

PREVALENCE AND RISK FACTORS OF CHRONIC DISEASES OF LIFESTYLE IN ENDURANCE RUNNERS

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List of Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
ANS	Autonomic Nervous System
ATP	Adenosine Triphosphate
AVP	Arginine Vasopressin
BDNF	Brain Derived Neurotrophic Factor
BMI	Body Mass Index
CDL	Chronic Diseases of Lifestyle
COPD	Chronic Obstructive Pulmonary Disease
CRD	Chronic Respiratory Disease
CT Scan	Computed Tomography Scan
CVD	Cardiovascular Disease
DNA	Deoxyribonucleic acid
EAH	Exercise-associated Hyponatremia
ET-1	Endothelin 1
FACET	Five-a-day Community Evaluation Tool
FEV1	Forced Expiratory Volume in one second
GI	Gastrointestinal
HDL	High-density Lipoprotein
HIV	Human Immunodeficiency Virus
IPAQ	International Physical Activity Questionnaire
LDL	Low-density Lipoprotein
MHC	Myosin Heavy Chain
MRI	Magnetic Resonance Imaging
NCD	Non-communicable Diseases
NF-KB	Nuclear Factor Kappa-light-chain-enhancer of activated B cells
PGC-1a	Peroxisome proliferator-activated receptor Gamma Coactivator 1-alpha
PHC	Primary Healthcare
RPE	Rate of Perceived Exertion
SCD	Sudden Cardiac Death
TB	Tuberculosis
UCT	University of Cape Town
USA	United States of America
UV	Ultraviolet
VO ₂ max	Maximum Consumption of Oxygen
WHO	World Health Organization

Standard Units of Measurement

mmHg	Millimetres of Mercury
mmol.l ⁻¹	Millimoles per Litre
kg.m ⁻²	Kilograms per Metre Squared
cm	Centimetres
g	Grams
kg	Kilograms
m	Meters
km	Kilometres
min	Minutes

Glossary of Terms

Chronic Diseases of Lifestyle	A group of diseases, including type 2 diabetes, cardiovascular disease, chronic respiratory disease and certain cancers, most commonly breast, lung and colon cancer, that are grouped together as they share similar risk factors and disease patterns (1,2).
Modifiable Risk Factors for Chronic Diseases of Lifestyle	Adaptable and controllable behavioural and physiological signs that the body is not well and when left untreated has the possibility of developing into chronic diseases of lifestyle. Risk factors include: raised blood pressure, high body mass index, increased body fat percentage, increased waist circumference, increased blood cholesterol concentration, impaired blood glucose concentration, smoking, dietary intake and less than 150 minutes of moderate to vigorous intensity physical activity (3–5).
Non-Modifiable Risk Factors for Chronic Diseases of Lifestyle	Environmental and physiological factors that can not be changed, but increase the possibility of developing chronic diseases of lifestyle. These factors include age and income (6–9)
Body Mass Index	An indicator of body fat. It is measured by dividing weight (kilograms) by the square of height (metres) (10).
Blood Pressure	The pressure at which blood is pushed against the artery walls as it is pumped by the heart (11).
Physical Activity	Specific, focused time in which ordered and structured activity occurs, which involves repeating body movements to achieve an improvement or maintenance of certain physiological properties (12).
Endurance Running	Running a distance of at least three kilometres, twice a week regardless of the speed or time to complete (13).
Aerobic Activity	Physical activity that requires oxygen to sustain the bodily functions needed for the activity (14).
Anaerobic Activity	Short lasting physical activity that is not dependant on oxygen to provide energy (14).

Myocardial Infarction	A blockage to an artery that supplies the muscles of the heart resulting in death of that portion of the heart muscle (15).
Ischaemic Stroke	A blockage to an artery that supplies a portion of the brain, causing permanent or temporary brain cell death in that portion of the brain (15).
Peripheral Artery Disease	A blockage to the arteries in the extremities, most commonly the legs, commonly causing amputation (15).
Haemorrhagic Stroke	A burst artery in the brain usually as a result of high blood pressure (15).
Heart Failure	The inability of the heart to pump sufficient blood for the body (15).
Arrhythmia	An abnormal rhythm of the heart (15).
Heart Valve Problem	The valves in the heart not functioning correctly (15).
Borg Scale of Perceived Exertion	A numeric scale evaluating how hard an individual perceives they are working (16).
NF-KB (Inflammatory Marker)	A protein complex that plays a role in regulating the immune response to an infection (17).
Lymphadenopathy	Lymph nodes that are abnormal in their size, consistency or number (18).
VO ₂ Max	The maximum consumption of oxygen that the body can consume over a period of physical activity (19).

Abstract

Background

Chronic diseases of lifestyle (CDL) are associated with high rates of morbidity and mortality in South Africa. Although prevalence of CDL has been established in the general population, there is limited research regarding the prevalence and risk factors for CDL in individuals taking part in regular physical activity. Endurance running is a popular sport, with growing levels of participation. Anecdotally, many individuals who participate in endurance running do not undergo formal pre-participation cardiovascular screening. It is also unclear if endurance runners are meeting the World Health Organisation's recommended weekly moderate to vigorous intensity physical activity hours, or if they have other risk factors for CDL. It is therefore important to establish the prevalence and risk factors of CDL in this active population.

Aim and Objectives

The aim of this study was to determine the prevalence of CDL and the associated risk factors in endurance runners in South Africa. The specific objectives of the study were: (a) to determine the presence of risk factors for the development of chronic diseases of lifestyle, including body mass index (BMI), waist circumference, body fat percentage, blood pressure, blood glucose, blood cholesterol, smoking history, dietary intake and weekly physical activity time in South African endurance runners; (b) to determine the presence of non-modifiable risk factors to the development of CDL, namely age and income, in South African endurance runners; (c) to determine whether South African endurance runners are fulfilling the World Health Organization's recommended weekly moderate to vigorous intensity physical activity hours; and (d) to assess whether there are any relationships between the running characteristics, namely weekly training hours, running speed and level of competition; and the risk factors for chronic diseases of lifestyle.

Methods

This study had an analytical, cross-sectional design. Two hundred participants between the ages of 18 to 69 years old, who reported endurance running as their main sport, and ran at least three kilometres twice a week for the past year were included in the study. Participants were excluded if they were pregnant or within six months post-partum, had an injury that required a minimum of two weeks rest or did not complete the questionnaire or physical testing component of the testing process. Participants were recruited through local running clubs and running races in the areas of Nelspruit, Mpumalanga and Cape Town, Western Cape.

All participants gave written informed consent, and completed a questionnaire including socio-demographic characteristics, running training characteristics, the International Physical Activity Questionnaire short questionnaire, the modified Borg scale of perceived exertion, and the five-a-day community evaluation tool. Body mass, stature, skin folds and waist circumference were assessed. Blood pressure was measured using an automatic blood pressure monitor. A finger prick test was used to determine random blood glucose and cholesterol concentrations. Participants were requested to fast for three hours prior to testing to standardise the test in a non-fasted state (20).

Results

One hundred and twenty four (62%) participants were found to have at least one risk factor for CDL. A high BMI was the most common risk factor for CDL (n=90; 45%). Nineteen participants (9.5%) did not meet the recommended duration of 150 minutes of physical activity per week. Seven percent of female participants (n=7) smoked, which is equivalent to the female population average of South Africa. Multiple risk factors were identified in fifty seven (28.5%) participants, ranging from two risk factors (n=37; 18.5%) to six risk factors (n=1; 0.5%). The majority of participants had no prior medical diagnosis of CDL or risk factors for CDL. The overall self-reported prevalence of a medically diagnosed CDL was 5.5% (n=11). Type 2 diabetes was the most commonly diagnosed CDL (n=6; 3%). Waist circumference, systolic blood pressure and cholesterol were significantly elevated in the older age group. There were no significant differences in risk factors for CDL according to income status. Female runners had significantly higher average sitting times compared to male runners. In addition, participants with a BMI ≥ 25 kg.m⁻² had significantly slower 10 km running speeds and lower average weekly training distance, compared to participants with BMI within normal ranges.

Conclusion

A high prevalence of risk factors for CDL was identified in South African endurance runners. The majority of endurance runners included in this sample are fulfilling the World Health Organisation's recommended weekly moderate to vigorous intensity hours. However, the endurance runners in this study remain at risk for developing a CDL due to the presence of other risk factors for CDL. The knowledge and awareness of risk factors for CDL among South African endurance runners needs to be further investigated. Health care professionals are required to improve the prevention and management of risk factors of CDL through education and promotion of healthy lifestyles. A stronger emphasis on the prevention of risk factors for CDL in South African endurance runners is needed.

Chapter 1: Introduction and Scope of the Dissertation

1.1 Introduction

Chronic diseases of lifestyle (CDL) are preventable diseases that have become a global epidemic (21). Chronic diseases of lifestyle are a group of diseases that share similar causes, related to an unhealthy lifestyle comprising of inactivity, poor dietary habits and tobacco use (2,21). In South Africa, CDL have become a significant burden to the country due to substantial costs associated with management and treatment (22). It is estimated that CDL account for 65% of worldwide deaths annually. As CDL have similar risk factors, it is possible for individuals to present with multiple diseases, thereby placing the health care professionals and the health care system under greater stress to manage patients with multiple comorbidities (5).

Chronic diseases of lifestyle are considered preventable diseases, and include type 2 diabetes, cardiovascular disease, chronic respiratory disease and certain cancers, most commonly breast, lung and colon cancer (21,23). The burden of CDL may be prevented and managed by addressing the unhealthy lifestyle choices such as improving the physical activity levels, healthy eating habits and smoking cessation, amongst others (5,23). Risk factors for CDL are considered as 'warning signs' that the human body is potentially heading towards a diseased state (3). The modifiable risk factors include: a consistently raised blood pressure greater than 140/90 mmHg; random blood glucose concentrations higher than 7.8 mmol.l⁻¹; random total cholesterol concentrations higher than 6.2 mmol.l⁻¹; body mass index (BMI) higher than 25 kg.m⁻²; waist circumference greater than 88 cm in females and 102 cm in males; body fat percentage greater than 32% in females and 25% in males; smoking; and less than 150 minutes of moderate to vigorous physical activity per week (3,5,21). The majority of South Africans have at least one of these risk factors (24). Chronic diseases of lifestyle take years to become fully established once a risk factor is present; therefore leaving opportunity to intervene and prevent the onset of the disease (25). Prevention of the development of the risk factors through a healthy lifestyle will maintain a minimal risk profile for CDL throughout a person's lifespan (2). Having a single risk factor increases the risk of developing a chronic disease of lifestyle substantially and every additional risk factor further increases that risk (2). The onset of the disease, once it has progressed from risk factors to the disease is made by a medical practitioner through clinical and laboratory examinations (26).

Other related factors may also contribute to the development of CDL. Non-modifiable risk factors are additional factors that, place an individual at a greater risk for developing CDL, but are not variable resulting in their presence increasing the risk of CDL. Contributing factors include age and income (6). Income has the potential to influence the lifestyle choices, such as food purchases and physical activity levels (8).

In addition, there is an increase in the number of people living with CDL and a higher prevalence of comorbidities as the population age increases (9).

It has been widely acknowledged that exercise has many beneficial effects on an individual's physical status (27). The beneficial effects include improved heart and lung capacity, increased muscle strength and endurance, improved muscle and joint flexibility, decrease or maintenance of a healthy body weight, increased life expectancy and an improved immune function (12). However inactivity remains a significant concern in South Africa, with two-thirds of the population not meeting the weekly physical activity requirements, and activity levels decreasing steeply with increasing age (24). The World Health Organization (WHO) recommends 30 minutes of moderate to vigorous intensity physical activity for five days of the week, or a total of 150 minutes weekly (28). Endurance running is a popular form of physical activity that attracts many people annually (29). Endurance running is a form of aerobic exercise that substantially increases heart rate and energy usage (30). Regular endurance running improves the functioning of the cardiovascular, respiratory and muscular systems, resulting in improved functioning and strength capacity (30).

It is commonly perceived that endurance runners are healthy, and that running will protect them against CDL (31,32). However endurance running addresses only one of the risk factors for CDL, namely physical activity levels (32). Individuals who participate in regular endurance running may experience the health benefits from running, but they have the potential to remain at risk for the development of CDL if they have not also addressed other risk factors and contributing factors for CDL (32). It is also possible that endurance runners may not be training sufficiently to fulfil the required 150 minutes of moderate to vigorous physical activity each week needed to reduce the risk of CDL (21). It is therefore unclear whether endurance runners have a decreased risk for developing CDL primarily because of their increased physical activity levels associated with endurance running training; or whether endurance runners have a high prevalence of the other risk factors for CDL and remain at risk of developing CDL.

1.2 Problem Statement

Much attention has been given to CDL and the risk factors in the general population; however there is limited research regarding the prevalence and risk factors for CDL in individuals taking part in regular physical activity. Anecdotally, many individuals who participate in endurance running also do not undergo formal pre-participation medical screening.

In addition, it is unclear if endurance runners are meeting the WHO's recommended weekly moderate to vigorous intensity physical activity hours. Further, people who participate in regular endurance running may assume that running has a protective effect that counteracts any other potential risk factor for CDL.

Given the increased participation in endurance running as a sport, it is important to establish the prevalence of risk factors for CDL in this population, to ensure that appropriate pre-participation screening and interventions can be developed. Furthermore, a more comprehensive understanding of the quantity of physical activity by endurance runners may allow for the development of appropriate interventions and educational strategies.

1.3 Aims and Objectives

1.3.1 Aim

The aim of this study was to determine the prevalence of chronic diseases of lifestyle and associated risk factors in endurance runners in South Africa.

1.3.2 Objectives

The specific objectives were:

- To determine the presence of risk factors for the development of CDL, including BMI, waist circumference, body fat percentage, blood pressure, blood glucose concentration, blood cholesterol concentration, smoking history, dietary intake and weekly physical activity time in South African endurance runners.
- To determine the presence of non-modifiable risk factors to the development of CDL, namely age and income, in South African endurance runners.
- To determine whether South African endurance runners are fulfilling the WHO's recommended weekly moderate to vigorous intensity physical activity hours.
- To assess whether there are any relationships between the running characteristics, namely weekly training hours, running speed and level of competition; and the risk factors for CDL.

1.4 Plan of Development

In preparation for the investigative phase of this dissertation, a comprehensive review of the literature on CDL, risk factors for CDL, and endurance running will be presented (Chapter 2). This will be followed by a description of the analytical, cross-sectional study that was designed to investigate the prevalence of CDL and the risk factors for CDL in endurance runners (Chapter 3). A summary and conclusion chapter (Chapter 4), including recommendations for future research, will complete this dissertation.

Chapter 2: Literature Review

2.1 Introduction

The prevalence of CDL, also known as non-communicable diseases (NCD), has increased significantly in the past 20 years (21,33,34). Numerous risk factors for CDL have been identified, and if these risk factors are addressed early and efficiently, there is a potential to prevent progression to a diseased state (9). South Africa is a country with high poverty rates and limited access to healthcare; therefore it is common that risk factors are diagnosed late with the disease progression occurring by the time an individual presents to the healthcare system. This results in the focus being on disease treatment of CDL rather than disease prevention (34). Physical activity, for example endurance running, is an essential component of CDL prevention and management (35). This literature review will highlight the growing contribution of CDL to the burden of disease particularly in the South African context. The different types of CDL will be examined; and their risk factors and lifestyle factors that contribute to the development of CDL will also be explored. The last section of the review will briefly describe the key physiological effects of physical activity and endurance running and the association between exercise and prevention of CDL.

Literature was accessed through Google Scholar and PubMed. Keywords that were used included: *“chronic diseases of lifestyle”, “non-communicable diseases”, “burden of CDL”, “burden of non communicable disease”, “burden of disease South Africa”, “cause of CDL”, “type 2 diabetes”, “cardiovascular disease”, “atherosclerosis pathophysiology”, “chronic respiratory disease”, “COPD pathophysiology”, “cancer”, “breast cancer”, “colon cancer”, “lung cancer”, “hypertension”, “running”, “endurance running”, “physical activity”, “hypercholesterolemia”, “high cholesterol”, “risk factors”, “inactivity”, “sedentary lifestyle”, “smoking”, “tobacco use”, “effect of smoking”, “obesity”, “BMI”, “body fat percentage”, “CDL disease progression”, “benefits physical activity”, “exercise”, “pathophysiology of chronic diseases of lifestyle”, “treatment of chronic disease of lifestyle”, “chronic diseases of lifestyle in South Africa”, “chronic diseases of lifestyle World Health Organization”, “South African health care”, “physical activity benefits”, and “world mortality causes”*. Combinations of these keywords were used in the database searches. Articles referenced within relevant journal articles that had been found were also searched.

2.2 Burden of Disease

Chronic diseases of lifestyle have become a significant global public health concern. Over the last twenty years, more deaths have been attributed to CDL than infectious diseases (36). Lozano et al (2012) reported on the world mortality causes and rates from 1990 to 2010. Of the 52.8 million deaths over this period, CDL accounted for 34.5 million deaths (65.5%), making it the highest category of reported deaths across the world (37). The economic burden of CDL is also substantial. For example, the estimated lifelong cost of treating an individual with type 2 diabetes if diagnosed at 40 years old is more than USD200 000 (38). In May 2000, the WHO recognized the severity of CDL by adopting the “global strategy for prevention and control of non-communicable diseases”. Since then the WHO has adopted several regulations and strategies including the “Global Action Plan for the prevention and control of NCD for the period 2013-2020” (36). The strategies and programmes are aimed at equipping governments with plans to prevent, manage, and control the risk factors, as well as research and monitor trends for CDL with the overall goal to reduce the mortality from CDL by 25% by the year 2025 (33). However death rates from CDL have not yet reached a plateau and are continuing to rise each year; and if they continue to rise at the same rate, the death rates from CDL are predicted to rise by 15% by the year 2020 (39).

2.2.1 Burden of Disease in South Africa

South Africa is a unique country with high incidences of infectious diseases, non-infectious diseases, maternal and child health issues, and trauma and crime related injuries, making health care a multi-factorial and comprehensive challenge (22,34,40–42). The infectious disease burden mainly comprises the human immunodeficiency virus (HIV), acquired immune deficiency syndrome (AIDS) and tuberculosis (TB) (33,34). In 2015, CDL accounted for 55.5% of the deaths across South Africa; while communicable diseases accounted for 33.4%; and maternal and child illnesses and injuries accounted for 11.1% of the deaths in South Africa (43). The multiple causes of morbidity and mortality has put severe strain on the health care system in South Africa, with the country’s time and health care resources having to be split over several equally important diseases (21,22).

The health care system in South Africa is further stressed by the wide disparity in the wealth distribution of the country. The wealth distribution among the country is one of the widest in the world, with the top 10% of South Africans earning 58% of the total income of the country; and the bottom 70% earning only 17% of the country’s income (40). South Africa has also had a period of rapid, unplanned urbanisation resulting in high levels of unemployment and a high number of people living in poverty within an urban environment (44). Extreme poverty results in a lack of access to health care and the basic requirements for health, namely; clean running water, adequate nutrition, education, access to jobs and proper housing (40).

Poverty also results in higher incidences of infectious diseases and crime-related injuries; and urbanisation leads to an increase in non-infectious diseases (21). Therefore, in South Africa the combination of poverty and urbanisation has led to a high incidence of individuals living with multiple morbidities (41,44).

Furthermore, improved access to antiretroviral drug treatment for HIV/AIDS has resulted in an increased population age and survival rates in South Africa (40,44). An increasing population age allows more time for the risk factors for CDL to arise and for CDL to progress and develop, which is a trend that South Africa has experienced (44). Dugas et al (2017) revealed that South Africa currently has one of the highest rates of weight gains in the world with an average of 1.54 kg per year per person (45). Recent mortality data showed a slight increase in deaths due to type 2 diabetes, hypertensive heart disease, and breast, cervical and colon cancers (34). Mortality due to ischaemic heart disease, chronic obstructive pulmonary disease and lung and oesophageal cancer remained relatively unchanged (34).

Access to healthcare in South Africa is mainly through the primary healthcare (PHC) clinics with trained nursing sisters managing the consultation (41,46). The management of hypertension has been identified as the most common chronic health reason for attending a PHC clinic. Almost half of the individuals presenting to PHC clinics with CDL, had co-morbidities (41,46). Chronic diseases of lifestyle accounted for 14% of all consultations. However, it is possible that a high number of patients with CDL or risk factors for CDL are left undiagnosed and inadequately treated, as the nursing staff may not have the necessary capacity, time, equipment and skills to diagnose and appropriately treat CDL, and often miss the presence of co-morbidities (46,47). Treatment of CDL can only be done effectively with an understanding of the underlying disease progression, and the contribution of multiple morbidities (41). Only once the disease is fully understood can it be adequately managed and treated (41). The following section of the review will provide a more detailed description of the pathophysiology and management of different CDL.

2.3 Chronic Diseases of Lifestyle

Chronic diseases of lifestyle are a group of diseases that account for millions of deaths across the world each year (39). They have become a world-wide epidemic with the cause being mainly as a result of exposure over many decades to an unhealthy lifestyle comprising of inactivity, poor dietary habits and tobacco use (2,48). Chronic diseases of lifestyle include type 2 diabetes, cardiovascular disease (CVD), chronic respiratory disease (CRD), and certain cancers, most commonly breast, lung and colon cancer (21,42). These diseases are grouped together as they are closely related and share similar causes and disease progressions (49).

A low grade chronic, systemic inflammation has been associated with each of these diseases and is an important part of the pathogenesis of CDL (17). The underlying chronic, systemic inflammation places excessive strain on the body and results in the body constantly attempting to heal itself (39).

Chronic low grade inflammation leads to the development of insulin resistance, atherosclerosis, neurodegeneration, and tumour growth, thus increasing the pathways for developing CDL. Therefore, a systemic low grade inflammation has a direct effect on the progression of CDL (50). The characteristics of a low grade chronic inflammation is a two-to-three-fold increase in the systemic concentrations of pro-inflammatory and anti-inflammatory cytokines (17). Inflammation, which is intended to repair the body, is dangerous to the body in high concentrations and has a toxic effect causing cell death (51). There are several risk factors for these diseases, the presence of which suggest that a person may be at risk for developing CDL (9). The risk factors include: high blood pressure, obesity, high cholesterol concentration, impaired blood glucose control, physical inactivity and smoking (39). These risk factors are reversible and if they are managed appropriately and in a timely manner, then it is possible to prevent the onset of CDL (49).

The prevention and treatment of CDL needs to be aimed at more than just a biomedical model. Multifactorial contributing factors need to be addressed, including social, cultural and behavioural aspects. Many governments have aimed at reducing the risk of developing CDL through initiatives such as tobacco taxation, smoke free public spaces, regulation of food standards and labelling, media campaigns to increase physical activity and community interventions to improve physical activity (36). However, many primary care facilities are inadequately equipped to detect early signs of certain CDL, especially cardiovascular disease, and are not able to adequately address the long-term management of CDL (33). To rectify this problem, changes need to be made from a government level to increase their distribution of finances, workforce, service provision, medicines and information towards the prevention and management of CDL (33). The prevalence, pathophysiology, diagnosis and management of different types of CDL will be discussed in the following subsections.

2.3.1 Type 2 Diabetes

2.3.1.1 Disease Prevalence

Over the past 20 years, there has been a significant increase in the number of people living with type 2 diabetes (28). In 2016, 29 million Americans were reported to be type 2 diabetic, with three times that pre-diabetic. (38). In 2014, there were an estimated 422 million people living with type 2 diabetes globally. Prevalence rates are still increasing, and are expected to be much higher today (28).

Type 2 diabetes has risen in the ranking of causes of death, from the 13th most common cause of death globally in 1990; to the 9th most common cause of death in 2010 (37). Type 2 diabetes is the eighth highest cause of mortality and the second highest cause of natural deaths in South Africa. In 2015, a reported 28 872 people died from type 2 diabetes in South Africa (43). It is possible that the majority of these cases could have been prevented if the risk factors had been adequately and timeously addressed (28).

2.3.1.2 Pathophysiology

Type 2 diabetes is a chronic disease characterised by abnormal blood glucose control resulting from adverse alterations in insulin secretion and utilisation (52). Type 2 diabetes is caused by a combination of resistance of the body to the insulin that is produced and inadequate production of insulin by the pancreas (52). In a normal functioning body, the pancreas produces insulin on demand through the beta cells located within the pancreas (28). Obesity is a major risk factor for the development of type 2 diabetes. In obese individuals, an elevated Endothelin 1 (ET-1) is seen. ET-1 is a vasoconstrictor peptide, which is found in the lining of the blood vessels. Excessive adipose tissue releases high concentrations of fatty acids into the blood, which stimulates the ET-1 system. Excessive and prolonged ET-1 concentrations result in chronic vasoconstriction and resistance to the circulating insulin (53). Poor insulin control leads to an increase in blood glucose concentration or hyperglycaemia (52). Concurrently, in type 2 diabetes the body's adipose tissue releases pro-inflammatory cytokines and hyperglycaemia activates the Nuclear Factor Kappa-light-chain-enhancer of activated B cells (NF-KB) inflammatory markers, which result in a low grade systemic inflammation (17,53,54).

Symptoms of type 2 diabetes include excessive and abnormally large production of urine, excessive thirst, weight loss, blurred vision, fatigue, impairment of growth, delayed healing and susceptibility to infections (52).

2.3.1.3 Diagnosis and Management

A diagnosis of type 2 diabetes is made through the laboratory assessment of fasting blood glucose (26). Early diagnosis of type 2 diabetes is essential to management, as the longer an individual lives with undiagnosed diabetes, the worse their prognosis (28). Hyperglycaemia that is left untreated can result in damage or decreased functioning to the eyes, kidneys, nerves, heart and blood vessels (52). The main cause of morbidity and mortality is due to cardiovascular complications, which can cause myocardial infarctions, strokes, kidney failure, leg amputations and damage to the eyes and nerves (28).

The goal of treatment of type 2 diabetes is to achieve and maintain blood glucose concentration within normal parameters, and to prevent the complications associated with type 2 diabetes (30). In type 2 diabetes, it is possible to improve blood glucose control through oral glucose lowering medication, diet and exercise (52).

Exercise and diet modification are the preferred treatment choices for managing type 2 diabetes. However, due to the increased sedentary lifestyles the majority of patients are choosing to use the oral glucose lowering medication as their first and usually only line of treatment. The medication has several adverse side effects, whereas an exercise programme that is individually designed has a greater chance of improving the health of the individual and has very few adverse effects (12).

2.3.2 Cardiovascular Disease

2.3.2.1 Disease Prevalence

Cardiovascular disease has remained as the highest cause of death across the world for the past 20 years (37). Coronary heart disease is the most common cause of morbidity and mortality in the world, with an average of one in every six people suffering from a new or recurrent myocardial infarction (55). In the United States of America (USA), an estimated 92.1 million people have a CVD (15). Diseases of the circulatory system are the second highest cause of all mortality in South Africa, accounting for 17.8% of all deaths in 2015. The incidence of mortality due to CVD in South Africa is rising yearly, emphasising the harmfulness of CVD (43).

2.3.2.2. Pathophysiology

Cardiovascular disease is a broad term that is used to define diseases that affect the heart and vascular system (55). Cardiovascular disease encompasses myocardial infarctions, ischaemic and haemorrhagic strokes, heart failure, arrhythmias, heart valve abnormalities and peripheral artery disease (55). Myocardial infarctions and ischaemic strokes are the most common cause of morbidity and mortality within the cardiovascular diseases, and results from atherosclerosis (15,56,57).

Atherosclerosis is an inflammatory process that occurs in reaction to the build-up of plaque over many years in the walls of the arteries of the body (15,58,59). The plaque causes narrowing of the artery restricting the blood flow and has the potential to eventually break off from the wall of the artery forming a clot, which migrates down the artery until it settles and obstructs blood flow (56). The process of atherosclerosis formation begins when excessive blood cholesterol, glucose or pressure accumulates and damages the lining of the artery wall (56). The damage causes the endothelial cell wall to attempt to repair itself with pro-inflammatory markers making the cell wall more permeable, allowing an accumulation of fats, calcium and cellular waste substances in the artery wall to occur (58). This results in pathological thickening on one portion of the blood vessel (56). The thickening further attracts low density lipoprotein (LDL) cholesterol to the area, which results in growth of the thickened cell wall (56). As the area continues to thicken, the centre becomes avascular and the cells begin to die with the core becoming necrotic (56).

In an effort to repair the cell wall, the necrotic core gets covered in a thick fibrous cap made up of smooth muscle and collagen cells (56). The fibrous cap is important to contain the plaque in a specific area against the vessel wall; however as the plaque continues to develop the fibrous cap thins, and it is at this point that the plaque is vulnerable to be ruptured and dislodged (56). Less commonly, the necrotic core can erode through the artery wall causing the artery to rupture (56).

There are a wide variety of symptoms of CVD, which range from no symptoms to chest pain, shortness of breath, pain or numbness in the extremity affected, sweating, nausea, slurred speech, and paralysis on one side of the body (15).

2.3.2.3. Diagnosis and Management

A diagnosis of CVD is often difficult to make, as CVD may have no symptoms, and then may suddenly present acutely, for example, a myocardial infarction or stroke resulting in severe morbidity or mortality (60). There are various tests available to determine the functioning of the heart, such as an electrocardiogram, or echocardiogram, which a medical professional will recommend if suspecting heart abnormalities (60). Screening individuals for cholesterol levels is recommended in males over the age of 40 and females over the age of 50, as well as those who have a known risk factor for CVD such as obesity, hypertension, smoking or diabetes (60,61).

The management of CVD incorporates treatment to stabilise an individual and to minimise any risk of CVD through medication usage, surgery, increasing activity levels, smoking cessation and a healthy eating plan (15,60).

2.3.3 Chronic Respiratory Disease

2.3.3.1 Disease Prevalence

Chronic respiratory disease (CRD) is the fourth highest cause of mortality in the world (62). An estimated one billion people across the world live with a form of CRD (63). Chronic respiratory diseases are estimated to be higher in high income countries with greater urbanisation, due to pollutants and smoke in the air (63). In 2015, South Africa ranked CRD as the ninth highest cause of natural death and it accounted for 12 667 deaths that year (43). In previous years, CRD had been ranked as the tenth highest cause of natural death, showing that the prevalence of CRD is growing in South Africa (15).

2.3.3.2 Pathophysiology

Chronic respiratory diseases is a term used to describe several diseases that affect the lungs and airways (63). The variety of diseases classified under the term CRD include amongst others: chronic obstructive pulmonary disease (COPD), sleep apnoea syndrome, chronic rhinosinusitis, emphysema and chronic bronchitis (63). They are all characterised by airflow limitations that are not completely reversible (64).

Chronic rhinosinusitis is inflammation of the sinuses around the nasal passage causing blockage of the nasal passage and mucus build up. It is the most common of the chronic respiratory diseases with a high morbidity but low mortality rates. Chronic obstructive pulmonary disease is the highest cause of mortality from CRD and is caused by an abnormal airway inflammatory reaction in response to an allergen, which could be smoke, dust mite, pollen or air pollutants; resulting in air flow limitation (63,65). When an allergen is present in the lungs, the body stimulates an inflammatory response with the aim of neutralising the allergen but the allergen persists and the acute inflammatory response becomes persistent inflammation in the lining of the airways. In COPD, inflammation results in cell wall remodelling, with an increased mass in smooth muscle and mucous production in the airways. The increased smooth muscles cause a greater muscle force in the airways resulting in the airways closing more quickly and trapping in air in the airways (66). The symptoms of CRD include a consistent cough with or without secretions, shortness of breath, bleeding from the respiratory passages, wheeze and pain in the chest or throat (63).

2.3.3.3. Diagnosis and Management

Chronic respiratory disease is suspected in an individual with a history of a cough lasting longer than three months, excessive sputum production, and shortness of breath (67). The forced expiratory volume in one second (FEV₁) test assesses the volume of air a person is able to blow out in one second, and a decreased FEV₁ reading is found in individuals with CRD (63).

Treatment for COPD is not curative, but is aimed at addressing the symptoms and preventing disease progression. Medication aims to manage symptoms and prevent exacerbations. Lifestyle modifications, including smoking cessation and increased physical activity, are recommended (65,66,68). Cardiovascular disease is a common complication of COPD due to the strain on the heart when the lungs are compromised (69).

2.3.4 Cancer

2.3.4.1 Disease Prevalence

Every day there are an estimated 4 500 new diagnoses of cancer, with approximately 1 600 deaths daily from cancer, in the USA (70). The highest incidence of cancer is reported in countries with high urbanisation and westernised countries such as the USA, New Zealand and Canada (71). Breast, lung and colorectal cancer are the most prevalent cancers in females, and prostate, lung and colorectal cancer are the most prevalent in males in the USA (70).

Lung cancer is the leading cause of mortality amongst all the various cancers, with it being the fifth most common cause of deaths worldwide, with colorectal, stomach and liver cancers also ranking in to the top twenty causes of death globally (37). In 2015 cancer, including all types of cancer, was ranked as the sixth highest cause of death in South Africa, accounting for 9.1% of all deaths (43). The most commonly diagnosed cancer for South African males is prostate cancer, and breast cancer for South African females (72).

2.3.4.2. Pathophysiology

Cancer is caused by both internal and external factors. Internal factors are hormonal, genetic and immune conditions; and external factors are made up of environmental factors such as smoking, poor diet and physical activity and solar ultraviolet (UV) radiation (54). The cancers attributable to environmental factors have risen steeply over the past 20 years and are expected to continue rising with no adequate preventative measures in place yet (54). Environmental factors have been shown to be linked to some degree to 90% to 95% of all cancers, with environmental factors being important in colorectal, lung, breast and skin cancer (54).

Adipose tissue has an endocrine function, which regulates energy homeostasis, metabolism, inflammation, immunity and hormone balance. Adipose tissue secretes many hormones and cytokines which are called adipokines. An increase in adipose tissue results in imbalances in adipokines secretion, such as the inhibition of the anti-inflammatory adipokines and an increase in the pro-inflammatory adipokines. Leptin is one adipokine, which promotes growth and development of neoplastic cells and decreases insulin sensitivity. Visfatin and resistin are both adipokines, which are pro-inflammatory and stimulate signalling pathways (73).

They are important cancer promoting pathways and increase endothelial growth, which increases tumour metastasis and growth. High concentrations of visfatin and resistin have both been linked to colon cancer, postmenopausal breast cancer and prostate cancer. Skeletal muscle also has hormones and cytokines called myokines. Myokines counteract the effect of adipokines by having an anti-inflammatory effect on the body. Therefore a good balance between myokines and adipokines is essential for preventing the low grade inflammation and cancer promotion that occurs when adipokines are not sufficiently neutralised (73).

Lung cancer is strongly linked with tobacco smoking, with almost 90% of diagnosed lung cancer cases involving tobacco smoke. However, the link between the toxins in tobacco smoke and lung cancer is not fully understood (74). It is known that cigarette smoking activates the inflammatory marker NF- κ B, thereby causing chronic low grade inflammation in the lungs; and that over 60 tumour initiating carcinogens are found in tobacco smokes (54,74,75). Cigarette smoking is not only strongly associated with lung cancer, but also increases the progression of the disease (75). Skin cancer is one form of cancer that is caused by environmental factors but does not have a chronic low grade inflammatory response underlying the formation of the cancer. Skin cancer is caused by deoxyribonucleic acid (DNA) lesions in the skin as a result of excessive direct solar UV light (76).

2.3.4.3. Diagnosis and Management

A diagnosis of cancer is made after relevant tests have been performed, to confirm the presence of cancer cells. The tests could include removing a small portion of the suspected cancer cells through a biopsy for laboratory testing, blood tests, urine tests, colonoscopy, computed tomography (CT) scans, x-rays or magnetic resonance imaging (MRI) scans. The earlier a diagnosis of cancer is made, the greater the chance of survival (18).

Due to the high impact of environmental factors on cancer; a main focus should be on cancer prevention and not only treatment (54). Cancer prevention strategies should include the priority goals of smoking cessation, eating a healthy diet, exercising regularly, avoiding direct sun exposure and appropriate medical check-ups (54). Treatment of cancer depends on the type and severity of the cancer (77). Treatment options include surgery, chemotherapy, immunotherapy, hormone therapy and radiation therapy (77).

2.3.5 Section Summary: Chronic Diseases of Lifestyle

Chronic diseases of lifestyle include type 2 diabetes, cardiovascular disease, chronic respiratory disease and cancer (28). They are grouped together as they share similar disease pathophysiology and prevention strategies. The incidence of CDL is increasing, despite being preventable through a healthy lifestyle of eating a balanced diet, participating in physical activity and stopping smoking (78). In the next section of the review the risk factors and contributing factors of CDL will be further explored.

2.4 Cause of Chronic Diseases of Lifestyle

An unhealthy lifestyle, maintained over several years, is the cause of CDL (2,23). Examples of leading an unhealthy lifestyle include: making constant poor nutritional decisions, living a sedentary lifestyle and continuous tobacco use (25). Restoring a healthy lifestyle equips the body to fight a diseased state, making it possible to prevent, delay or reverse any CDL (5).

One of the main contributing influences to the world-wide increase in CDL has been rapid urbanisation and economic growth, resulting in dramatic changes in environment, which are ultimately exposed as changes to diet and lifestyle (79). Easier access to processed and high sugar food and beverages, with greater availability of television, internet and motorised transport, have contributed towards the higher obesity rates globally (79). Furthermore, the risk of developing CDL is calculated according to the current country of residence, and not influenced by the birth county (80). For example, the eastern world has very low cancer rates, but an individual moving from an eastern country to a western country develops the same chance of developing CDL as the westerners residing in that country (80). This emphasises the importance of environmental factors for most chronic diseases in our world (54).

By leading an unhealthy lifestyle over several years, the body develops warning signs to communicate that it is not well and heading towards a diseased state. These warning signs are known as the risk factors for CDL (42). The risk factors are either modifiable or non-modifiable risk factors (7). Risk factors for CDL provide the warning system before CDL develops and if managed early and appropriately it is possible to prevent the onset of the disease (42). Without the risk factors we would not be aware of the development of CDL, as the disease progressions is commonly not felt nor shown (9). Risk factors are measurable and easily detected with appropriate screening tests (42). The risk factors for CDL are categorised into modifiable and non-modifiable risk factors. The modifiable risk factors include: obesity, high blood pressure, high blood cholesterol concentrations, impaired blood glucose concentrations, smoking, dietary intake and not performing 150 minutes of moderate to intense physical activity weekly (9,78). The non-modifiable risk factors include: age, gender and income (7). Obesity is measurable through an increased waist circumference, high body fat percentage and high BMI (9). The normal and abnormal values or ranges for each risk factor are described in Table 2.1. Individuals often present to the health care system when they have at least one risk factor and before the onset of a CDL, therefore leaving ample opportunity to manage the risk factor and prevent the disease onset (9).

Table 2:1: Normal and abnormal values for the risk factors for CDL. Table adapted from National Department of Health (2013); Wikstrom (2015); Martin-Timon (2014); World Health Organization (2016); and World Health Organization (2011) (4,9,28,78,81).

Risk Factor	Normal	Abnormal
Blood pressure (mmHg)	< 120/80	≥ 140/90
Total cholesterol (mmol.l ⁻¹)	< 5.0	≥ 6.2
Random blood glucose (mmol.l ⁻¹)	< 7.0	≥ 7.8
Waist circumference (cm)	Females < 88 Males < 102	Females ≥ 88 Males ≥ 102
Body fat percentage (%)	Females < 32 Males < 25	Females ≥ 32 Males ≥ 25
Physical activity (minutes)	≥ 150 minutes of moderate to vigorous intensity weekly	< 150 minutes of moderate to vigorous intensity weekly
BMI kg.m ⁻²	18.5-24.9	≥ 25
Smoking	No	Yes

2.4.1. Modifiable Risk Factors for CDL

2.4.1.1. Obesity

Obesity is a state in which there is excessive adipose tissue of a sufficient extent to produce adverse health effects (82). A calorie intake that exceeds energy expenditure results in the accumulation of adipose tissue (79). Obesity is a world-wide problem, not just in the western or high income countries and has become one of the most common risk factors of CDL (79). The USA reported an estimated expenditure of USD147 billion in 2008 on obesity related complications (79). South Africa has one of the highest rates of weight gains in the world, with an average of 1.5 kg per person per year (45). Obesity can be directly linked to 5% of the world wide deaths due to CDL (42). Obesity is a known risk factor for CVD, type 2 diabetes and cancer; and obese individuals have a high incidence of multi-morbidity (9). The three commonly used methods of measuring obesity are a BMI calculation, waist circumference measurement and body fat percentage (83). It is not necessary to have abnormal findings on all three tests to be at risk of developing CDL (82).

Body mass index accounts for an individual's body mass in relation to their stature. A BMI is easy and affordable to test, and utilises very little equipment (64). A normal BMI is between 19 kg.m⁻² and 24.9 kg.m⁻². The WHO estimates that 2.3 billion people are overweight, with a BMI of above 25 kg.m⁻², and 700 million are obese, with a BMI over 30 kg.m⁻² (39). The prevalence of an abnormal BMI is increasing worldwide. In 1998, 45% of males and 72% of females had a BMI above 25 kg.m⁻² and 10 years later, in 2008, 50% of males and

75% of females had a BMI above 25 kg.m⁻² (42). A limitation of the BMI reading is that it does not account for fat distribution, nor does it separate fat mass from muscle mass. A high concentration of body fat in the abdominal region is dangerous, placing excessive stress on the body's organs (10,64). Athletes tend to have higher fat-free body mass in relation to their height, resulting in high BMI values without necessarily having excessive body fat (84).

A waist circumference measurement is a more reliable measure of visceral fat (64). Males have greater waist circumferences than females, as their body fat distribution leans toward upper body fat while females body fat is distributed more in the lower body (10). Visceral fat causes a network of inflammatory pathways leading to the development of a chronic, systemic low grade inflammation, while subcutaneous fat has little negative effect on the body (50,85). The presence of excess visceral fat is a known risk factor for the development of impaired glucose and type 2 diabetes. An increased waist circumference is a better predictor of type 2 diabetes than a high BMI (82,86).

Body fat percentage determines the amount of total body fat and is expressed as a percentage. It does not describe body fat distribution nor does it indicate muscle mass (83). There are several different measurement techniques to measure body fat percentage, with most methods requiring large, expensive equipment. The most commonly used technique is the measurement of skinfolds from different sites on the body using callipers (87). A body fat percentage reading of below 32% in females and 25% in males is considered normal (88). Females carry more subcutaneous body fat than men and require a higher essential body fat for survival than males; therefore their body fat percentage measurements are higher than males (86).

2.4.1.2. High Blood Pressure

Hypertension is a condition in which the pressure in the blood vessels is permanently high; and the higher the pressure the greater effort required of the heart to circulate the blood. Normal blood pressure is 120/80 mmHg and hypertension is diagnosed when blood pressure is higher than 140/90 mmHg; on at least two separate occasions (11). High blood pressure has a strong link to the likelihood of having a stroke and is a known risk factor for CVD (9). Restoring blood pressure to normal significantly reduces the risk of CDL (89).

High blood pressure rarely causes any noticeable symptoms resulting in the possibility of it going undetected for a long time (89). High blood pressure is responsible for 13% of deaths due to CDL worldwide. In South Africa, the prevalence of high blood pressure increases with population age. In 1998, 60% of males and 57% of females above 65 years of age had hypertension; which increased to 78% of males and 71% of females in 2008 (42). Hypertension is treated with various antihypertensive medication, which lowers blood pressure, and lifestyle modifications (89).

2.4.1.3. High Cholesterol

Cholesterol is a fatty substance that is found in all cells in the body and is vital for the body's normal functioning; however excessive cholesterol in the blood can lead to the development of atherosclerosis (61). Persistently high cholesterol concentrations strongly indicate a higher risk of CVD (39). However, Ravnskov (2016) concluded that high cholesterol and mortality are inversely associated in people over the age of 60 years (90). While an elevated cholesterol has become increasingly controversial, it is still recognised as a risk factor for CDL (15,90).

Cholesterol measurements may be divided into three groups, namely: total cholesterol, low-density lipoprotein (LDL) cholesterol and high-density lipoprotein (HDL) cholesterol. Abnormal cholesterol values are seen when the total cholesterol measures above 6.2 mmol.l^{-1} , the LDL cholesterol is greater than 3.5 mmol.l^{-1} and the HDL cholesterol is less than 1.0 mmol.l^{-1} (81). Measuring LDL and HDL cholesterol is challenging as it requires a 12 hour fast and laboratory testing. Total cholesterol can be tested in a non-fasted state using cheaper, point of care equipment resulting in cholesterol testing being available to more people. Total cholesterol is a good indication as to the state of LDL and HDL cholesterol and if the total cholesterol is abnormal then further laboratory testing is advised (20). A raised cholesterol concentration is estimated to be found in 34% of South Africans (42). The most common treatment of elevated total or LDL cholesterol concentrations is usually with diet modification and medication. "Statins" medication have been found to reduce CVD risk by 25% to 35% (61).

2.4.1.4. Impaired Blood Glucose Concentration

Impaired blood glucose concentrations are often referred to as a state called pre-diabetes, and if not controlled will result in chronic high blood glucose concentration and eventually type 2 diabetes (91). Abnormal blood glucose concentration is a strong risk factor for type 2 diabetes (52). Impaired blood glucose is responsible for 6% of deaths due to CDL worldwide (42) An estimated 11% of South Africans have raised blood glucose concentration (42).

A diagnosis of pre-diabetes is made through an oral glucose tolerance test; which involves monitoring blood glucose concentration after an ingestion of glucose following a 12 hour fast and an haemoglobin A1c finger prick test; which determines the concentration of haemoglobin bound to glucose (91,92).

2.4.1.5. Smoking

Tobacco smoke can be inhaled actively or passively and can be inhaled through smoking cigarettes, cigars or pipes (93). The life expectancy of a smoker is estimated at 13 years less than a non-smoker with a healthy weight (94). Tobacco smoking is responsible for an estimated 9% of annual deaths due to CDL worldwide (42). There has been a substantial decrease in the overall number of tobacco smokers in South Africa, with the highest prevalence of smokers in the age groups 35 to 54 years old. In 1998, 48% of males and 15% of females in the age group 35 to 54 years old smoked, which decreased to 37% and 10% respectively by 2008 (42).

Light smoking is regarded as smoking less than 20 cigarettes a day, and heavy smoking involves smoking more than 20 cigarettes a day (93). Light and heavy cigarette smokers both show an increased risk of developing a CDL; with smoking itself being the risk factor, not the number of cigarettes smoked in a day (93). Smoking cessation reduces the risk of developing a CDL (75). Nicotine has the ability to suppress the appetite and increase the energy expenditure in light smokers, commonly resulting in lower body weight in light smokers. Heavy smoking leads to increased body weight and redistribution of body fat to central obesity and insulin resistance. An increased distribution of fat centrally is influenced by the cortisol concentration in the body and smokers have been shown to have increased circulating plasma cortisol concentrations (94). Smoking is a strong risk factor for CRD, lung cancer, CVD and type 2 diabetes (69,95). Male smokers are shown to have a 23 times higher risk of developing lung cancer and female smokers a 17 times higher risk, than non-smokers (54). Smoking prevention or cessation is strongly advocated to minimise the risk of developing a CDL (9).

2.4.1.6. Nutrition

Nutrients, obtained through healthy diets, are essential to maintain normal cellular and molecular functioning (96). A healthy diet includes consuming five or more fruit and vegetables daily, removing excess salt, eating less fried foods, eating more lean meat and dairy products, consuming fish weekly, eating more whole grains, and decreasing sugar products (97,42,98). Insufficient intake of healthy foods leave an individual vulnerable to not receiving vital nutrients, resulting in nutrient deficiency (98,99). A lack of nutrients can also have a great impact on mood, activities of daily living, energy levels, intellect and physical activity (99). Nutrients are vital to equip the body to fight disease; and without sufficient nutrients, the body is vulnerable to diseases developing and growing (98).

Western diets are commonly high in saturated fat and refined carbohydrates, with large portion sizes, resulting in high incidence of obesity (99). Nutrient deficient obesity, resulting from excessive calorie intake with concurrent deficiency in nutrients, causes an inability of the body to utilise calories effectively with toxic by-products. The toxic by-products potentially contribute in increased inflammation, infection and disease

(96,99). Globally, an estimated two billion people are affected by nutrient deficient obesity (96). In South Africa, there is a high prevalence of nutrient deficient obese adults (42). Treating options for nutrient deficient obesity involves eating a healthier diet, with a diverse range of food products, multivitamin supplementation and medical intervention (96). Making healthy food choices requires education, counselling and access to healthy food (100). In South Africa, a potential barrier to making healthy food choices is the possible limited access to fresh fruit and vegetables in townships or rural areas, with smaller food stores unable to stock a wide variety of healthy food options (42,100).

2.4.1.7. Physical Inactivity

Physical inactivity is described as the inability to meet the WHO's recommendation of 150 minutes of moderate to vigorous intense physical activity per week (97). The prevalence of physical inactivity is the highest of all the risk factors, with females being more inactive than males (101,102). In South Africa, an estimated 77% of females and 62% of males are physically inactive (42). Globally, physical inactivity can be directly linked to 6% of deaths due to CDL. An estimated 10% of all CDL worldwide could be avoided if physical activity levels increased moderately without any other additional lifestyle changes (32,42). Physical activity is able to increase the body's energy expenditure balancing the energy consumed from food (103). There is also a steep decline in physical activity levels as the population increases with age (39).

A direct link has been shown between physical inactivity and an increased risk of breast, colon, prostate and pancreatic cancer. Sedentary females who developed breast cancer showed higher serum concentrations of estradiol, lower concentrations of the hormone binding globulin, greater body fat percentages and higher serum insulin concentration at time of diagnosis compared to females who were participating in regular physical activity (54).

One of the theories for an increased risk of colon cancer with inactivity is believed to be due to the increased time it takes for gastrointestinal emptying, thereby allowing more time for carcinogenic substances to be in the gastrointestinal system (54).

Physical activity provides a wide spectrum of health benefits in reducing the risk factors for CDL and the prevalence of CDL as shown in Table 2.2. There is strong scientific evidence that physical activity reduces the risk of early death, coronary heart disease, stroke, type 2 diabetes, breast and colon cancer, high blood pressure, obesity, depression, loss of cognitive function and injurious falls (23,104,105). The physiological benefits of physical activity include increased cardiovascular and pulmonary functioning, muscle strength, muscle endurance, muscle and joint flexibility, bone strength and decrease or maintenance of body weight (12,103,106,107).

Table 2:2: Summary of studies investigating the effects of physical activity on CDL and the risk factors for CDL.

Study	Study design	Sample size	Participants	Duration of trial	Exercise type and intensity	Effect of exercise
Church et al 2007(108)	Randomised dose-response trial	464 females	Postmenopausal, sedentary females, 45 to 75 years old	6 months	Aerobic, varied intensity	Decreased waist circumference, despite no weight change
Dalleck 2009 (109)	Randomised dose-response trial	33 females	Sedentary 45 to 75 years old	12 weeks	Aerobic, varied intensity	Decrease in body fat percentage, body mass, waist circumference and HDL cholesterol
Dimeo 2012 (110)	Randomised controlled trial	50 participants	Sedentary males and females with resistant hypertension	12 weeks	Aerobic, moderate to vigorous	Decreased blood pressure
DiPietro 2006 (111)	Randomised controlled trial	25 females	Sedentary females 60 years and older	9 months	Aerobic mild, moderate and vigorous	Improved insulin sensitivity. Greatest in the vigorous aerobic group
Finucane 2010 (112)	Randomised controlled trial	100 participants	Sedentary males and females 60 to 75 years old	12 weeks	Moderate to vigorous	Decreased weight, BMI, waist circumference
Friedernreich 2011 (113)	Randomized controlled trial	320 participants	Sedentary males and females 50 to 74 years old	1 year	Moderate to vigorous	Decreased insulin resistance, decreased metabolic biomarkers associated with breast cancer
Glenn et al 2015 (35)	Prospective analysis	15645 participants	Males and females 40 to 79 years old with adult onset diabetes	5 to 12 years	Moderate to vigorous	Increased physical activity linked to decreased mortality risk and increased sedentary time associated with an increased mortality risk

Study	Study design	Sample size	Participants	Duration of trial	Exercise type and intensity	Effect of exercise
Lin et al 2015 (114)	Meta-analysis	7487 participants from 169 articles	Males and females 18 to 90 years old	Mean 12 weeks	Varied forms of moderate to vigorous	Lowered total cholesterol concentration, increased HDL concentration, improved fasting glucose concentration, increased insulin sensitivity and decreased systemic inflammatory markers
Nordby 2012 (115)	Randomised controlled trial	60 participants	Sedentary overweight males 20 to 40 years old	12 weeks	Aerobic moderate to vigorous	Decreased weight, increased insulin sensitivity, decreased abdominal fat
Nocon 2008 (116)	Systematic review	33 articles including 883 372 participants	Males and females 16 to 94 years old	4 years to 20 years	Aerobic and anaerobic moderate to vigorous	35% decrease in cardiovascular mortality, 33% decrease in all-cause mortality
O'Donovan 2005 (117)	Randomised controlled trial	42 participants	Sedentary males 20 to 35 years old	24 weeks	Aerobic moderate or vigorous	Increased pulmonary function, decreased LDL and total cholesterol
Oguma 2004 (118)	Systematic review	30 articles	Females 15 to 101 years old	5 to 32 years	Moderate to vigorous	Decreased CVD, CHD and stroke risk
Swift 2014 (103)	Literature review	Unknown	Unknown	6 weeks to 5 years	Aerobic moderate to vigorous	Decrease or maintenance of body weight, decrease fat mass
Thompson 2010 (119)	Randomised controlled trial	41 participants	Sedentary males	26 weeks	Aerobic moderate to vigorous	Decreased inflammatory markers
Weston 2013 (107)	Meta-analysis	10 articles with 273 participants	Unhealthy, sedentary males and females	Unknown	Aerobic moderate to vigorous	Increased cardiorespiratory fitness

2.4.2. Non-modifiable Risk Factors for CDL

2.4.2.1 Age

The prevalence of CDL and co-morbidities increases with the population age (9,120). Risk factors that are present from a young age may take several years to develop into CDL, commonly resulting in an older age at diagnosis of CDL (121). Pre-existing risk factors have a higher probability of developing into CDL with increased age (122). However, a high prevalence of CDL is emerging in teenagers and young adults (123). The risk factors for CDL which are commonly identified after years of unhealthy living are now presenting in young adults. This results in young adults being susceptible to developing CDL and it cannot be assumed that individuals are immune from developing CDL due to their young age (123).

The risk for CVD doubles with every 10 mmHg increase in systolic blood pressure in the age group of 55 years to 64 years (122). Chomistek et al (2015) determined the average age at diagnosis of CVD in females was 50 years old (2). Conversely, Stevens et al (2009) found a significant growth in BMI in younger years that stabilises by the age of 50 years, where after it slowly decreases (10). However, the fat distribution changes from predominantly adipose fat before the age of 50 years to a higher proportion of visceral fat after the age of 50 years, resulting in an increased waist circumference (10,83,120). In South Africa, 77% of individuals over the age of 50 years have hypertension, 72% of females over the age of 50 years are overweight, and a significant decline in physical activity levels as the population age increases is found (124,125). A slightly higher BMI in people over the age of 65 years has a potentially protective function, where individuals with a BMI of above 23 kg.m⁻² but below 30 kg.m⁻² have shown improved cognitive functioning, decreased sign of osteoporosis and decreased depressive symptoms than individuals with a BMI below 23 kg.m⁻² (121)

Physiological changes associated with aging include a decrease in muscle strength and muscle mass, a decrease in production of growth hormone and testosterone, and decreased responsiveness to thyroid hormones (121,126). An increased risk of disability and loss of function is associated with increased age (122).

Regular physical activity in an older age is protective against the loss in muscle strength and muscle mass and is able to maintain good muscle quality. Good quality muscle prevents against fat deposits in muscle, which is favourable as increased fat deposits in muscle is linked to insulin resistance (126). Therefore, physical activity maintained into older age reduces disability, maintains function and provides a survival advantage (126,127).

2.4.2.2. Income

Food prices and food affordability are important factors in determining food choices and healthy eating options, especially in South Africa where there is a high percentage of low income households. Healthier diets are more expensive than unhealthy diets as high energy, processed foods with added sugar are much cheaper than nutrient rich foods (100). In South Africa, food can account for 38% to 71% of the total household expenditure (128,129). Any change in food prices may result in a decline in the quality of food purchased in favour of cheaper, high energy- but low nutrient based foods (128). Temple (2010) found that a healthier diet in South Africa cost between R5 to R10 more per person per day than a diet commonly eaten by low income households (100).

Household income is a measure of poverty (8). The South African government has classified the income per household into several categories, with no income being R0 per household per month, low income R1 to R19 200 per household per month, middle income R19 201 to R307 200 and upper income as above R307 200 per household per month (8). In the 2011 South African census, 48% of the population was categorised as middle income household, 29% as low income households, 16% as no income households and only 7% as high income households (8). Individuals from low income households in South Africa are considered poor, and therefore may need financial assistance with access to health, education, basic services and welfare (8). A higher percentage of a low income households monthly income will be spent on food, compared to a middle income household; and a change in food price can have considerable effect on a low income household purchases (128). Jolliffe (2011) showed that for the past 35 years there has actually been no link between poverty and overweight or obesity; and that the commonly held belief that poor people have higher BMI's is untrue. However, being overweight or obese as a poor person has greater complications in South Africa as access to healthcare is limited and continuous care is often not possible (129). Poverty increases the possibility of being exposed to behavioural factors leading to an increase risk of CDL (33). Poverty decreases the chance of making healthy eating choices (33).

Poor people have less access to nutritious foods and areas or opportunities for safe physical activity (42). Therefore, in the South African context, combating CDL needs to also include poverty alleviation, job creation, improved public transport and equal health services (42).

2.4.3. Multiple Risk Factors

The presence of a single risk factor is important in the potential development of CDL. However, multiple risk factors are often found in individuals at risk for CDL. The lifestyle and behavioural habits associated with the risk factors frequently cause one risk factor to lead to another risk factor (130).

Van Zyl et al (2012) examined 694 rural and 565 urban participants to determine the prevalence of risk factors for CDL in rural and urban settings in South Africa. Both settings had distinct risk factors profiles, and there was a high proportion of undiagnosed CDL in both urban and rural settings. Hypertension rates were at 62.6% in the rural communities and 43.8% in the urban communities and majority had uncontrolled hypertension despite being on hypertensive medication. There were high obesity rates, with 57.6% of rural females and 48.6% of urban females being classified as either overweight or obese. Physical inactivity levels were significantly higher in the urban group with 66.5% reporting a sedentary lifestyle, compared to 27.3% in the rural community (39). In the urban communities, the most common risk factors were physical inactivity and obesity. In rural communities, the most common risk factors were hypertension and obesity (39).

Wikström et al (2015) assessed the data from 32 972 individuals over a 10 year period, to determine which risk factors have a high predisposition for the development of multiple CDL, or multi-morbidity. Smoking, obesity and physical inactivity resulted in the greatest risk of multi-morbidity. In addition, hypertension was also a strong risk of multi-morbidity in the type 2 diabetics. Not making sufficient changes to these risk factors after the diagnosis of a single CDL results in a high possibility of developing further CDL (9).

Physical inactivity and obesity often coexist, with sedentary behaviour commonly leading to obesity; and similarly, obese individuals are less likely to participate in physical activity (130,131). Conversely, maintaining physical activity levels is protective against weight gains (23). Long et al (2015) evaluated 33 120 middle aged individuals and determined that maintaining moderate physical activity, a normal BMI and not smoking significantly decreases the risk of developing type 2 diabetes. The incidence of type 2 diabetes increased 14% for every 1.5 kg.m⁻² increase in BMI above 25 kg.m⁻², regardless of age, socioeconomic status and family history (132).

Furthermore, Hamman (2006) revealed that physical activity without weight loss, in individuals with abnormal BMI values, has significant protection against the risk of type 2 diabetes. However, a weight loss of greater than five kilograms with physical activity increased that protection against the risk of developing type 2 diabetes (133). Increasing physical activity levels without making nutritional changes, has major health benefits in decreasing diastolic blood pressure, decreasing LDL cholesterol, stabilising blood glucose concentration and protection against premature death (17).

Females who maintain physical activity from young adulthood into middle age gain an average of 6.1 kg less than females who do not maintain their physical activity programme (134).

Chomistek et al (2015) assessed the incidence of CVD in 69 247 females over an 18 year period and determined the prevalence of risk factors precluding the CVD incident. Over the 18 years, 456 females had CVD incidents and 31 691 females had at least one risk factor for CVD, with hypertension and high cholesterol being the most common risk factors (2). The females who had a CVD incident had physical inactivity and a high BMI as their most common risk factors. The risk for developing a CVD increased with every additional risk factor (2). Similar findings were observed in a study of 42 847 males aged 40 to 75 years in the USA (135). The males with no risk factors had the lowest risk profile for CVD. The risk for CVD increased proportionally with the addition of each risk factor (135).

Each of the risk factors is important and having only one risk factor is enough to leave an individual vulnerable to developing CDL (39). However, the more risk factors an individual has, the higher the risk for developing CDL, as each risk factor is an independent risk factor for CDL (131). Regardless of how many modifiable risk factors an individual may have, the non-modifiable risk factors may further increase their risk of developing CDL (7).

2.4.4 Section Summary: Causes of Chronic Diseases of Lifestyle

Leading an unhealthy lifestyle over many years is the cause of CDL. The risk factors are the warning signs that the body is not well and when present over several years have the potential to develop into CDL (2,4,9,23). The risk factors for CDL, including obesity, high blood pressure, increased BMI, increased waist circumference, high body fat percentage, elevated blood cholesterol, impaired blood glucose, smoking, dietary intake and inactivity are preventable, reversible and treatable. Each risk factor is important and can lead to a chronic disease of lifestyle, however each additional risk factor increases the potential of developing a chronic disease of lifestyle (2,39,130). The non-modifiable risk factors contribute towards developing CDL through older age and low income (4,97,98,100). Endurance running is one manner in which to eliminate the inactivity risk factor (28). Endurance running will be further explored in the following section.

2.5 Endurance Running

Endurance running is a popular form of aerobic physical activity that is convenient and growing in popularity worldwide (13,29). Endurance running participation has increased over the past 20 years, with approximately 19 million people completing a road race of any distance in 2013 (13). Endurance running is convenient and easily accessible as it requires minimal equipment and can be performed from any location at a convenient time (29,136). Endurance running is classified as running distances ranging from three kilometre upwards, regardless of what speed or duration it takes an individual to complete the run (13). Therefore, running is a sport that the majority of South Africans will be able to participate in, either socially or at an elite level.

2.5.1 Volume of Endurance Running

The WHO recommends that an adult should perform a minimum of 30 minutes of moderate to vigorous intensity physical activity for five days of the week; or 150 minutes of moderate to vigorous intensity physical activity each week, of which at least 75 minutes should be aerobic exercise. This has been widely accepted across the world (28).

However, regular participation in running that does not fulfil the WHO weekly time requirements has still shown beneficial health effects (13). Decreased mortality rates have been found in runners who only complete 30 to 59 minutes per week (137). Some physical activity is always better than no physical activity, and when beginning physical activity from a previously inactive state, significant health benefits are seen with volumes that are much lower than the WHO recommendations (104). There is also an upper limit at which no further health benefits are seen and the risk of injuries and a cardiovascular event becomes significantly higher; however, this limit varies amongst runners and is difficult to predict. Lee (2017) discovered the first signs of this limit to be running in excess of 50 kilometres per week; however, the majority of the runners did not displayed negative consequences, indicating they had not all reached their limit (13).

2.5.2. Duration of Endurance Running

The runners who begin running early in life and continue to run throughout their life have the greatest longevity benefits (13). Health benefits of an endurance running programme can be seen after only eight weeks of training, but maximal health benefits are seen one year after beginning an endurance running programme. In the first year of endurance running, the longer the duration of the running programme the greater the health benefits received. Running for a duration of greater than one year maintains the health benefits achieved in the first year (136).

2.5.3 Intensity of Endurance Running

The intensity of endurance running describes how hard an individual worked to complete the run (104). Endurance running is generally performed at moderate or vigorous intensities. Intensity is difficult to prescribe as it is difficult to measure (16). The best way to measure intensity is through a peak aerobic power test such as maximum oxygen consumption (VO_2 max) test. However, a VO_2 max test requires expensive equipment and expert administration making it an impractical test for majority of runners (16). Other common forms of intensity monitoring and prescription include heart rate monitoring and the modified Borg scale of the rate of perceived exertion (RPE) (16). Heart rate monitoring requires a heart rate monitor and is based on the maximum possible heart rate an individual can obtain. The modified Borg scale is a freely available, self-reported scale from 6 to 20 ranging from “no exertion at all” to “very, very hard”. Moderate intensity involves running at 40% to 60% of an individual’s VO_2 max, maintaining a heart rate between 50% and 75% of the maximum heart rate, or 12 to 13 on the modified Borg scale. Vigorous intensity is running at 60% to 100% of VO_2 max, reaching a heart rate above 76% of the maximum heart rate, or 14 to 20 on the modified Borg scale (16).

Running at either a vigorous or moderate intensity results in extensive health benefits (104). Energy utilisation is greater in vigorous physical activity, however a moderate intensity run with a longer duration can equate to the same energy utilisation as a vigorous intensity run of short duration (104).

2.5.4 Physiological Effects of Endurance Running

Running significantly reduces the risk of morbidity and early mortality resulting in runners having an increased life expectancy with less disability (29). Running increases life expectancy by an average of three years; and performing half of the recommended weekly physical activity levels still increased life expectancy by 1.8 years (13). Running has many health benefits to the cardiorespiratory, musculoskeletal, metabolism, endocrine and neurological systems (13,131,138,139).

Endurance running affects the risk factors for CDL through a decrease in cholesterol and blood pressure concentration, improved body composition, increased insulin sensitivity, and stabilisation of blood glucose concentration (13). The human body responds to endurance running according to the length and regularity of the physical activity (131). Despite the many beneficial health outcomes of endurance running, there are risks involved in endurance running (136). Endurance running has a high prevalence of musculoskeletal injuries, gastrointestinal (GI) problems, environmental illnesses, exercise associated hyponatremia (EAH), respiratory and cardiovascular problems (140,141). Notwithstanding the known risks for exercising, the benefits far outweigh the risk of running in most of the population (137).

2.5.4.1 Cardiorespiratory System

Running for five months or more has been shown to increase the cardiorespiratory function by increasing VO_2 max by 15% to 25%; and conversely, inactivity through bed rest can decrease VO_2 max by 26% (19). An increased cardiorespiratory fitness shows a well-functioning oxygen transport and utilisation system, improved autonomic tone of the blood vessels, improved cell functioning and the body's ability to breakdown clots (19). A decrease in atherosclerosis, caused by improved arterial dilation and endothelial functioning, is an effect of endurance running (131).

Zilinski (2015) determined that non-elite runners training for a marathon had left ventricular, right ventricular and left atrial dilation, with an improved left ventricular resting phase. This allowed the heart to receive and pump more blood per beat with the heart resting more efficiently between each beat. The exercise capacity of the cardiorespiratory system, such as VO_2 max, and exercise performance were significantly improved for all runners (139).

The greatest risk to endurance running is sudden cardiac death (SCD). Sudden cardiac death occurs during or immediately after aerobic exercise in individuals with no known history of heart disease (137). Eighty three to 86% of reported cases occurred before the age of 40 years, with a higher incidence in males (137). The incidence of SCD is very low with Schwabe et al (2014) reported an overall incidence of 0.05 per 1 000 runners (136,141). The cause of SCD may be from fragile atherosclerotic plaque that shears off during exercise or from an unknown underlying disorder of the heart muscle or conduction system (137). Another possible cause of SCD is due to right ventricular overload causing right ventricular dysfunction and an increase in pulmonary artery pressure (142). Although the very rare risk of SCD is increased with running, the long term benefits of running decreases the risk of a CVD so substantially making the risk of a cardiovascular event significantly less in runners than in the inactive population (137). Exercise-induced bronchospasm is the most commonly noted respiratory condition associated with endurance running (140).

2.5.4.2. Musculoskeletal System

The exercise-regulated muscle gene peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1a) is responsible for the adaptations seen in skeletal muscle during endurance running. Proliferator-activated receptor gamma coactivator 1-alpha is expressed during running, but rapidly stops once the running has ceased in untrained individuals, while elevated PGC-1a concentration are seen constantly, outside of the running time, in individuals who perform regular physical activity. The primary control to the changes in skeletal muscle is by the PGC-1a gene, which responds to a decrease in adenosine triphosphate (ATP) and altered fuel demands and is responsible for converting muscle fibres into type I and IIa during endurance running.

The PGC-1 α gene is also responsible in aiding the depression of the systemic inflammatory effects through mediating the skeletal muscle production and release of myokines (131). A muscle contraction produces and releases myokines. If muscles are not contracted sufficiently they are not able to produce the necessary mediators to facilitate the anti-inflammatory effect (50,131).

The release of myokines during and after endurance running causes a localised increase in the uptake of glucose and fat oxidation within the muscle, and a global response of increased muscle growth, increased lipid metabolism and increased bone mineral content (50). Endurance running activates and strengthens skeletal muscle, which also has an endocrine function by producing and releasing cytokines, thereby raising the systemic concentration of cytokines, which have an anti-inflammatory action (17). Therefore regular moderate to vigorous intensity endurance running has a systemic anti-inflammatory effect (50,131).

The oxidative capacity of muscle refers to an increase in the number and activity of mitochondria in muscle cells and an increase and reorganisation of the muscle contractile proteins, known as myosin heavy chain (MHC) isoforms. Muscle fibres can be explained according to their MHC isoforms structure as either fast twitch, type IIa, IIb and IIx, or slow twitch, type I (143). Importantly, type IIa, IIx and I are found in human skeletal muscle, with type IIb muscle fibres only found in animal skeletal muscle (143).

Type I and IIa muscle fibres rely mainly on oxidative pathways to sustain their activity (143). Endurance running causes a MHC reorganisation from type IIx muscle fibres to type IIa and improves the functioning of the type I muscle fibres. Therefore endurance running increases the number of type I and IIa muscle fibres and conversely an increase in the number of type I and IIa muscle fibres increases the endurance capacity of the muscles (131). Type I and IIa muscle fibres have a red appearance and are characterised by high mitochondria volumes and vascularisation and increased myoglobin (131). They are slower to contract and resistant to fatigue with low peak forces generated allowing an endurance runner to keep going at the same pace for extended periods of time (131). Adaptations to skeletal muscle from running allow the muscle to more efficiently use products for ATP production, the energy system, resulting in a quicker uptake of glucose and fatty acid oxidation. The faster glucose uptake results in blood glucose stabilisation and fatty acid oxidation prevents fatty acid from developing into atherosclerosis (143).

Endurance running increases bone mineral density by stimulating the rate of new bone formation, decreasing the rate of bone reabsorption and maintaining the correct balance of minerals in the bone. However, running excessive distances each week for extended periods of time may be associated with a loss in bone mineral density. Runners who run in excess of 80 to 100 kilometres per week are at risk of diminishing their bone mineral density as a result of excessive bone turnover (144).

Musculoskeletal injuries, resulting in an impaired ability to continue running, are the most common ailment of the musculoskeletal system. Musculoskeletal injuries can result from an acute injury or a chronic injury. Chronic injuries are usually as a result of excessive load over a period of time (140). The incidence of musculoskeletal injuries is approximately 30 injuries per 1000 hours of running (136).

2.5.4.3. Metabolism

Adipose tissue plays an important role in metabolism through storing and releasing energy. During periods of high-energy demand such as running, adipose tissue releases the stored energy into the blood system. Low energy periods, such as inactivity and consuming food, results in excess energy being stored in adipose tissue.

An imbalance between the low and high energy periods can result in excess adipose tissue formation to store the oversupply of energy (138). Endurance running increases the metabolism of adipose tissue allowing for maintenance or decrease in the volume of stored adipose tissue (136).

Skeletal muscle needs glucose to sustain the energy needed for an endurance run. Glucose needs to be transported to the muscle, otherwise skeletal muscle will be depleted of glucose within seconds. One pathway that restores muscle glucose is a muscle contraction, as this stimulates the glucose uptake into the muscle, which can be independent of insulin (143).

Therefore, it is possible for a run to stabilise blood glucose concentration in insulin resistant individuals. Once a run is complete, skeletal muscle continues to utilise an increased amount of glucose for up to 48 hours (143).

2.5.4.4. Endocrine System

Running places stress on the body due to the high physical demand of running. The stress causes the release of several stress hormones, namely cortisol, epinephrine and growth hormone. These hormones are vital to maintaining the body in a state of homeostasis by stimulating the release of stored energy thereby increasing the supply of energy to the body (138). The stress hormones all cause an improved immune systemic response, thereby boosting the immune system and enabling the body to fight diseases appropriately (131). However, overtraining can cause a decrease in the immune system response and increased susceptibility to infections (145). In addition, one severe but avoidable consequence of endurance running is exercise-associated hyponatremia (EAH). Exercise-associated hyponatremia is the overconsumption of fluids beyond which the body is able to excrete resulting in fluid overload and excessive dilution of the serum sodium (146). The hormone arginine vasopressin (AVP) regulates body water homeostasis. Endurance running has been shown to result in an increase of AVP production resulting in the body holding onto fluids (147).

Exercise-associated hyponatremia is a life-threatening condition, requiring urgent medical attention; and several reported cases of death have occurred following endurance events (146).

2.5.4.5 Neurological System

Running affects the autonomic nervous system (ANS) by decreasing sympathetic activity and increasing parasympathetic activity, which results in a decrease in heart rate and blood pressure (148). The sympathetic ANS releases neurotransmitters and hormones, which increase the contraction and frequency of a heart beat while the parasympathetic ANS has the opposite effect (148).

Brain derived neurotrophic factor (BDNF) is a protein that facilitates growth, protection and regeneration of nerves, cell survival and formation, retention and recall of memory. It is produced in the central nervous system as well as in blood vessels. A decrease in BDNF is thought to be a risk factor for Alzheimer's disease and major depression, as these individuals have lowered BDNF concentration (149). A lowered BDNF has also been found in type 2 diabetics as elevated blood glucose reduces the BDNF found in blood (149). Endurance running increases the release of BDNF from the brain during running, which remains elevated even when at rest (149).

Running also improves cognitive function and decreases depressive symptoms (13). Running increases positive feelings of well-being. Runners have shown significantly fewer symptoms of depression, anger and stress than inactive individuals. Running is able to assist in the treatment of clinical depression by reducing the symptoms of clinical depression. Runners have shown greater performance on tasks involving learning, attention and memory (150).

2.5.4.6. Gastrointestinal System

Gastrointestinal (GI) problems are a common complaint during endurance running (151). Gastrointestinal symptoms include nausea, vomiting, abdominal cramping, diarrhoea or GI bleeding resulting from a range of causes such as mechanical injury, incorrect fluid ingestion, medication or changes in GI motility (140). The presence of a GI complaint can range from mild, where a run is able to be continued; to severe, where a run has to be halted and medical attention required. During endurance running, splanchnic hypo-perfusion results in decreased blood flow to the gastrointestinal system due to increased demands on the heart, lungs and musculoskeletal systems (151).

Mechanical damage to the gastrointestinal system results from the high impact involved in running where the jostling of the system can result in intestinal lining damage. Foods, such as those with high fructose concentrations, energy drinks or supplements, as well as dehydration can exacerbate the gastrointestinal symptoms. The use of non-steroidal anti-inflammatory drugs is known to cause a significant increase in gastrointestinal problems during endurance exercise (151).

2.5.5. Section Summary: Endurance Running

Endurance running is a highly recommended form of aerobic physical activity due to the many beneficial effects it has on the body. Maintaining a weekly volume of at least 150 minutes at a moderate to vigorous intensity for a duration of a year is sufficient to receive the beneficial adaptations that running causes on the body (28,136). The effect of running on the body is evident through the changes to the cardiorespiratory, musculoskeletal, metabolism, endocrine and neurological functioning. Running does involve some risks; however, the benefits generally outweigh these risks and endurance running is recommended as an important form of physical activity (13,131,138,139,141). The following section will review the benefit of endurance running specifically relating to CDL and the risk factors for CDL

2.6. Endurance Running and Chronic Diseases of Lifestyle

Endurance running significantly reduces the risk of mortality and morbidity (136). However, limited data are available regarding the disease profile of endurance runners. The majority of research focuses on inactive individuals who begin running as a means to manage or prevent risk factors or CDL; and does not focus on an assumed healthy population of endurance runners to determine their health profile (152). Hoffman et al (2014) examined 1212 ultra-marathon runners to determine their health profiles, and found that the ultra-marathon runners were healthier with fewer medical conditions in comparison to the general population. These findings are summarised in Table 2.3 (152,153).

Table 2:3: Health profiles of ultra-marathon runners. Table adapted from Hoffman and Kirshnan (2014); and U.S. Department of Health and Human Services (2012) (152,153).

CDL and Risk Factor	Diagnosis	Prevalence in ultra-marathon runners (%)	Prevalence in general population (%)
Type 2 diabetes	Type 2 diabetes	0.7	8.9
CVD	Coronary heart disease	0.7	6.6
	Stroke	0.2	2.7
Chronic Respiratory Disease	Chronic bronchitis	2.3	4.4
Cancer	Prostate	0.2	1.0
	All cancer	4,5	8.2
Risk Factors	Obesity	4.3	62
	High blood pressure	7.6	26

Williams (2009) found that higher running mileage, such as marathon running, is associated with decreased prevalence and incidence of type 2 diabetes, high blood pressure and high cholesterol (154). Marathon runners consumed less blood pressure- and cholesterol-lowering medication than the general population, irrespective of their BMI (154). When accounting for BMI, the marathon runners with a normal BMI had a significantly lower incidence of type 2 diabetes, high blood pressure and high cholesterol than the runners with abnormal BMI (154).

Hespanhol-Junior (2015) also examined the health benefits of endurance running in a previously inactive population and reported significant reductions in body mass, body fat percentage and cholesterol concentration with an increase in cardiorespiratory fitness after one year of running (136).

Further, Lee et al (2014) conducted a prospective, observational cohort study over a 28 year period with 55 137 participants to determine the effect of physical activity on different health outcomes. They classified the participants as either runners or non-runners; and for the runners, they further grouped them according to time, frequency, distance and speed (29). Three major findings were established. Firstly, runners had a 30% and 45% lower risk of all-cause and CVD mortality compared to non-runners; secondly, running at any dose, even the lowest dose group, had significant health benefits; and thirdly, persistent running over an period of time was associated with increased mortality reduction (29). Therefore, running has important beneficial effects and should never be halted but rather adapted to different, more manageable volume of running (29).

In addition, in patients with COPD, Stav (2009) reported a pulmonary rehabilitation programme involving endurance running over three years inhibited the progression in airway obstruction and increased pulmonary endurance (155). Endurance running does not reverse airway obstruction but slows the progression (68,155). An increase in secretion removal and a decrease in exacerbations of COPD were seen over the three years (155).

Finally, post-menopausal females participating in endurance running had lower oestrogen and androgen concentration, which are elevated in breast cancer. Endurance running lowers the risk of developing cancer by stabilising blood glucose concentration, as insulin resistance is a biomarker for breast, colon, pancreas, endometrial, and stomach cancer. Endurance running strengthens the immune system enabling the immune system to recognise and eliminate abnormal cells more efficiently thereby preventing cancerous growth (145).

2.7 Summary of the Literature

Chronic diseases of lifestyle have become a serious concern globally, and result in more deaths than infectious diseases (36). Health care in South Africa is challenged by the high incidence of CDL, infectious diseases, and crime and trauma related injuries, causing a high prevalence of multiple morbidities (22,34,40–42). Chronic diseases of lifestyle, caused by an unhealthy lifestyle, all share similar disease causes and progression (2,49). The risk factors of CDL enable the detection, prevention or reversal of a diseased state (9,42,78,130). Contributing factors provide additional understanding of individuals that may be at higher risk of developing CDL due to their presence (97,100,129,156). Knowledge of the risk factors and contributing factors create a deeper understanding of CDL and attempts to combat the growing worldwide prevalence of CDL (1,97). Endurance running has numerous health benefits, making it an efficient and successful manner to eradicate physical inactivity (13,68,136,137,140,157). Individuals who are physically inactive are at high risk of developing CDL; however, research on the prevalence of CDL in individuals who are physically active, particularly in the South African context, is limited (29,136,145,152,154,155).

The limited research has provided the necessity for this study to determine the prevalence of risk factors and CDL in a physically active group of endurance runners in South Africa.

Chapter 3: The Prevalence and Risk Factors of Chronic Diseases of Lifestyle in Endurance Runners

3.1 Introduction

The incidence of CDL has rapidly increased over the past several years, making this group one of the highest global causes of disability and mortality (37). Early identification and management of risk factors for CDL is essential to prevent disease onset and progression (6). Regular participation in physical activity is important to prevent CDL, and endurance running is a popular form of physical activity (30). Endurance runners are generally perceived as 'healthy'; however, little is known about the prevalence of CDL and associated risk factors in this South African population. Endurance runners may experience the health benefits from running, but they have the potential to remain at risk for the development of CDL if they have not also addressed other risk factors and contributing factors for CDL (32). Accordingly, the aim of this study was to determine the prevalence of chronic diseases of lifestyle and associated risk factors in South African endurance runners. The specific objectives of this study have been described in Section 1.1.2 (page 3).

3.2 Methods

3.2.1 Research Design and Participants

This study had an analytical, cross-sectional design. Two hundred participants were recruited for the study through local running clubs and running races in the greater Nelspruit, Mpumalanga and Cape Town, Western Cape area. The regions that were included in this study were based on the location of the student researcher during the study period. Running club secretaries were emailed the advertisement and were requested to distribute it among their members (Appendices I and II). The student researcher also attended the club events, such as weekly club runs and time trials, and running races to recruit volunteers. Convenience sampling was used, as volunteers who met the study inclusion criteria were included on a "first come, first served" basis.

3.2.2 Inclusion Criteria

Male and female runners aged between 18 and 69 years of age, and who self-identified endurance running as their main sport were included in the study. Participants were required to run at least three kilometres twice a week for at least one year prior to inclusion in the study. This ensured the minimum requirements were met to be defined as an endurance runner and to receive the potential health benefits of endurance running (13,104,136,137).

3.2.3 Exclusion Criteria

Female runners who were pregnant or who were less than six months post-partum were excluded from the study, due to the physiological changes that may occur during pregnancy such as increased waist circumference, weight and blood pressure (158). Runners were also excluded if they reported a two-week or more rest period from running training in the three months prior to the study, as any prolonged change in habitual training loads might alter the influence of endurance running training on risk factors for CDL (159). Participants were also excluded if they did not complete the questionnaire component of the study or the physical testing component of the study respectively, as well as if they indicated brisk walking as their main sport.

3.2.4 Sample Size Calculation

Data from a previous hypertension prevalence study were used to ensure that the sample size would provide sufficient statistical power (160). The prevalence of hypertension was selected as the outcome measure that would be used to determine the required sample size for this study. Required sample size for hypertension was calculated using a smallest relative risk of 5, and disease incidence of 10%, and a prevalence of exposure of 30%. With statistical significance accepted as $p < 0.05$, sample sizes of 134, 180 and 222 participants provided 80%, 90% and 95% statistical power for hypertension respectively. Therefore, 200 participants were recruited for this study to ensure sufficient statistical power.

3.2.5 Measurement Instrumentation

3.2.5.1 Informed Consent Form

All participants were requested to complete an informed consent form before taking part in the research study (Appendix III). The informed consent form contained information regarding the background to this study, and explained why the research was necessary and important. All testing procedures were clearly explained. The benefits and risks of taking part in the study were described and the right to withdraw from the study at any point was emphasised.

3.2.5.2 Study Questionnaire

The study questionnaire was comprised of the International Physical Activity Questionnaire (IPAQ) short questionnaire, the modified Borg scale for perceived exertion, the five-a-day community evaluation tool (FACET), as well as a self-designed component to determine socio-demographic characteristics and running training characteristics (Appendix IV). The questionnaire was completed by the participants prior to the anthropometric testing.

Van Poppel et al (2010) showed good validity of the IPAQ short questionnaire in determining levels of activity (161). The modified Borg scale for perceived exertion was used to standardise participant responses to questions regarding exercise intensity and to differentiate between moderate and vigorous intensity activity (162). The FACET has also shown acceptable validity in determining fruit and vegetable intakes (163). As some of the previously validated components of the questionnaire were only available in English, and with the time constraints associated with the minor dissertation, we decided not to translate the questionnaire into other languages. However, a research assistant was available to assist participants to complete the questionnaire if any difficulties with reading or comprehending English were identified.

3.2.5.2.1 Questionnaire Validation

The self-developed section of the questionnaire was used to determine sociodemographic and running training characteristics. The study questionnaire was developed in conjunction with the research protocol. Once formal ethical approval had been granted, the questionnaire was submitted for review by a panel of four experts in the physiotherapy and endurance running fields to determine content and construct validity. The expert panel assessed whether the questionnaire was clear, easy to understand and assessed the appropriate information without any possibility for misunderstandings. Any feedback and recommendations given by the panel of experts was addressed and amendments were made until the final version was accepted by all members of the expert panel.

3.2.5.3 Blood Pressure

Blood pressure was assessed using an automatic blood pressure monitor (Omron M6 Comfort IT Upper Arm Blood Pressure Monitor). Participants were required to be seated for three minutes before blood pressure was measured. Systolic and diastolic pressure were recorded. The validity and reliability of the Omron M6 Blood Pressure measuring device has been previously established (164).

3.2.5.4 Finger Prick Test: Blood Glucose and Blood Cholesterol

Blood glucose and cholesterol concentrations were determined by sampling capillary blood from a finger prick (165). Participants were requested to fast for three hours prior to testing. The three-hour fast was required to standardise the test in a non-fasted state. Angelantonio et al (2009) showed that a lipid assessment can be simplified to a total cholesterol or HDL cholesterol concentration test in a non-fasted state, and this test is accurate for screening for risk factors for vascular disease (20). Wannamethee et al (2011) determined that testing blood glucose and cholesterol in a non-fasted state is an accurate screening test to determine potential risk factors for CDL, as the individuals at risk were identified correctly through a fasted and non-fasted state (166).

Testing was performed with participants in a seated position. The finger selected for the capillary blood sampling was first cleaned with an alcohol swab and left to dry for twenty seconds. The finger prick was performed using an Accu-Chek Safe T Pro Uno lancing device on the outer section of the top of the chosen finger. Two samples of blood were obtained from a single finger prick. The first sample was used to determine total blood serum cholesterol concentration using a blood cholesterol meter (Accutrend GCT Meter). The second sample was used to determine blood glucose concentration (Accu-Chek Active). The validity of these tests has been previously established (165,167). Intra-rater reliability of these tests was assessed during a feasibility study.

3.2.5.5 Anthropometric Measurements

Sum of skinfolds, waist circumference, body mass, stature and BMI were assessed. Participants were assessed barefoot and wearing shorts and a vest or sports bra. The sum of six skinfolds (triceps, subscapular, suprailiac, abdomen, thigh and calf) was assessed as described by Withers, Craig, Bourdon, & Norton (1987) (168). Body fat was expressed as a percentage of body mass (169). Waist circumference (cm) was measured half way between the 10th rib and top of the iliac crest with a tape measure (170). Body mass (kg) was assessed using a calibrated scale and stature (m) was measured using a vertical measuring tape. Body Mass Index ($\text{kg}\cdot\text{m}^{-2}$) was calculated (171).

3.2.6 Feasibility Study

A feasibility study was performed prior to the main study to pilot the study questionnaire and to assess the intra-rater reliability of physical testing procedures. Ten participants who matched the inclusion criteria for the main study were included in the feasibility study. However, data from the feasibility study were not included in the main study.

Participants completed the questionnaire; and all physical testing procedures were performed three times to assess intra-rater reliability. Intra-rater reliability results are shown in Appendix V. Overall, all physical testing procedures had high intra-rater reliability (0.92-0.99). The full study procedure was also piloted to determine the feasibility of the testing procedure and to make any adjustments to facilitate data collection.

3.2.7 Testing Procedure

The study commenced once formal ethical approval had been granted from the UCT Faculty of Health Sciences Human Research Ethics Committee (Appendix VI). The study questionnaire was validated, and feasibility test was conducted. Participants were recruited from local running clubs and running races in the greater Nelspruit and Cape Town areas.

Testing was performed at running clubs and races in a private room or within a closed gazebo. Written informed consent was obtained from all participants (Appendix III). Participants were then requested to complete the study questionnaire (Appendix IV). Blood pressure was assessed. This was followed by the capillary blood sampling to determine blood cholesterol and blood glucose concentration. Anthropometric measurements were then performed, including sum of skinfolds, waist circumference and body mass and stature. All testing was completed in one session, and the duration of testing was approximately 20 minutes. On completion of testing all participants were given an information pamphlet that included individual test results, the expected normal values of the tested parameters and information regarding CDL, risk factors and disease prevention (Appendix VII). Participants who tested positive for risk factors for CDL were referred to local medical practitioners for further care and management.

3.2.8 Statistical Analyses

Statistical analyses were performed using Statistica 13 software program (StatSoft, Inc. 2013) STATISTICA (Data analysis software system, version 8, www.statsoft.com). During the feasibility study, correlational analyses were used to assess intra-rater reliability. The Shapiro-Wilkes test for normality was used to establish that all data were normally distributed. An independent t-test was used to determine differences in numeric data between two groups. Binary coding of risk factors and contributing factors for CDL are shown in Table 3.1. Categorical data were analysed using frequency tables and the Pearson's Chi-squared measure of association. One-way ANOVA tests were performed to compare categorical and numeric data, with multiple independent groups, such as physical activity levels and the physical tested data. Data are presented as mean \pm standard deviation or frequencies (numbers and percentages). Statistical significance was accepted as $p < 0.05$.

Table 3.1: Binary codes for risk factors and contributing factors to CDL.

Descriptive characteristics	Binary code 0	Binary code 1
Gender	Female	Male
Smoking history	Never smoked or ex-smoker	Current smoker
Medically diagnosed CDL	No	Yes
Medically diagnosed risk factor	No	Yes
Income per household per month (ZAR)	≤ ZAR20 000	>ZAR20 000
Age (years)	<50	≥ 50
Blood pressure (mmHg)	< 140/90	≥ 140/90
BMI (kg.m ⁻²)	< 25	≥ 25
Waist circumference (cm)	< 88cm females < 102cm males	≥ 88cm females ≥ 102cm males
Body fat percentage (%)	< 32% females < 25% males	≥ 32% females ≥ 25% males
Glucose (mmol.l ⁻¹)	< 7.8	≥ 7.8
Cholesterol (mmol.l ⁻¹)	< 5.0	≥ 5.0
Perform 150 minutes or more of physical activity a week	Yes	No

3.2.9 Ethical Considerations

Formal ethical approval for this study was granted by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (627/2016) (Appendix VI). This study adhered to the ethical principles outlined in the Declaration of Helsinki (Fortaleza, Brazil, 2013) (172). The study commenced once ethical approval had been obtained. Written informed consent was obtained from all participants prior to testing (Appendix III). Individual privacy was maintained and no personal identifying information was recorded. The confidentiality of data was protected by coding all data. The code allocation was held in a password-protected document. Further, all data was captured in a spreadsheet and were stored in a password protected laptop. Data were shared with the study supervisors for analysis. Any publication arising from this research study will not identify individual participants.

3.2.9.1 Risks to Participants

The potential risks were explained to the participants during the process of obtaining written informed consent. Participants were required to undergo a finger prick test which had the possibility of infection due to piercing the skin. Every effort was taken to ensure that the environment was clean through cleaning the participant's finger with an alcohol swab to disinfect participants' finger prior to the finger prick. A new, sterile lancing device was used for each participant. After the finger prick a cotton wool swab was used to hold pressure against participants' finger to stop the bleeding and this was secured to the finger with a sticky strip. Participants may have felt slight discomfort with the measurement of the skin folds as the callipers used for testing may have pinched their skin slightly. There was also a potential risk of participants becoming distressed if risk factors for CDL were identified during the testing procedure, particularly if participants who may have been unaware of their risk. This was minimised by careful explanation of all tests and with the provision of an information pamphlet on completing of testing (Appendix VII). In addition, participants at risk for CDL were referred to their local medical practitioner for further investigation and management.

3.2.9.2 Benefits to Participant

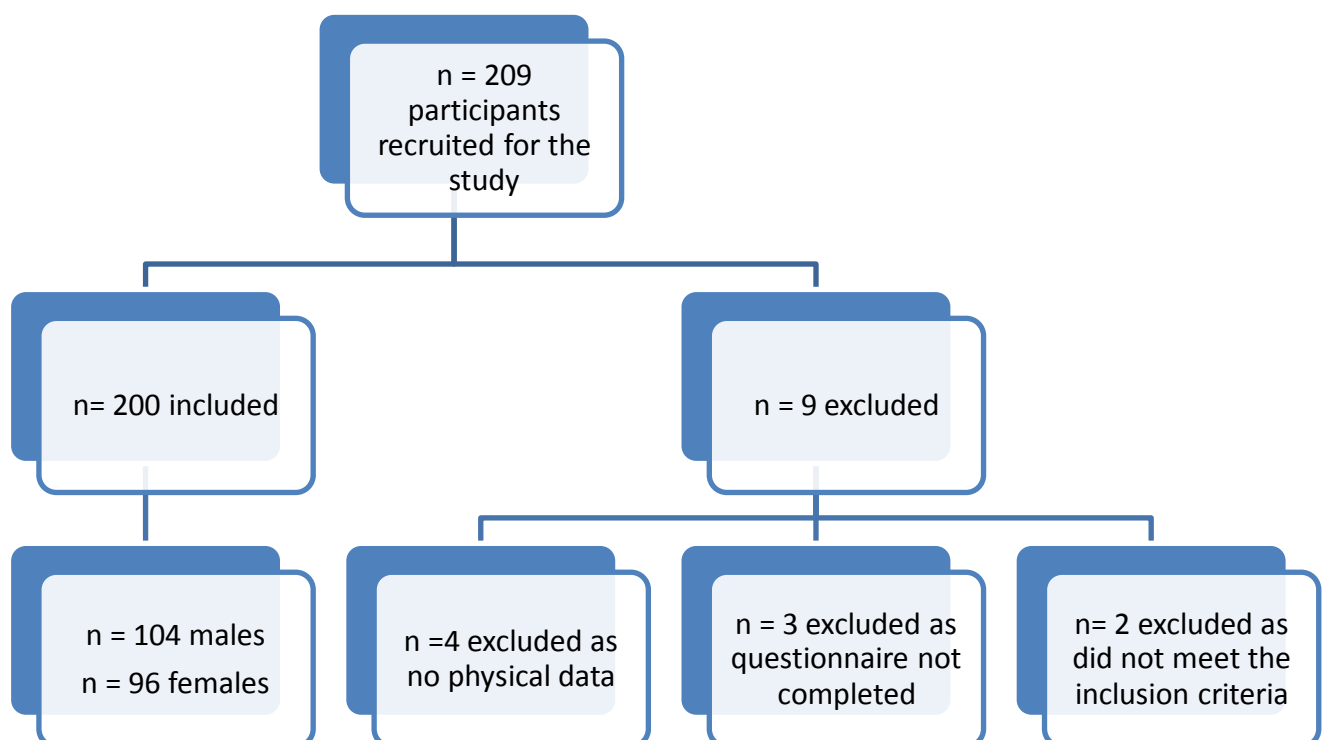
There were no direct individual benefits to participants in this study. Participants received their individual test results immediately after testing, as well as an information pamphlet regarding risk factors for CDL (Appendix VII). The main potential benefit from taking part in this study was screening and potential identification of risk factors for CDL. This would facilitate referral and appropriate management, and hopefully a future reduction in disease risk.

3.3 Results

3.3.1 Study Sample

The study sample is summarised in Figure 3.1. Two hundred and nine participants were recruited for this study between 1 January 2017 and 13 May 2017. Nine participants were excluded from the study after data collection was completed. Four participants were excluded as they did not complete the physical testing portion of the study. Three participants were excluded as they had failed to answer the majority of the sections in the study questionnaire. Two participants were identified as not meeting the inclusion criteria, with one participant reporting that they were a walker and not an endurance runner; and the other participant being older than the upper age limit for inclusion (69 years of age). Therefore, data from 200 participants (males: n=104; females: n=96) were included for analysis.

Figure 3.1: Summary of study sample.



3.3.2 Prevalence of Risk Factors for Chronic Diseases of Lifestyle

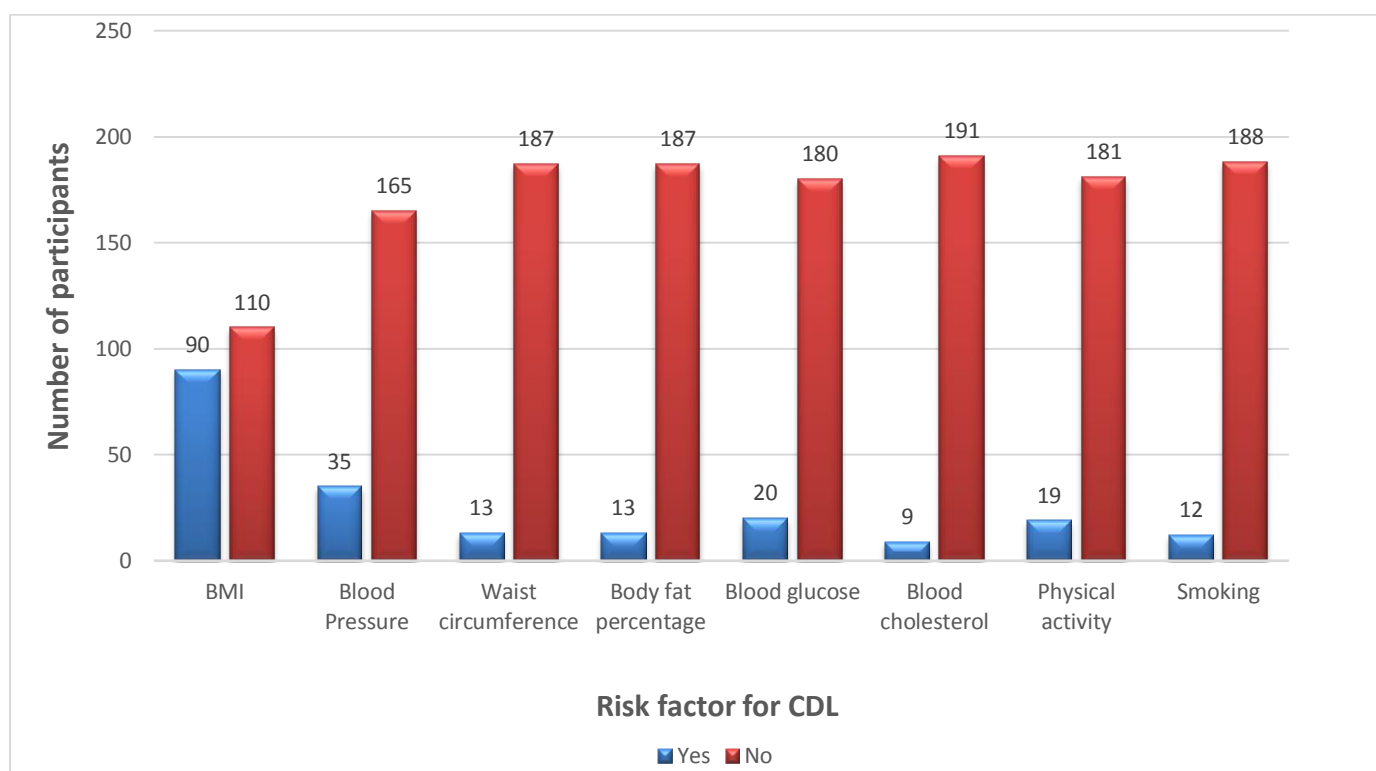
One of the main objectives of this study was to determine the prevalence of modifiable risk factors for CDL in endurance runners. Modifiable risk factors that were assessed in this study included: BMI $\geq 25 \text{ kg.m}^{-2}$; blood pressure $\geq 140/90 \text{ mmHg}$; waist circumference of $\geq 88 \text{ cm}$ (females) or $\geq 102 \text{ cm}$ (males); body fat percentage $\geq 32 \%$ (females) or $\geq 25 \%$ (males); blood glucose $\geq 7.8 \text{ mmol.l}^{-1}$; blood cholesterol $\geq 6.2 \text{ mmol.l}^{-1}$; smoking; nutritional education; and performing less than 150 minutes of moderate to vigorous physical activity per week (9,11,42,78,91). The overall prevalence of risk factors for CDL is shown in Table 3.2. One hundred and twenty four (62%) of participants were found to have at least one risk factor for CDL. There was no significant difference in the overall prevalence of risk factors for CDL between male and female runners.

Table 3.2: Overall prevalence of risk factors for CDL in female runners (n=96), male runners (n=104) and the total sample (n=200). Data are expressed as numbers (n) and percentages (%).

	Females (n=96)	Males (n=104)	Total sample (n=200)	χ^2	p
Risk factors for CDL	53 (26.5%)	71 (35.5%)	124 (62%)	6.04	0.42
No risk factors for CDL	43 (21.5%)	33 (16.5%)	76 (38%)		

The prevalence of individual risk factors for CDL in this total sample of endurance runners is shown in Figure 3.2. A high BMI was the most common risk factor for CDL (n=90; 45%), followed by high blood pressure (n=35; 17.5%) and high glucose concentration (n=20; 10%). Interestingly, 19 participants (9.5%) did not meet the recommended duration of 150 minutes of physical activity per week (Figure 3.2).

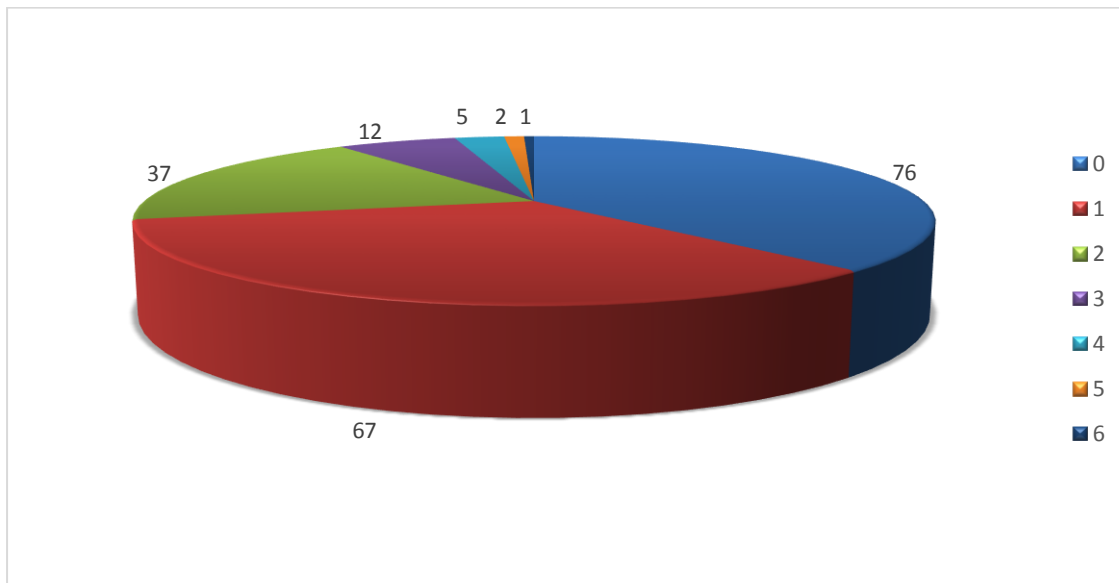
Figure 3.2: The prevalence of individual risk factors for CDL in endurance runners (n=200). Data are shown as numbers of participants with (blue) and without (red) individual risk factors for CDL.



The abnormal BMI ranged between 21.96 kg.m⁻² and 35.26 kg.m⁻² for males, and 21.15 kg.m⁻² and 40.70 kg.m⁻² for females. Abnormal blood pressure ranged between a systolic of 140 to 170 mmHg, with the diastolic between 91 to 101 Hg. The male participants with an elevated waist circumference measured between 102 and 113 cm, and the female participants measured between 88 and 103 cm. An elevated blood glucose ranged between 7.8 and 12.6 mmol.l⁻¹ and an elevated cholesterol ranged between 6.2 and 11.5 mmol.l⁻¹. Lastly, the abnormal body fat percentage range for males was 25.09 to 33.67 % and females 32.02 to 42.03 %.

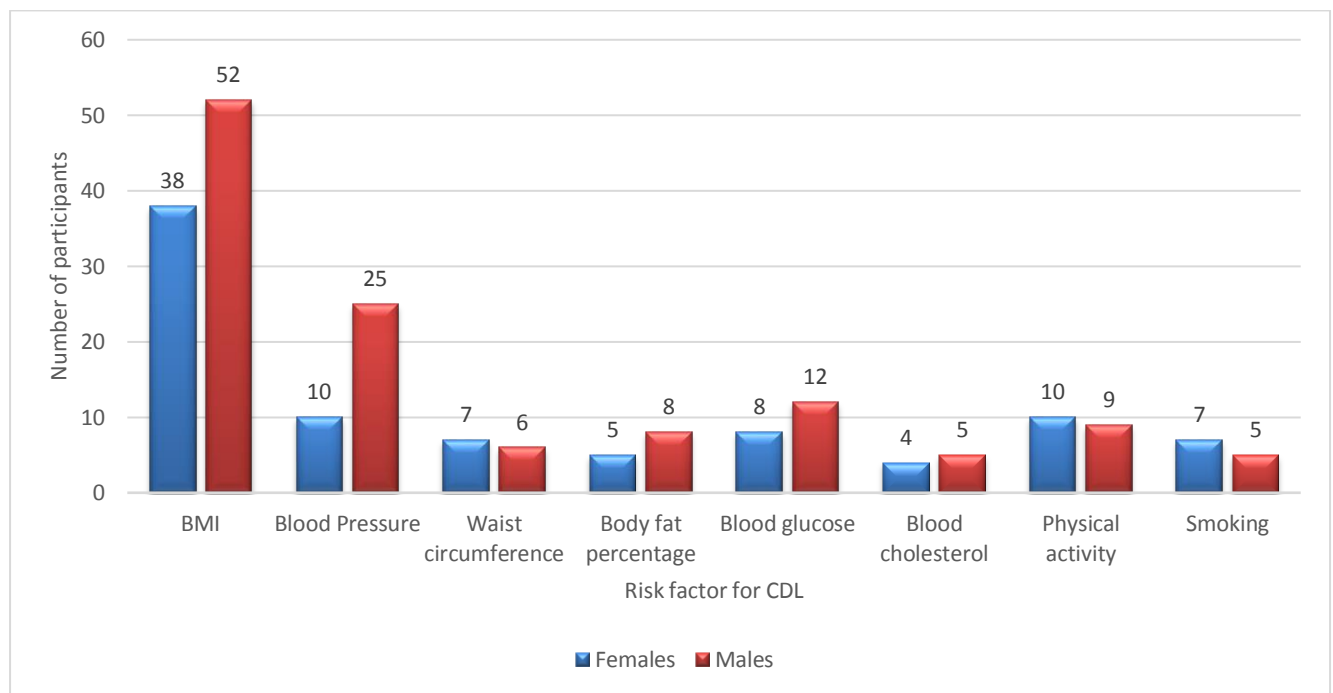
The number of individual risk factors for CDL in endurance runners (n=200) is shown in Figure 3.3. Of the 124 participants that had risk factors for CDL, the majority of the participants had a single risk factor for CDL (n=67; 33.5%). Multiple risk factors for CDL were identified in 28.5% (n=57) participants, ranging from two risk factors (n=37; 18.5%) to six risk factors (n=1; 0.5%).

Figure 3.3: The number of endurance runners (n=200) presenting with individual risk factors for CDL.



The prevalence of risk factors for CDL in male (n=104) and female (n=96) endurance runners is shown in Figure 3.4. A high BMI was the most common risk factors for CDL for the males (n=52; 50%), followed by high blood pressure (n=25; 24%) and elevated blood glucose (n=12; 12%). Similarly, a high BMI was also the most common risk factor for CDL for the females (n=38; 40%); followed by high blood pressure (n=10; 10%); and physical inactivity (n=10; 10%). Female endurance runners showed a higher prevalence of physical inactivity and smoking than males (Figure 3.3).

Figure 3.4: The prevalence of individual risk factors for CDL in male (n=104) and female (n=96) endurance runners. Data are shown as numbers of female (blue) and male (red) participants with individual risk factors for CDL.



The risk factors for CDL in female and male participants are shown in Table 3.3. There were significant differences in all anthropometric measurements between males and female participants ($p < 0.02$). There was also a significant difference in average systolic blood pressure between male and female participants ($p = 0.003$); however there were no significant differences in average diastolic blood pressure or any other risk factors for CDL.

Table 3.3: Risk factors for CDL in female runners (n=96), male runners (n=104) and the total sample (n=200). Data are expressed as mean \pm standard deviation.

	Females (n=96)	Males (n=104)	Total sample (n=200)	t	p
Stature (m)	1.64 \pm 0.05	1.76 \pm 0.07	1.7 \pm 0.08	13.26	0.0001**
Body mass (kg)	65.3 \pm 11.2	78.9 \pm 11.8	72.4 \pm 13.3	8.3	0.002**
BMI (kg.m ⁻²)	24.1 \pm 3.9	25.3 \pm 3.2	24.7 \pm 3.6	2.29	0.02*
Waist circumference (cm)	74.7 \pm 8.8	84.5 \pm 9.9	79.8 \pm 10.6	7.34	0.0001**
Body fat percentage (%)	21.9 \pm 5.6	17.1 \pm 5.5	19.3 \pm 6.0	-6.15	0.0001**
Blood pressure systolic (mmHg)	116.5 \pm 14.6	128.9 \pm 13.5	122.7 \pm 15.2	6.06	0.003**
Blood pressure diastolic (mmHg)	79.1 \pm 9.2	80.4 \pm 9	79.8 \pm 9	0.99	0.32
Glucose (mmol.l ⁻¹)	5.5 \pm 1.4	5.6 \pm 1.8	5.6 \pm 1.6	0.79	0.43
Cholesterol (mmol.l ⁻¹)	4.8 \pm 0.7	4.6 \pm 0.9	4.7 \pm 0.8	-1.45	0.15
Weekly physical activity (min)	228.9 \pm 91	227.8 \pm 87	228.3 \pm 88.9	-0.09	0.93

* $p < 0.05$; ** $p < 0.01$

3.3.4.4 Nutrition

3.3.4.4.1 Self-reported food consumption

Table 3.6 shows the self-reported portion sizes of food types, classified according to food items that are non-fruit or vegetables, food items that are fruits, and food items that are vegetables, consumed in the previous 24 hours.

Table 3.6: Self-reported portion sizes of food types (non-fruit or vegetables, fruits and vegetables) consumed in the previous 24 hours for the total sample. Data are expressed as numbers and percentages.

Non-fruit or vegetable foods in the previous 24 hours (n=200)					
Portion size	Breakfast cereal	Chips	Fish	Baked potato	Meat
0	90 (45%)	151 (75.5%)	149 (74.5%)	159 (79.5%)	43 (21.5%)
1	90 (45%)	38 (19%)	42 (21%)	32 (16%)	85 (42.5%)
2	15 (7.5%)	9 (4.5%)	5 (2.5%)	8 (4%)	42 (21%)
3	3 (1.5%)	2 (1%)	1 (0.5%)	0 (0%)	15 (7.5%)
4+	2 (1%)	0 (0%)	3 (1.5%)	1 (0.5%)	15 (7.5%)
Fruit in the previous 24 hours (n=200)					
Portion size	Fruit for breakfast	Fruit as a between meal snack	A glass of pure, unsweetened fruit juice	Fruit as a starter to a meal	Fruit as a dessert
0	120 (60%)	104 (52%)	161 (80.5%)	162 (81%)	163 (81.5%)
1	51 (25.5%)	47 (23.5%)	24 (12%)	27 (13.5%)	24 (12%)
2	15 (7.5%)	35 (17.5%)	5 (2.5%)	6 (3%)	6 (3%)
3	9 (4.5%)	9 (4.5%)	7 (3.5%)	4 (2%)	4 (2%)
4+	5 (2.5%)	5 (2.5%)	3 (1.5%)	1 (0.5%)	3 (1.5%)
Vegetables in the previous 24 hours (n=200)					
Portion size	A bowlful of homemade vegetable style soup	Portion of vegetables with main meal	A vegetable based meal	A bowlful of salad	
0	180 (90%)	82 (41%)	143 (71.5%)	130 (65%)	
1	12 (6%)	52 (26%)	36 (18%)	44 (22%)	
2	5 (2.5%)	40 (20%)	10 (5%)	15 (7.5%)	
3	3 (1.5%)	21 (10.5%)	3 (1.5%)	5 (2.5%)	
4+	0 (0%)	5 (2.5%)	8 (4%)	6 (3%)	

3.3.4.4.2 Knowledge regarding nutrition as a contributing factor to the development of CDL

Only sixty six (33%) participants identified that five or more portions of fruit and vegetables is the recommended number of portions in the majority of dietary guidelines. A significant higher proportion of female participants identified the recommended 'five or more per day' compared to male participants ($\chi^2=21.6$; $p=0.002$). However, the majority of participants identified that regular intake of fruit and vegetables reduces the risk of stroke, cancer and heart disease (Table 3.7).

Table 3.7: Participants knowledge regarding regular intake of fruit and vegetables in reducing the risk of developing CDL. Data are expressed as numbers and percentages.

	Strongly agree	Agree slightly	Neutral	Disagree slightly	Strongly disagree
Stroke	116 (59%)	38 (19%)	36 (18%)	4 (2%)	6 (3%)
Cancer	105 (52.5%)	42 (21%)	37 (18.5%)	7 (3.5%)	9 (4.5%)
Heart disease	125 (62.5%)	40 (20%)	28 (14%)	1 (0.5%)	6 (3%)

3.3.4.4.3 Factors affecting the consumption of fruit and vegetables

Factors influencing regular intake of fruit and vegetables is shown in Table 3.8. The quality and cost of fruit and vegetables were the most important factors influencing regular consumption of fruit and vegetables. In contrast, the weight of shopping bags was the least important factor influencing consumption of fruit and vegetables.

Table 3.8: Factors influencing regular consumption of fruit and vegetables for the total sample (n=200). Data are expressed as numbers and percentages.

	Very unimportant	Unimportant	Neutral	Important	Very Important
The money I have to spend on fruit and vegetables	17 (8.5%)	40 (20%)	61 (30.5%)	53 (26.5%)	29 (14.5%)
The price of fruit and vegetables	11 (5.5%)	33 (16.5%)	67 (33.5%)	70 (35%)	19 (9.5%)
My knowledge about ways to prepare fruit and vegetables	12 (6%)	45 (22.5%)	64 (32%)	59 (29.5%)	20 (10%)
The time I have to prepare fruit and vegetables	8 (4%)	34 (17%)	88 (44%)	52 (26%)	18 (9%)
How easy it is for me to get to the shops	15 (7.5%)	39 (19.5%)	73 (36.5%)	49 (24.5%)	24 (12%)
How heavy my shopping bag is to carry	62 (31%)	53 (26.5%)	53 (26.5%)	23 (11.5%)	9 (4.5%)
Likes and dislike of my family for fruit and vegetables	15 (7.5%)	44 (22%)	69 (34.5%)	59 (29.5%)	13 (6.5%)
The quality of fruit and vegetables available	9 (4.5%)	7 (3.5%)	37 (18.5%)	76 (38%)	71 (35.5%)

3.3.3. Prevalence of Medically Diagnosed CDL and/or Risk Factors for CDL

The overall self-reported prevalence of a medically diagnosed CDL was 5.5% (n=11). Type 2 diabetes was the most commonly diagnosed CDL (n=6; 3%); followed by cancer (n=3; 1.5%); heart disease (n=1; 0.5%); and stroke (n=1; 0.5%). High blood pressure (n=16; 8%) and high blood cholesterol concentration (n=16; 8%) were the only self-reported medically diagnosed risk factors for CDL. The majority of participants had no prior medical diagnosis of CDL or risks factors for CDL.

3.3.4 Non-Modifiable Risk Factors

This study also aimed to determine the presence of non-modifiable risk factors to the development of CDL, namely age and income, in endurance runners.

3.3.4.1. Socio-demographic Characteristics

Socio-demographic characteristics of participants are shown in Table 3.4. There were no significant differences in age, income and number of adults or children living in the household between male and female participants. The mean age of participants in this study was 40.2 ± 11.5 years (range: 18 to 69 years). The number of adults living in each participant's household ranged from one to seven adults; and the number of children under the age of 16 living in each household ranged from zero to six children.

Table 3.4: Socio-demographic characteristics of female runners (n=96), male runners (n=104) and the total sample (n=200). Data are expressed as mean \pm standard deviation; and numbers and percentages.

	Female (n=96)	Male (n=104)	Total sample (n=200)	t	p
Age (years)	39.8 \pm 10.7	40.5 \pm 12.3	40.2 \pm 11.5	0.39	0.69
Income (ZAR)				χ^2	P
<2000	1 (0.5%)	5 (2.5%)	6 (3%)	7.97	0.53
2000-5000	3 (1.5%)	7 (3.5%)	10 (5%)		
5001-10000	4 (2%)	3 (1.5%)	7 (3.5%)		
10001-20000	10 (5%)	13 (6.5%)	23 (11.5%)		
20001-30000	17 (8.5%)	11 (5.5%)	28 (14%)		
30001-40000	14 (7%)	9 (4.5%)	23 (11.5%)		
40001-50000	8 (4%)	8 (4%)	16 (8%)		
50001-100000	18 (9%)	20 (10%)	38 (19%)		
>100000	6 (3%)	8 (4%)	14 (7%)		
Unknown	15 (7.5%)	20 (10%)	35 (17.5%)		
Household					
Adults (n)					
1	21 (10.5%)	18 (9%)	39 (19.5%)	2.07	0.91
2	41 (20.5%)	50 (25%)	91 (45.5%)		
3	18 (9%)	19 (9.5%)	37 (18.5%)		
4	13 (6.5%)	12 (6%)	25 (12.5%)		
5	2 (1%)	3 (1.5%)	5 (2.5%)		
6	0 (0%)	1 (0.5%)	1 (0.5%)		
7	1 (0.5%)	1 (0.5%)	2 (1%)		
Children (n)					
0	61 (30.5%)	62 (31%)	123 (61.5%)	6.03	7.65
1	15 (7.5%)	14 (7%)	29 (14.5%)		
2	16 (8%)	17 (8.5%)	33 (16.5%)		
3	3 (1.5%)	8 (4%)	11 (5.5%)		
4	0 (0%)	2 (1%)	2 (1%)		
5	1 (0.5%)	0 (0%)	1 (0.5%)		
6	0 (0%)	1 (0.5%)	1 (0.5%)		

3.3.4.2 Age

An analysis of risk factors for CDL according to age (≥ 50 years; or < 50 years) showed that waist circumference ($p=0.01$), systolic blood pressure ($p=0.04$) and cholesterol ($p=0.01$) were significantly elevated in the older age group. There were no other significant differences in risk factors for CDL according to age (Table 3.5).

Table 3.5: Analysis of risk factors for CDL according to age: ≥ 50 years ($n=46$) or < 50 years ($n=154$). Data are expressed as mean \pm standard deviation and numbers and percentages.

	< 50 years ($n=154$)	≥ 50 years ($n=46$)	t	p
Stature (m)	1.71 \pm 0.1	1.71 \pm 0.1	0.13	0.9
Body mass (kg)	72.09 \pm 13.2	73.49 \pm 13.9	-0.62	0.54
BMI ($\text{kg}\cdot\text{m}^{-2}$)	24.64 \pm 3.7	25.13 \pm 3.6	-0.79	0.43
Waist circumference (cm)	78.78 \pm 10	83.26 \pm 12	-2.54	0.01*
Body fat percentage (%)	19.15 \pm 6.5	20.15 \pm 4.4	-0.98	0.33
Blood pressure systolic (mmHg)	121.52 \pm 14.6	126.67 \pm 16.7	-2.03	0.04*
Blood pressure diastolic (mmHg)	79.33 \pm 9	81.35 \pm 9.2	-1.33	0.18
Glucose ($\text{mmol}\cdot\text{l}^{-1}$)	5.56 \pm 1.7	5.73 \pm 1.5	-0.62	0.54
Cholesterol ($\text{mmol}\cdot\text{l}^{-1}$)	4.66 \pm 0.8	4.98 \pm 0.8	-2.45	0.01**
			χ^2	p
Smoking	12 (6%)	0 (0%)	3.81	0.05

* $p < 0.05$; ** $p < 0.01$

3.3.4.2 Income

An analysis of risk factors for CDL according to income status [\geq ZAR 20 000 ($n=119$); $<$ ZAR 20 000 ($n=46$); or missing ($n=35$)] showed that there were no significant differences in risk factors for CDL according to income status in this study.

3.3.5 Physical Activity Levels and Risk Factors for Chronic Diseases of Lifestyle

Physical activity levels of female and male runners are shown in Table 3.9. There was a significant difference in average sitting time between male and female runners, with female runners having higher average sitting times compared to male runners ($t=2.05$; $p=0.04$). There were no other significant differences in physical activity levels between female and male runners.

Table 3.9: Physical activity levels of female runners (n=96), male runners (n=104) and the total sample (n=200). Data are expressed as mean \pm standard deviation.

	Females (n=96)	Males (n=104)	Total (n=200)	t	p
Vigorous physical activity	32.7 \pm 13	32.7 \pm 12.5	32.6 \pm 24.4	-0.09	0.94
Moderate physical activity	66.8 \pm 75.7	87.6 \pm 82.2	77.6 \pm 79.6	1.86	0.06
Walking	92.5 \pm 103.4	107.3 \pm 122.1	100.2 \pm 113.5	0.92	0.36
Sitting	347.5 \pm 125.2	309.4 \pm 136.3	327.7 \pm 132.2	-2.05	0.04*

* $p < 0.05$

There were no significant differences in any risk factor for CDL (including blood pressure, BMI, waist circumference, body fat percentage, and blood glucose or cholesterol concentration) when analysed comparing the time spent on vigorous physical activity, moderate physical activity, walking and sitting.

3.3.6 Running and Risk Factors for Chronic Diseases of Lifestyle

Endurance running training characteristics of female and male runners are shown in Table 3.10. There was a significant difference in average weekly training distance, with male runners having higher average weekly training distances, compared to female runners ($t=2.49$; $p=0.01$).

Table 3.10: Endurance running training characteristics of female runners ($n=96$), male runners ($n=104$) and the total sample ($n=200$). Data are expressed as mean \pm standard deviation.

	Female ($n=96$)	Males ($n=104$)	Total ($n=200$)	t	p
Running experience (years)	8.1 \pm 7.7	12.5 \pm 11.0	10.4 \pm 9.8	-1.07	0.28
Running frequency (d.wk ⁻¹)	3.6 \pm 1.4	3.8 \pm 1.4	3.8 \pm 1.4	1.39	0.16
Average training session duration (min)	64.5 \pm 23	60.8 \pm 25	62.6 \pm 24.3	-1.07	0.28
Average weekly training distance (km)	40.4 \pm 15.1	46.6 \pm 19.2	43.6 \pm 17.6	2.49	0.01*
Average weekly training duration (min)	228.9 \pm 91.0	227.8 \pm 91.0	228.3 \pm 88.9	-0.08	0.93

* $p<0.05$

Male runners also had significantly faster running speeds for 5 km, 10 km, 21.1 km and 42.2 km race distances compared to female runners ($p<0.01$).

Table 3.11 shows an analysis of average weekly training duration, average weekly training distance, and average 10 km running speed to the presence of risk factors for CDL. Participants with a BMI ≥ 25 kg.m⁻² had significantly slower 10 km running speed ($t=2.23$; $p=0.03$) and lower average weekly training distance ($t=3.26$; $p=0.001$), compared to participants with BMI within normal ranges. There were no other significant differences in training characteristics according to the presence of risk factors for CDL.

Table 3.11: Analysis of average weekly training duration, average weekly training distance, and average 10 km running speed according to the presence of risk factors for CDL. Data are expressed as mean \pm standard deviation and numbers and percentages.

		Average weekly running training duration (min) (n=200)	t	p	Average weekly running training distance (km) (n=200)	t	p	10 km running speed (min.km ⁻¹) (n=196)	t	p
Blood pressure (mmHg)	$\geq 140/90$	231.1 \pm 77.8	0.03	0.97	42.3 \pm 13.5	0.49	0.63	5.5 \pm 0.9	0.4	0.69
	< 140/90	231.7 \pm 91.9			43.9 \pm 18.4			5.6 \pm 1.1		
BMI (kg.m ⁻²)	≥ 25	222.7 \pm 79.8	1.27	0.20	39.2 \pm 13.5	3.26	0.001**	5.7 \pm 1.1	-2.24	0.03*
	< 25	238.9 \pm 96.4			47.2 \pm 19.7			5.4 \pm 1.0		
Body Fat Percentage (%)	≥ 32 (females); ≥ 25 (males)	206.9 \pm 84.3	0.99	0.32	38.5 \pm 12.8	1.09	0.28	5.4 \pm 1.4	0.54	0.59
	< 32 (females); < 25 (males)	233.3 \pm 89.7			44.0 \pm 17.9			5.6 \pm 1.0		
Waist Circumference (cm)	≥ 88 (females); ≥ 102 (males)	212.7 \pm 70.7	0.77	0.44	37.7 \pm 11.7	1.23	0.22	5.7 \pm 1.3	-0.55	0.58
	< 88 (females); < 102 (males)	232.5 \pm 90.6			43.9 \pm 17.8			5.5 \pm 1.0		
Glucose (mmol.l ⁻¹)	≥ 7.8	224.5 \pm 57.4	0.37	0.70	39.5 \pm 13.2	1.10	0.27	5.8 \pm 1.2	-1.55	0.12
	< 7.8	232.4 \pm 92.4			44.1 \pm 18.0			5.5 \pm 1.0		
Cholesterol (mmol.l ⁻¹)	≥ 6.2	238.3 \pm 101.6	0.65	0.52	42.2 \pm 13.9	0.24	0.81	5.3 \pm 0.9	0.62	0.53
	< 6.2	226.7 \pm 86.8			43.7 \pm 17.8			5.5 \pm 1.0		
Smoking	Yes	184.3 \pm 76.9	1.90	0.06	37.6 \pm 14.8	1.22	0.22	5.6 \pm 1.0	0.11	0.91
	No	231.2 \pm 89.0			44.0 \pm 17.7			5.5 \pm 1.0		

*p<0.05; **p<0.01

There were no significant differences in any risk factor for CDL (including blood pressure, BMI, waist circumference, body fat percentage, and blood glucose or cholesterol concentration) when analysed according to the event participants were training towards, namely a Parkrun™, half marathon, full marathon, ultra-marathon or no specific event.

3.3.7 Summary of Results

One hundred and twenty four (62%) participants were found to have at least one modifiable risk factor for CDL. A high BMI was the most common risk factor for CDL (n=90; 45%), followed by high blood pressure (n=35; 17.5%) and high blood glucose concentration (n=20; 10%). Nineteen participants (9.5%) did not meet the recommended duration of 150 minutes of physical activity per week. Multiple risk factors for CDL were identified in fifty seven participants (28.5%), ranging from two risk factors (n=37; 18.5%) to six risk factors (n=1; 0.5%).

The overall self-reported prevalence of a medically diagnosed CDL was 5.5% (n=11). Type 2 diabetes was the most commonly diagnosed CDL (n=6; 3%); followed by cancer (n=3; 1.5%); heart disease (n=1; 0.5%); and stroke (n=1; 0.5%). High blood pressure (n=16; 8%) and high blood cholesterol (n=16; 8%) were the only self-reported medically diagnosed risk factors for CDL. The majority of participants had no prior medical diagnosis of CDL or risk factors for CDL.

Waist circumference, systolic blood pressure and cholesterol concentrations were significantly elevated in the older age group. There were no significant differences in risk factors for CDL according to income status. With regards to physical activity levels, female runners had higher average sitting times compared to male runners. There were no significant differences in risk factors according to time spent on vigorous physical activity, moderate physical activity, walking and sitting. Further, participants with a BMI ≥ 25 kg.m⁻² had significantly lower average weekly training duration and slower 10 km running speed, compared to participants with BMI within normal ranges. These results will be discussed in Section 3.4.

3.4 Discussion

3.4.1 Modifiable Risk Factors for Chronic Diseases of Lifestyle

The risk factors that have been identified as causative factors for the development of a CDL were investigated for each participant. The modifiable risk factors included a BMI of above 25 kg.m⁻², blood pressure 140/90 mmHg or higher, a waist circumference of 88 cm for females and 102 cm for men or greater, body fat percentage above 32% for females and 25% for males, blood glucose concentrations 7.8 mmol.l⁻¹ or higher, blood cholesterol concentrations 6.2 mmol.l⁻¹ or higher, smoking; nutritional education; and performing less than 150 minutes of physical activity a week (1,42).

3.4.1.1 Prevalence of Risk Factors for Chronic Diseases of Lifestyle

A very high prevalence of modifiable risk factors was discovered, with the majority of participants (n = 124; 62%) having at least one risk factor for CDL and 28.5% of participants having more than one risk factor. One participant was found to have six risk factors for CDL, and reported that he was unaware of his risk factor status and had not been diagnosed by a medical professional with CDL. The high prevalence of risk factors in the participants was unexpected, as previous research has reported significantly lower risk factor prevalence in runners compared to the general population of South African and USA (152,154,173). In some instances the prevalence of risk factors for CDL in the participants is higher than the reported risk factors in the general population of South Africa and USA, as shown in Table 3.12. The high prevalence of modifiable risk factors in this population group of endurance runners is worrisome. During the testing process, it was our impression that the majority of the participants had a good awareness of their BMI, blood pressure and waist circumference as they are easy and commonly measured and were therefore not surprised by the results. However, the majority of the participants had not had their body fat percentage, glucose or cholesterol tested before or in recent times and were most interested in those results. Routine medical examinations at a primary care facility or general practitioner in South Africa routinely includes height, weight and blood pressure. Further testing is usually not performed unless specifically indicated. Since the majority of the risk factors are silent and present with no symptoms, testing for these risk factors may occur too late (34). However, we also recognise that participants who did not know their full health status may have been more likely to volunteer for this study; and therefore, volunteer bias may have contributed to the overall high prevalence of risk factors in our study.

Table 3.12: Comparison of the prevalence of risk factors for CDL between endurance runners in this study, the general South African population and the general USA population. Data extracted from World Health Organization Global Status Report (2014); South African National Department of Health (2016); and Statistics South Africa (2015) (1,4,8).

Risk Factor	Findings of this study	South African Population	USA Population
BMI (kg.m ⁻²)	40% females, 50% males	68% females, 31% males	63% females, 72% males
Waist Circumference (cm)	7% females, 5% males	Unknown	Unknown
Body Fat Percentage (%)	5% females, 8% males	Unknown	Unknown
Blood Pressure (mmHg)	10% females, 24% males	46% females, 44% males	16% females, 20% males
Blood Glucose (mmol.l ⁻¹)	8% females, 12% males	10% females, 11% males	9% females, 10% males
Blood Cholesterol (mmol.l ⁻¹)	4% females, 5% males	36% females, 31% males	Unknown
Smoking	7% females, 5% males	7% females, 37% males	16% females, 22% males
Physical Activity	10% females, 9% males	56% females, 46% males	42% females, 28% males

3.4.1.2 Obesity

A BMI of 25 mmHg or above was shown to be the most prevalent risk factor, with 90 participants (45%) [38 females (40%); 52 males (50%)] falling into the overweight or obese category for BMI readings. While the prevalence of abnormal BMI is lower than the South African population, it is much higher than the prevalence found by Hoffman (2014), who reported a 4.3% prevalence of overweight and obesity in runners (152,174). It was also unexpected to find more males than females with an abnormal BMI, as the prevalence of female obesity is much higher in South Africa, with females more than 50% more likely to be overweight or obese than males (175). In non-athletic individuals, BMI is assumed to increase as adiposity increases; whereas a muscular male or female may have a high BMI due to the increased muscle mass (176). Nevill et al (2010) found the BMI of endurance runners over-estimated their adiposity; however, this finding applied to males and females and does not explain the high prevalence of abnormal male BMI found in this study (176).

The reason for running was not investigated in this study, but one possibility of why fewer females had abnormal BMI's could be due to the female perception of the ideal body image, resulting in females taking more precautionary action towards achieving the perceived ideal body shape. Case (2009) found that, in South Africa, female's perception of the ideal body is stronger than males (175). This may have resulted in more females running for the purpose of maintaining or losing weight than males.

Of the 90 participants who had a high BMI, only 13 (6.5%) had an increased waist circumference and 13 (6.5%) had an increased body fat percentage. A combination of increased BMI, waist circumference and body fat percentage was found in 7 participants (3.5%); whereas a combination of increased BMI with either an increased waist circumference, or body fat percentage was found in 19 participants (9.5%). Importantly; a BMI reading is limited in that it does not account for the distribution of fat across the body and the fat versus lean mass distribution (84,177). Athletes tend to have higher fat-free mass in relation to their height resulting in a high BMI without necessarily being overweight (84). Kruschitz et al (2013) found that female athletes had significantly higher BMI values than female non-athletes; but 50% to 60% lower subcutaneous adipose tissue than female non-athletes, concluding that a BMI reading is not an accurate measurement of body fatness in athletes. This may be a contributing factor to the high prevalence of abnormal BMI found in this study; however, the prevalence of an abnormal BMI in this study is still higher than other research on endurance runners (152). Excessive body fat in the abdominal region, expressed through a high waist circumference, is a strong indicator for the possible development of type 2 diabetes. High body fat percentage suggests a wide distribution of fat around the body. Abnormal body fat percentage and BMI have the potential to lead to the development of any of the CDL (39,82,86).

3.4.1.3 Blood Pressure

High blood pressure was the second most common risk factor occurring in 35 participants (17.5%). The reported statistics for the general population in South Africa is that 46% of females and 44% of men aged 15 years and older have high blood pressure (174). The prevalence of high blood pressure in the general population in South Africa increases with age, with a less than 20% prevalence in those aged 24 years and younger, but an 84% prevalence in those aged 65 years and older (174). The prevalence of high blood pressure in our study was much lower than the general population; however, the age range for inclusion in this study was limited to 18-69 years. While overall prevalence of high blood pressure was lower in this group of endurance runners compared to the general population; it is still concerning that high blood pressure was the second most common risk factor, particularly as endurance running has been shown to decrease blood pressure (139).

3.4.1.4 Blood Glucose

Elevated blood glucose concentration of above 7.8 mmol.l⁻¹ were identified in 20 participants (10%). This is similar to the prevalence in the general population of South Africa and unexpectedly high for endurance runners (4). An elevated blood glucose after a three hour fast is a concern as impaired blood glucose is a strong risk factor for type 2 diabetes and resultant CVD (39). To make the testing convenient to the runners, the majority of participants were tested after a run. All the participants consented to partaking in a three hour fast prior to testing; however, compliance with the three hour fast was not actively monitored by the student researcher. These factors potentially decreased the standardisation of the test, due to the lack of homogeneity in the run distance and intensity prior to testing; and the possibility that participants consumed food or beverage that they may not have deemed important and were possibly tested in an unfasted state. However, irrespective of these potential methodological flaws, elevated blood glucose concentration in endurance runners are concerning, as running should help maintain the blood glucose through a well-controlled feedback system (13,143).

3.4.1.5 Blood Cholesterol

A low prevalence of elevated blood cholesterol concentration was observed, with 9 participants (4.5%) testing positive for elevated blood cholesterol concentration. This group prevalence is much lower than the prevalence reported in a general South African population (4). The blood cholesterol test performed in this study tested for total blood cholesterol, and did not differentiate between LDL and HDL cholesterol. Endurance running is known to reduce the circulating concentration of LDL cholesterol and improve the atherosclerotic profile of an individual. An elevated total cholesterol concentration is influenced by either an increased LDL cholesterol concentration or elevated HDL cholesterol concentration, or a combination of elevated LDL and HDL cholesterol concentrations (139). Further testing is advised to determine LDL and HDL cholesterol concentrations.

3.4.1.6 Physical Activity

One hundred and eighty one participants (90.5%) fulfilled the required 150 minutes of moderate to vigorous physical activity each week. For those fulfilling the required 150 minutes of weekly physical activity, the intensity was classified as vigorous, as every participant described their running characteristics as vigorous physical activity. Importantly, the nineteen participants who do not fulfil the required weekly physical activity time will still receive health benefits from their running (13). However, they remain at risk for developing CDL as the volume of physical activity is not sufficient to combat the risk for CDL (1).

This study highlights the importance of educating endurance runners regarding the need to fulfil the required 150 minutes of weekly physical activity to overcome the risk for developing CDL. Further research studies should investigate endurance runners' knowledge regarding weekly physical activity requirements and potential barriers and facilitators to meeting weekly physical activity requirements.

3.4.1.7 Smoking

One hundred and fifty five participants (77.5%) had never smoked, followed by 33 participants (16.5%) who categorized themselves as ex-smokers and 12 participants (6%) were current smokers [7 females (7%); 5 males (5%)]. It is reported that 37% of males and 7% of females over the age of 15 years are current smokers in the general population of South Africa (174). (4). Mohlenkamp et al (2008) reported a 4.6% prevalence of smoking in marathon runners, which was a significantly lower prevalence than non-runners (178). Therefore, the prevalence of current smokers amongst this sample of endurance runners is higher than expected. One possible explanation for the higher prevalence of smoking in the female participants is that smoking cessation has poorer outcomes in females, with a higher prevalence of depressive and withdrawal symptoms following smoking cessation (179,180). Another possible factor for the high prevalence of smoking in the female participants is the weight loss effect that smoking creates, which may appeal to females more than males (94). Nicotine is an appetite suppressant that aids weight loss or weight maintenance (94). Smoking is a strong risk factor for CVD, CRD and cancer (69,95); therefore, the high prevalence of smoking in our study is concerning. This study reveals the need for improved awareness regarding the risks of smoking in the South African running population. Further investigation of risk behaviours in endurance runners is also needed to understand perceptions and beliefs regarding behaviours that increase or decrease disease risk.

3.4.1.8 Nutrition

A chronic lower consumption of daily fruit and vegetable intake is associated with an increased risk of developing a CDL (98). National guidelines recommend consuming at least five portions of fruit and vegetables daily to consume the vitamins and minerals that the body needs (181). Only 33% of the participants (n=66) accurately answered that the recommended daily intake is at least five portions of fruit and vegetables daily. However, over two thirds of the participants correctly agreed that eating more fruit and vegetables would reduce their risk of having a stroke, cancer or heart disease (154, 147, 165 participants respectively) (98). These questions were designed to test the knowledge of the participants with regards to fruit and vegetable intake and did not investigate the difference between knowledge of fruit and vegetable intake; and actual daily fruit and vegetable intake.

This study highlights the need for improved nutrition awareness and education in South Africa as the majority of participants were not aware of the national guidelines of fruit and vegetable intake (100,128).

3.4.2 Medically Diagnosed Chronic Diseases of Lifestyle and/or Risk Factor

The highest prevalence of a medically diagnosed CDL was type 2 diabetes with six participants (3%) stating they had been diagnosed as diabetic by a medical professional. However, it was not determined whether the 6 participants with type 2 diabetes had begun running after their diagnosis to aide in the management of the disease, or if the disease occurred while participating in a running programme. The self-reported prevalence of CDL was also much lower than the reported prevalence in the general population of South Africa, which is expected in a population group of endurance runners (182). Sixteen participants (8%) reported a medical diagnosis of high blood pressure, which is lower than the prevalence of high blood pressure found in the participants through the testing procedure (n=35; 17.5%). High blood pressure remains one of the highest undiagnosed conditions in South Africa due to its silent nature of commonly presenting with no symptoms (183).

The higher prevalence of undiagnosed high blood pressure, compared to medically diagnosed high blood pressure, found in this study confirms that endurance runners may also suffer from undiagnosed high blood pressure and should be advised to perform regular blood pressure testing.

3.4.3 Non-Modifiable Risk Factors

3.4.3.1. Age

The participants in this study varied in age from 18 to 69 years old with a mean age of 40.2 ± 11.5 years. The majority of the participants were younger than 50 years. The worldwide prevalence of a new diagnosis of risk factors and CDL is greatest in those between 50 years and 65 years (2). However, the prevalence of risk factors and CDL in young adults is rising, resulting in a need for increased awareness of possible risk factors and CDL in young adults.

Therefore the inclusion age for the participants in the study was 18 years old and the cut off age was 69 years old (122). An increased age does not cause a CDL but aging has the potential to increase the chance of developing a CDL through physiological changes associated with aging (120,121).

In this study, waist circumference, systolic blood pressure and cholesterol were significantly elevated in the older age group (≥ 50 years) compared to the younger age group; however all values were still within the normal, acceptable range for the risk factors. Moderate to vigorous intensity physical activity that is maintained into older age is able to assist with maintaining a favourable body composition in the older athletes (120).

3.4.3.2 Income

In this study, 23% of the participants lived in households that earned no income or were low income households, which is a smaller percentage than the reported statistics of the population of South Africa where 44.5% live in no income or low income households (8). A household's income status is a good indication of household food security, with lower income households more susceptible to food shortages and vulnerable to food price increases (184). Coping strategies in times of difficulty in purchasing adequate food include buying smaller portions of certain foods, switching to different types of food, reducing the diversity of food or skipping a meal (184). An average of two adults per household was noted. The majority of households had no children living in them. The number of people living in a household has a strong influence on the wealth of the household, as the more members who do not earn an income the greater the household income is divided (8,184).

No associations between income status and risk factors for CDL were found in the study. A common assumption is that individuals from low income households tend to be more overweight than middle or high income households due to their inability to purchase a healthy, nutrient rich diet; but it is also possible for middle or high income households to be overweight due to the easy access to food and food security (129,184,185). Neither of the assumptions were confirmed in this study, suggesting that a more detailed investigation of the role of income and food security in active populations is needed.

3.4.4 Physical Activity Levels and Modifiable Risk Factors for Chronic Diseases of Lifestyle

In this study, female runners had higher average sitting times compared to male runners. Increased sedentary time is associated with an increased risk of developing type 2 diabetes, cancer and CVD (127,186,187). Health education needs to include the detrimental effect of prolonged sitting, especially in a group of individuals who are meeting the weekly physical activity requirements. Importantly, the time spent on vigorous, moderate, walking and sitting physical activity was reported subjectively through a self-reported questionnaire. Acquiring information subjectively is less accurate than an objective measure, allowing the potential for bias with under or over reporting (188,189).

Over estimating physical activity levels in self-reported questionnaires is more prevalent due to social desirability to meet the activity requirements, misinterpretation of the questions or a lack of memory call (189). Objective measures of physical activity is possible using accelerometers (189). Further research, using objective measures, is needed to evaluate physical activity levels and risk factors for CDL in endurance runners.

3.4.5 Running and Modifiable Risk Factors for Chronic Diseases of Lifestyle

In this study, participants with a BMI ≥ 25 kg.m⁻² had significantly slower 10 km running speed and decreased weekly running training distance, compared to participants with a BMI within the normal ranges. However, no difference existed between the duration of weekly training for participants with elevated or normal BMI. Williams (2009) found that the time it took to complete a race was not indicative of risk factors for CDL. Therefore, running slowly is not causative of an elevated BMI but a high BMI can cause a slower speed of running (154).

This affirms the findings of this study that participants with elevated BMI ran at slower speeds, while fulfilling the WHO's recommended weekly minutes. Individuals with elevated BMI have a greater effort in horizontal forward motion and decreased mechanical efficiency that requires increased muscle action and energy usage (190).

3.4.6 Study Limitations

Several limitations were identified that may have impacted the results of this study. While every effort was made to test the participants at a convenient time and situation, several runners may have been unable to access the testing venues. The cost of transport is a hindering factor in South Africa, which may have resulted in runners not being able to attend club runs or races. Running clubs require joining fees and club running outfits and races require entry fees. As recruitment for this study was based at running clubs and races, we recognise that this is a potential factor that may have limited participation from runners of low income groups.

Additional potential barriers to physical activity in South Africa include family and work responsibility, safety concerns, lack of childcare, limited opportunities in rural areas, language barriers, perceived irrelevance of the physical activity, expensive club outfits and sporting equipment, self-consciousness, poor health and lack of confidence (191,192). This study was not designed to address these additional barriers to participation in physical activity, and it is therefore possible that these barriers may have unintentionally limited study participation.

Participants who did not know their current risk factor status or were concerned about their risk factors may have been more inclined to participate in this study. Similarly, individuals who were aware of their risk status may not have volunteered for the study resulting in a potential bias in sample recruitment of participants with a higher possibility of having a risk factor. In addition, past medical history was not determined, which would have been relevant to determine if any participants had been diagnosed with a risk factor or CDL that they had overcome and no longer had as a diagnosis. We only determined participants' current medical diagnosis of CDL and risk factors for CDL. In addition, participants' reasons for running as a sport were not explored.

It is possible that participants may have started running to improve their health status; and had that they may have already seen a positive impact of running on their health, despite still having a risk factor. Further, as this study was cross-sectional in design, we were unable to explore any changes or improvements in risk factors over time.

Chapter 4: Summary and Conclusion

Chronic diseases of lifestyle are a growing concern, as the morbidity and mortality rates continue to rise worldwide despite many initiatives aimed at preventing and reducing the incidence of CDL. Chronic diseases of lifestyle are preventable through the correct management of the modifiable and non-modifiable risk factors (2). Endurance running is a popular sport with many health benefits (13,131,138,139). However, it is unclear if individuals who regularly participate in endurance running as a sport are fulfilling the physical activity requirements; and monitoring and preventing their risk factors for CDL. To the knowledge of the researchers, this is the first study that has attempted to determine the prevalence of CDL and the associated risk factors in a sample group of endurance runners in South Africa.

Based on the findings of this dissertation, the study objectives described in Section 1.3.2 (page 3) may be answered as follows:

- *To determine the presence of risk factors for the development of CDL, including BMI, waist circumference, body fat percentage, blood pressure, glucose concentration, cholesterol concentration, smoking history, dietary intake and weekly physical activity time in South African endurance runners.*

A very high prevalence of risk factors for CDL was found in the South African endurance runners (n=124; 62%). The most prevalent risk factor was a high BMI, followed by high blood pressure, then abnormal blood glucose concentration. The prevalence of a high BMI in males was higher than the general population in South Africa. The majority of the South African endurance runners with a high BMI had normal waist circumference or body fat percentage. However, the high incidence of elevated BMI found in the South African endurance runners is still concerning as it is higher than that reported to be found in endurance runners (84,152). The prevalence of high blood pressure was lower than the general population in South Africa, but was still higher than expected, particularly as endurance running is known to lower blood pressure and improve cardiovascular function (4,139,182). An elevated blood glucose concentration, found in twenty participants, is deeply concerning as it is strongly associated with the development of type 2 diabetes (55,193). A low prevalence of abnormal blood cholesterol was found in the South African endurance runners. Seven percent of females were current smokers which equates to the prevalence of smoking in the South African female population (4). This finding was higher than expected for a group of female endurance runners. Only one third of the participants accurately determined that five or more portions of fruit and vegetables consumed daily is the national recommendation. However, two thirds of the participants acknowledged that increasing their consumption of fruit and vegetables daily would decrease their risk of developing a stroke, cancer or heart disease.

Importantly, nineteen participants did not fulfil the recommended weekly physical activity time and maintain a risk for developing CDL through physical inactivity.

- *To determine the presence of non-modifiable risk factors to the development of CDL, namely income and age, in South African endurance runners.*

There were no significant differences between income and risk factors of CDL in the South African endurance runners. Waist circumference, systolic blood pressure and cholesterol were all significantly elevated in the participants above the age of 50 years; however the values were still within the acceptable, normal ranges.

- *To determine whether South African endurance runners are fulfilling the WHO's recommended weekly moderate to vigorous intensity physical activity hours.*

Despite wide variations in running volume, intensity and duration that was observed in endurance runners in this study, the majority of the participants did meet the WHO's recommended weekly physical activity levels. However, 19 participants (9.5%) did not meet the required weekly physical activity levels. This is of concern, because runners may assume a protective effect of endurance running, but may be unaware of their increased risk for the development of CDL. Females reported sitting more during the day than males, which has the potential to increase the risk of developing CDL as an increase in sedentary behaviour, irrespective of the amount of endurance running, increases the risk of CDL (127).

- *To assess whether there are any relationships between the running characteristics, namely weekly training hours, running speed and level of competition; and the risk factors for CDL.*

Participants with high BMI's ran at slower speeds over a 10 km distance and ran less kilometres in per week, compared to participants with normal BMI. However, participants with high BMI's completed the same duration of training weekly as the participants with normal BMI. There were no further differences between the running characteristics and risk factors for CDL.

In conclusion, this study identified a high prevalence of risk factors for CDL in South African endurance runners. Endurance runners continue to remain at risk for the development of CDL due to the high prevalence of risk factors for CDL. This study has highlighted a critical need for improved better health awareness among South African endurance runners to minimise the possibility of developing CDL. Endurance runners should be advised to partake in pre-participation screening and regular medical assessments. There is an urgent imperative for educational interventions to educate and empower endurance runners regarding risk factors for CDL and their lifestyle choices. Further, health care professionals are required to improve the prevention and management of the risk factors for CDL in endurance runners through education and promotion of healthy living. A reduction in the prevalence of risk factors for CDL in South African endurance runners can only be achieved through concerted and combined efforts of health care professionals and endurance runners.

Chapter 5: References

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Appendix I: Letter to Running Club Secretaries



UNIVERSITY OF CAPE TOWN



Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery;

Occupational Therapy; Physiotherapy; Disability studies

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30 November 2016

Club Secretary

To: Whom This May Concern

Re: Participants required for University of Cape Town Physiotherapy study

I am a Masters student at the University of Cape Town. I am currently researching and completing a study to determine the prevalence of chronic diseases of lifestyle in runners.

I am looking to recruit runners for my study who are older than 18 years, have been running for a minimum of one year and run at least twice a week. The study will require the runners to fill out a questionnaire and have their physical status measured through the testing of their blood pressure, body fat percentage, waist circumference, body mass index, blood glucose and blood cholesterol concentration.

I would like to conduct the testing at the running club so that it is convenient for the runners. Do you have a room that I would be able to use for the testing? If no space is available I will find a venue of convenience for the runners close to the running club to conduct the testing.

I have attached the study advertisement for interested participants and I would appreciate your assistance in distributing the advertisement to the runners.

Please contact me if you have any questions or concerns, or require further information regarding the study.

Kind Regards

Sarah Kelly

BSc Physiotherapy (UCT)

Tel: 083 643 1005

MALE AND FEMALE RUNNERS NEEDED FOR A UCT STUDY

The study aims to determine the prevalence of chronic diseases of lifestyle and the risk factors for chronic diseases of lifestyle in runners.

Study Outline

I am a Masters student at the University of Cape Town and I am conducting a study to determine the prevalence of chronic diseases of lifestyle and the associated risk factors in runners. The study aims to provide information as to whether runners are susceptible to the chronic diseases of lifestyle, which are type 2 diabetes, cardiovascular disease, chronic respiratory disease and cancer and the risk factors for these chronic diseases of lifestyle, which are a high blood pressure, impaired glucose tolerance, high cholesterol concentration, high BMI, high waist circumference, smoking and physical inactivity.

You will be required to attend one 20 minute testing session at your local running club. You will be required to fill out a questionnaire and have your physical health status measured. The questionnaire will ask after your medical history, training history, nutritional health and socioeconomic status. The physical testing will be to take your blood pressure, height, weight, waist circumference, skinfold measurement, blood glucose concentration and blood cholesterol concentration.

Those interested in participating should:

- Be between 18 and 70 years old
- Have been running for at least a year
- Run at least twice a week

Benefits of participating in the study:

- You will find out your blood pressure, BMI, body fat percentage, cholesterol and blood sugar concentration.
- Information pamphlet on chronic diseases of lifestyle and how to prevent them.

If you are interested in taking part in this study or would like additional information, please contact

Sarah Language

083 643 1005 / sarah.language456@gmail.com

Appendix II: Advertisement



Runners needed as research participants in a University of Cape Town study

Study title: Prevalence and risk factors of chronic diseases of
lifestyle in endurance runners

Who can take part:

- males and females 18 years or older
- if you consider running as your main sport and run at least twice a week.
- If you have not eaten in the past 2 hours

What does it require of you:

1. Fill out a questionnaire
2. Have the following measured:
Blood glucose, blood cholesterol, blood pressure, body mass index, waist circumference, body fat percentage

If you are interested:

Please contact Sarah on
0836481005 /
sarah.language456@
gmail.com

Testing will be done at
your local running club
or LowMed
Physiotherapy
Department

The testing takes 30
minutes

Testing between
December 2016 and
April 2017

University of Cape Town

Department of Health and
Rehabilitation Department
of Health and Rehabilitation

Physiotherapy Division

Sarah Language

Appendix III: Informed Consent Form



UNIVERSITY OF CAPE TOWN



Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery;

Occupational Therapy; Physiotherapy; Disability studies

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MSc Exercise and Sports Physiotherapy Study: The Prevalence and Risk Factors for Chronic Diseases of Lifestyle in runners.

Informed Consent Form

Dear Participants

I am a Masters student at the University of Cape Town in the Division of Physiotherapy. I will be conducting a study to determine the prevalence of chronic diseases of lifestyle and the risk factors for chronic diseases of lifestyle in endurance runners. Information obtained from this study will be used to complete my mini-dissertation, which is part of my fulfilment of the MSc Exercise and Sports Physiotherapy program.

This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town. The UCT Human Research Ethics Committee can be contacted on 021 406 6338 for if you have any questions regarding your rights and welfare as a participant in this study.

Chronic Diseases of Lifestyle are diseases that result from poor dietary habits, an inactive lifestyle and tobacco use. The diseases include diabetes type 2, cardiovascular disease, chronic respiratory disease and certain cancers. There are certain risk factors which are warning signs from your body that if left untreated may result in the development of the disease. These risk factors include a high blood pressure, high blood glucose concentration, high blood cholesterol concentration, increased waist circumference and BMI, smoking and performing less than 150minutes of moderate-to-vigorous physical activity per week. Chronic diseases of lifestyle have become a big problem in our country however there is poor research looking at the prevalence of the diseases in an assumed, healthy group of runners.

For this study you will be asked to attend only one session, lasting approximately thirty minutes at your local running club or physiotherapy practice where the questionnaire and testing will be completed. You will need to have not eaten or drunk any liquids for three hours prior to the testing. You will be required to travel to your local running club or physiotherapy practice at your own expense as there is no funding available for this study. You have the right to withdraw from this study at any point without any consequence to yourself. This study will be supervised by Dr Theresa Burgess from the University of Cape Town. Please take the time to read through this form thoroughly before signing.

Testing Procedure:

The testing procedure will last approximately thirty minutes. You will be asked to complete a questionnaire regarding your medical history, nutritional habits, socioeconomic status, training, and competition history. Once you have completed the questionnaire your physical measurements will be taken. This includes your height, weight, waist circumference, skin folds, blood pressure, blood glucose and blood cholesterol. The first measurement taken will be your blood pressure. This will be taken using a blood pressure cuff. Following that you will be required to stand against a vertical scale to measure your height and stand on a scale to determine your weight. Your height and weight will be used to calculate your body mass index. Your waist circumference will be measured as the diameter around your waist using a tape measure. Seven skin folds will then be measured using callipers to determine your body fat percentage. Lastly your index finger on your non-dominant hand will be sterilized using an alcohol swab and pricked to obtain a blood sample to measure your glucose and cholesterol concentration. Your finger will be covered with a cotton wool ball and pressure applied to stop bleeding.

All data will be kept on a password protected file for the duration of the data analysis and once completed all records will be permanently deleted.

Potential Risks:

One of the potential risks is the discovery that you may have a risk factor for chronic diseases of lifestyle that you were previously unaware of. Any participants who is found to have abnormal measurements with the testing will be referred to the relevant health professional in order for further investigations and management. Another potential risk is that you are required to have your finger pricked to obtain a blood drop sample. A finger prick test has the possibility of causing an infection due to piercing the skin. Every effort will be taken to ensure that your finger is clean through disinfecting your finger with an alcohol swab to prior to the finger prick. A new, sterile needle will used for each participant. After the finger prick a cotton wool swab will be held with pressure against your finger to stop the bleeding and secured to the finger with a sticky strip. You might feel slight discomfort with the measurement of the skin folds as the callipers used for testing may pinch your skin slightly.

Benefits:

You will be given the values on all of your physical measurements taken so that you can know your current medical status with regards to the risk factors for chronic disease of lifestyle. This information will be useful in managing your medical state. You will also be given an information pamphlet regarding chronic diseases of lifestyle and the risk factors for chronic diseases of lifestyle. This information will be useful in empowering you to manage your health state in order to prevent the onset of chronic diseases of lifestyle.

Insurance:

UCT has taken out insurance in the event of a research/trial-related injury, i.e. harm suffered as a result of participation in the trial. UCT agrees to pay all reasonable medical expenses in accordance with the Association of the British Pharmaceutical Industry Guidelines (ABPI) in the event of an injury or side-effect resulting directly from your participation in the trial.

The ABPI guidelines recommend that UCT should compensate you, without you having to prove that UCT is at fault, for any injury resulting from any procedure carried out in accordance with the protocol for this study.

UCT will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by

- The use of unauthorised medicine or substances during the study
- Any injury that results from you not following the protocol requirements or the instructions that the study doctor may give you
- An injury that results from negligence on your part

Questions or Concerns:

If at any time you have any questions about the study, please feel free to contact any of the individuals listed below. You are assured that all enquiries will remain confidential.

Sarah Language

LowMed Physiotherapy Department

30 Orange Street

West Acres

Nelspruit

Telephone number: 083 643 1005 / 013 741 3824

Email: sarah.langauge456@gmail.com

Dr. T. Burgess

Division of Physiotherapy

School of Health and Rehabilitation

University of Cape Town

Groote Schuur Hospital

Anzio Road

Observatory

Telephone number: 021 406 6171 / Fax number:
021 406 6323

Email: Theresa.burgess@uct.ac.za

By placing your signature below, it serves as confirmation that you have had adequate time to read through the study information, that you have understood the consent form and that you are willing to participate in this study. You have the right to withdraw at any time and you may ask questions at any time during the study. All information recorded during this study will remain confidential, and no participants will be identified in the event of future publication. Your signature is further confirmation that you are aware of the possible risks involved in this study.

Signature of Participant/witness

Name (Please Print)

Date

Signature of Investigator

Name (Please Print)

Date

Appendix IV: Questionnaire



UNIVERSITY OF CAPE TOWN



Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery;

Occupational Therapy; Physiotherapy; Disability studies

F45 Old Main Building, Groote Schuur Hospital Observatory, Cape Town, W Cape, 7925

Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534 Fax: +27 (0) 21 406 6323

MSc Exercise and Sports Physiotherapy

Chronic Diseases of Lifestyle and Runners study

Questionnaire

The information used in this questionnaire will only be used for research purposes within the scope of this study. All information will be kept strictly confidential.

Instructions:

Please complete all the sections in this questionnaire before having your measurements taken.

Answer each question by filling in the details in the allocated space or checking one or more of the option boxes.

Informed consent form must be completed prior to filling out the questionnaire.

Investigator:

Sarah Language

Contact number: 083 643 1005

Email: sarah.language456@gmail.com

Supervisor:

Dr Theresa Burgess

Contact number: 021 406 6171

Email: Theresa.burgess@uct.ac.za

Section A: Personal Details

1. Date of Birth:

2. Gender:

Male Female

3. Which of these apply to you"

- Current smoker
- Ex-Smoker
- Never smoked

4. How many people live in your household (including yourself)

Adults and children over the age of 16 _____

Children under the age of 16 _____

5. We are interested to know how exercise and diet are related to income and would like you to complete the question below. If you would prefer not to answer this question please leave it blank.

What is your total gross household monthly income before tax and including benefits?

- | | |
|---|---|
| <input type="checkbox"/> Less than R2 000 | <input type="checkbox"/> R30 000-R40 000 |
| <input type="checkbox"/> R2 000-R5 000 | <input type="checkbox"/> R40 000-R50 000 |
| <input type="checkbox"/> R5 000-R10 000 | <input type="checkbox"/> R50 000-R100 000 |
| <input type="checkbox"/> R10 000-R20 000 | <input type="checkbox"/> More than R100 000 |
| <input type="checkbox"/> R20 000-R30 000 | |

Section B: Level of Activity

This section of the questionnaire will ask you about the time you spent being physically active in the **last 7 days**. Please think about the activities you do at work, as part of your house and garden work, to get from place to place, and in your spare time for recreation, exercise or sport.

For all the questions in this section you will be required to refer to table 1 to differentiate between moderate and vigorous activity. It is accepted that fairly light – somewhat hard (rating 10-14) is considered moderate activity and hard – very hard (rating 15-20) is vigorous activity.

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Table 1. The Borg Rating of Perceived Exertion Scale

Think about all the **vigorous** activities that you did in the **last 7 days**. Think *only* about those physical activities that you did for at least 10 minutes at a time.

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

_____ **days per week**

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

_____ **hours per day**

_____ **minutes per day**

Think about all the **moderate** activities that you did in the **last 7 days**. Think *only* about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

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

_____ **hours per day**

_____ **minutes per day**

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

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

_____ days per week

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

_____ hours per day

_____ minutes per day

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

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

_____ hours per day

_____ minutes per day

Section B: Medical History

1. Have you ever been diagnosed with any of the following by a medical doctor or been given medication for any of them?

- | | |
|--|--|
| <input type="checkbox"/> Arthritis | <input type="checkbox"/> High blood pressure |
| <input type="checkbox"/> Asthma | <input type="checkbox"/> High cholesterol |
| <input type="checkbox"/> Cancer | <input type="checkbox"/> Hyperglycaemia (high blood sugar) |
| <input type="checkbox"/> COPD | <input type="checkbox"/> Hypoglycaemia (low blood sugar) |
| <input type="checkbox"/> Diabetes | <input type="checkbox"/> Stroke |
| <input type="checkbox"/> Heart disease | |

2. Do you suffer from

- | | |
|--|--|
| <input type="checkbox"/> Chest pain | <input type="checkbox"/> Palpitations |
| <input type="checkbox"/> Swollen ankles | <input type="checkbox"/> Fainting spells |
| <input type="checkbox"/> Unexplained shortness of breath | |

3. Does anyone in your family have any of the following medical conditions?

- | | |
|------------------------------------|--|
| <input type="checkbox"/> Arthritis | <input type="checkbox"/> Heart disease |
| <input type="checkbox"/> Asthma | <input type="checkbox"/> High blood pressure |
| <input type="checkbox"/> Cancer | <input type="checkbox"/> High cholesterol |
| <input type="checkbox"/> COPD | <input type="checkbox"/> Stroke |
| <input type="checkbox"/> Diabetes | |

4. Do you use any prescribed medication to treat chronic medical conditions or injuries?

Section C: Nutrition

1. Have you eaten any of these foods in the last 24 hours? 1 portion = 1 serving

Portion Size	1	2	3	4	5
Breakfast cereal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit for Breakfast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chips	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit as a between meal snack	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A glass of pure, unsweetened fruit juice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit as a starter to a meal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A baked potato	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A bowlful of home-made style vegetable soup	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Portion of vegetables with main meal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any type of meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A vegetable based meal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any type of fish	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A bowlful of salad	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit as a dessert	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. How many portions of a combination of fruit and vegetables do you think health experts would recommend eating every day?

None	<input type="checkbox"/>	Five	<input type="checkbox"/>
One	<input type="checkbox"/>	Six	<input type="checkbox"/>
Two	<input type="checkbox"/>	Seven or more	<input type="checkbox"/>
Three	<input type="checkbox"/>	Don't know	<input type="checkbox"/>
Four	<input type="checkbox"/>		

3. How many portions of fruit and vegetables do each of the following provide?

- A small glass (150ml) of unsweetened orange juice _____
- One glass of diluted orange squash _____
- A thin slice of tomato _____
- Three heaped tablespoons of carrots _____
- One medium sized apple _____
- One small raspberry flavoured yogurt _____

4. How important are the following to you in deciding how much fruit and vegetables you eat?

	Very Unimportant	Unimportant	Neutral	Important	Very Important
The money I have available to spend on fruit and vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prices of fruit and vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My knowledge about ways to prepare fruit and vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The time I have to prepare fruit and vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How easy it is for me to get to the shops	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How heavy my shopping bag is to carry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Likes and dislikes of my household for fruits and vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The quality of fruit and vegetables available	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Do you think you will increase the number of fruit and vegetables you eat in the next year?

6. By eating more fruit and vegetables, I think that people can reduce their chances of getting...

	Strongly Agree	Agree Slightly	Neutral	Disagree Slightly	Strongly Disagree
Stroke	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cancer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Back Pain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hearing Problems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Heart Disease	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section D: Training History

1. How many days a week do you run?

2. What is your average weekly mileage?

- 0-30 km/week
- 31-40 km/week
- 41-50 km/week
- 51-60 km/week
- 61-70 km/week
- 71-80 km/week
- 81-90 km/week
- 91-100 km/week
- >100 km/week

3. For how many years have you been running?

4. Have you completed any of the following races in the past 12 months? How many have you completed in category?

5. What event are you currently training for?

- | | | | |
|--------|------------------------------|-----------------------------|---------|
| 10km | <input type="checkbox"/> yes | <input type="checkbox"/> no | number: |
| 21.1km | <input type="checkbox"/> yes | <input type="checkbox"/> no | number: |
| 42.2km | <input type="checkbox"/> yes | <input type="checkbox"/> no | number: |
| >50km | <input type="checkbox"/> yes | <input type="checkbox"/> no | number: |

6. At what speed would you complete the following races? Place an X in the appropriate box

	5km	10km	21.1km	42.2km	>50km
3:45min/km-4min/km					
4min/km-4:30min/km					
4:30min/km-5min/km					
5min/km-5:30min/km					
5:30min/km-6min/km					
6min/km-6:30min/km					
6:30min/km-7min/km					
7min/km-8min/km					

7. Do you currently participate in another form of exercise aside from running? If yes, please state what form of exercise.

8. Do you or did you suffer from any symptoms of a running injury in the past 3 months?

9. If yes, did the symptoms result in the inability to run? For how long were you unable to run?

Appendix V: Feasibility Study

INTRA-RATER RELIABILITY OF MEASUREMENTS REQUIRED FOR DETERMINING BLOOD PRESSURE, WAIST CIRCUMFERENCE, SKIN FOLDS, GLUCOSE, AND CHOLESTEROL IN ENDURANCE RUNNERS

VII.I Background

Intra-rater reliability is the ability of an investigator to accurately perform a specific testing method repeatedly, over a period of time (194). For this study, it is essential that the information gathered demonstrates satisfactory intra-rater reliability to ensure the accurate collection of a participant's measurements in determining the risk factors for CDL.

VII.II Aim

The aim of this feasibility study was to determine:

1. The intra-rater reliability of anthropometry measurements, including waist circumference and skin folds.
2. The intra-rater reliability of the tests utilising machines, with established validity, to determine blood pressure, blood glucose, and blood cholesterol.

VII.III Methodology

a. Participants

Ten participants (n=10), including 5 females (n=5) and 5 males (n=5), were included in the feasibility study. The participants fulfilled the inclusion criteria for the main study.

b. Testing Procedure

The ten participants were each tested three times at a single session. All testing was performed by the researcher.

1. Blood pressure (mmHg) was assessed using an automatic blood pressure monitor (Omron M6 Comfort IT Upper Arm Blood Pressure Monitor).

Participants were required to be seated for three minutes before blood pressure was measured. Systolic and diastolic pressure were recorded.

2. Blood glucose concentration was assessed using an Accu-Chek Active glucose meter. A finger prick was performed using an Accu-Chek Safe T Pro Uno lancing device on the outer section of the top of the chosen finger. A blood drop was collected on a test strip and inserted into the meter. Participants were requested to fast for three hours prior to testing (165). Testing was performed with participants in a seated position.
3. Blood cholesterol concentration was assessed using a blood cholesterol meter (Accutrend GCT Meter). A second drop of blood from the single finger prick was collected and inserted into the meter.
4. Six skinfolds (triceps, subscapular, suprailiac, abdomen, thigh and calf) were measured using skinfold calipers. Body fat is expressed as the sum of the six skinfolds, as described by Withers, Craig, Bourdon, & Norton (1987) (168).
5. Waist circumference (cm) was measured half way between the 10th rib and top of the iliac crest with a tape measure (170).

c. Statistical Analysis

Data were analysed using a spreadsheet specifically designed for this purpose downloaded from www.sportsci.org. Typical error of measurement and intra-class coefficients were assessed, and reported with their respective 95% confidence intervals. Intra-rater reliability was accepted as $r \geq 0.7$. All data are presented as the mean \pm standard deviation.

d. Results

Table 1: Intra-rater reliability of blood pressure, blood glucose, blood cholesterol, skin folds, and waist circumference on participants in the feasibility study (n=10). Data are expressed as typical error and intra-class coefficients (ICC) with their 95% confidence intervals (CI) and mean \pm standard deviation.

Measurement		Typical error (95% CI)	ICC (95% CI)	Mean \pm standard deviation
Blood pressure (mmHg)	Systolic	3.02 (2.33-4.42)	0.92 (0.81-0.97)	127 \pm 10
	Diastolic	1.74 (1.34-2.54)	0.98 (0.94-0.99)	80.0 \pm 9.4
Blood glucose (mmol.l ⁻¹)		0.11 (0.09-0.16)	0.99 (0.98-1.0)	5.5 \pm 0.8
Blood cholesterol (mmol.l ⁻¹)		0.05 (0.04-0.07)	1.00 (1.00-1.00)	4.9 \pm 1.2
Skin Folds (mm)	Triceps	1.72 (1.32-2.51)	0.96 (0.89-0.99)	16.1 \pm 7.2
	Subscapular	1.50 (1.15-2.19)	0.94 (0.85-0.98)	13.7 \pm 5.3
	Suprailiac	1.53 (1.18-2.24)	0.94 (0.84-0.98)	11.6 \pm 5.3
	Abdominal	1.99 (1.53-2.91)	0.94 (0.86-0.98)	19.7 \pm 7.1
	Thigh	1.82 (1.40-2.66)	0.97 (0.93-0.99)	20.1 \pm 9.5
	Calf	1.76 (1.35-2.57)	0.97 (0.93-0.99)	16.2 \pm 9.2
Waist circumference (cm)		1.67 (1.28-2.44)	0.98 (0.94-0.99)	81.6 \pm 9.6

VII.VIII Summary and Conclusion

Intra-rater reliability is expressed as typical error (95% confidence error) and intra-class coefficient (95% confidence interval). Acceptable intra-rater reliability is accepted as $r \geq 0.7$. Therefore, the results reported above indicate satisfactory intra-rater reliability for each measurement.

Appendix VI: Human Research Ethics Committee Approval



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee



Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone (021) 406 6626
Email: stucate.thomas@uct.ac.za

Website: www.health.uct.ac.za/fhs/research/humanethics/forms

15 November 2016

HREC REF: 627/2016

Dr T Burgess
Health & Rehabilitation Sciences
F45, Old Main Building
GSH

Dear Dr Burgess

PROJECT TITLE: PREVALENCE AND RISK FACTORS OF CHRONIC DISEASE OF LIFESTYLE IN ENDURANCE RUNNERS (MPhil candidate- Ms S Kelly)

Thank you for your response to the Faculty of Health Sciences Human Research Ethics Committee dated 4th November 2016.

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

Approval is granted for one year until the 30th November 2017.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period. (Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)


Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

The HREC acknowledge that the student, Sarah Kelly will also be involved in this study.

Yours sincerely


PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

HREC 627/2016



FHS016: Annual Progress Report / Renewal

HREC office use only (FWA20001637; IRB00001938)			
This serves as notification of annual approval, including any documentation described below.			
<input checked="" type="checkbox"/> Approved	Annual progress report	Approved until next renewal date	30 Nov 2018
<input type="checkbox"/> Not approved	See attached comments		
Signature Chairperson of the HREC		Date Signed	6/4/18

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol Information

Date when submitting this form	6 th April 2018		
HREC REF Number	627/2016	Current Ethics Approval was granted until	30 November 2017
Protocol title	Prevalence and Risk Factors of Chronic Diseases of Lifestyle in Endurance Runners		
Protocol number (if applicable)			
Are there any sub-studies linked to this study?	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		
If yes, could you please provide the HREC Ref's for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal investigator	Dr Theresa Burgess		
Department / Office Internal Mail Address	Theresa.burgess@uct.ac.za		

Appendix VII: Information Pamphlet

My Personal Data

Date:

BMI:

Waist Circumference:

Body fat %:

Blood Pressure:

Cholesterol levels:

Glucose levels:

**If you have any questions
please contact Sarah on**

083 643 1005 /

sarah.language456@gmail.com

OR

**Contact your local doctor for a
medical examination**

CHRONIC DISEASES OF LIFESTYLE



**AND THE RISK
FACTORS**

Chronic diseases of lifestyle are a group of diseases including:

- Type 2 Diabetes
- Cardiovascular Disease
- Chronic Pulmonary Disease
- Cancer

The onset of chronic diseases of lifestyle are as a result of decades of exposure to an unhealthy diet, lack of exercise and smoking

Risk Factors

Risk factors indicate your body is heading towards the development of a chronic disease of lifestyle.

The risk factors are abnormal or elevated values from the norms on the following page.

Normal Values

Blood Pressure	Below 140/90
Blood Glucose	Below 6mmol.l-1
Blood cholesterol	Below 5.5mmol.l-1
Waist Circumference	Females less than 88cm Men less than 102cm
Exercise	150minutes of moderate-to-intense weekly

Body Fat Percentage		
Description	Females	Men
Essential Fat	10-13%	2-5%
Athletes	14-20%	6-13%
Fitness	21-24%	14-17%
Normal	25-31%	18-24%
Obesity	≥32%	≥25%

Body Mass Index	
Classification	BMI
Underweight	<18,5
Normal	18,5-24,9
Overweight	25,0-29,9
Obesity	>30

Running

Running is an effective way of decreasing the risk factors for Chronic Diseases of Lifestyle.

Since you are already a runner, keep going!

The World Health Organization recommends exercising for 150 minutes every week.

Health benefits of running:

- Increased cardiovascular fitness
- Lowers blood pressure
- Stabilizes blood glucose
- Lowers cholesterol levels
- Decreases or maintains body weight
- And many more



