, it is clear that both ends of the equation need to be considered in pursuit of healthful living – especially with regards to cardiovascular health. This is due to the fact that both physical activity and physical inactivity have profound and disparate influence on the cardiovascular system [20,27,65]. Furthermore, as mentioned previously, the present physical activity recommendations are predominantly derived from analyses of the impact of physical activity on cardiovascular health [53]. What is left is to investigate research relating to techniques used to monitor cardiovascular responses to physical activity. A vast amount of research has been conducted with respect to cardiovascular response to both endogenous and exogenous influences, with conclusions of these studies generally converging to a common agreement. That is, the state of the cardiovascular system is critically dependant on its capacity as a complex biological system to adaptively respond to dynamically changing circumstances. Technological progression and years of research have provided scientists and clinicians with ample methods to monitor and screen for cardiovascular complications. However, scientific advancement in methodological approaches is welcomed - particularly those aiming to improve accuracy and efficiency, whilst maintaining the necessary simplicity to serve as global diagnostic tools.

The succeeding portion of the literature review will focus on heart rate variability (HRV) analyses as an established method of cardiovascular screening. More so, emphasis will be placed on the use of this method in gaining insight to the cardiovascular response to different variables of physical activity, namely: mode, duration and intensity. Further reference is made to HRV in relation to physiologic and lifestyle determinants.

2.4 Heart Rate Variability analysis

Numerous studies refer to HRV analysis as an important physiological assessment which permits non-invasive insight to the cardiac autonomic balance which is based on the adeptness of the autonomic nervous control mechanism [66]. HRV is derived from electrocardiograph (ECG) recordings by way of time and frequency domain analysis [66-68].

2.4.1 Analysis in time domain

Analysis in time domain entails the calculation of the average value and standard deviation of intervals between successive R-waves of the ECG [67,68]. This is done by converting the ECG into a tachogram (**Figure 2.3**) and performing statistical analysis on the scope of resultant histogram [68].

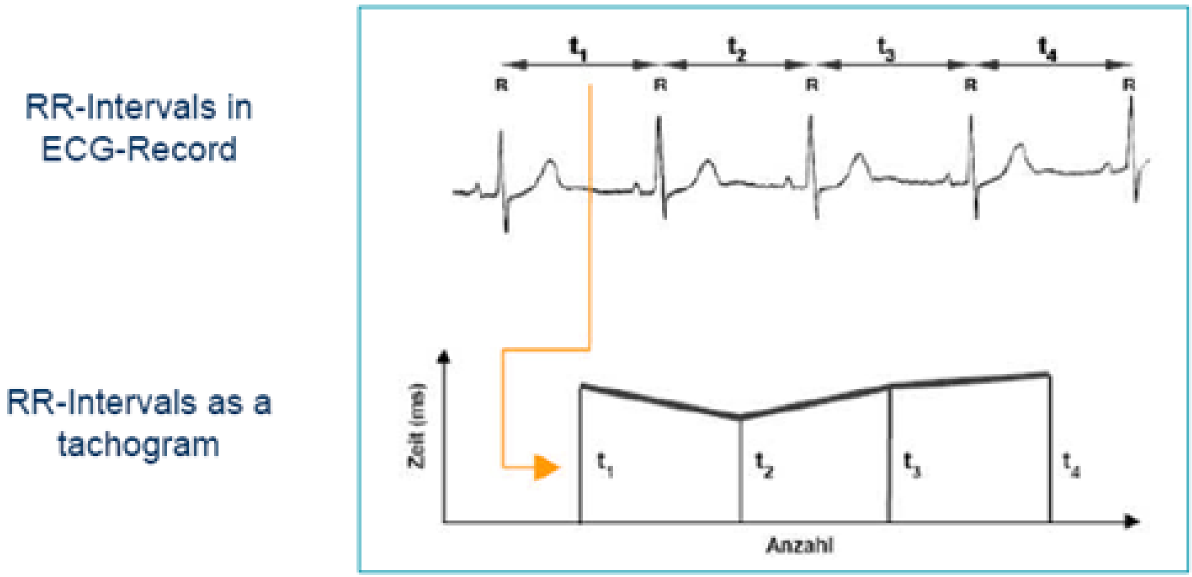

Figure 2.3: Heart rate variability analysis in time domain [68].

Although time based analysis serves as a crude statistical measure of short-term and long-term variability, it lacks to distinguish between distinct biological signals [69]. However, studies have found this total measure of variation to be clinically useful in prognosis of cardiovascular conditions [69]. This has been reinforced by studies which indicate that a reduction in overall heart rate variability is strongly correlated with increased mortality in patients with various cardiovascular complications [70].

2.4.2 Analysis in frequency domain

Variation in time series can be mathematically converted, by way of spectral analysis, into frequency domains (**Figure 2.4**) which provide information about the functionality of sympathetic and parasympathetic divisions of the autonomic control mechanism [68,69,71]. The low frequency (LF) domain, which ranges from 0.04 to 0.15 Hz, corresponds to baroreflex control and imitates the dual (sympathetic and parasympathetic) modulation of HRV [71]. On the other hand, the high frequency (HF) domain ranges from 0.15 to 0.40 Hz and reflects the cardiac vagal tone, which is calculated from respiratory sinus arrhythmia amplitude [72]. The LF/HF ratio depicts the autonomic balance [68]. A ratio greater than two indicates a sympathetic dominant cardiovascular control mechanism [68].

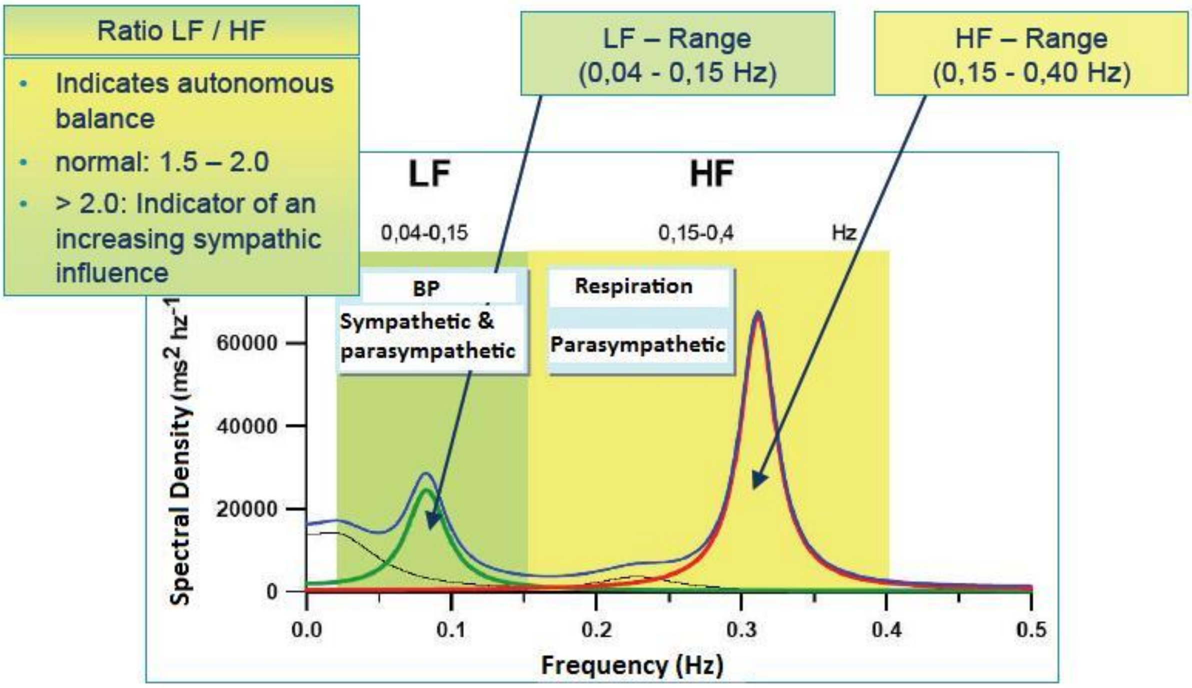

Figure 2.4: Heart rate variability analysis in frequency domain [68].

Studies have proven a linear association between altered frequency components of HRV and increased severity of existing disease states, such as coronary heart disease and myocardial infarction [69]. Separate studies have shown that both time and frequency analysis of HRV derived from ECG recordings have been used to determine time to mortality in patients with cardiovascular disease [73].

Within the literature, reference is made to both short-term (5-30 min) and long-term (24-48 hour) HRV assessment methods [66,69,71,73]. However, a common agreement on which serves as a more accurate or valuable analysis is yet to be reached. Some studies indicate that there is a correlation between short- and long-term results [74], whilst others suggest that long-term assessments serve as better cardiac diagnostic tools [75,76]. A study performed by Hamilton et al [77] has further complicated this debate by comparing HRV from ECG's lasting only ten seconds to a cardio vagal tone measured over a five minute period. The study concluded that the HRV analysis was able to accurately predict the five minute mean cardio vagal tone. This confirms the findings of Dikecligil and Mujica-Parodi [66], which point out the possibility that short-term HRV may be able to correlate with long-term predictions, but without the necessary inconvenience.

In addition to the recognized relationship between altered HRV and cardiovascular risk, ample research has been done with regard to the link between psychological stress and HRV [71,78]. An increased LF/HF ratio and a significantly lower HF component have been correlated with self-reported or perceived stress [78], work stress [79], acute emotional stress [66], depression [80] and anxiety [71]. These aberrations in HRV have been confirmed in individuals with pre-diagnosed clinical anxiety disorders [81], as well as normal, healthy individuals who are faced with mental stress [78]. Interestingly, a study on patients with Post Traumatic Stress Disorder (PTSD) found patients to exhibit similar total HRV when compared to case-controls [71]. However, research concludes that increased sympathetic dominance and a decreased vagal tone, as well as raised systolic blood pressure and increased heart rate reactivity to stressful events, have detrimental effects on the overall cardiovascular condition [80].

The association between physical activity and HRV has sparked profound interest over the past decade. While a considerable amount of studies have been performed with regard to this aspect, results remain inconclusive. The majority of the research supports the theory that endurance training [82-84] and aerobic exercise [67,85,86] increases HRV, which implies improved cardiovascular autonomic regulation. The precise cardioprotecive mechanism responsible for these findings are yet to be fully elucidated, however, long term endurance training has been associated with increased parasympathetic activity [83,84] and/or reduced sympathetic activity and resting heart rate [84]. Although numerous studies are in agreement that augmented vagal modulation has beneficial cardiovascular effects, consensus is yet to be reached on the degree of increased parasympathetic tone required to induce sufficient cardioprotective outcomes [73].

It is widely accepted that athletes have significantly higher HRV when compared sedentary populations [67]. This is confirmed by various cross-sectional studies comparing highly trained athletic groups with sedentary controls [67,87]. These studies generally report an overall improvement in various HRV indexes, including time and frequency domain parameters, for both males and females across most age-group categories [67]. Nonetheless, there is still disagreement with regard to whether or not exercise training results in increased HRV in the general population or previously sedentary individuals. Literature refers to various longitudinal/intervention studies whose results are in support of the notion that increased physical activity and exercise training amongst non-athletes have positive outcomes pertaining to autonomic control mechanisms [67,82-85]. However, the opposite has also been reported, with numerous studies indicating no training-induced reduction of heart rate and/or HRV parameters [67,87-90].

The controversy surrounding this topic prevails due to inconsistent study protocols pertaining to training duration, intensity and mode. Furthermore, longitudinal studies often lack large subject numbers and control groups, resulting in conflicting findings. Jurca et al [85] found that modest amounts of exercise at moderate intensity over short period of time (2 months) was substantial enough to result in a significant increase in overall HRV and decrease heart rate when compared to a sedentary control group. Questions regarding the possibility that increased exercise doses or extended trial periods may result in a further increase in HRV remain unanswered. On the other hand, Loimaala et al [88] conducted a study to test the effect of a 5 month high intensity and low intensity endurance training program on two groups of sedentary middle-aged participants. Results indicated no substantial increase in HRV, whilst a significant decrease in resting heart rate was only observed in the high-intensity group. The authors suggested that an exercise training programme should be followed for a prolonged period of time (possibly years) in order for cardiac autonomic regulation to be modified to sequentially bring about beneficial cardioprotective effects.

Literature provides sufficient evidence that the type and mode of exercise greatly influences the conferred autonomic-enhancing effect. Sloan et al [87] contrasted the cardiac autonomic effect of aerobic conditioning with that of strength training in a large sample of healthy young men and women and found that, in sedentary young adults, aerobic conditioning but not strength training enhances autonomic control of the heart. These results are concordant with the findings of Madden et al [82] who concluded that strength training, as opposed to endurance training, has no significant impact on HRV in a group of older female subjects. This difference was found to persist in both time and frequency domains when comparing the HRV of aerobically-trained versus anaerobically trained athletes [91]. These findings suggest that strength and endurance training possibly function via different mechanisms in order to enhance cardiac autonomic regulation [67,82,91]. The effect of different intensities of physical activity on HRV has delivered contesting results. Rennie et al [86] conducted a cross-sectional study to contrast the outcomes of moderate and vigorous activity and concluded that both intensities suffice an increased HRV. However, this is in contrast with a study which found no dose-response result on HRV between moderate- or high intensity exercise interventions [88].

The advantageous effects of aerobic exercise have been implicated not only in healthy sedentary populations, but also in accelerated recovery of post-myocardial infarction patients and heart transplant recipients [67] as well as individuals suffering from hypertension [20]. A large population-based study found both vigorous and moderate leisure time activities to correlate with increased HRV measurements, which result in reduced risk of coronary heart disease [86].

These findings point toward aerobic exercise training as a valuable appendage or substitute to traditional drug therapy, thus prompting a possible shift from pharmacological to lifestyle interventions to augment HRV parameters and improve cardiac electrical stability [73,86]. These beneficial cardioprotective mechanisms enhance overall cardiovascular health and reduce occurrence of sudden cardiac arrest and cardiovascular mortality, and decreases the risk of developing cardiovascular related diseases [73,86]. This implies life-long, habitual exercise as a vital activity for longevity and a generally healthy life [86,88].

Even though the beneficial effects of exercise training is widely recognised, it should be emphasized that numerous studies have provided evidence that prolonged imbalance between training intensity/frequency and rest/recovery sessions result in unwanted physiological adaptations [86]. Over-training has been associated with both structural changes within the cardiovascular system, such as hypertrophy, as well as changes in the autonomic control mechanism [86,92]. Autonomic dysregulation is thought to be provoked by the hormonal imbalance which is associated with over-training [86]. From a clinical perspective two overtraining syndromes pertaining to autonomic regulation have been identified: a vagal/parasympathetic type and a sympathetic type [86,93]. The sympathetic over-training syndrome is hypothesized to be greatly influenced by psychosocial and emotional stress factors [93]. Other studies hypothesize that the sympathetic tone is significantly amplified during the early phases of an over-trained state, resulting in increased LF power in the frequency domain [86,94]. However, once an advanced stage of over-training has been reached there is a shift in the control mechanism, implying decreased sympathetic activity and excessively enhanced parasympathetic modulation [86,92,94]. The cardiac autonomic imbalance brought about by vagal dominance in over-trained athletes results in HRV changes which may suggest that these altered parameters could serve as a prognostic indication of over-training, however, this remains highly speculative [67].

Besides physical fitness, the literature proposes numerous other physiologic and life-style determinants of HRV. Age has proven to be one of the most influential physiological factors [67]. Increased age is associated with attenuated parasympathetic autonomic modulation resulting in reduced global measures of HRV [67,84]. Several interventional exercise studies report no changes in HRV as a measure of cardiac function amongst middle-aged and older adults, whereas a significant increase was found amid young adults [67]. These findings suggest that physiological aging may be coupled with reduced responsiveness to sympathetic stimulation [67,84]. Gender is also a major determinant of HRV, thus implying gender-related differences with respect to autonomic cardiovascular regulation [67,84,95]. Males below the age of 40 years seem to have higher HRV measures in all parameters except HF power [67]. The decreased LF power and increased HF HRV power in females suggests that females have attenuated sympathetic control and augmented parasympathetic control of heart rate [67,84]. These gender-specific differences may shield females from cardiac arrhythmias [67], lower the risk of developing coronary heart disease [95], and serve as a protection mechanism for women during times of increased cardiac stress, thus contributing to the reduced cardiovascular risk and improved longevity in females [84]. Despite gender differences with regard to autonomic regulation, endurance training has proven to enhance HRV in both sexes [84]. It is suggested that ethnicity should also be considered when interpreting HRV data, as the effect of race on HRV has been testified in certain studies [85]. Furthermore, time of day of recording [96], as well as lifestyles habits such as smoking, alcohol and drugs [95] has been shown to be minor determinants of HRV.

Literature also refers to important general differences pertaining to HRV with respect to heart rate and certain anthropometric measurements, such as body mass index (BMI). A study by Tsuji et al [96] proved an inverse relationship between heart rate and all measures of HRV. This implies that HRV declines with increasing mean heart rate. Heart rate and HRV are considered dependant variables as both are subjective to autonomic regulation [85]. In light of this, it is important to take into consideration the impact of heart rate when evaluating HRV [96]. This is particularly important in exercise intervention studies to ensure that the changes in HRV are not the result of lower resting heart rate [85]. Furthermore, body weight, measured in terms of body mass index (BMI) is also thought to influence HRV [86,97]. More specifically, it has been found that high BMI measurements resemble reduced parasympathetic modulation [86]. A study by Vallejo et al [97] found that BMI values of less than 19 and greater than 30 kg/m^2 are associated with decreased time domain HRV parameters.

From the literature review it is clear that recurrent studies have been conducted with respect to HRV analysis, especially over the past few decades. This is due to the fact that HRV is an approved and scientifically comprehensive method for the study of autonomic functionality. The proposed study includes a method which incorporates the use of the Viport^{TM} device, which provides direct measurements of four clinical parameters, namely: heart rate, heart rhythm, QRS duration and the cardio stress index – which is directly derived from the short term HRV measurement. When reviewing the literature, only a single study was found to include the Viport^{TM} test in the research methodology. The study was conducted to evaluate cardiovascular effects of anaesthetic medications on cardiac stress using cardio stress index (CSI) and rate pressure product (RPP) and to determine which of them are useful in evaluating cardiac stress [98]. CSI was determined by means of the ECG analysis of the Viport^{TM} device and RPP was calculated by multiplying HR by systolic blood pressure [98]. Although RPP has been used as one of the calculation methods of induced stress for years, the results of the study showed that the CSI was able to illustrate existing stress levels better and more efficiently [98].

In light of this, the proposed study has been designed to mutually incorporate an established method for HRV monitoring, as well as a relatively new method for non-invasive heart health data sampling. By including both of these methodologies the study will provide data on overall cardiovascular health, along with more specific data pertaining to the level of cardiac stress.

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Chapter 3

Study 1 *- Cardiovascular Health Risk Among University Students (Career Counselling)*

3.1 Key focus of the study

The kids are all right, aren't they? Do career counsellors know their clients? Do students know their own cardiovascular (CVD) status? Traditional career guidance focuses on individuals' abilities, interests and personality. However, within the world of work a person's health is important and can influence the individual's ability to be effective and efficient within his/her career. Therefore, students are perhaps thought to be less at risk for CVD because they are assumed to be physically active, well-informed and because of their age.

3.2 Background of the study

The implications of the results are that university students are unaware of their cardiovascular health and that it may have an effect on their careers. This study was one of the first attempts to link students' awareness of the risk of CVD to their choice of career. Therefore career counsellors and human resource management practitioners may use this information within their scope of practice. Further, the academic implication of this study is that Social Sciences, Humanities and Economic Sciences can use this information to prepare students to cope with the complex situation in terms of the risk of CVD.

Most health awareness campaigns focus on people over the age of 35 years. In this instance, the focus was on second-year university students. The aim was to teach students how to assess cardiovascular health and identify at-risk individuals. We investigated the cardiac stress, blood pressure and heart rate of 162 second-year university students.

Based on this introduction of the study it is therefore necessary to investigate the background to CVD, CVD amongst students and the negative effect of CVD in the workplace.

3.3 Trends from the research literature

CVD is a chronic health problem worldwide and is a leading cause of death nowadays [1]. Some of the risk factors during the development of CVD include advanced age, high blood pressure, diabetes, hypercholesterolemia, stress and physical inactivity [2]. A link is found between psychosocial distress and CVD and is identified as an important public health issue [3]. Previous research was predominately focused on how to control and/or overcome CVD through physical activities [4]. Nevertheless, limited research was done on the awareness of the risk of CVD among undergraduate students by career counsellors.

Transformation in the workplace resulted in significant changes in the nature of work at organisations and increase pressure on employees [5]. In the past studies focus on the well-being of the employees, however others found more health problems compared with the general employees [6, 7].

3.4 Research objectives

The research purpose was to describe the cardiovascular health of second-year university students and to make career counsellors aware of the risk of CVD among undergraduate students. Consequently, the study has therefore two specific objectives:

3.4.1 Objective 1:

To show students how to measure blood pressure, heart rate and cardiac stress. In the process, students were shown the status of their cardiovascular health and to educate students who are registered for the physiology course on how CVD can be quantified.

3.4.2 Objective 2:

To measure second year students' CVD risk.

As explained earlier, cardiovascular disease can result in heart problems which could lead to death. It is expected that university students who are studying towards a qualification will most probably enter a specialised field in the labour market. However, should a student who has already been diagnosed with a CVD, enter the labour market, he/she would probably not be able to work up until retirement age. Early retirement or death of the employee would mean that the organisation will experience a loss due to the support that has to be provided for traumatised employees, the impact the event may have on their performance and the need to embark on a recruitment process in order to appoint, select and, subsequently, train new employees.

3.5 Review of the research literature

3.5.1 Background to cardiovascular disease

A person's cardiovascular system is the network that connects the heart and blood vessels (the "highway of life") [8]. The heart functions through regular rhythmic phases of contraction and relaxation of the heart muscle, known as the cardiac cycle, and it can be detected by listening to the sound of the heart valves [9]. Cardiovascular health risk is a multilevel concept that exists at individual, team, and organisational levels. Therefore, building the capacity to embark on research in health systems is a priority. Morbidity and mortality due to cardiovascular disease is on the rise in sub-Saharan Africa [10]. Screening, in order to identify risk factors, is an important tool which is used to educate the public about the prevention and management of cardiovascular disease.

Career counsellors should not only focus on the symptoms and risk factors associated with CVD, but should ensure that their clients are also aware of risk factors that may impair heart and related functions [8,9,11]. According to Bergh (2011) cardiovascular damages occur as a result of illness, ageing and lifestyle. According to Yusuf *et al.* (2004), factors such as smoking, a history of hypertension, diabetes, abdominal obesity, psychosocial factors, a lack of daily consumption of fruits and vegetables, regular alcohol consumption and low levels of regular physical activity were all significantly related to acute myocardial infarction [12].

3.5.2 Cardiovascular disease among students (and the negative effect in the workplace)

The heart rate is influenced by factors such as exercise, stress, emotional excitement, illness and fear [9]. A sector that has been largely overlooked with regard to cardiovascular disease is university students. Students are perhaps thought to be less at risk for cardiovascular diseases because they are assumed to be physically active, well-informed and because of their age. However, given the amount of time spent on sedentary activities such as attending classes, the protective effect of physical activity is diminished in this population. In addition, it has been found that education levels do not increase awareness of or belief in the benefits of a healthy lifestyle [13].

If students effectively understand undesirable health risks and use this information to empower themselves it could enhance personal and/or organisational objectives [14]. One of these undesirable health risks, according to Schnall *et al.* (2000), is cardiovascular disease that causes morbidity and mortality in the industrialised world [15]. It represents a public health problem and is a pandemic. It has been projected that cardiovascular diseases will climb from the second most common cause of death in 1990 to the most common cause of death in 2020. In the United States an estimated 250 000 to 350 000 people die yearly because of heart diseases [15]. In 1991 cardiovascular disease was the leading cause of death among South Africans, other than blacks where cardiovascular disease ranked third. Cardiovascular disease, therefore, has a severe impact on the economy of South Africa [16]. Mabry, Turner, and Hunt (2012) indicate that the World Health Organisation estimated that over 3 million people die yearly due to heart disease, stroke, cancer and related sedentary lifestyles [17].

The death of an employee in the workplace has numerous negative consequences for the organisation. The organisation may have to embark on a recruitment process in order to search for and select a qualified and competent candidate for that position. Further, the successful candidate will need training which the organisation will have to provide. Training refers to a short-term changing effort that is planned and which is intended to modify attitudes, beliefs, skills, or knowledge to improve the performance in a working environment [18].

The death of an employee could also result in employees experiencing trauma which may have a negative impact on the organisation, because traumatised employees need counselling. Trauma could also result in high absenteeism and limit the individual's effectiveness and performance. A traumatic event is defined as an individual's experience of a threat to his or her physical wellbeing or life or the experience of an extreme emotional disturbance due to the witnessing of an incident that involves a severe threat to another person's life or death of another person [19].

A variety of employee problems (drug abuse, alcoholism, cardiovascular and hypertension) result in higher levels of stress, lower productivity, increased absenteeism and turnover [5, 20]. Analysing risk factors of an employee and the employee's resources can lead to the early detection of potential future health risks [7].

Considering the above literature review, the following research questions can be posed:

Objective 1: Are students aware of their blood pressure, heart rate and cardiac stress?

Objective 2: Are students aware of the risk of CVD?

3.6 Research design

3.6.1 Research approach

The study was a quantitative, cross-sectional study [21] to find a fit between individual employees and organisational expectations and the changing nature of work in terms of cardiovascular diseases that may affect careers. A cross-sectional design involves selecting one or more samples from the populations at one time. The researchers used the data that were collected from the sample to describe the population at that point of time [22].

3.7 Research methods

3.7.1 Research participants

The sample used in this research study consisted of 162 undergraduate university students, between the ages of 18 and 25 years. Clearance was granted by the institution's Research Ethics Committee of the Faculty of Health Sciences. Students, who were studying the cardiovascular system as part of their physiology course, participated in the study as part of the practical requirements for the module. Informed consent was obtained from the students before their participation. Subjects were asked to sit quietly and complete a biographical questionnaire before testing.

3.7.2 Measuring instruments and research procedure

Cardiovascular health was investigated using measures for cardiac stress, blood pressure (BP) and heart rate.

3.7.2.1 Viport measurements

The *Cardio Stress Index* (CSI) *and heart rate* were measured using a Viport. The Viport device measure heart rhythm and heart rate [4]. While the subject was seated and maintaining an upright posture, the upper two electrodes of the Viport were placed on his/her first intercostal space. The reading was taken for two minutes, while the subject was breathing naturally, avoided sudden movements and did not speak. Viport is an innovative heart and stress screening technology which allows for efficient and quick electrocardiograph (ECG)-based assessment of the heart health [4]. The CSI is a sensitive indicator of stress, and is considered analogous to heart rate variables [4, 23, 24].

3.7.2.2 Blood pressure measurements

Blood pressure readings were measured using a sphygmomanometer. The absolute readings were recorded and these were rated as normotensive, pre-hypertensive or hypertensive according to the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure guidelines [25]. Caution was taken not to alarm subjects with abnormal readings. Given that single blood pressure readings can result in up to 66% false positives for hypertension [26], subjects with a systolic blood pressure of more than 120mmHg or a diastolic reading higher than 80mmHg had their readings taken three times for confirmation (the mean of these three readings was used for analysis) and they were advised to consult their doctors. To ensure that the practical education objective of the testing was attained, students also attended a compulsory practical pre-lecture scheduled in class time.

3.8 Statistical analysis

Statistical analysis was conducted using SPSS 17.0 [27]. Descriptive data were calculated for the whole sample. The sample was then split into two groups according to CSI readings. Between-group differences were computed using the independent samples t-test ($p \leq 0.05$). The odds ratio was calculated for CSI and hypertension.

3.9 Results

Objective 1: To show students how to measure blood pressure, heart rate and cardiac stress.

In the process, students were shown the status of their cardiovascular health and to educate students who are registered for the physiology course on how CVD can be quantified.

Students studying the cardiovascular system as part of their physiology course participated in the study as part of the practical requirements for the module. Therefore students could take note of the risk of CVD.

Objective 2: To measure second year students' CVD risk

The sample consisted of 129 females and 33 males, all between the ages of 18 and 25 years (mean age=20.419 y, SD=1.102). The mean CSI (36.099%, SD=24.131) is above the accepted limit for healthy cardiac stress (20%). The mean heart rate, systolic and diastolic blood pressures are within their respective accepted ranges. The mean heart rate is 83.093, SD=14.792; mean systolic BP is 119.889mmHg, SD=12.649 and mean diastolic BP is 72.901SD=9.943.

The results were split according to two CSI results groups - normal readings (CSI≤20%) and poor CSI readings (CSI>20%). The two groups were compared using independent sample t-tests ($p<0.05$). The mean, standard deviation (SD) and p-value for age, heart rate and blood pressure across the two groups are shown in **Table 3.1**. The two groups differed significantly on heart rate and diastolic blood pressure.

Table 3.1: The mean, standard deviation (SD) and *p*-value for age, heart rate and blood pressure across the the cardio stress index (CSI) groups

	CSI class	Mean	Std. Deviation	*P*-value
Age (y)	≤20%	20.3273	1.23310	0.404
	>20%	20.4808	1.02380	
Heart rate (bpm)	≤20%	74.8182	8.76249	0.001
	>20%	87.3868	15.47445	
Systolic BP (mmHg)	≤20%	119.2364	12.00149	0.618
	>20%	120.2925	13.05444	
Diastolic BP (mmHg)	≤20%	70.6364	8.90352	0.032
	>20%	74.1698	10.27570	

The odds for high blood pressure (pre-hypertension or hypertension) and CSI were calculated. The odds ratio is 1.73.

Although the mean readings for heart rate and blood pressure were within acceptable limits, 90 (55.6%) students had high blood pressure. Seventeen of these (18.9%) were hypertensive (stage 1) and the rest were pre-hypertensive [25]. There were 90 students (55.6%) who exhibited high blood pressure, with 73 (45.1%) of these were identified as pre-hypertensive and 17 (10.5%) with stage 1 hypertension.

Furthermore, 105 students (64.9%) exhibited elevated cardiac stress. Nearly 10% of the sample exhibited elevated cardiac stress, heart rate and blood pressure.

There were 105 (64.8%) students that presented with elevated CSI. CSI is analogous to heart rate varability [24]. A CSI reading of $\leq$ 20% reflects normal HRV, while CSI > 20% indicates decreased HRV. Low HRV is related to a cardiovascular disease [28]. Unfortunately, 64 (61%) of the students with elevated CSI readings also exhibited high blood pressure. The odds ratio for high blood pressure (pre-hypertension or hypertension) when CSI is greater than 20% is 1.73. This indicates that students with high CSI have 1.73 times the odds of exhibiting high blood pressure (pre-hypertension or hypertension) compared to students with normal CSI.

Only a few students exhibited an elevated heart rate and only 23 (14.2%) showed a heart rate above 100bpm. However, 16 (69.6%) of these students presented with elevated CSI and blood pressure as well. This means that 9.9% of the sample exhibited poor heart rate variability, an elevated heart rate and elevated blood pressure. The two CSI groups differed significantly with regard to heart rate (p=.001) and diastolic BP (p=.032). In both cases, the group with CSI > 20% had higher readings. Age did not influence the results (p=.404).

3.10 Discussion

A person's cardiovascular system does not only connect the heart and blood vessels [8], but also influence morbidity and mortality [10]. Therefore, the implications of the cardiovascular risks between students cause the importance that a networking ability between Social Sciences, Humanities and Economic Sciences should be developed. These diverse networks vests individuals with the capacity to identify and develop contacts and alliances in respect of the risk of university students' CVD [29]. It is in the interest of the individual if professionals within these networks create a common language to make students aware of the status of their cardiovascular health and to educate them on how to identify these risks.

The results of the study suggest that nearly 10% of the sample had higher cardiac stress, and had high heart rate and high blood pressure levels. A number of students (105) presented with elevated CSI. A total of 64 of the sample with higher CSI readings also had high blood pressure. Of the students, 9.9% exhibited poor heart rate variability, elevated heart rate and blood pressure. The results therefore indicate that screening and education of the youth with regard to cardiovascular health is important. These findings also have potential implications for both practice and research, particularly if future studies are developed based on these findings. As a result, these findings amplify the need to make young South African's aware of their cardiovascular risks to reduce the estimated amount of people that die yearly due to heart disease, stroke, cancer and related sedentary lifestyles [15-17].

Using practical training as a means to educate students about their own cardiovascular health may be more feasible as opposed to a public health campaign as a large-scale effort to screen this population. Further, career counsellors and psychologists that work with students need to consider and advise students about health risks when they select a career. It may be advisable to explore whether students should have a health advisor who can educate them about a healthy lifestyle.

From the results above, it is clear that there is a need for university students to change their lifestyle in order to prevent cardiovascular diseases from becoming prevalent among them. One method is for them to engage in physical activity because of its rehabilitative and preventive effects, especially with diseases such as cardiovascular disease, stroke, diabetes as well as obesity [17, 30].

Cardiovascular disease, which could be present without clinical symptoms or signs, can be prevented through a change of lifestyle, intervention and medication [31]. The findings of the study and the literature review contributed to an increased magnification of an intervention to make students aware of their cardiovascular risks. The researchers are therefore of the opinion that young South African's should be made aware of their cardiovascular risks from early ages. The research also applies value to all practitioners in the above-mentioned study fields as an interdisciplinary network towards the communication to empower personal and organisational objectives towards a healthier lifestyle. The study cannot be generalised to all situations due to the small sample used in this study.

3.11 Conclusion

The kids are all right, aren't they? From this research it was found that 90 students had high blood pressure. Seventeen students were hypertensive (stage 1) and the rest were pre-hypertensive. There were 73 students who were pre-hypertensive and 17 students had stage 1 hypertension. Furthermore, 105 students exhibited elevated cardiac stress. Nearly 10% of the sample exhibited elevated cardiac stress, an elevated heart rate and blood pressure level. There were 105 students that present with elevated (CSI). Unfortunately, 64 of the students with elevated CSI readings also exhibited high blood pressure. Of the sample, 9.9% exhibited poor heart rate variability, an elevated heart rate and blood pressure level.

Do career counsellors know their clients? These findings highlight the important role that CVD factors play in the workplace. The student and career counsellor must be aware of the complexity of health and how it could impact on the choice of the right career path. Additionally, the method used in this research study was employed to educate students to learn more about how CVDs can be quantified, and raise awareness of the risk of CVDs among university students. CVD factors arguably contribute most to individual differences and therefore must be considered in all workplaces. In the work environment it is the career specialist and management that have to take cognisance of the biological impact of CVDs within the organisation. It is important to facilitate health and safety during career counselling in order to encourage students to take care of their health and be aware of CVDs that may impair their career choice and path.

Perhaps it is the illusion that youth equals health that has led us to focus almost exclusively on CVDs among older population groups. This data does highlight some serious concerns about the risk of cardiovascular complications among the youth.

Therefore, building a supportive youth may contribute to a highly effective workforce that holds empowered employees to take charge of their health within the workplace. Thus, this will enable organisations to remain viable in a highly competitive global environment.

3.12 Limitations of the study

The limitations of the study make it difficult to generalise the results of the study because only university students were involved in this study. Further, the university students form part of one specific university within South Africa. Therefore generalising these results of other students may not be appropriate. The size of the sample is relatively small compared to the population of the specific university. Another limitation is that this study was cross-sectional in nature and yields correlational rather than causal evidence.

3.13 Suggestions for further research

Further studies should concentrate on other risk factors such as smoking, a family history of cardiovascular events and kidney function. There is a need for further screening and education in this population. Further research should focus on more universities nationally and internationally. This study empowers different sciences to overcome the limitations of the current research.

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Chapter 4

Study 2 *- Cardiovascular Health Screening among South African Students*

4.1 Introduction

Cardiovascular disease is a chronic health problem and remains the leading cause of death in modern society [1]. Risk factors for the development of cardiovascular disease include advanced age, a history of high blood pressure, hypercholesterolemia and diabetes mellitus, as well as modifiable risk factors such as stress and physical inactivity [2]. Studies done by Brotman *et al.* (2007) established the link between psychosocial distress and cardiovascular disease and identified this as an important public health issue [3]. Studies also claim that people suffer an increased level of stress in the period before myocardial infarction [4]. This confirms the notion that chronic stress has a particularly precarious impact on the cardiovascular system and should be seen as one of the major risk factors contributing to the multifactor aetiology of cardiovascular disease [4]. Furthermore, accumulating evidence identifies physical inactivity as the most prevalent behavioural factor contributing to the cardiovascular disease epidemic facing modern civilization [5]. An international case control study of risk factors for cardiovascular disease found that physical inactivity was one of the major contributors to heart disease, with data indicating that 12% of myocardial infarctions may be attributed to physical inactivity , second to hypertension (18%) and similar to type 2 diabetes mellitus (10%) [2]. Epidemiological studies consistently identify a strong linear association between coronary heart disease and sedentary lifestyles [5].

The plausible benefits of increased physical activity stretch over a range of cardio protective mechanisms such as decreasing myocardial oxygen demands, increasing vascular supply and improving autonomic nervous control [5,6]. However, the degree of protection offered by physical activity is not clear. By investigating the various levels and types of physical activity that people engage in, while monitoring their cardiovascular health, researchers may be able to explain the role of physical activity in promoting heart health and provide simple guidelines for healthier lifestyles.

The present study was designed to compare the cardiovascular health of students from two tertiary institutions and to determine cardiac stress levels and possible health risks precipitated by the students' contrasting lifestyles. Institution 1 is a traditional tertiary institution focusing on teaching and learning, while Institution 2 provides an organised, daily physical training programme in addition to its academic programme.

Although literature refers to an ample number of studies on cardiovascular health, stress and physical activity, these topics are usually investigated either individually or in association with one other factor, while little or no research deals with all three issues simultaneously. More importantly, the novelty of this study is attributed to the methodology and equipment used. The Viport is a relatively new medical device that provides direct CSI measurements which directly calculates an individual's stress levels and current cardiovascular state.

4.2 Methods & Materials

4.2.1 Participants

The study sample (n=286) comprised second-year students from the University of Pretoria (Institution 1: n=158) and training recruits from the South African Police Service (SAPS) (Institution 2: n=128). Men and women of various ethnic groups participated in the study, with ages ranging from 18-60 years.

The inclusion criterion for the study was a signed informed consent, whilst participants with cardiovascular and related chronic diseases were excluded from the study. The students from Institution 1 spend an average of eight hours a day in classes. None indicated participation in more than light physical activity. The students in Institution 2 spend at least one hour a day engaging in moderate (organised) physical activity and the rest of the day in classroom studies.

4.2.2 Research Design

An observational, cross-sectional study design was used to compare the cardiovascular health of university students with the training sample. Variables included were: age, gender, PSI, systolic and diastolic blood pressure, BMI, and the variables obtained with Viport^{TM} included: CSI, HR, heart rhythm and QRS duration.

4.2.3 Ethical Consideration

The study procedure was approved and clearance was obtained from the Research Ethics Committee of the Faculty of Health Sciences of the University of Pretoria, South Africa, in accordance with the principles of Helsinki Declaration (Protocol 46/2010).

4.2.4 Equipment & Procedures

Preceding the testing procedures, questionnaires were handed out to the participants to obtain biographical information and medical histories. The questionnaire included an emotional health section, adapted from Prentice's wellness assessment tool [7]. This section of the survey aimed to determine the perceived stress index (PSI) of participants on a scale from 0-8. A lower score indicates a higher subjective stress level. All testing was carried out on the same day.

4.2.4.1 Cardio Stress Index

A non-invasive diagnostic method commonly used to assess heart functionality and current health status of the heart, is heart rate variability (HRV) analysis [8]. This detailed analysis of heart rate fluctuation provides information on the modulation of the heart by the autonomic nervous system in response to a variety of dynamic circumstances [8,9]. As the human heart is constantly influenced by external and internal stimuli, it requires dynamic innervations by both the sympathetic and parasympathetic divisions in order to react appropriately to the constant change [8]. Alterations in the HRV pattern provide early and perceptive indications of compromised heart health [8,9]. This implies that a healthy individual with an adequately functioning autonomic control mechanism should have a high variability in heart rate [8]. Conversely, reduced HRV implies a possible underlying pathological condition that causes maladaptive responses of the autonomic nervous system to stimuli [8]. For instance, during times of psychosocial distress the heart undergoes adjustment reactions such as increased heart rate and reduction of the variation range of cardiac cycles, suggesting changes in the co-ordinated sympathovagal balance and implying a sympathetic dominant control mechanism [8].

Innovative heart and stress screening technologies such as the Viport™ allows for quick and efficient electrocardiograph (ECG)-based assessment of heart health. This portable device allows for various HRV variables to be transferred via algorithms into the cardiac stress index (CSI) which provides an indication of the current stress loading of the heart [10]. High HRV translates into a low CSI percentage of between 0-25%, thus implying a low stress level and healthy variability [10]. Alternatively, clinically significant lowered heart rate variation measurements transform into high CSI readings, ranging above 25%, indicating a high cardiac stress load and associated cardiovascular risk [10]. The CSI is a sensitive indicator of stress, and is considered analogous to HRV [6,11].

A battery operated Viport™ device was used to determine the CSI (%) of the participants. The device also provides additional information about heart rhythm, heart rate (HR) and QRS duration. Prior to testing, subjects positioned themselves in a seated, relaxed manner. The three metal corners (electrodes) of the Viport™ were moistened with conducting gel, after which the device was placed on the left side of the chest. The correct measurement position was identified by placing the index finger on the left collarbone of the subject, and then affixing the Viport™ approximately three finger-widths below this position. Participants were instructed to breathe calmly and avoid talking and movement for the two-minute duration of the test. A CSI reading of 20% or less is indicative of high HRV, thus representing a normal cardiac stress load. A heart rate of between 60-80 beats per minute (bpm) is considered normal and QRS complex duration should lie between 60-110 milliseconds (ms).

4.2.4.2 Blood Pressure

While each participant remained in a seated position, auscultatory systolic and diastolic blood pressures were measured (left arm) at Korotcoff sounds I and IV, using the cuff manometry method [12].

4.2.4.3 Body Composition

Body mass index (BMI) was determined from height and weight measurements (kg) and a Seca Leicester portable height measure to determine stature (m) of each student. Formula used for the calculation of BMI: (Weight/ $(\text{Height})^2$) [12].

4.2.4.4 Statistics

The descriptive statistical analysis was conducted by means of Number Cruncher Statistical System (NCSS 2007) statistical software. A within-group analysis was performed to determine the means and standard deviations for each variable and, concurrently, a within-group normality test for each of the variables was carried out by means of a Shapiro-Wilk test. Furthermore, a comparison of the relevant variables was compiled by way of an independent sample t-test. The level of significance was set at $p \leq 0.05$.

4.3 Results

Descriptive statistics of the two participating groups are presented in **Table 4.1**. The t-test confirmed significant differences between the groups with regard to BMI, PSI, HR and blood pressure.

Table 4.1: Selected characteristics (mean ± SD) of participants (N=286)

Variable	Institution 1 (*n=158*)	Institution 2 (*n=128*)	p-value
Age (years)	20.4 ± 1.1	39.6 ± 8.8	*p*=0.000
Body Mass Index (kg.m$^{2)}$	23.3 ± 4.5	27.8 ± 7.3	*p*=0.000
Perceived stress Index	5.6 ± 1.6	7.1 ± 1.9	*p*=0.012
Heart rate (bpm)	83.1 ± 14.8	76.4 ± 13.3	*p*=0.000
Systolic blood pressure (mmHg)	119.9 ± 12.6	132 ± 16.9	*p*=0.001
Diastolic blood pressure (mmHg)	72.9 ± 9.9	86.1 ± 12.2	*p*=0.017

Results of the gender-based and combined comparative analysis pertaining to mean CSI and average CSI risk of the participants are presented in **Table 4.2** and **Figure 4.1**. The mean CSI of students from Institution 1 were found to be significantly higher than that of Institution 2. The overall risk percentage of Institution 1 was also found to be significantly higher. Interestingly, results indicate that females from Institution 1 had the highest CSI of all the participating groups.

Table 4.2: Gender and group comparisons of mean CSI and average CSI risk

Variable	Institution 1	Institution 2	*p*-values
Mean CSI Males	32.91	29.44	*p*=0.261
Mean CSI Females	37.24	24.38	*p*=0.000
Mean group CSI	36.09	27.26	*p*=0.001
Male CSI risk (%)*	46	40	*p*=0.05
Female CSI risk (%)*	60.32	33.93	*p*=0.005
Total CSI risk (%)*	57.23	37.50	*p*=0.005

*CSI ≥ 25% indicates risk

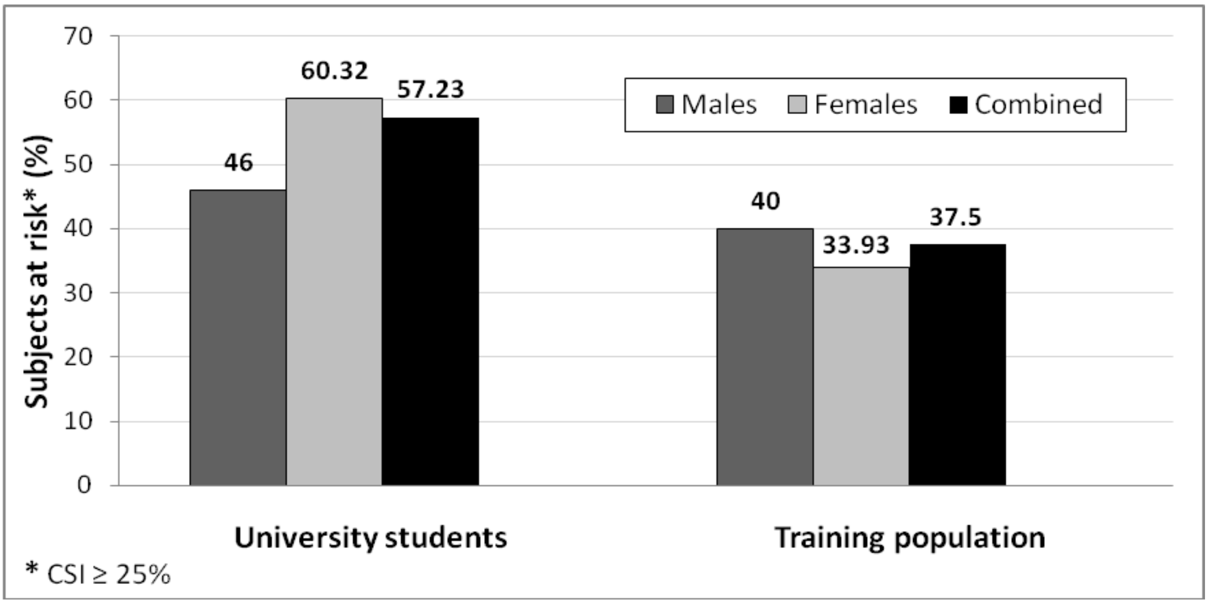

Figure 4.1: Percentage of subjects indicating CSI risk.

Comparisons based on mean CSI values in relation to age showed a significant difference (*p* =0.005) when results of the two institutions were compared. However, a within-group comparison of mean CSI for the four different age categories of Institution 2 showed no significant difference. **Table 4.3** summarizes these findings.

Table 4.3: Comparison of mean CSI by age groups

Age group (years)	Institution 2		Institution 1	
	Number of subjects	Mean CSI (%)	Number of subjects	Mean CSI (%)
18 – 30	21	25.38*	158	36.09*
31 – 40	45	24.80	---	---
41 – 50	48	28.33	---	---
51 – 60	9	33.22	---	---

*p = 0.005

4.4 Discussion

Results of this study indicate that the CSI readings of both men and women from Institution 1 were significantly higher (p<0.001) than those of participants from Institution 2. When comparing subgroups, females from Institution 1 appear to have the highest CSI (37.24%), whilst women participants from Institution 2 showed the lowest CSI (24.38%). The total percentage of students from Institution 1 who appear to be at risk amounts to an alarming 57.23%. Conversely, a total of 37.50% of subjects from Institution 2 indicated CSI readings above 25%.

Furthermore, when comparing mean PSI between the two groups, results indicate a significantly higher PSI for students from Institution 1. This could also be linked to the higher mean HR of the students, as stress levels result in increased HR [13]. Further analysis of the results (**Table 4.1**), clearly that there is a significantly higher mean BP amongst the individuals from Institution 2, in contrast to students from Institution 1. This could be attributed to the notable age difference between the groups, as previous studies state that systemic vascular resistance increases with age, resulting in elevated BP [14].

In order to eliminate age as a confounding variable in the findings, the study compared the mean CSI of university students and a same-age subgroup of the training population, and also conducted a further within-group comparison of mean CSI between the different age categories of the training population. The results showed that there was still a significant difference in the mean CSI between university students and the training population, but no significant difference in the mean CSI results between the various age categories within the training population was found (**Table 4.3**). These results were unforeseen as previous studies generally indicated a decrease in HRV with advancing age, thus implying a parallel increase in CSI with age [15]. In theory, this finding could be attributed to the fact that these students are subjected to a set daily physical routine which improves their physical fitness and decreases stress-related risk.

Our findings are in accordance with those of previous studies which show that an increased level of physical activity is accompanied by a reduction in perceived stress

[16]. Research also reveals that aerobic exercise promotes health by reducing the intensity of the stress response and shortening the time it takes to recover from stress [17]. A study conducted by Knapen *et al* (2009) found that physical activity at a self-selected intensity is associated with a reduction in the level of anxiety and an improvement in subjective well-being [18]. A few of the potential physiological mechanisms of exercise thought to be responsible for these results include: increased norepinephrine, serotonin and beta-endorphins, as well as increased parasympathetic activity [18]. These findings implicate the potential of exercise therapy for anxiety disorders [18].

Furthermore, research has shown that regular moderate physical activity improves autonomic nervous system compliance and stability [5]. This cardio protective mechanism has a positive impact on one's heart rate variability, allowing an increased cardiovascular adaptability to internal and external stimuli and ultimately resulting in a reduced CSI [6]. Studies have found that regular moderate physical activity, such as light endurance training in the form of jogging three times a week, increases HRV [6]. Improved HRV values could be observed after only a few weeks of training [6].

4.5 Conclusion

Regular monitoring of physiological stress levels by means of CSI measurements may help individuals recognise premature risk factors, thus allowing an opportunity to respond accordingly by adopting healthy lifestyle modifications such as relaxation exercises and increased physical activity [10]. Physical activities along with stress management are modifiable lifestyle behaviours [19]. Lifestyle behaviours represent the single most controllable influence over health prospects and are the most important determinants of well-being [20].

The results of this study support the notion that increased physical activity promotes overall cardiovascular health and may serve as a powerful antidote to stress. Although it is generally accepted that high BMI values are indicative of overweight or sedentariness, it should be noted that BMI calculation does not compensate for the muscular component of individuals. This implies that well-built, muscular individuals may be wrongly labelled as overweight.

Future studies should include biochemical markers of stress (e.g. salivary cortisol) and heart health (e.g. triglycerides) that could be correlated with CSI results.

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Chapter 5

***Study 3** - The Influence of an Intense Training Program on Cardio Stress Index among Armed Services Recruits*

5.1 Introduction

Humans experience many stressors that impact their physiological and psychological functioning. These stressors can be classified as psychological, physical, internal and external [1]. Chronic mental stress is a psychological stressor; over-exertion and excessive training are classified as physical stressors, while infections, as well as certain diseases, are classified as internal stressors [1]. Demanding lifestyles incorporating all three types are becoming increasingly common. All these stressors affect our bodies and are associated with activation of the sympathetic nervous system (SNS) and hypothalamic-pituitary adrenal axis, with the intermittent release of stress hormones such as catecholamines and cortisol that have an influence on the physiological processes of the body [2]. The circulatory system, especially the heart, is of the utmost importance and is largely affected by these fluctuations [2].

There is a strong association between stress and the development of cardiovascular disease (CVD), in particular hypertension. Hypertension is one of the major risk factors for CVD, which is eventually an asymptomatic condition with many individuals unaware of the burden experienced by their bodies in order to maintain normal functioning.

Physical activity is recommended in the prevention and rehabilitation of CVD and to control high blood pressure (BP), and has grown in popularity taking into account that many anti-hypertensive medications have severe side effects [3-5]. In numerous physical activity studies, regular physical activity has been shown to cause a decrease in heart rate (HR) as well as an increase in heart rate variability (HRV) [3,6-9]. Screening has become very important in the identification of cardiovascular conditions and serves as a guideline on how to proceed with the treatment of these conditions [10]. Especially, non-invasive screening techniques are gaining greater importance as they can provide a perspective into the human body and its functional processes.

One such technique is the (heart rate variability) HRV examination which involves measuring the variation in the RR interval length (the time taken between successive heart contractions) and the change from one cardiac cycle to another (cardiac regulation) [10-14]. This technique also provides information regarding the functioning of the autonomic nervous system (ANS) [10,13-14].

The ANS involves two branches, the (SNS) and the parasympathetic nervous system (PNS). HRV is an indicator of the active interaction and equilibrium between the SNS and the PNS [12, 15-16]. Activity of the SNS increases HR and decreases HRV, while activity of the PNS decreases HR and increases HRV.

An essential hypothesis of frequency-domain HRV is, within the ANS, the SNS and PNS branches influence the HR in a frequency-dependent manner, and exhibit a reciprocal activity relationship [13,17]. Inter-individual variations in HRV measurements in resting participants have been partially described by using age, gender and exercise training status [13]. HRV in a healthy individual is high; therefore a decreased HRV could be used a diagnostic tool for CVD, which if monitored periodically, can prevent the CVD associated mortality and morbidity [18-21]. Using HRV for screening does have limitations as there are high rates of non-diagnostic results consequent due to patients' inability to reach age-predicted heart rates [10]. Such non-diagnostic results are also seen in patients with neurological impairment, peripheral vascular disease, and orthopaedic limitation as well as in patients with poor motivation [10]. The Cardio Stress Index (CSI) is derived from HRV with an inverse relationship existing between these two variables. A high HRV indicates a low CSI and vice versa [1].

Current techniques such as rate pressure product (RPP) have been used to calculate the amount of stress induced by anaesthesia and surgery [2]. RPP is calculated by multiplying HR by systolic blood pressure (SBP) [2,22-23]. Several studies have been conducted with the aim of finding symptomatic signs for diagnosis of cardiac dysfunction and for identifying if the cardiac system is under stress [2,22]. Myocardial oxygen consumption has been identified to be related to HR, SBP and

RPP [2]. With CSI the stress level is more efficiently demonstrated and it been shown to effectively identify cardiovascular function or dysfunction [1].

Studies have shown that trained athletes have higher HRV compared to sedentary individuals, suggesting that exercise training can increase HRV in normal populations [24]. However, the overtraining syndrome is assumed to be consequence of an imbalance between long-term inappropriate high training volume and too little time for regeneration [25,26]. Alterations in the ANS have been presented as a mechanism underlying the signs and symptoms of the overtraining syndrome [27]. A study which examined ANS activity in several middle distance runners suggested that intense training shifted the cardiac autonomic balance toward a predominance of the sympathetic over the parasympathetic drive which was represented by a decrease in HRV [27]. Thus, it is critical to determine the health and performance capabilities of high performance athletes and fresh armed service recruits who typically undergo intense chronic training. Currently there is limited knowledge on the potential impact of intense chronic training on the stress experienced by the heart of armed service recruits.

The aim of this research project was to investigate the influence of an intense training program on the cardiac health using the CSI.

5.2 Methods

5.2.1 Study design

An observational cohort study design was used allowing the investigation of the influence of the intervention of an intense training programme on the CSI. Measurements were taken at weeks 1 (baseline), 12 and 20.

5.2.2 Participants

The study was conducted on 202 infantry service recruits (men = 115; woman = 87) between the ages of 18 and 24 years and of various ethnicities. Each participant voluntarily participated in the study and understood the nature of the risks involved. Informed consent was obtained and the study was explained in detail to each participant. Approval for the study was obtained from the Institution's Research

Ethics Committee and gate-keeper permission was obtained from the Armed Services (South Africa). The inclusion criterion for the study was a signed informed consent, whilst participants with cardiovascular and related chronic diseases were excluded from the study.

5.2.3 Apparatus & procedures

The Viport^{TM} (Energy-Lab Technologies GmbH, Burchard Str. 21, D-20095 Hamburg) device was used to measure CSI, heart rhythm, HR in beats per minute (bpm) and QRS duration in milliseconds (ms). Prior to testing, participants positioned themselves in a seated, relaxed manner. The three metal corners (electrodes) of the Viport^{TM} were moistened with conducting gel, after which the device was placed on the left side of the chest, taking caution to ensure that all three electrodes were in contact with the skin of the participant. The correct measurement position was identified by placing the index finger on the left clavicle of the participant, and then affixing the Viport^{TM} approximately three finger-widths below this position. Once the Viport^{TM} was correctly positioned, the measurements were obtained by a simple push of the start button. Participants were instructed to breathe calmly and to avoid talking and movement for the two minute duration of the test. The audible signal at the end of each measurement indicated the appropriate time to remove the Viport^{TM} from the chest and record the results from the display. A CSI reading of 20-25% or less is indicative of high HRV, thus representing a normal cardiac stress load. The normal HR for an adult is recommended to be between 60 and 80 bpm and the QRS duration between 60-110 ms [1]. A rhythmic or non-rhythmic heart beat is represented by a yes or no on the screen and standard deviation of R-R interval (SDRR) readings indicates the standard deviation as an absolute degree of HRV in milliseconds (ms). The CSI is a sensitive indicator of stress, and is considered analogous to HRV [28, 29].

Resting BP was measured while each participant remained in a seated posture, auscultatory SBP and DBPs were measured at Korotkoff sounds I and IV using a mercury sphygmo-manometer. Readings were recorded as systolic/diastolic in millimetres of mercury (mmHg).

5.2.4 Intervention

The armed service recruits followed a standardized Basic Military intervention training program (BT) over a 20 week period. This program is based on the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription and consisted of vigorous exercise, above 6 metabolic equivalents (METs) for 2 hours a day [29, 30], for the 20 week duration of the study. Training consisted of 48 physical training sessions of forty minutes each. **Table 5.1** summarizes the time allocated for each physical training component.

Table 5.1: Time dedicated to each physical training (PT) programme component during Basic Military training (BMT) [30].

PT programme component	**Resistance**	**Time (min) allocated during BMT period**	**No. of exercises completed during BMT period**
Warm-up	None	322	–
Upper body muscle endurance exercises	BW	-	28[†]
	BW + 20kg wooden poles	-	64[††]
Abdominal body muscle endurance exercises	BW	-	28[†]
	BW + 20kg wooden poles	-	64[††]
Lower body muscle endurance exercises	BW	-	28[†]
	BW + 20kg wooden poles	-	64[††]
Jogging	None	950	-
Interval training	None	213	-

BW = body weight.
[†]From week 1 completed three sets of 10–12 repetitions of exercises performed by muscle groups in this body region and from weeks 1–2 completed two sets of 10–12 repetitions, progressing to three sets of 10–12 repetitions in weeks 3–4 of exercises performed by muscle groups in this body region.
[††]From weeks 5 to 12 completed all exercises with 20 kg wooden poles in pairs performed by muscle groups in this body region, starting with two sets of 10–12 repetitions and progressing to three sets of 10–15 repetitions.

5.2.5 Statistics

All data collected from the three evaluation sessions were captured using Microsoft Excel. Statistical analysis was performed using IBM SPSS Statistics 19.0 software. Repeated measures ANOVA was used to analyse and interpret the data. Post hoc analyses (Bonferroni) consisted of paired t-tests to facilitate pairwise comparisons of week 1 with week 12, week 1 with week 20, and week 12 with week 20. A Bonferroni adaption was used to avoid an increased probability of a type I error due to the risk of multiple testing.

5.3 Results

A total of 225 recruits were included in the study however, statistical analyses were only possible on 202 of these recruits due to incomplete data from 10% of the subjects. The results of the pairwise comparisons of the three data sets are presented in Table 5.2. Descriptive statistics for men are displayed in

Table 5.3 and for woman in **Table 5.4**.

Table 5.2: Total sample mean (±SD) for weeks 1, 12 & 20

	Week 1	Week 12	Week 20	Comparisons	P Value
CSI (%)	31.88 (± 20.93)	24.05 (± 17.51)	23.12 (± 18.55)	Week 1 & 12 Week12 & 20 Week 1 & 20	$p < 0.05$ $p = 0.505$ $p < 0.05$
HR (bpm)	82.78 (± 12.79)	71.66 (± 11.10)	77.25 (± 10.58)	Week 1 & 12 Week12 & 20 Week 1 & 20	$p < 0.05$ $p < 0.05$ $p < 0.05$
SBP (mmHg)	126.38 (± 12.66)	126.14 (± 12.19)	115.08 (± 9.89)	Week 1 & 12 Week12 & 20 Week 1 & 20	$p = 0.788$ $p < 0.05$ $p < 0.05$
DBP (mmHg)	76.85 (± 8.05)	74.40 (± 7.56)	67.84 (± 7.58)	Week 1 & 12 Week12 & 20 Week 1 & 20	$p < 0.05$ $p < 0.05$ $p < 0.05$

Table 5.3: CSI, HR and BP data of males (n= 115) for weeks 1, 12 and 20

Week		Mean	SD	Minimum	Maximum
1	**CSI (%)**	24.28	18.11	9	100
	HR (bpm)	77.41	11.74	57	126
	Systolic BP (mmHg)	131.42	13.89	107	194
	Diastolic BP (mmHg)	76.84	7.41	54	98
12	**CSI (%)**	22.58	17.75	9	86
	HR (bpm)	71.45	10.59	44	104
	Systolic BP (mmHg)	130.53	11.01	106	164
	Diastolic BP (mmHg)	74.62	7.87	50	93
20	**CSI (%)**	23.02	20.26	9	100
	HR (bpm)	75.24	10.62	52	115
	Systolic BP (mmHg)	119.53	10.51	88	175
	Diastolic BP (mmHg)	67.18	7.30	46	90

Table 5.4: CSI, HR and BP data of females (n= 87) for weeks 1, 12 and 20

Week		Mean	SD	Minimum	Maximum
1	**CSI (%)**	41.98	22.16	9	100
	HR (bpm)	90.11	11.09	62	111
	Systolic BP (mmHg)	121.52	10.10	90	146
	Diastolic BP (mmHg)	77.39	8.54	60	99
12	**CSI (%)**	24.19	16.02	9	100
	HR (bpm)	78.85	9.92	56	98
	Systolic BP (mmHg)	120.98	11.45	97	167
	Diastolic BP (mmHg)	73.77	7.40	51	93
20	**CSI (%)**	23.44	16.94	9	99
	HR (bpm)	79.91	9.95	59	108
	Systolic BP (mmHg)	110.95	9.42	95	139
	Diastolic BP (mmHg)	68.51	7.88	53	89

CSI and heart rate averages remained within the normal ranges for men during all three testing occasion. Baseline readings for woman were significantly higher (week 1) and normalized later. QRS duration average remained within normal ranges for the total population over the three testing occasions.

The results for the total population indicated a statistically significant difference (decrease) in CSI between week 1 and 12 (from 31.88% to 24.05%; $p<0.05$) as well as between week 1 and 20 (from 31.88% to 23.12%; $p<0.05$). There was an overall decrease in CSI for both men and woman from week 1 to week 20.

In terms of the results for HR, there was a statistically significant difference (decrease) noted in HR between week 1 and 12 (from 83 bpm to 72 bpm; $p<0.05$) as well as between week 1 and 20 (from 83 bpm to 77 bpm; $p<0.05$) and a slight increase in HR from week 12 to week 20 (from 72 bpm to 77 bpm; $p<0.05$).

There was no statistically significant difference in SBP, between week 1 and 12 (from 126 mmHg to 126 mmHg; $p=0.788$) but there was a difference between week 1 and 20 (from 126 mmHg to 115 mmHg; $p<0.05$) as well as between week 12 and 20 (from 126 mmHg to 115 mmHg; $p<0.05$). DBP results indicated a statistically significant difference (decrease) between week 1 and 12 (from 77 mmHg to 74 mmHg; $p<0.05$), between week 1 and 20 (from 77 mmHg to 68 mmHg; $p<0.05$) and between week 12 and 20 (from 74 mmHg to 68 mmHg; $p<0.05$).

5.4 Discussion

The findings from the present study are supported by numerous other studies which show that regular physical activity decreases HR as well as increases HRV [3,6-9]. It may be postulated that the increase in HR from week 12 to week 20 may be an indication that these recruits were suffering from “functional overreaching” which has been reported to develop when individuals go through/put through a strenuous training over a number of weeks without sufficient rest. Symptoms relating to fatigue; poor or irregular heart rate; high resting heart rate (relative to normal) and irritability have been reported in such individuals; however this study did not assess those parameters directly [31].

The decrease in DBP over the 20 weeks is important as DBP is considered to be indicative of CVD as it is closest to the mean arterial pressure (MAP) within the circulatory system. A decrease in SBP (pre - 126 ± 3 mmHg, post - 111 ± 4 mmHg) and DBP (pre – 76 ± 3 mmHg, post - 67 ± 3 mmHg) was also reported by Jouanin et al, (2004) in military recruits following a five week, physically and psychologically challenging Ranger course, whereas Clarkson et al, (1999) reported no significant change in DBP and SBP in 35 British male recruits after ten-weeks of basic training [32, 33].

Our findings are in concurrence with the majority of similar research studies which supports the theory that endurance training [6,9,33] and aerobic exercise [8,34-36] increases HRV, which implies improved cardiovascular autonomic regulation. The precise cardio-protective mechanism/s responsible for these findings are yet to be fully elucidated, however, long term endurance training has been associated with increased parasympathetic activity [6,34] and/or reduced sympathetic activity and resting heart rate[6]. Although numerous studies are in agreement that augmented vagal modulation has beneficial cardiovascular effects, consensus is yet to be reached on the degree of increased parasympathetic tone required to induce sufficient cardio-protective outcomes [37].

5.5 Conclusion

Physical inactivity is a primary risk factor for developing CVD, whereas regular physical activity will increase cardiac output. This in turn increases cardiovascular fitness thereby enhancing the ability to perform various tasks, improving the ability to function and is associated with a feeling of well-being.

Several studies have been conducted with the aim of finding simple signs to diagnose cardiac dysfunction and to identify whether the cardiac system is under stress [2,22]. The Viport™ and CSI provide physicians with a non-invasive technique to enable the detection of cardiovascular abnormalities and physiological stress that could lead to disease, thereby assisting in the prevention of the development of CVD. Hence, a method is provided that enables practitioners to monitor progress of treatment, whether it is exercise or pharmacologically based.

This study illustrates that exercise has the potential to be incorporated into a preventative treatment plan with the aim of reducing cardiovascular risks. Therefore we conclude that intense physical activity/exercise level is being well tolerated by most fresh recruits and the CSI method is a reliable, dependable, non-invasive technique to monitor cardiovascular stress.

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Chapter 6

***Study 4** – A Comparison between the Cardio-Stress Indices of Active and Sedentary Populations*

6.1 Introduction

Modern lifestyle places a great deal of unnecessary stress on the body. Such stress can be either physiological or psychological in nature, and both have a negative effect on morbidity and mortality. The increasingly passive way of life that has become characteristic of the time in which we live has resulted in a notable increase in the prevalence of lifestyle disorders, such as hypertension (high blood pressure), Type 2 diabetes (high blood glucose due to insulin resistance), atherosclerosis (accumulation of fatty materials on artery walls) and vascular pathology [1,2]. When compared to other lifestyle disorders, it appears that cardiovascular disease (CVD), specifically coronary artery disease (CAD), has the highest morbidity rate [1,2]. This is the result of the release of epinephrine and norepinephrine during stressful situations, causing an increase in blood pressure, heart rate and vasoconstriction, which in turn results in decreased blood flow and an increased risk of myocardial infarction [1]. CVD may share co-morbidity factors with other lifestyle ailments, such as diabetes mellitus Type 2 and hypertension [1,2]. Hypertension, a primary risk factor for CAD, is a major cause for concern, since it generally remains asymptomatic until significant pathological damage has occurred, at which point the risk of disorders such as myocardial infarction increases exponentially [1,3]. Chronic stress due to lifestyle disorders affects cardiovascular health along with other physiological systems, resulting in an overall increase in the patho-physiological symptoms of such disorders [4]. Prolonged exposure to such stresses and the hormones that are consequently released, such as epinephrine, suppress the immune system [1]. This is due to the overstimulation of the sympathetic adrenal medullary axis and an overall state of dyshomeostasis within the body [4,5]. Stressors, which are not only physiological by nature, are encountered daily [6]. Since emotional stress is regarded as subjective and will depend mainly on the individual's own perception of the situation, it is virtually impossible to completely avoid a stressor that cannot be objectively quantified [7]. Such stressors will nevertheless affect the heart, and therefore the heart's ability to handle stress is vital when it comes to dealing with situations that are perceived as emotionally stressful [7 -10]. Many of today's leading causes of mortality and morbidity can be prevented if certain stressors are managed correctly, or are dealt with timeously [1, 11]. CAD can be aggravated, for example if the heart is placed under unnecessary emotional stress, which will increase the probability of preventable morbidity [1,12].

Recently, participation in physical exercise has gained popularity as a precaution to prevent disease, specifically hypertension and CVD [13]. When one compares the former definition of health to its modern definition, the popularity of preventive measures in lifestyle is clear. According to Sharkey and Gaskill [1], health was previously defined as *"… an absence of disease*", whereas today health is defined as *"…a state of complete physical, mental, and emotional well-being, not merely the absence of disease or infirmity*". The latter definition confirms that a modern lifestyle demands that numerous choices regarding physiological and psychological aspects need to be made to ensure general health. Neglect to make such choices will lead to more costly and time-consuming choices later in life. Physical exercise has numerous lifestyle- and illness-related benefits. Regular endurance-type exercises have been shown to decrease blood pressure, concentrations of serum triglycerides and low-density lipoprotein, the risk of stroke or transient ischemic attacks (TIAs) and the risk of certain cancers (such as prostate and breast cancer) [1]. Regular endurance-type exercises have also been shown to increase the concentration of high-density lipoprotein cholesterol, insulin sensitivity and the effectiveness of the immune system [1]. Evidence also exists that myocardial oxygen consumption is related to heart rate (HR), blood pressure (BP) and resting pulse pressures [14]. However, highly competitive, exhausting or threatening exercise can place tremendous stress on the heart, resulting in negative effects [1,7]. Therefore, as stated earlier, it is very important to increase the heart's ability to effectively handle such stress in order to decrease the negative effects [1,7,8]. With increased exercise and a more efficient cardiovascular system, less stress is placed on the system, thus decreasing epinephrine and cortisol release and increasing the positive benefits of exercise and physical activity [1,12,13].

The cardio-stress index (CSI) is used to determine the effectiveness with which the cardiovascular system can handle a stressor that is applied to it [9,15]. The CSI is composed of two factors, namely resilience and vulnerability. Resilience occurs when a potentially stressful experience or stressor is correctly managed or successfully adapted to provide a positive benefit to the system [9,10,16]. Vulnerability occurs when a stressor is not effectively adapted or managed, causing a negative result [9,15]. The CSI is measured as a percentage (%), with values ranging from 0-20%, which is classified as normal, and 50-100%, which is classified as highly increased [17]. The Viport™ is a heart- and stress-screening tool which enables a quick and efficient ECG-based assessment of current heart health and determines, amongst other values, the CSI [17]. The Viport™ also determines heart rate variability (HRV), measured in milliseconds (ms), heart rhythm (rhythmic or arrhythmic), HR in beats per minute (bpm) and the QRS wave duration in ms (depolarisation of heart ventricles). The CSI is generated through the conversion of HRV, QRS duration, HR and the rhythm at which the heart beats by using specific algorithms [14,17]. HRV is determined by the standard deviation of the R-R interval (SDRR) readings, which corresponds with the difference in time (measured in ms) between two R peaks in two consecutive heartbeat cycles [18-21]. When HRV and CSI values are compared, a high HRV relates to normal CSI values since the cardiovascular system adapts and handles the stress more effectively [17].

The ANS is comprised of the SNS and the PNS and maintains homeostasis [16,22]. The ANS values provide an indication of the reliability of the correlation between the two subsystems [17,21,23,24]. The sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) exhibit a frequency-dependent influence on HR [18, 23]. The SNS is effective when a stressor that disrupts homeostasis is applied to the body, thus the SNS also promotes the re-establishment of homeostasis [16,22]. The PNS promotes the maintenance of homeostasis at rest [16,22]. Total HRV is an indicator of the influence of the autonomic nervous system (ANS) and its management of body stressors. Previous studies have indicated that activity levels can result in significant fluctuations in the HRV readings of populations [19,20]. The HRV readings of healthy individuals are generally higher, since the value provides an indication of how readily the heart can change in order to adjust to its surroundings and to maintain homeostasis within the body [18]. As stated earlier, high HRV values are linked to normal CSI values [17]. A lower HRV is usually considered a risk factor for CVD [17]. However, HRV is not a conclusive diagnostic tool for heart disorders, since there are other pathologies that can also result in a lower HRV [21].

According to earlier information, the overall contribution of the activity levels on the CSI can be determined by comparing active and sedentary populations with differing activity levels. Apart from CSI, other factors, such as HRV, BP and the resting HR, should also be taken into account when determining the contribution of activity level to body stressors due to lifestyle choices. This research project aims to prove that an active lifestyle that includes chronic regular endurance exercise will have a positive effect on the CSI, with a decrease in BP and HR. This will ultimately lead to a higher HRV value, which will reflect greater stress adaptation and maintenance. Results from the research would provide insight into the impact of modernised society on lifestyle and overall health.

6.2 Methods

6.2.1 Study design

The study is aimed at comparing a sedentary population with an active population undergoing a 20-week training programme. This study was able to determine the impact of physical activity on cardiovascular risk by comparing a control and intervention group over a 20 week time frame. Thus, serving as a longitudinal study with self-controls for within group comparisons, as well as a comparative study between the two populations.

6.2.2 Participants

The three hundred and twenty-eight participants who participated in the study consisted of both males and females between the ages of 18 and 24 years. The 202 infantry service recruits endured 20 weeks of basic military training whilst the sedentary population (n=126) was sourced from a traditional tertiary institution focusing on attending lectures. Participants from both populations were required to attend three testing sessions, which were held in Week 1, Week 12 and Week 20. Week 1 of the testing of the military population coincided with the commencement of their first week of basic training, whilst Week 1 of the testing of the sedentary population occurred in the second week of February, which was the beginning of their academic year. All the participants completed a lifestyle, blood pressure and cardio stress index assessment to ensure the availability of an overall lifestyle evaluation for each member of both groups.

Each participant voluntarily participated in the study and understood the nature of the risks involved. Informed consent was obtained and the study was explained in detail to each participant. Approval for the study was obtained from the Institution's Research Ethics Committee and gate-keeper permission was obtained from the Armed Services (South Africa). The inclusion criterion for the study was a signed informed consent, whilst participants with cardiovascular and related chronic diseases were excluded from the study.

6.2.3 Apparatus & procedures

6.2.3.1 Blood pressure

Resting BP was measured while each participant remained in a seated posture, auscultatory SBP and DBPs were measured at Korotkoff sounds I and IV using a mercury sphygmo-manometer. Readings were recorded as systolic/diastolic in millimetres of mercury (mmHg).

6.2.3.2 Cardio stress index

The CSI was assessed using a ViportTM, a heart and stress screening tool which enables a quick ECG-based assessment of current heart health. This device allows for various HRV parameters to be transferred into the CSI via algorithms. CSI, heart rhythm, resting HR (bpm) and QRS duration in milliseconds (ms) were measured. Prior to testing, participants were seated and relaxed. The three metal corners (electrodes) of the Viport^{TM} were moistened with conducting gel, after which the device was placed on the left side of the chest, taking care to ensure that all three electrodes were in contact with the participant's skin. The correct measurement position was identified by placing the index finger on the participant's left clavicle before affixing the Viport^{TM} approximately three finger-widths below this position. Once the Viport^{TM} was correctly positioned, measurement commenced. Participants were instructed to breathe calmly and avoid talking and movement for the duration of the two-minute test. The audible signal at the end of each measurement indicated the appropriate time to remove the Viport^{TM} from the chest and record the results shown on the display screen. A CSI reading of 20-25% or less indicates high HRV, ie a normal cardiac stress load. Normal HR for an adult should measure between 60 and 80 bpm and the QRS duration should be between 60 and –110 ms [17]. A rhythmic or non-rhythmic heartbeat is represented by a 'Yes' or 'No' on the screen and a deviation of R-R interval (SDRR) readings indicates standard deviation as an absolute degree of HRV in ms.

6.2.4 Intervention

The military service recruits followed a standardized Basic Military intervention training program over a 20 week period. This program is based on the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription and consisted of vigorous exercise, above 6 metabolic equivalents (METs) for 2 hours a day [25,26], for the 20 week duration of the study. Training consisted of 48 physical training sessions of forty minutes each. **Table 6.1** summarizes the time allocated for each physical training component [25].

Table 6.1: Time dedicated to each physical training (PT) programme component during Basic Military training (BMT) [25].

PT programme component	Resistance	Time (min) allocated during BMT period	No. of exercises completed during BMT
Warm-up	None	322	–
Upper body muscle endurance exercises	BW	-	28†
	BW + 20kg wooden poles	-	64††
Abdominal body muscle endurance exercises	BW	-	28†
	BW + 20kg wooden poles	-	64††
Lower body muscle endurance exercises	BW	-	28†
	BW + 20kg wooden poles	-	64††
Jogging	None	950	-
Interval training	None	213	-

BW = body weight.
†From week 1 completed three sets of 10–12 repetitions of exercises performed by muscle groups in this body region and from weeks 1–2 completed two sets of 10–12 repetitions, progressing to three sets of 10–12 repetitions in weeks 3–4 of exercises performed by muscle groups in this body region.
††From weeks 5 to 12 completed all exercises with 20 kg wooden poles in pairs performed by muscle groups in this body region, starting with two sets of 10–12 repetitions and progressing to three sets of 10–15 repetitions.

6.2.5 Statistics

Data recorded after Weeks 1, 12 and 20 were captured confidentially. A repeated-measures MANOVA (Multivariate Analysis of Variance) was used to statistically analyse the results to guard against an inflated Type I error. Post hoc analyses consisted of paired t-tests for pairwise comparisons of the data. Data from Weeks 1, 12 and 20 were compared within the populations to determine improvement or decline as a result of physical activity levels.

6.3 Results

No significant difference was found when the baseline (Week 1) CSI readings for the two populations were compared. However, the results for Weeks 12 and 20 did show statistically significant differences in the CSI values of participants from the sedentary and the active populations. The systolic and diastolic BP readings, as well as HR between groups, also revealed a significant difference (p = 0.001) between the two sample populations.

Table 6.2: Comparison of CSI % results for Weeks 1, 12 & 20 (mean ± SD)

Population	Week 1	Week 12	Week 20	Level of significance
Sedentary population (*n*=126)	28.4 (± 21.1)	30.3 (± 20.0)	31.04 (± 23.2)	w1 and w12 w12 and w20 w1 and w20
Active population (*n*=202)	31.88 (± 20.9)	24.05† (± 17.5)	23.12† (± 18.6)	w1 and w12* w12 and w20 w1 and w20*

w = week.

†, Significant difference between the sedentary and active population.

*, $p < 0.05$

The within-group comparison of CSI results in **Table 6.2** clearly shows a significant decrease in the mean CSI percentage of the active population from Week 1 to Week 20, whereas a slight increase in the sedentary population's CSI was observed over the same time period. **Table 6.3** indicates that similar results were found when the mean HR of the two populations were compared, with the active population's mean HR showing a significant decline whilst the sedentary population's HR increased slightly.

Table 6.3: Comparison of HR (bpm) results for Weeks 1, 12 & 20 (mean ± SD)

Population	Week 1	Week 12	Week 20	Level of significance
Sedentary population (*n*=126)	78.2 (± 13.3)	81.6 (± 12.8)	80.7 (± 14.2)	w1 and w12* w12 and w20 w1 and w20
Active population (*n*=202)	82.78 (± 12.8)	71.66† (± 11.1)	77.25† (± 10.6)	w1 and w12* w12 and w20* w1 and w20*

w = week.

†, Significant difference between the sedentary and active population.

*, $p < 0.05$

When comparing systolic BP (**Table 6.4**), one notices a gradual decline in the active population's results from Week 1 to Week 20, whereas those for the sedentary population peaked during Week 12. Diastolic BP (**Table 6.5**) declined in both populations, but more so in the active population.

Table 6.4: Comparison of systolic BP (mmHg) for Week 1, 12 & 20 (mean ± SD)

Population	Week 1	Week 12	Week 20	Level of significance
Sedentary population (*n*=126)	124.2 (±15.1)	128.6 (±13.4)	121.1 (±13.1)	w1 and w12* w12 and w20* w1 and w20
Active population (*n*=202)	126.38 (± 12.7)	126.14 (± 12.2)	115.08† (± 9.9)	w1 and w12 w12 and w20* w1 and w20*

w = week.
†, Significant difference between the sedentary and active population.
*, $p < 0.05$

Table 6.5: Comparison of diastolic BP (mmHg) for Week 1, 12 & 20 (mean ± SD)

Population	Week 1	Week 12	Week 20	Level of significance
Sedentary population (*n*=126)	80.7 (±7.8)	84.3 (±9.2)	78.5 (±9.3)	w1 and w12* w12 and w20* w1 and w20*
Active population (*n*=202)	76.85 (± 8.1)	74.40† (± 7.6)	67.84† (± 7.6)	w1 and w12* w12 and w20* w1 and w20*

w = week.
†, Significant difference between the sedentary and active population.
*, $p < 0.05$

6.4 Discussion

The sedentary population has slightly lower CSI, HR and systolic BP, but higher diastolic readings in the first week. Even though it was lower, the CSI was still considered slightly raised as it was above the optimal range (0-20%). However, neither of the groups showed pre-existing signs of cardiovascular pathology, as is shown by the QRS duration, which is within the correct range.

Data collected during Week 12 produced a significant decline in the CSI and HR of the active population. This implies a decrease in these readings after the onset of the interventional physical training programme. A steep decline in the CSI values of the active population during Weeks 1 to 12, followed by a plateau in the decline (Weeks 12 to 20) was observed. This indicates that although an active lifestyle showed an initial significant decrease in CSI, it may not have been the only contributing factor. The sedentary population showed a gradual increase in their CSI throughout the 20-week trial, with the steepest difference occurring between Week 1 and Week 12. This could be attributed to the different increasing stressors the students were exposed to as the end-of-semester examinations drew closer. Overall, the CSI results suggest a decline in CSI readings as fitness levels increased. This correlation is supported by the cardiovascular fitness results of the two populations. VO_2max was used as a measure of fitness and showed a strong association correlation with CSI results. When fitness levels during Week 1 were compared, the sedentary population indicated higher cardiovascular fitness than the intervention group. However, the VO_2max of the active population increased during the first 12 weeks of the training programme to become significantly higher than that of the control group.

When considering the resting HR, it was found that although the mean HR of the sedentary population was initially lower than that of the active population, the commencement of the semester showed a slight increase in the overall HR of the sedentary population. This increase may be indicative of higher physiological stress, since it is known that the SNS is activated in times of stress and will increase the HR. The higher physiological stressors could be explained by the increasing workload and imminent examination as the semester progressed. At the commencement of the physical training programme the active population showed a significantly lowered heart rate, which is to be expected when fitness levels increase. During the baseline assessment, both the diastolic and systolic BP of the groups were within the normal range. The sedentary population's BP remained relatively constant throughout the 20-week testing period. There was a slight peak at the time of the 12-week test, which could be attributed to their bodies' adjustment to the changing stressors during the examination period. The active population showed a decline in both systolic and diastolic BP, with the reading for Week 20 being well within the desirable range. Since hypertension was earlier identified as one of the primary problems of lifestyle disorders, these are very significant findings.

6.4.1 Strengths

The Viport^{TM} and CSI provide medical practitioners with a non-invasive technique which enables them to detect cardiovascular abnormalities as well as physiological stress that could lead to disease, possibly assisting practitioners in the prevention of the development of CVD at a later stage in life. It also provides them with a tool that allows them to monitor progress of treatment, even if the treatment is exercise or pharmacological based. This research illustrates that exercise has the potential to be incorporated into a prevention and/or treatment plan for individuals suffering from CVD. Therefore physical exercise is becoming increasingly important in daily routines and lives of individuals.

6.4.2 Weaknesses

CSI, is sensitive to sleep quality, physical activity, smoke and caffeine. Although participants were advised to avoid these things before testing, it is difficult to control all aspects.

6.5 Conclusion

The study showed that an active lifestyle is associated with a lower CSI and related measurements. Stress has been shown to affect everyone and cannot be entirely avoided, but moderate activity levels can assist the body in adequately dealing with the disruption of homeostasis that it may cause. However, there are many other modifiable factors that should be considered when trying to reduce susceptibility to these disorders, including diet, lifestyle habits (smoking/alcohol usage) and psychological stress. The study also supports reports that an active lifestyle contributes towards lowering BP and thus adequately preventing hypertension, which is a major cause of morbidity in individuals with lifestyle disorders [27,28].

Our findings support the notion that physical activity is considered to be one of the most important interventions for decreasing various cardiovascular complications and risks [11]. Evidence shows that increased physical activity corresponds with reductions in cardiovascular disease mortality and morbidity, whereas sedentary lifestyles exhibit a robust association with deteriorated heart health [1,11,27]. In an international case control study of risk factors for cardiovascular conditions, physical inactivity was found to be one of the major behavioural contributors to heart disease, with data indicating that 12% of myocardial infarctions can be attributed to physical inactivity is [27].

In addition to the wide scope of cardio-protective benefits, physical activity also has favourable indirect mechanisms for reducing cardiovascular risk. Regular participation in physical activity has been shown to augment the mind-body relationship, thus implying improved physiological responses to psychological demands, such as attenuated blood pressure responses to mental stress [11,28]. Possible mechanisms may involve increased neurogenesis and neurotrophin expression in the brain [28]. Furthermore, studies have shown that aerobic exercises reduce anxiety, promote relaxation and decrease tension, thus promoting an overall improvement in subjective well-being [11,29].

Comprehensively, people leading an active lifestyle will have improved physiological resources to deal with the many stressors experienced daily and will have a lower CSI than those who lead a sedentary lifestyle.

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Chapter 7

Integrated discussion & conclusion

"Give about 2 hours everyday to exercise, for health must not be sacrificed to learning." – Thomas Jefferson [1]

The planning and design of this study was based on the notion that participation in physical exercise promotes cardio protective mechanisms and thus contributes to attaining improved cardiovascular functioning. Our findings are in accordance with previous studies which have highlighted the physiological benefits of increased physical activity [2, 3] whilst emphasizing the adverse health consequences of sedentary lifestyles [4, 5]. While earlier research intended to determine the role of physical activity, this study endeavoured a novel approach toward the measurement of heart health among individuals leading sedentary and active lifestyles. Outcomes of this study confirm the general consensus that increased physical activity leads to improved cardiovascular health [2].

In 2009, Steven Blair [6] referred to physical inactivity as "…*the biggest public health problem of the 21st century*". According to the World Health Organization physical inactivity is rated the fourth primary cause of death globally, attributing to the cause of an estimated 3.3 million deaths per annum [7]. The Lancet recently labelled physical inactivity a pandemic which should be prioritised for public health action [8]. A study by Lee *et al.* [9] yielded figures which indicate that 6 –10% of the major non-communicable diseases of coronary heart disease, type 2 diabetes, and breast and colon cancers are ascribed to physical inactivity worldwide. This figure escalates even further for specific diseases (e.g., 30% for ischaemic heart disease) [8]. Furthermore, research regarding life expectancy estimates that inactive people would gain 1.3 – 3.7 years from age 50 years by shifting to a more active lifestyle [10].

These findings place inactivity in a similar lifestyle risk bracket as the established risk factors of smoking and obesity [9]. Although identified as a global pandemic with negative repercussions on health, life expectancy and economy, it is vital to elucidate that inactivity still remains a modifiable risk factor [11]. At the 66th General Assembly of the United Nations Dr. Jacques Rogge, President of the IOC made the following statement: "*The problem is acute, the solution is at hand. It is a grim picture, except for one thing: We can do something about it.*" [11]. Astonishingly, despite the increase in research, publishing of position statements, recommendations and activity guidelines made available over the past few years; the number of deaths caused by non-communicable diseases persist to rise [11].

Increased mortality and morbidity associated with physical inactivity has called for strong advocacy to incorporate physical activity assessment and prescription as a routine part of the disease prevention and treatment prototype [3]. Thereby emphasising behavioural change as the principal component of all clinical programmes for the avoidance and management of chronic disease [11]. Furthermore, the sedentary population should be considered at high risk of disease; therefore, whilst advocating the health benefits of exercise, the adverse effects of inactivity should be stressed in aim of conquering the struggle against inactivity [12].

Despite ample research revealing strong association between present-day sedentary lifestyles and detrimental health outcomes, particularly pertaining to cardiovascular disease, it is clear that inactivity has become a modern epidemic [2, 3]. Furthermore, regardless of physical activity prescriptions of 150 minutes/week of moderate intensity physical activity which has been correlated with health preservation and longevity [2, 3], sedentary behaviour remains ubiquitous [13].

In light of the ever-rising cardiovascular complications associated with physical inactivity as the underlying cause, it is not only essential to encourage physical activity among sedentary populations, but also to equip such individuals with the necessary screening tools to determine and monitor cardiovascular risk. Taking this into account, the aim of this investigation was to explore the empirical association between the heart health status of an active and sedentary South African lifestyle by means of a novel device. With the aforementioned objective in mind, four different studies were completed in order to deliver the subsequent concluding remarks.

7.1 Study 1

Study 1 is revealed in chapter 3 of this dissertation. This study sought to investigate the cardiovascular status of 162 undergraduate university students in order to determine whether, despite their youth, students remained at risk of cardiovascular complications. Astonishingly, results from this study indicate that a number of students between the ages of 18 and 25 in a university setting present with preeminent cardiovascular risk, with high CSI, elevated heart rate and blood pressure.

These findings portray the necessity of screening and education among South African youth with regard to cardiovascular health. These findings also have potential implications for both practice and research, particularly if future studies are developed based on these findings. As a result, these findings amplify the need to make young South African's aware of their cardiovascular risks to reduce the estimated amount of annual deaths due to heart disease, stroke, cancer and related risks associated with sedentary lifestyles [14-16].

Perhaps it is the illusion that youth equals health that has led us to focus almost exclusively on CVDs among older population groups. This data does highlight some serious concerns about the risk of cardiovascular complications among the youth.

7.2 Study 2

Study 2 is presented in chapter 4 of this dissertation. The second study pursued to compare the cardiovascular health of individuals from two tertiary institutions and to determine cardiac stress levels and possible health risks precipitated by the students' contrasting lifestyles. The study sample (n=286) comprised second-year students from the University of Pretoria (Institution 1: n=158) and training recruits from the South African Police Service (SAPS) (Institution 2: n=128).

In sequel to study 1, study 2 permitted the comparison of a sedentary and active South African population, however some discrepancies originated due to the notable age difference between the groups. Nevertheless, results gained from this cross-sectional comparison between the populations indicate significantly higher cardiac risk amongst the sedentary population. However, it was thought necessary to design supplementary studies in order to fully elucidate conclusive findings pertaining to the initial objective of this investigation.

7.3 Study 3

Study 3 is described in chapter 5 of this dissertation. This study forms the initial part of a series of two studies which was completed over a 20-week period. Study 3 was conducted on 202 infantry service recruits between the ages of 18 and 24 years. A pre- post intervention study design was incorporated in pursuit of determining the influence of an intense training programme on cardiovascular variables of a population over a 20 week time-frame.

Results yielded from this study indicate a significant decrease in overall cardiovascular risk, as tested over three intervals (week 1, week 12, and week 20) during the 20 week training period. Hence, concluding that exercise holds promise as a principle component of preventative treatment plan intent on reducing cardiovascular risks. Furthermore, the findings confirm the notion that the intense physical activity/exercise level is being well tolerated by most fresh recruits within the military setting.

7.4 Study 4

Study 4 is presented in chapter 6 of this dissertation. The discoveries made in the aforementioned study (study 3) steered the planning and execution of the final study (study 4). As a sequel to study 3, this study was designed as a longitudinal study with self-controls for within group comparisons, as well as a comparative study between the two contrasting populations. The objective of the study was to compare a sedentary population with an active population undergoing a 20-week training intervention. Thus, affording the opportunity to determine the impact of physical activity on cardiovascular risk by comparing two divergent South African lifestyles over a 20-week time frame. The 202 infantry service recruits of study 3 served as the intervention group, while the control group comprised of 126 sedentary university students.

Findings from this study conveyed strong association between the active population and decreased CSI and related heart health measurements in comparison to results of the sedentary population. Therefore, conclusions of study 4 support the notion that physical activity is considered to be one of the most important interventions for decreasing various cardiovascular complications and risks [5].

The standardized 20-week training program employed by the training academy was conducted under controlled FITT (frequency, intensity, type, time) conditions for the intervention population of study 3 and study 4; consequently subsidising existing knowledge pertaining to expected changes impelled by physical activity.

7.5 Overall Findings

The four studies reprise the inevitability and importance of a physically active lifestyle in the pursuit of health and longevity. Results yielded in all of the aforementioned studies offer empirical evidence of the influence of physical activity on cardiovascular health, thereby, substantiating earlier findings as described in previous chapters.

Ample research exists which aims to correlate physical activity and cardiovascular health promotion. This investigation shows that CSI, as measured by the Viport^{TM}, can be used as a measure of cardiovascular risk and as an innovative approach to cardiovascular screening.

7.6 Conclusion

This research validates a positive trend of association between a physically active lifestyle and improved heart health, thereby implying reduced cardiovascular risk. The investigation confirmed the need for public health action against inactivity in order to conquest the battle of this modern epidemic. In the combat against cardiovascular disease it is clear that focus should be shifted from pharmacological treatment to behavioural prevention.

As a principle component of this preventative approach it is vital that individuals are equipped with screening technology that enables early detection and monitoring of probable cardiovascular complications. Several novel ideas were introduced in this research, including the endorsement of the CSI method as a reliable, dependable, non-invasive technique to directly observe cardiovascular stress.

7.7 References

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Appendix A: **Subject information & informed consent**

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TITLE : Effect of gender & lifestyle on Cardio Stress Index & Heart Rate Variability

INTRODUCTION

You are invited to volunteer for a research study. This information leaflet will help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the investigator. You should not agree to take part unless you are completely happy about all the procedures involved.

WHAT IS THE PURPOSE OF THIS STUDY

The aim of the study is to determine the effects of a 20-week physical training program on overall heart health and compare these findings with a same-age control group where no training will take place.

WHAT IS THE DURATION OF THIS STUDY?

The testing will be completed over a time frame of 20 weeks. Various measurements will be taken in order to determine overall heart health. Heart rate variability, heart rate, cardio stress index, physical fitness, body composition and psychological stress levels will be tested on week 1, 12 and 20 with the help of various physiological tests and questionnaires.

EXPLANATION OF PROCEDURES TO BE FOLLOWED

This study involves completing several tests and questionnaires. Each questionnaire has to be completed at the beginning of each testing session so that the investigators can be informed of recent developments. Participants are required to fill these questionnaires in three times (week 1, week 12, week 20).

Questionnaires include the following:

- Personal & family medical history questionnaires

  This questionnaire requests that information regarding any diseases/conditions that the participant may have or has a history of to determine compliance of criteria and risks that may be involved. The estimated completion of this section is 5 minutes.

- Emotional & stress-related questionnaires

  This emotional health and personal stress inventory sections are adapted from Prentice's wellness assessment tool. This section of the survey aimed at determining the perceived stress index (PSI) of participants.

- Fitness/lifestyle-related questionnaires.

  These consist of four questionnaires, namely: paffenbarger physical activity questionnaire; lifestyle evaluation; nutritional evaluation; and fitness index of Kasari. These questionnaires provide insight into the participants' lifestyle and level of physical activity. Based on this information, a sense of wellness can be obtained and to an extent, perceived wellness. The estimated completion time for all questionnaires in this section is 5-10 minutes.

- Physiological tests pertaining to heart health and body composition.

  These tests will be conducted to empirically determine the participants' state of physical wellness. The assessments will consist of the various health-related and skill-related components of wellness.

- Fitness tests to determine physical fitness levels.

  This constitutes the physical assessments that comprise the skill-related component of physical wellness. The assessments will comprise press-ups, crunches and the 3-minute step test.

NOTE:

It is important that you let the investigator know of any medicines (either prescriptions or over-the-counter medicines), alcohol or other substances that you are currently taking.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This research study protocol was submitted to the faculty of Health Science research Ethics Committee, University of Pretoria and written approval has been granted by that committee.

WHAT ARE YOUR RIGHTS AS A PARTICIPANT IN THIS STUDY?

Your participation in this trial is entirely voluntary and you can refuse to participate or stop at any time without stating a reason. Your withdrawal will not affect your access to other medical care or your career at the SANDF or your studies at the University of Pretoria. The investigator retains the right to withdraw you from the study if it is considered to be in your best interest. If it is detected that you did not give an accurate history you may be withdrawn from the study at any time.

You are entitled to psychological assistance at any point in the study and a psychologist will be on site should any difficulties be experienced. The psychologist will be available for the duration of the entire study to offer support and assistance where needed. The contact details of the psychologist is as follows: Name: Dr. Nicoleen Coetzee
Contact number: 0844008394

MAY ANY OF THESE STUDY PROCEDURES RESULT IN DISCOMFORT OR INVOLVE ANY SORT OF RISKS?

The only discomfort may be the fitness tests, in which muscular soreness and fatigue may be experienced, as well as possible emotional discomfort owing to the personal nature of certain questions. No blood will be drawn and no invasive procedures will be used.

CONFIDENTIALITY

All information obtained during the course of this study is strictly confidential. Data that may be reported will not include any information which identifies you as a participant. In connection with this research, it might be important to the Faculty of Health Science Research Ethics Committee, the section Sports Medicine, University of Pretoria, as well as your doctor, to be able to review your medical records.

Any information uncovered regarding your tests result or state of health as a result of your participation in this research study will be held in strict confidence. You will be informed of any finding of importance to your health or continued participation in this study but this information will not be disclosed to any third party in addition to the ones mentioned above without your written permission. The only exception to this rule will be cases in which a law exists compelling us to report individuals infected with communicable diseases. In this case, you will be informed of our intent to disclose such information to the authorized state agency.

Note that should the scores obtained in the psychological evaluations indicate be below the clinical threshold (indicating a psychological disorder such as depression), the participant will be referred to Dr. Nicoleen Coetzee for further evaluation and assistance. It is within the participant's right to decline the offer of psychological support.

INFORMED CONSENT

I hereby confirm that I have been informed by the investigator, E Henning, about the nature, conduct, benefits and risks of the research study. I have also received, read and understood the above written information (Patient Information Leaflet and Informed Consent) regarding the research study.

I am aware that the results of this study, including personal details regarding my sex, age, date of birth, initials, health and performance will be anonymously processed into a study report.

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 this study.

Participant's name

………………………………………………………………………
(Please print)

Participant's signature…………………………………………...

Date………………………………………………………………

I, E Henning herewith confirm that the above participation has been informed fully about the nature, conduct and risks of the above study.

Investigators name: Evangeline Henning

Investigator's signature………………………………………

Date………………………………………………………………

Witness's name*……………………………………………..

Witness's signature…………………..Date………………...
(Please print)

*Consent procedure should be witnessed whenever possible.

Appendix B: **Data Sheet**

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QUESTIONAIRE AND INDEMNITY FORM

Subject Number: Number ______________ Date: DD | MM | YEAR

INDEMNITY

I hereby declare that I fully understand the procedure of the evaluation and I had the opportunity to discuss all relevant matters. I participate in the evaluation exercises at my own risk and won't hold the University of Pretoria responsible for any injury obtained.

____

Signed Date

PERSONAL AND BIOGRAPHICAL INFORMATION

Gender: [M] Male [F] Female

Ethnicity: [B] Black [C] Coloured [I] Indian [A] Asian [W] White

Age: YRS ______ Dominant hand: RIGHT/LEFT ______

Please note, ethnicity is solely required for research purposes, and not indented to be discriminative in any way or form.

PERSONAL AND FAMILY MEDICAL HISTORY

Do any of your immediate family members (grandparents, parents, brother(s) or sister(s) suffer from, or take medication for the following health factors?

- [ ] Heat attack
- [ ] Heart disease
- [ ] Lung disease
- [ ] Any cancer
- [ ] Overweight
- [ ] High blood pressure
- [ ] High cholesterol levels
- [ ] Any dependency
- [ ] Renal disease
- [ ] Connective tissue disease
- [ ] Autoimmune disease
- [ ] Liver disease
- [ ] Neurological disease
- [ ] Psychiatric disease
- [ ] None

Have any of your immediate family members (grandparents, parents, brother(s) or sister(s) died from the following health factors?

- [ ] Heat attack
- [ ] Heart disease
- [ ] Lung disease
- [ ] Any cancer
- [ ] Overweight
- [ ] High blood pressure
- [ ] High cholesterol levels
- [ ] Any dependency
- [ ] Renal disease
- [ ] Connective tissue disease
- [ ] Autoimmune disease
- [ ] Liver disease
- [ ] Neurological disease
- [ ] Psychiatric disease
- [ ] None

Do you suffer or take medication for the following chronic conditions?

- [ ] Heat attack
- [ ] Heart disease
- [ ] Lung disease
- [ ] Any cancer
- [ ] Overweight
- [ ] High blood pressure
- [ ] High cholesterol levels
- [ ] Any dependency
- [ ] Renal disease
- [ ] Connective tissue disease
- [ ] Autoimmune disease
- [ ] Liver disease
- [ ] Neurological disease
- [ ] Psychiatric disease
- [ ] None

PERSONAL STRESS INVENTORY

Choose YES (Y) of NO (N) for each question	***Y***	***N***
1. I have frequent arguments.	Y	N
2. I often get upset at work/school/university.	Y	N
3. I often have neck and/or shoulder pains due to anxiety/stress.	Y	N
4. I often get upset when I stand in long lines.	Y	N
5. I often get angry when I listen to the local, national or world news or read the newspaper.	Y	N
6. I do not have a sufficient amount of money for my needs.	Y	N
7. I often get upset when driving.	Y	N
8. At the end of a day I often feel stress-related fatigue.	Y	N
9. I have at least one constant source of stress/anxiety in my life (e.g., conflict with boss, neighbour, mother-in-law etc.).	Y	N
10. I often have stress-related headaches.	Y	N
11. I do not practice stress management techniques.	Y	N
12. I rarely take time for myself.	Y	N
13. I have difficulty in keeping my feeling of anger and hostility under control.	Y	N
14. I have difficulty in managing time wisely.	Y	N
15. I often have difficulty sleeping.	Y	N
16. I am generally in a hurry.	Y	N

FITNESS INDEX OF KASARI

Choose the most appropriate statement in frequency, intensity and time that most accurately reflect your level of physical activity.

Frequency	More than 6 times per week	F
	3 to 5 times per week	F
	1 to 2 times per week	F
	A few times per month	F
	Less than one time per month	F
Intensity	Sustained heavy breathing and perspiration	I
	Moderate high aerobic activities and intermittent sport activities that result in sustained heavy breathing and perspiration (step aerobic, stair-stepping, speed walking, tennis, racquetball, squash)	I
	Moderate aerobic activities (normal bike riding, jogging, low impact aerobics	I
	Low to moderate aerobic and sports activities (recreational volleyball, moderate speed walking)	I
	Light aerobic exercise (normal walking, golfing)	I
Time	More than 30 minutes	T
	20 to 30 minutes	T
	10 to 20 minutes	T
	Less than 10 minutes	T

Appendix C: **Data Capture Form**

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DATA CAPTURE FORM (1)

Subject number: Number　　Date: DD | MM | YEAR

BODY MASS

Height (cm):	1	2	Weight (Kg):	1	2

CIRCUMFERENCES

Neck (cm):	1	2	Shoulder (cm):	1	2
Arm (cm):	1	2	Chest (cm):	1	2
Forearm (cm):	1	2	Wrist (cm):	1	2
Waist (cm):	1	2	Abdomnl (cm):	1	2
Hip (cm):	1	2	Prox Thigh(cm):	1	2
Mid Thigh (cm):	1	2	Distl Knee (cm):	1	2
Knee (cm):	1	2	Calf (cm):	1	2
Ankle (cm):	1	2			

SUB-CUTANEOUS FAT

Biceps (mm):	1	2	Triceps (mm):	1	2
Sub-scap (mm):	1	2	Abdomnl (mm):	1	2
Suprailiac(mm):	1	2	Thigh (mm):	1	2
Calve (mm):	1	2	Supraspn (mm):	1	2
Pectorl (mm):	1	2			

HEART RATE VARIABILITY

Vent Rate (bpm): ________ PR int. (ms): ________

QRS Dur. (ms): ________ QT/QTc int. (ms): ________ | ________

P/QRA/T axis: ________ | ________ | ________

RV5/SV1 amp.: ________ | ________ RV5+SV1 amp.: ________

VI-PORT

CSI (%): 1 | 2 HR (bpm): 1 | 2

Rhytm (Y/N): 1 | 2 QRS Dur. (ms): 1 | 2

RRSD (ms): 1 | 2

BLOOD PRESSURE

Syst (mmHG): 1 | 2 Diast (mmHg): 1 | 2

FITNESS

*Sit and Reach: Thigh | Shins | Toes

*Use sit and reach box and do modified sit and reach test

**Push-ups (#/1 min): 1 Type of push-up: Half/Full

* *All men do full push-up and all women do half push-up

Sit-ups (#/1 min): 1

3-Min Step test (pulse/15 sec) 1