FACULTY OF COMMUNITY AND HEALTH SCIENCES

RESEARCH THESIS

TITLE OF THESIS:	Insulin resistance, physical activity and physical fitness in adults residing in a northern suburb of Cape Town
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KEY WORDS:

Insulin resistance, diabetes, HOMA-IR, physical activity, GPAQ, health-related physical fitness.

DECLARATION

I declare that *Insulin resistance, physical activity and physical fitness in adults residing in a northern suburb of Cape Town* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: Clare Bartels Date: 30 June 2011

Signed: …….

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ABSTRACT

Insulin resistance has shown to be a precursor to a number of lifestyle-related chronic diseases and abnormalities in adults and is affected by a number of factors including genetics, age, physical activity and acute exercise, diet, obesity, body fat distribution and medication. Physical activity has shown to have marked effects on improving sensitivity to insulin though various physiological mechanisms, and numerous correlation studies have identified a relationship between these two variables, suggesting the beneficial role of exercise on insulin resistance. This study aimed to identify a relationship between current levels of physical activity, physical fitness and insulin resistance in adults between the ages of 35 and 65 years of age residing in a northern suburb community in Cape Town.

A total of 186 volunteers participated in this study ranging from healthy individuals to those with diagnosed chronic conditions. Insulin resistance (determined by the homeostasis model assessment of insulin resistance), physical activity (measured by the Global Physical Activity Questionnaire) and five health-related physical fitness tests were measured. The five components included body composition, determined by body mass index and waist circumference, the 3-minute cardiorespiratory step test, the handgrip muscle strength test, one-minute crunches for muscle endurance and the sit-and-reach flexibility test. Spearman correlation was used to

identify the relationships between the homeostasis model assessment of insulin resistance, age, body composition and physical activity and fitness. Results showed that body mass index and waist circumference were the only two variables which produced significant correlations with the homeostasis model assessment of insulin resistance ($p < 0.019$). No physical activity or fitness data produced significant scores with the homeostasis model assessment of insulin resistance. Body mass index in men was the only significant predictor of HOMA-IR and explained 37% of the variance in insulin resistance, whereas in women, only waist circumference was related to HOMA-IR, but explained less than 16% of the variance. Associations between reported MET-minutes from the Global Physical Activity Questionnaire and the four fitness tests indicated significance with handgrip strength ($\rho = 0.17$; $p = 0.039$), one-minute crunches ($\rho = 0.18$; $p = 0.024$) and sit-and-reach flexibility ($\rho = 0.17$; 0.034).

This study has shown that body composition is an important component in influencing insulin resistance therefore physical activity interventions should be targeted at increasing physical activity levels and reducing body weight.

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CONCEPTS AND DEFINITIONS

INSULIN RESISTANCE

Insulin resistance is a pathological state resulting from the inability of the peripheral target tissues (usually muscle) to respond effectively to normal circulating concentrations of insulin. In insulin-resistant conditions, there is a decreased glucose clearance in response to insulin (Shanik et al., 2008; Petersen & Shulman, 2002; LeRoith & Zick, 2001; Bouché, Serdy, Kahn & Goldfine, 2004).

INSULIN SENSITIVITY

Increased insulin sensitivity is determined by the ability of insulin to promote glucose uptake and utilization, and is characterized by the muscle being more sensitive to the actions of insulin (Bouché et al., 2004; Goodyear & Khan, 1998).

DIABETES MELLITUS

Diabetes mellitus is a group of metabolic disorders resulting from defects in insulin secretion, insulin action or both. Insulin is produced in the β-cells of the pancreas and is responsible for the regulation of glucose metabolism. There are two main subgroups of diabetes, namely type 1 and type 2. Type 2 diabetes is caused by insulin resistance and defects in tissue sensitivity to insulin. It is also caused by an insulin secretary defect

and is often associated with elevated insulin concentrations (American College of Sports Medicine, 2010).

IMPAIRED GLUCOSE TOLERANCE

Impaired glucose tolerance (IGT) indicates a state of increased risk of progression to diabetes and denotes the range between normal glucose tolerance and diabetes. IGT is defined by the value between 7.7-11.0 mmol·L $^{-1}$ in an oral glucose tolerance test (ACSM, 2010).

IMPAIRED FASTING GLUCOSE

Impaired fasting glucose (IFG) includes the zone between the upper limit of normal fasting plasma glucose and the lower limit of the diabetic fasting plasma glucose. IFG is defined by the value between 5.5-6.93 mmol·L^{-1} (ACSM, 2010).

PHYSICAL ACTIVITY

Physical activity is defined by any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure. Physical activity guidelines include a moderate amount of physical activity such as 30 minutes of brisk walking on most, if not all days of the week (ACSM, 2010; U.S. Department of Health and Human Services, 1996). In this study physical activity incorporates occupational, transport-related and recreational activity.

METs (INTENSITY)

METs (metabolic equivalents) are defined as multiples of the resting metabolic rate and can be expressed in terms of oxygen consumption per unit body mass. One MET is equivalent to 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (McArdle, Katch & Katch, 2010) and is commonly used to express the intensity of an activity. In this study, intensity will be expressed as MET-min per week. These values will then be classified into three categories of low, moderate and high according the amount of physical activity achieved in one week (WHO, n.d.).

HEALTH-RELATED PHYSICAL FITNESS TESTING

Health-related physical fitness includes cardiorespiratory endurance (aerobic capacity), muscular strength, muscular endurance and flexibility. These tests are important for the performance of activities of daily living and quality of life.

CARDIORESPIRATORY FITNESS / AEROBIC CAPACITY

Aerobic capacity is the ability to perform large muscle, dynamic, moderate to high intensity exercise for prolonged periods of time. Cardiorespiratory fitness is considered health-related as low levels of cardiorespiratory fitness is associated with an increased risk for premature death from all causes and specifically from cardiovascular disease, increases in cardiorespiratory fitness is associated with a reduction in death from all causes and high levels of cardiorespiratory fitness is associated with

higher levels of habitual levels of physical activity, which in turn is associated with many health benefits (ACSM, 2010).

MUSCULAR STRENGTH

Muscle strength is defined as the maximal force that a muscle or muscle group can generate at a specific velocity (Baechle & Earl, 2000). Strength can be measured either statically (no movement) or dynamically (movement resulting in muscle length changes) (ACSM, 2010). Static strength will be used to determine overall body strength in the proposed study.

MUSCULAR ENDURANCE

Muscle endurance is defined as the ability of a muscle group to execute repeated contractions over a period of time sufficient to cause muscular fatigue, or to maintain a specific percentage of the maximum voluntary contraction for a prolonged period of time (ACSM, 2010).

FLEXIBILITY

Flexibility is the ability to move a joint through its complete range of motion and is significant in order to carry out activities of daily living. Maintaining flexibility of all the joints facilitates movement (ACSM, 2010).

CHAPTER ONE

INTRODUCTION

"The exercise boom is not just a fad; it is a return to 'natural' activity—the kind for which our bodies are engineered and which facilitates the proper function of our biochemistry and physiology. Viewed through the perspective of evolutionary time, sedentary existence, possible for great numbers of people only during the last century, represents a transient, unnatural aberration."
(Eaton, Konner & Shostak, 1988)

Chapter one explores the background of chronic disease, its development over time and how physical inactivity has influenced this growth. Insulin resistance, a precursor to a number of chronic diseases, is described, as well as its link with physical activity. The two major conditions associated with insulin resistance, obesity and type 2 diabetes, are also discussed.

1.1 PHYSICAL ACTIVITY AND CHRONIC DISEASE

The human genome is designed for physical activity. From the late Paleolithic (Late Stone Age) era approximately 10 000 years ago, until the mid nineteenth century, our ancestors lived as hunters, gatherers, scavengers, toolmakers and farmers among many other activities performed in order to survive (LaMonte, Blair & Church, 2005; Roberts & Barnard, 2005). For most of our human history, physical activity not only took the form of physical labour, but also as cultural and recreational activities such as dancing. During this period, physical activity was an

obligatory and integral part of our ancestral existence (Booth, Chakravarthy, Gordon & Spanenberg, 2002).

Since the dawn of the twentieth century however, within just a few generations, the physical demands of laborious work, domestic chores and recreational activities have progressively and drastically declined, and have nearly been extinguished within industrialised and westernised societies (Sparling, Owen, Lambert & Haskell, 2000). Occurring concomitantly, this period has given rise to non-communicable, chronic diseases of lifestyle (CDL), some almost unknown in previous centuries (Booth, Chakravarthy & Spangenberg, 2002). A chronic disease of lifestyle develops over a number of years, with its pathogenic manifestations only becoming diagnosed once overt. For many, the disease culminates in disability and premature morbidity, adding to human suffering and economic burden (Harlen & Harlen, 2009, World Health Organization [WHO], 2005).

The onset and progression of chronic diseases of lifestyle are mediated by an interaction between genetic factors and the environment, known as gene-environment interaction (Roberts & Barnard, 2005). However, over the past 10 000 years, the genetic composition of the genome has remained predominantly unchanged, which suggests an alteration of the human environment as a possible cause (LaMonte et al., 2005; Roberts & Barnard, 2005; Booth, Gordon, Carlson & Hamilton, 2000). The development of CDL's are, however, highly dependent on our genetic

make-up, but these genetic factors only predispose us to these diseases, with the environmental factors determining whether the disease manifests or not. These environmental factors are largely lifestyle related, namely physical inactivity and poor diet, but also include smoking, alcohol consumption and stress (Roberts & Barnard, 2005).

Globally, chronic diseases have accounted for an estimated 35 million deaths out of 58 million deaths from all causes; which is double the number of deaths from all infectious diseases (including HIV/AIDS, tuberculosis and malaria), maternal and peri-natal conditions and nutritional deficiencies combined (WHO, 2005). In addition, the latter are projected to decline by three percent over the next ten years whereas in the same period, deaths due to chronic diseases are projected to increase by 17% (Puoane, Tsolekile, Sanders & Parker, 2008; WHO, 2005).

Within westernised societies, non-communicable diseases are the leading causes of death. These include cardiovascular disease (coronary artery disease, hypertension, stroke and heart failure), type 2 diabetes, metabolic syndrome and cancer. What is of major concern, however, is the steady and dramatic growth currently being seen in developing countries, where many of these health problems were previously non-existent (WHO, 2009; Harlen & Harlen, 2009; Puoane et al, 2008; Roberts & Barnard, 2005; WHO, 2005). In 2005, the World Health Organisation reported that 80% of chronic disease deaths occur in low and middle income countries, where the majority of the world's population is found.

In many developing countries, the major contributing factors leading to increased chronic diseases are lifestyle changes associated with urbanisation and westernisation, linked to epidemiological, demographic and nutritional changes (Puoane et al., 2008; Omran, 2005; Booth et al., 2002a; Booth et al., 2000b). Fezeu, Balkau, Kengne, Sobngwi & Mbanya (2007) recently noted that "Africa is currently experiencing one of the most rapid demographic and epidemiological transitions in world history." South Africa is one of many countries in Africa experiencing rapid epidemiological, demographic and nutritional change (Fezeu et al., 2007; Levitt, 2003; Vorster, 2002; Lambert, Bohlmann & Kolbe-Alexander, 2001). In concert with this change are poverty-related infectious diseases, including HIV/AIDS, lifestyle-related non-communicable diseases and violence related injuries (Levitt, 2003; Vorster, 2002; Lambert et al., 2001; Steyn & Bradshaw, 2001). As a result of this multiple burden of diseases, an astounding 40% of South African adults die from lifestyle-related non-communicable disease, or chronic diseases of lifestyle (Bradshaw et al., 2004).

1.2 INSULIN RESISTANCE: A PRECURSOR TO CHRONIC DISEASE

Insulin resistance has shown to be a precursor to a number of lifestyle-related chronic diseases and abnormalities in adults (Schenk, Saberi & Olefsky, 2008). It is a condition affected by a number of factors, including genetics, age, physical activity and acute exercise, diet, obesity, body fat distribution and medication (Khan, 2003). Although much elucidation is still required to determine genetics as an aetiological factor, it is possible

that specific components of the human gene interact with the environment, resulting in this pathophysiological abnormality (Schenk et al., 2008; Lebovitz, 2006). Clinical studies on healthy individuals have however revealed that genetic mutations associated with insulin resistance are rare. Instead, a host of different genes may contribute to its development, for example, obesity genes (Stumvoll, Goldstein & van Haeften, 2005; Kahn, 2003; Hanson et al., 2000; Xia et al., 1998). In westernised societies, the most common environmental factors causing insulin resistance are a sedentary lifestyle (physical inactivity), obesity, diet and ageing (Schenk et al., 2008; Boule et al., 2005; Houmard et al., 2004; Khan, 2003; Grundy et al., 1999).

To date, no global or national prevalence data exists for insulin resistance, however, Bonora et al. (2007) have reported that up to twenty five percent of individuals have a reduction in insulin sensitivity, which is comparable to those with type 2 diabetes with good glycemic control. They further report that approximately 30% to 40% of people from developed, affluent countries are found to be less sensitive to insulin and estimate that hundreds of millions, perhaps billions of people live with this condition. The degree of insulin resistance among those affected is rather inconsistent however, but usually progresses over a number of years.

One vital function of insulin is the regulation of glucose metabolism, which is controlled by the ability of insulin to promote the uptake of glucose and its utilisation into target tissues, predominantly skeletal muscle, adipose

tissue and the liver. This ability is described as insulin sensitivity (Bouché, Serdy, Kahn & Goldfine, 2004; Short et al., 2003). When sensitivity to insulin is diminished and the ability of insulin to mediate glucose uptake and utilisation impaired, insulin resistance results (Schenk et al., 2008; Shanik et al., 2008; Reaven, 2005; Wilcox, 2005; Bouché et al., 2004; Goodpaster & Wolf, 2004; Henry, 2003). Over time, while the body is in this state, compensatory hyperinsulinemia can result in order to maintain normal blood glucose levels (Wilcox, 2005).

The pathogenic state of insulin resistance does not merely cease at a reduced sensitivity to insulin but progressively worsens over time if no intervention exists. Initially, the condition remains covert, and can be found in a significant number of apparently healthy individuals (Zoeller, 2007; Abdul-Ghani, Tripathy & DeFronzo, 2006c; Chen, Sullivan & Quon, 2005; Petersen & Shulman, 2002). Although concealed, it can have devastating effects, due to being recognised as an independent predictor of several age-related diseases (Facchini, Hua, Abbasi & Reaven, 2001). Table I and II highlight the various conditions associated with insulin resistance (Assah, Brage, Ekelund & Wareman, 2008; Schenk et al., 2008; Tomlinson et al., 2008; Reaven, 2005; Wilcox, 2005; Bloomgarden, 2004b; Fletcher & Lamendola, 2004). In addition, the complications arising from this condition are rather calamitous, as it is a strong

Table I. Clinical Syndromes and Abnormalities Associated With Insulin Resistance

- Type 2 diabetes
- Metabolic syndrome (including obesity)
- Cardiovascular disease, including cardiovascular disease events such as myocardial infarction and sudden death
- Essential hypertension
- Polycystic ovary syndrome
- Non-alcoholic fatty liver disease
- Certain forms of cancer
- Obstructive sleep apnoea

Table II. Abnormalities Associated With Insulin Resistance / Compensatory Hyperinsulinemia

- Some degree of glucose intolerance
  - Impaired fasting glucose
  - Impaired glucose tolerance
- Dyslipidemia
  - Increased triglycerides
  - Increased postprandial accumulation of triglyceride-rich lipoproteins
  - Decreased high-density lipoproteins
  - Decreased low-density lipoprotein-particle diameter (small, dense, LDL particles)
- Endothelial dysfunction
  - Increased mononuclear cell adhesion
  - Increased plasma concentration of cellular adhesion molecules
  - Increased plasma concentration of asymmetric dimethylarginine (ADMA)
  - Decreased endothelial-dependant vasodilatation
- Procoagulant factors
  - Increased plasminogen activator inhibitor-1
  - Increased fibrinogen
- Hemodynamic changes
  - Increased sympathetic nervous system activity
  - Increased renal sodium retention
- Markers of inflammation
  - Increased C-reactive protein (CRP) and leukocyte count
  - Increased white blood cell count
- Abnormal uric acid metabolism
  - Increased plasma uric acid concentration
  - Decreased renal acid clearance
- Increased ovarian testosterone secretion
- Obstructive sleep apnea

predictor of type 2 diabetes (Bonora et al., 2007; Gillies et al., 2007; Lawler, Fraser, Ebrahim & Smith, 2007; Zoeller, 2007; WHO Consultation, 2006) and the metabolic syndrome, and is strongly associated with obesity, these conditions being the most commonly associated with insulin resistance (Shanik et al., 2008; Schenk et al., 2008; Meigs et al., 2007; Katz et al., 2000).

1.2.1 Obesity

Insulin is a critical hormone in regulating the functioning of adipose tissue. It reduces the breakdown of triglycerides in adipose tissue, the process known as lipolysis. As a result, the circulation of free fatty acids is reduced (Eckel & Grundy, 2006). In adipose tissue, insulin is antilipolytic, inhibiting the release of fatty acids from the adipocytes by decreasing the activity of the hormone-sensitive lipase and adipose triglyceride lipase (Schenk et al., 2008).

The role of obesity in insulin resistance is the fact that a larger mass of adipose tissue is itself insensitive to insulin, which in turn promotes insulin resistance. In obese individuals, fatty tissue becomes insensitive to the action of insulin, resulting in a greater breakdown of triglycerides. Furthermore, adipose tissue produces a host of other substances, such as adipokines, which, in the presence of obesity, are produced in abnormal amounts and impact on the control mechanisms regulating cell activity in other tissues (Eckel & Grundy, 2006).

1.2.2 Type 2 Diabetes Mellitus

Diabetes mellitus presents itself in two main forms: type 1 and type 2 diabetes mellitus (Brownlee, 2001). The most prevalent form of this condition is type 2, as it is diagnosed in approximately 90% to 95% of those with diabetes (International Diabetes Federation, n.d.; Grundy et al., 1999). Although the physiological basis for developing this condition is not yet known, investigators have reported a number of possible contributing factors including insulin resistance and increased hepatic glucose output (Matveyenko, Veldhuis & Butler, 2006; Rizvi, 2004). However, it is insulin resistance that is thought to be the dominant feature as it characterises nearly all individuals with this condition (Goodpaster & Wolf, 2004).

The development of type 2 diabetes mellitus can be described as an initial development of insulin resistance, followed by an increase in insulin secretion by the β-cells to counter for the diminished insulin action. The ongoing insulin resistance and β-cell secretion results in hyperinsulinemia and, in those with the appropriate genetic make-up, β-cell secretion eventually becomes insufficient to compensate for the hyperglycemia (Brownlee, 2001).

1.3 THE ENVIRONMENTAL FACTOR: PHYSICAL ACTIVITY

Throughout history, the notion that physical activity contributes to enhanced health, improves physical function and promotes longevity has been widely promoted. In fact, structured amounts of physical activity for health benefits were recommended as early as the fifth century B.C. by the ancient Greeks

(U.S. Department of Health and Human Services, 1996). Today, it is increasingly recognised that physical activity is an important environmental factor, forming an important component of health and health promotion (Perkins & Clark, 2001).

The benefits of physical activity range from improved muscular function and strength to improved psychological wellbeing. Several of these benefits are highlighted in Table III (ACSM, 2010, Myers, 2003). However it is not only the improved functioning of the body that physical activity is known for, it also serves to prevent and reduce the risk of many conditions, particularly chronic diseases of lifestyle. Specifically, physical activity is shown to reduce the risk of cardiovascular disease, type 2 diabetes, colon and breast cancer, obesity, hypertension, bone and joint disease and depression (ACSM, 2010; Lambert & Kolbe-Alexander, 2006; Li et al., 2006; Taylor et al., 2004; Chakravarthy, Joyner & Booth, 2002; Blair, Cheng, Holder, 2001; Lee & Skerrett, 2001; Perkins & Clark, 2001; Warburton, Gledhill & Quinney, 2001; Blair & Brodney, 1999; Wei et al., 1999; U.S. Department of Health and Human Services, 1996). Myers et al. (2004) demonstrated this when they identified a 50% reduction in risk of death from all cause mortality and cardiovascular disease in those who are physically fit or active.

Table III. Benefits of Regular Physical Activity and/or Exercise

- Improves cardiovascular and respiratory function by:
  - Improves maximal oxygen uptake due to both central and peripheral adaptations
  - Lowering minute ventilation at a given submaximal intensity
  - Lowering heart rate and blood pressure at a given submaximal intensity
  - Increasing capillary density in skeletal muscle
  - Increasing exercise threshold for the accumulation of lactate in the blood
  - Increasing exercise threshold for the onset of disease signs or symptoms
- Reduces coronary artery disease risk factors by:
  - Reducing resting systolic and diastolic blood pressures
  - Increasing serum high-density lipoprotein cholesterol and decreased serum triglycerides
  - Reducing total body fat and intra-abdominal fat
  - Reducing insulin needs and improving glucose tolerance
- Decreases morbidity and mortality:
  - Higher activity/fitness levels are associated with lower death rates from coronary artery disease
  - Higher activity/fitness levels are associated with lower incidence for combined cardiovascular disease, coronary artery disease, stroke, type 2 diabetes, osteoporotic fractures, breast and colon cancer and gallbladder Disease
- Other benefits include:
  - Decreased anxiety and depression
  - Enhanced physical function and independent living in older persons
  - Enhanced feelings of wellbeing
  - Enhanced performance of work, recreational and sport activities
  - Reduced risk of falls and injuries from falls in older persons
  - Prevention or alleviation of functional limitations in older adults

In contrast, physical inactivity, recognized internationally as a major independent modifiable risk factor for increasing non-communicable diseases, augments the increased prevalence of cardiovascular disease, type 2 diabetes, metabolic dysfunction, obesity, hypertension, cancer and premature mortality (Joubert et al., 2007; Armstrong & Bull, 2006; Booth et al., 2002b; Chakravarthy et al., 2002; U.S. Department of Health and Human Services, 1996). Numerous findings support this association, including longitudinal cohort studies suggesting at least a 1.5 to 2 times higher risk of developing chronic diseases of lifestyle associated with physical inactivity (Joubert et al., 2007). Worldwide, the Global Comparative Risk Assessment has attributed physical inactivity to an estimated 1.92 million (3.3%) deaths. In South Africa, physical inactivity directly accounted for 17 037 (3.3%) deaths in the year 2000, and ranked ninth in the South African Comparative Risk Assessment of attributable deaths when compared with 17 other risk factors (Joubert et al., 2007).

Physical activity has been shown to have a major influence on insulin sensitivity and glucose metabolism in a variety of populations, ranging from healthy lean individuals to those with impaired glucose tolerance and type 2 diabetics (Plasqui & Westerterp, 2007; Henriksen, 2002). Furthermore, both endurance and resistance type training lead to improvement in glucose tolerance and glucose disposal in these subjects (Cheng et al., 2007; Karelis et al., 2007; Dunstan et al., 2002; Henriksen, 2002; Arciero, Vukovich, Holloszy, Racette & Kohrt, 1999). Conversely, physical inactivity

has shown to increase the risk of insulin resistance in normal weight, overweight and obese individuals (Booth et al., 2002a).

1.4 STATEMENT OF THE PROBLEM

This study presents two problems:

1.4.1 Chronic diseases worldwide, in South Africa and within the Western Cape are steadily increasing and are the leading causes of premature mortality in westernised countries and rising in developing countries. In South Africa, chronic diseases account for 40% of mortality, with cardiovascular disease, hypertension and type 2 diabetes mellitus as the dominant chronic diseases contributing to this mortality (Norman et al., 2007). In the Western Cape, ischaemic heart disease and type 2 diabetes are the leading chronic diseases. The risk factors contributing to these diseases include high blood pressure, excess body weight, high cholesterol, diabetes mellitus and physical inactivity (Norman et al., 2007). Insulin resistance has been linked to all these conditions and is said to be the underlying factor of the cluster of these risk factors.

1.4.2 Physical activity has been recognized to have protective effects against lifestyle-related disease including insulin resistance and type 2 diabetes, contributing to the reduction of the risk and incidence of these conditions. Globally, 17% of adults do not engage in regular physical activity. In South Africa, a staggering 76% of women and 63% of men are insufficiently active to gain the health benefits

associated with physical activity (Lambert & Kolbe-Alexander, 2006). Physical inactivity is associated with the increased prevalence of chronic disease and is ninth out of the 17 risk factors recorded in the South African Comparative Risk Assessment project (Joubert et al., 2007).

1.5 AIM OF THE STUDY

Insulin resistance has been implicated in the development of several metabolic conditions including type 2 diabetes and the metabolic syndrome. Therefore the aim of this study was to investigate if a relationship existed between insulin resistance and physical activity in adults between 35 and 65 years of age residing in a northern suburb community of Cape Town. The results obtained from this study could potentially assist in the development of intervention programs aimed at preventing and reducing the incidence of these conditions at a community level, a recommendation of the South African National Burden of Disease study (Bradshaw et al., 2004).

1.6 OBJECTIVES OF THE STUDY

The specific objectives of this study were:

1.6.1 To identify if a relationship existed between age, body composition, current levels of physical activity, physical fitness and insulin resistance.

1.6.2 To identify if a relationship existed between subjectively measured physical activity and objectively measured physical fitness.

1.6.3 To explore these relationships in order to determine the predictors of insulin resistance.

1.7 RESEARCH HYPOTHESIS

It was hypothesised that:

1.7.1 Participants in the insulin resistance group would have lower levels (poorer scores) of physical activity and fitness than those in the non insulin resistance group.

1.7.2 With advancing age, physical activity levels would decline and insulin resistance would increase.

1.7.3 There would be a significant moderate to strong positive association between body composition and HOMA-IR.

1.7.4 A significant moderate to strong inverse association would exist between physical activity, physical fitness and HOMA-IR, except for cardiorespiratory fitness in which a significant positive correlation was hypothesised.

1.7.5 There would be a significant moderate to strong positive correlation between subjectively measured physical activity (by questionnaire) and objectively measured physical fitness. The correlation between the questionnaire and cardiorespiratory fitness was hypothesized to

be negative whereas the correlation between the questionnaire and muscular strength, muscular endurance and flexibility was hypothesized to be positive.

1.7.6 Body mass index, cardiorespiratory fitness and muscular strength would predict insulin resistance in males and waist circumference, age and cardiorespiratory fitness would predict insulin resistance in females.

1.8 SIGNIFICANCE OF THE STUDY

Health-related research within the domain of physical activity has come to include a variety of connected research areas, often performed independent of one another. However, the overall accumulation of this knowledge in each area directly affects other areas within health-related research. Within the domain, health outcomes research aims to understand the relationships between physical activity and health of which the results have led to the development of guidelines and recommendations for physical activity within a population (Welk, 2002). As depicted in Figure 1, the present study is significant because of its role in health outcomes research in identifying the relationship between insulin resistance, a condition negatively affecting the health of many, and physical activity. This study therefore aids in contributing to the field of health-outcomes research by providing information about insulin resistance and physical activity, of which little is known within the South African mixed-ancestry population.

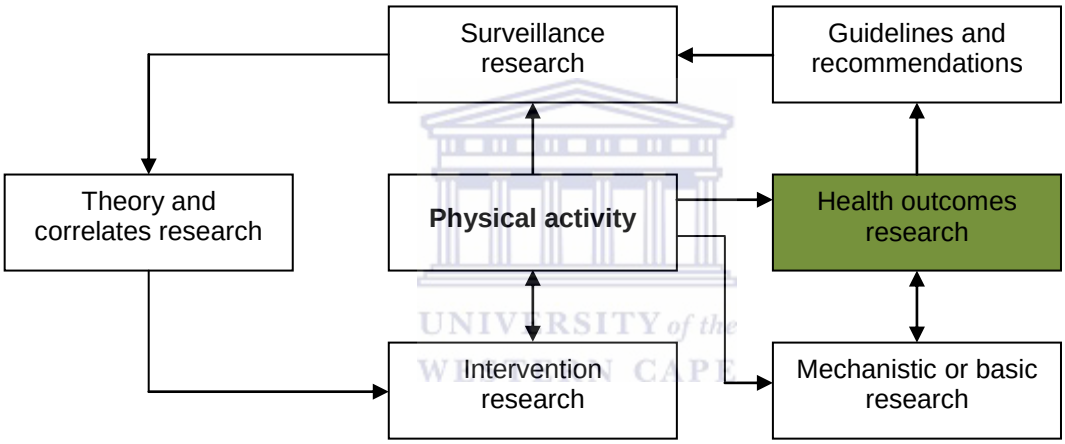

Figure 1. Conceptual Model Exhibiting Links Between Domains of Physical Activity

1.9 DELIMITATIONS

The study was delimited to:

1.9.1 Residents from a northern suburb in Cape Town

Inclusion criteria

1.9.2 Participants tested in the first phase of the community study aged between 35 and 65 years of age. Male and female participants were included.

1.9.3 Those with newly diagnosed type 2 diabetes (tested in the first phase of the study).

Exclusion criteria

1.9.4 All participants who had changed their physical activity status. These consisted of those who:

- began an exercise program
- increased their levels of physical activity
- stopped an exercise program
- decreased their levels of physical activity

1.9.5 Those who changed, began or stopped medication that could affect glucose levels or was receiving treatment with insulin or on oral hypoglycaemic agents at the time of testing.

1.9.6 Those who could physically undertake the fitness evaluation as well as those who suffered from a cardiac condition or physical disability.

1.9.7 Those who did not provide voluntary consent to participate in the study and acutely ill participants.

1.9.8 Pregnant women.

1.9.9 All participants who were taking antihypertensive medication were excluded from the cardiorespiratory physical fitness test only.

CHAPTER TWO

LITERATURE REVIEW

Chapter two presents the literature that was reviewed for this study. Review searches were conducted via the university library online service. Online databases, including PubMed and Ebscohost as well as EJournals were consulted. The keywords used in the title page this study were the keywords used in searching for the literature.

This chapter firstly discusses the cellular mechanisms of glucose uptake and insulin resistance, followed by the conditions associated with insulin resistance. Thereafter, health-related physical fitness is described, as well as the measurement of these fitness components. Lastly, studies relating to its association with insulin resistance was presented and its link with age.

The human body requires a continuous supply of energy in order to perform daily tasks and activities which are supplied by the breakdown of food via a series of chemical reactions. Energy is then generated through an energy-rich nucleotide compound called adenosine triphosphate (ATP) (McArdle, Katch & Katch, 2010). The main source from which this energy is derived is carbohydrates in the form of glucose. However ATP can also be provided by fats and to a lesser extent, proteins.

When placed under stress, as during physical exercise, the body responds through integrated functions involving various, perhaps all, of its body systems, including the musculoskeletal, endocrine, cardiovascular and respiratory systems. Physical exercise places increased demands on these systems, with the simultaneous increase in demand for energy and therefore glucose (McArdle et al., 2010). With sustained activity, each system begins to adapt by an improvement in the efficiency and capacity to generate and supply the body's energy needs (McArdle et al., 2010; U.S. Department of Health and Human Services, 1996).

2.1 CELLULAR MECHANISMS OF GLUCOSE UPTAKE

Insulin is a peptide hormone that functions to regulate energy homeostasis within the body by maintaining carbohydrate, lipid and protein metabolism. The functions of insulin are exerted across a variety of insulin target tissues, including liver, skeletal muscle and adipose tissue through several intracellular signalling pathways (de Luca & Olefsky, 2008). Specifically, insulin functions to reduce the production of glucose (gluconeogenesis) and promote its uptake and utilisation in muscle and adipose tissue. Insulin is also responsible for reducing the breakdown of triglycerides in adipose tissue, thereby limiting the circulation of free fatty acids and inhibits protein digestion from the gut, increasing the uptake of amino acids into the tissue cells (Eckel & Grundy, 2006; Pessin & Saltiel, 2000).

The endogenous process of insulin synthesis takes place within the β-cells of the Islets of Langerhans in the pancreas and is controlled by the

endocrine system (Porksen et al., 2002). Many factors influence the release of insulin, with glucose being the most important (Khan, McCulloch & Porte, 1997). As glucose is the primary source of cellular energy within the body it is essential that its equilibrium be maintained (Abdul-Ghani et al., 2006c). Homeostasis is achieved by the secretion of insulin by the β-cells, the suppression of hepatic (liver) glucose production and the stimulation of glucose uptake by the peripheral tissue (primarily muscle) (Petersen & Shulman, 2002). In the post-absorptive state, muscle tissue is responsible for the majority of whole-body glucose uptake (approximately 65% to 70%) (Abdul-Ghani et al., 2006c; Goodpaster & Wolf, 2004). Glucose uptake into muscle has numerous regulatory steps. The first is the delivery of glucose from the blood to the interstitial space surrounding the muscle cell; the second is the transmembrane transport from the interstitial space to the inside of the muscle cell and lastly the intracellular metabolism of glucose (Richter, Derave & Wojtaszewski, 2001). The transport of glucose across the cell membrane is a vital step in its overall metabolism (Jessen & Goodyear, 2005). In skeletal muscle cells, this transport can be stimulated by a number of pathways in addition to the insulin-stimulated pathway. Another is via muscle contraction, or physical exercise. Studies have shown that these two independent pathways are the most important stimulators of glucose transport (Geiger, Han, Wright & Holloszy, 2006; Jessen & Goodyear, 2005). But as glucose is hydrophilic, it cannot alone diffuse through the lipid bilayer of the cell membrane. For that reason, it is mediated by glucose transporter proteins known as facilitative glucose transporters (GLUTs) (de Luca & Olefsky, 2008; Karnieli & Armoni, 2008;

Wilcox, 2005; Bouché et al., 2004; Flores-Riveros, McLenithan, Ezaki & Lane, 1993). GLUT 4 serves as the major glucose transporter protein in muscle and adipose tissue (Karnieli & Armoni, 2008). In skeletal muscle, glucose uptake occurs by the translocation (movement) of GLUT 4 from the intracellular compartments of the cell to the cell membrane (de Luca & Olefsky, 2008; Schenk et al., 2008; McArdle et al., 2010).

Insulin stimulates the uptake of glucose via insulin-receptor signalling. Once insulin is released from the β-cells and reaches the target cells, it binds with an insulin receptor located on the cell membrane (Kido, Nakae & Accili, 2001; Le Roith & Zick, 2001; Pessin & Saltiel, 2000). Binding activates a cascade of events, including the tyrosine phosphorylation of substrate proteins known as insulin receptor substrates (IRS). Phosphorylated IRS in turn activates an important enzyme known as phosphotidylinositol 3-kinase (PI3-K), which forms one of the two major insulin-receptor signalling pathways (Wilcox, 2005; Kido et al., 2001; Jessen & Goodyear, 2005). PI3-K is the only essential downstream signalling molecule for insulin-stimulated GLUT 4 translocation leading to the transport of glucose across the cell membrane (Wilcox, 2005; Jessen & Goodyear, 2005; Pessin & Saltiel, 2000).

In contrast, exercise stimulates the uptake of glucose into skeletal muscle cells by different signalling mechanisms and intracellular pathways, although both muscle contraction and insulin induce translocation of GLUT 4 to the cell membrane (Plasqui & Westerterp, 2007; Geiger et al., 2006;

Holloszy, 2005; Jessen & Goodyear, 2005; Bouché et al., 2004; Le Roith & Zick, 2001; Pessin & Saltiel, 2000). A number of contraction-stimulated pathways that augment translocation have been proposed, including calcium signalling, 5'adenosine monophosphate-activated protein kinase (AMPK), Akt and AS160, nitric oxide and bradykinin (Jessen & Goodyear, 2005). Although these pathways have not been clearly elucidated, it is proposed that the former two pathways play a vital role in the translocation of GLUT 4 (Plasqui & Westerterp, 2007; Holloszy, 2005).

Once glucose has entered the cell, the production of energy through the generation of ATP is attained via glucose oxidation (breakdown) (Abdul-Ghani et al., 2006c; Bouché et al., 2004). When a surplus of glucose occurs, it is stored in its principal form known as glycogen, a process also regulated by insulin. During muscle contraction, the level of muscle glycogen has shown to have a regulatory effect on glucose uptake, found at the level of glucose transport (Richter, Derave & Wojtaszewski, 2001). Muscle glycogen synthesis forms a major pathway for glucose metabolism and accounts for most of the whole body glucose uptake (Wilcox, 2005; Perseghin, Petersen & Shulman, 2003; McArdle et al., 2010; Shulman, 2000)

2.2 THE CELLULAR MECHANISMS OF INSULIN RESISTANCE

The pathogenic state of insulin resistance has shown itself to be relatively common although the exact cellular mechanisms have not been clearly elucidated (Le Roith & Zick, 2001). This state can be found in the insulin-

sensitive tissues of skeletal muscle, liver and adipose tissue, presenting itself as (Schenk et al., 2008; Henry, 2003):

- decreased insulin-stimulated uptake of glucose into skeletal muscle
- impaired insulin-mediated suppression of hepatic glucose production thereby enhancing gluconeogenesis and glycogenolysis
- reduced ability of insulin to inhibit fat lipolysis in adipose tissue
- β-cell dysfunction of the pancreas

The gold standard for measuring insulin sensitivity and resistance is the glucose clamp technique, of which there are two methods: the hyperinsulinemic-euglycemic clamp, which measures insulin action (insulin sensitivity) and the hyperglycaemic clamp, which measures insulin secretion (Adbul-Ghani et al., 2006c). During the hyperinsulinemic-euglycemic clamp, peripheral tissue is the major site of glucose disposal (80% to 90%) therefore this clamp method predominantly tests the resistance within skeletal muscle. These tests however are invasive, expensive and time-consuming therefore they are generally not performed in studies with larger samples. Various other methods have been developed which are simpler and effective to use. One of these methods includes the homeostasis model assessment of insulin resistance (HOMA-IR). In epidemiological studies, this surrogate method is the most commonly used to determine insulin resistance (Abdul-Ghani et al., 2006c).

HOMA-IR is derived from fasting plasma glucose (FPG) and fasting plasma insulin (FPI) concentrations (Abdul-Ghani et al., 2006c). The product of FPG and FPI is an index of hepatic insulin resistance as FPG is primarily determined by hepatic glucose output and FPI is the dominant regulator of hepatic glucose production (Cherrington, 1999; DeFronzo, Ferrannini & Simonson, 1989). Studies by Matsuda and DeFronzo (1997) have however shown approximately 70% correlation between the clamp method and HOMA-IR, showing this correlation between hepatic and peripheral (muscle) insulin resistance.

In the insulin resistance state, impaired insulin signalling, defective glucose transport and glucose oxidation are the predominant causes of ineffective glucose uptake into the tissue cell (Pi-Sunyer, 2007; Henry, 2003). Impaired insulin signalling arises from changes in the insulin-receptor itself or any of its downstream processes (processes that occur after the binding of insulin to its receptor). Numerous studies have revealed that the downstream processes are responsible for the majority of the resistance to insulin (Garvey & Kolterman, 1988). These distal processes have identified decreased insulin stimulation of IRS phosphorylation and PI3-K activity (Henriksen, 2002).

Further downstream effects of insulin action can be seen in the impaired activation of glucose transport, and independent studies by Ciraldi, Kashiwagi, Dohm, and Garvey have proposed that defective glucose transport is a vital abnormality in insulin resistance (Dohm et al., 1988;

Garvey & Kolterman, 1988., Kashiwagi et al., 1983; Ciaraldi, Kolterman, Scarlett, Kao & Olefsky, 1982). Defective glucose transport stems from the diminished ability of GLUT 4 to move from the intracellular compartments to the cell surface despite normal expression (Bouché et al., 2004). In addition, GLUT 4 is reduced by 40% in obese people without type 2 diabetes and as much as 80% in those with type 2 diabetes (Garvey et al., 1991).

Stimulation of glycogen synthesis is one of the numerous steps in glucose oxidation (Le Roith & Zick, 2001). In the insulin resistance state, impaired muscle glycogen synthesis is associated with defective glucose oxidation. Perseghin et al. (2003) and Cline et al. (1999) found that glycogen synthesis in diabetic volunteers were noticeably reduced when compared to normal volunteers under postprandial conditions (hyperglycaemic and hyperinsulemic) showing reduced glucose transport. This highlights that defective muscle glycogen synthesis plays a major role in causing insulin resistance in those with type 2 diabetes (Petersen & Shulman, 2002).

Evidence shows that an increase in insulin sensitivity is mediated by the translocation of a greater number GLUT 4 to the cell surface in response to a given sub-maximal insulin stimulus. An increase in sensitivity is not bound to an insulin stimulus alone however, but also to other mediators that stimulate muscle glucose transport, such as exercise (Geiger et al., 2006). An increase in the metabolic action of insulin has been considered an important benefit of exercise for healthy people as well as for those with

insulin resistance (Richter et al., 2001). However, exercise does not only improve the sensitivity of glucose transport to insulin but also enhances the transport of glucose across the cell membrane independently of insulin (Holloszy, 2005), causing an immediate increase in muscle glucose transport. A single bout of moderate to high intensity endurance physical activity immediately has shown to improve insulin sensitivity, and as the acute effect of this activity wears off once the activity has ceased, it is replaced by an increase in insulin sensitivity (Geiger et al., 2006; Holloszy, 2005; Katz & Lowenthal, 1994).

This improvement in insulin sensitivity after the cessation of exercise is most likely its most important benefit (Hansen, Nolte, Chen & Holloszy, 1998) and is due to the contractile ability of muscle which enhances glucose transport activity. This pathway of glucose transport, activated by muscle contraction, appears to be normal within insulin resistant and type 2 diabetics (Henriksen, 2002). Detraining or cessation of exercise in contrast, reverses these effects, as a decrease in insulin sensitivity and glucose tolerance can be seen after two weeks. When a single bout of exercise resumes, insulin sensitivity and glucose tolerance reaches levels found in pre-exercise state (Katz & Lowenthal, 1994). After prolonged and heavy physical activity, glycogen synthesis is also of high priority in the previously exercised muscles in order to replace lost glycogen stores. Muscle glycogen synthase activity and glucose transport are therefore increased after exercise. Enhanced insulin sensitivity may last up to 48 hours after the cessation of activity (Richter et al., 2001).

2.3 INSULIN RESISTANCE AND ITS ASSOCIATED CONDITIONS

2.3.1 Overweight and Obesity

Body mass index (BMI) and waist circumference are simple, effective ways of classifying obesity and overweight in adults in the general population. Obesity is described as a BMI value of 30.0 $kg \cdot m^{-2}$ or greater and overweight is described as a value of between 25.0 and 29.9 $kg \cdot m^{-2}$ (ACSM, 2010; WHO, 2006). A waist circumference of greater than 102 cm for men and 88 cm for women also defines obesity, particularly central obesity (ACSM, 2010).

Overweight and obesity are defined as an excess accumulation of body fat that may have adverse effects on health (WHO, 2006). Globally, over 1.6 billion (66%) adults aged 15 years and older are overweight and at least 400 million (32%) are obese, with numbers predicted to rise dramatically to 2.3 billion overweight and 700 million obese by 2015. In South Africa, the Demographic and Health Survey found that out of 13 089 men and women above 15 years of age, 29.2% of men were overweight or obese and 9.2% had abdominal/central obesity while 56.6% of women were overweight or obese and 42% had abdominal/central obesity (Puoane et al., 2002). In women, this is particularly high, as nearly 30% between the ages of 30 and 59 years are obese (Goedecke, Jennings & Lambert, 2006). The study also indicated that women of mixed ancestry have the second highest prevalence of overweight and obesity (52%) and the highest prevalence of central obesity (42%). Moreover, women from urban areas were shown to have higher body mass index (BMI) scores than those from the rural areas.

BMI was also shown to increase with age. Men of mixed ancestry were shown to have the second lowest prevalence of obesity and overweight (31%) to African men (25%). In addition, older men and those from the urban areas were shown to have significantly higher BMI values than younger men and those from the rural areas (Goedecke et al., 2006).

Previously, obesity was considered a problem only in high-income countries, but is now steadily on the rise in low- and middle-income countries, particularly in urban environments (WHO, 2006). In South Africa, age, gender, demographics, ethnicity and socio-economic status all influence it (Goedecke et al., 2006). In addition, because of the risk factors associated with obesity, the International Statistical Classification of Diseases has classified obesity as a disease (Joubert et al., 2007) and has become the most common cause of insulin resistance and type 2 diabetes within the adult population (Petersen & Shulman, 2006). In fact, insulin resistance is present in approximately 90% of obese individuals with type 2 diabetes (Henry, 2003).

An inverse association exists between obesity and the metabolism of glucose. Increasing body weight appears to impair the ability of glucose to metabolise, predominantly as a result of resistance of some tissues to the effects of insulin on glucose uptake and therefore clearance from the blood. This suggests that excess body fat plays a causative role in the development of insulin resistance (Goodpaster & Wolf, 2004; Kahn, 2003; Stannard & Johnson, 2003). Danielsson and colleagues (2009)

demonstrated this when they administered a high calorie diet to a group of lean, insulin sensitive participants over a course of four weeks. During this period, participants gained 10% body weight and 19% body fat, with results showing moderate development of insulin resistance.

Furthermore, it appears that the quantity of fat is not as important as its distribution in determining insulin resistance (Petersen & Shulman, 2006; Svedberg, Bjorntorp, Smith & Lonnroth, 1992). Central / visceral body fat accumulation is more associated with insulin resistance than peripheral body fat accumulation due to more metabolically active visceral adipocytes. This has been consistently shown across genders, race and age in those with and without diabetes (Rosenberg, Jabbour & Golstein, 2005; Kahn, 2003; Svedberg et al., 1992). Within visceral fat, lipolysis (the breakdown of lipids with the release of free fatty acids [FFAs]) is more pronounced than in subcutaneous and peripheral fat, in addition to visceral fat cells being less sensitive to suppression of lipolysis by insulin. The released FFAs can directly block insulin-signaling pathways, leading to insulin resistance. In addition, visceral fat has direct access to the portal circulation. Increased amounts of FFAs being released into the portal circulation may impair the metabolism and action of insulin and increase gluconeogenesis in the liver (Rosenberg et al., 2005).

The accumulation of lipid within muscle and liver tissue has also shown to be of great importance and is shown to be strongly associated with insulin resistance, as well as with dyslipidemia and increased risk of hypertension

and glucose intolerance (Goodpaster & Wolf, 2004). Obesity leads to fat accumulation not only in the adipocytes, but in muscle and liver cells as well, resulting in insulin resistance in these organs (Petersen & Shulman, 2006).

2.3.2 Type 2 Diabetes Mellitus

Type 2 diabetes is a chronic non-communicable disease that currently threatens the health, wellbeing and economic welfare of almost every country in the world (Gillies et al., 2007). The disease, which has already been classified as an epidemic, has emerged over a number of decades and today is one of the most challenging health problems of the 21st century (International Diabetes Federation [IDF], 2006; Roberts & Barnard, 2005; Rizvi, 2004) as it has become associated with premature mortality and morbidity in most countries and of increasing concern in middle and low income countries (Zoeller, 2007; Joubert et al., 2007; Gillies et al., 2007; Bradshaw, Norman, Pieterse & Levitt, 2007; Lindström et al., 2006; Mennon et al., 2006; Petersen & Shulman 2006; Roberts & Barnard, 2005, IDF, 2004; Rizvi, 2004).

Globally, an estimated 230 million adults currently suffer from this disease with projections indicating a drastic rise to 333 million by the year 2025 (IDF, 2006). In sub-Saharan Africa, prevalence data in 1994 showed approximately three million Africans living with this condition, with projections indicating a two- to three-fold rise by 2010. Within sub-Saharan Africa, Nigerians have the highest number of people living with this

condition reaching an estimate of 1.2 million, followed by South Africa with 841 000, the Democratic Republic of Congo with 552 000, Ethiopia with 550 000 and Tanzania with 380 000 (International Diabetes Federation, World Health Organization-Afro & African Union, 2006). Globally, diabetes is the fifth leading cause of death and is ranked ninth in the Western Cape (Bradshaw et al., 2004).

A devastating consequence of diabetes is the various pathological processes leading to macrovascular and microvascular complications causing considerable suffering and disability (Rizvi, 2004; Brownlee, 2001). One of the most highlighted and significant diabetic complications are cardiovascular disease (CVD). Diabetes is recognised as a major, independent risk factor for cardiovascular disease in both men and women. Approximately 65% of people living with diabetes die of a cardiovascular disease making it the leading cause of death in those with diabetes (Grundy et al., 1999).

The process leading to diabetes is a slow and insidious one which can take between 10 and 20 years to develop before the disease becomes overt and diagnosed. This process involves the development of two pathophysiological conditions known as impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) (Zoeller, 2007; Abdul-Ghani et al., 2006c; Rizvi, 2004; Petersen & Shulman, 2002; Grundy et al., 1999) which are intermediate states in the transition from normoglycaemia (normal) to type 2 diabetes (WHO Consultation, 2006; Abdul-Ghani, Jenkinson,

Richardson, Tripathy & DeFronzo, 2006a; Abdul-Ghani et al., 2006c). Insulin resistance has shown not only to precede but also to be a strong pathogenic indicator for the development of both IGT and IFG (Bonora et al., 2007; Gillies et al., 2007; Lawler et al., 2007; Zoeller, 2007; Abdul-Ghani et al., 2006a; Chen et al., 2005; Perseghin et al., 2003; Petersen & Shulman, 2002; Unwin, Shaw, Zimmet & Alberti, 2002; Eschwege et al., 2001; Gabir et al., 2000; Shulman, 2000; Arciero, et al., 1999; Shaw et al., 1999; de Vegt et al., 1998; Reaven, 1988).

Insulin resistance precedes the conditions of IGT, IFG and type 2 diabetes, suggesting it not only plays a major role in their pathogenesis, but is also a powerful predictor for their later development (Abdul-Ghani et al., 2006c; Rizvi, 2004; Henry, 2003; Petersen & Shulman, 2002; Katz et al., 2000). This highlights the importance of intervening at the level of insulin resistance before it can progress.

2.4 PHYSICAL ACTIVITY, HEALTH-RELATED PHYSICAL FITNESS AND INSULIN RESISTANCE

Physical activity is defined as any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure and is described as a complex set of behaviours that include structured and unstructured activities (ACSM, 2010; Plasqui & Westerterp, 2007). Exercise forms a subclass of physical activity, comprising of planned and structured activities with repetitive bodily movement. These movements are performed in order to improve or maintain one or more components of

physical fitness, which are a collection of attributes an individual possesses or aims to possess relating to the ability to perform physical activity. These attributes are separated into either health-related or skill-related physical fitness. The attributes that have been specifically associated with health include cardiorespiratory fitness, muscle strength, muscle endurance and flexibility (ACSM, 2010; Plasqui & Westerterp, 2007; LaMonte et al., 2005; U.S. Department of Health and Human Services, 1996).

2.4.1 Measuring Physical Activity

Over the past few decades, the measurement of physical activity has evolved tremendously, creating a plethora of evidence linking physical activity and fitness to health outcomes (ACSM, 2010; U.S. Department of Health and Human Services, 1996). But physical activity has indeed proven to be a somewhat complex behaviour, making the measurement thereof equally intricate. More than 30 different methods have been used to assess physical activity (LaPorte, Montoye & Caspersen, 1985) ranging from subjective to objective measurements. Subjective measures include self-report, such as questionnaires, interviews and surveys, physical activity diaries and log books which record daily activity. Objective measures encompass direct and indirect calorimetry to measure the amount of energy expended during activity (through direct and indirect maximal oxygen uptake). Other measures include motion sensors such as pedometers and accelerometers (Bauman, Phongsavan, Schoeppe & Owen, 2006; Welk, 2002; U.S. Department of Health and Human Services, 1996).

Today, the most common means of evaluating physical activity in large groups of people is the subjective measurement of self-report utilising a questionnaire. Generally, the time span of recall questionnaires range from a period of one day to a lifetime and requires the participant to identify their levels of physical activity. This method is a simple and convenient way to assess physical activity for a number of reasons, such as its cost effectiveness and ease and short time with which it can be administered. It is also less likely to be manipulated and influence behaviour and does not require much effort by the participant (Armstrong & Bull, 2006; U.S. Department of Health and Human Services, 1996).

Physical activity is described in terms of four components: frequency, referring to the amount of days spent on the activity; duration, the amount of time spent on the activity; intensity, the level of effort placed into the activity, and mode, referring to the type of activity. Intensity and duration represent two important components affecting the difficulty of a particular task (McArdle et al., 2010). Numerous classification systems, including recall questionnaires, rank sustained physical activity for its difficulty based on energy expenditure (energy required to perform different physical activities) (U.S. Department of Health and Human Services, 1996).

Within the body, three factors determine total daily energy expenditure: 1) resting metabolic rate, 2) thermogenic effect of food consumed and 3) energy expended during physical activity and recovery. Energy expended during physical activity can be expressed as metabolic equivalents (METs),

which are defined as multiples of the resting metabolic rate and expressed in terms of oxygen consumption. One MET is equivalent to tissue consumption of 3.5 ml of oxygen per kilogram body weight per minute ($mL \cdot kg^{-1} \cdot min^{-1}$) and refers to when the body is at rest. As activities are usually rated according to light-intensity, moderate-intensity and vigorous-intensity, all activities are assigned an intensity unit based on their rate of energy expenditure (McArdle et al., 2010; Ainsworth et al., 1993). This form of exercise intensity is expressed as an absolute value because of the assigned intensity (U.S. Department of Health and Human Services, 1996). Light physical activity is defined as less than 3 METs, moderate activities are described as METs between three and six, and vigorous activities are defined as engaging in greater than 6 METs (ACSM, 2010).

The four components of physical activity can be performed in different domains (settings) which include occupational or work-related physical activity, transport-related physical activity, and/or physical activity during leisure time, such as recreational physical activity or exercise (Armstrong & Bull, 2006). Bauman et al. (2006) suggests that each of these domains could independently influence ill-health. As examples, low occupational-related physical activity where sedentary time at work is increasing and decreasing transport-related physical activity because of increases in travelling by motorised transport.

The Global Physical Activity Questionnaire (GPAQ) is one self-report instrument that utilises METs to estimate energy expenditure. The

questionnaire was developed particularly for developing countries keeping in mind that energy expenditures differ from developed countries because of differences in lifestyle (Armstrong & Bull, 2006). This was initiated by the World Health Organisation as part of the WHO STEPWise approach to monitoring chronic disease within developing countries and was accomplished within the framework aimed to produce sustainable, reliable and valid estimates of physical activity (Armstrong & Bonita, 2003).

In 2011, data from 22 African countries utilising the GPAQ was published. This study found that 83.8% of men and 75.7% of women met WHO physical activity recommendations of at least 150 minutes of moderate activity per week or equivalent. Additionally, physical activity both at work and for transport, including walking, largely contributed to overall physical activity, while physical activity during leisure time was rare (Guthold et al., 2011).

In South Africa, studies utilising recall questionnaires, including GPAQ and IPAQ, have been done to investigate levels of physical activity among various populations. The South African Demographic and Health Survey (SADHS), utilising the GPAQ, found 48% of South African men and 63% of women inactive (Department of Health, n.d.). In 2006, Lambert and Kolbe-Alexander reported a massive 70% prevalence of South Africans who are insufficiently active (minimally active or inactive). Furthermore, cross-sectional studies carried out in the north west of South Africa in 2002, indicated low levels of activity amongst both rural and urban women and

only 50% amongst these adults had sufficient activity levels to gain health benefits (Kruger, Venter, Vorster & Margetts, 2002). In 2004, Steyn et al. reported that residents in Mamre, situated in the Western Cape, accumulated less than the recommended level of physical activity with only 49.7% of this sample population achieving the recommendation of 150 minutes of accrued moderate intensity physical activity weekly. Results also indicated 40% of those younger than 35 years of age were insufficiently active and those aged 55 to 64 and above 65 reported 66% and 76% insufficient activity, respectively. These studies using GPAQ and IPAQ, particularly in South Africa, have shown the extent of low habitual physical activity, which in turn could have an impact on the chronic disease health status of many South Africans.

Physical activity has been correlated to insulin sensitivity and resistance by means of recall questionnaire as well as other means of subjective testing. These studies have shown that physical activity does have an influence on insulin sensitivity and glucose tolerance. This has been observed in a variety of populations, from healthy lean subjects to those with impaired glucose tolerance and type 2 diabetes (Assah et al., 2008; Balkau et al., 2008; Mayer-Davis et al., 1998).

In Iran, Esteghamati et al. (2009) investigated the association between HOMA-IR and physical activity, assessed by the Global Physical Activity Questionnaire (GPAQ) in a large national-representative sample of adults. After adjustment for age, area of residence, smoking, and BMI, total

physical activity ($r = -0.26$; p = 0.01 in males and $r = -0.21$, p = 0.01 in females) significantly correlated to HOMA-IR. Furthermore, they also found that the prevalence of physical inactivity increased linearly with increasing HOMA-IR quintiles.

In Taiwan, Chen, Chuang and Wu (2008) however found no significant correlation between HOMA-IR and the 7-day recall physical activity questionnaire administered to 151 volunteers (those included had at least one risk factor for metabolic syndrome) in their study but instead reported that objective measures of physical activity provide better predictions than subjective reports.

In healthy individuals, Perseghin et al. (2007) examined the association between habitual physical activity and insulin resistance in adults ranging from 19-62 years of age. A questionnaire was used to determine physical activity and insulin sensitivity identified by homeostasis model assessment (HOMA)-2 indexes. Insulin sensitivity was found to be the highest in the quartile group with the most physically active participants, progressively declining with declining physical activity. In the Insulin Resistance Atherosclerosis Study, habitual, non-vigorous physical activity, vigorous activity and overall activity were assessed by means of a one-year recall questionnaire. Sensitivity to insulin was found to be significantly higher with higher levels of physical activity which was consistent for total, vigorous and non-vigorous activities. Furthermore, frequency of participation was positively associated with insulin sensitivity (p = 0.001). This also suggests

that frequent physical activity and not isolated bouts of physical activity may be a key determinant of insulin sensitivity (Mayer-Davis et al., 1998).

2.4.2 Measuring Health-Related Physical Fitness

Health-related physical fitness tests are objective measures designed to evaluate fitness components related to health. These measures of fitness have been developed over a number of decades and are based on physiologic measurements that have good to excellent accuracy and reliability. The major components of health-related physical fitness include cardiorespiratory fitness, muscular strength and endurance, flexibility and body composition (U.S. Department of Health and Human Services, 1996).

Numerous studies have been undertaken to identify the relationship between components of physical fitness and insulin resistance / sensitivity. In a recent study by Chen et al. (2008), the association between measures of physical fitness to predict insulin resistance in adults at risk for type 2 diabetes was investigated. The study utilized HOMA-IR to determine insulin resistance. Clinical measures of physical fitness included body composition (BMI and waist circumference), cardiorespiratory fitness (3 minute step test), strength (handgrip strength), muscular endurance (1 minute sit-up test) and flexibility (sit-and-reach). In men, insulin resistance was significantly correlated with BMI (r = 0.40, p = 0.003), waist circumference (r = 0.39, p = 0.003) and cardiorespiratory endurance index (r = -0.30, p = 0.03). In women, significant associations between HOMA-IR

and measurements indicated a positive correlation with BMI (r = 0.60, p = 0.0005), waist circumference (r = 0.64, p = 0.0005) and handgrip strength (r = 0.31, p = 0.003) and negatively with flexibility (r = -0.26, p = 0.013), cardiorespiratory endurance (r = -0.45, p = 0.005) and age (r = 0.20, p = 0.047). This study showed that a relationship between insulin resistance and components of physical fitness does exist, particularly between body composition, cardiorespiratory fitness and strength. These results further demonstrated that measures of physical fitness can predict abnormal HOMA-IR (insulin resistance) in adults at risk for type diabetes. In women, age, waist circumference and cardiorespiratory fitness were predictors of insulin resistance and in men, BMI, cardiorespiratory fitness and muscle strength were predictors of insulin resistance. They found that age was not an independent predictor of insulin resistance after adjustment for physical fitness and physical activity in men.

Studies on chronic disease have focussed predominantly on three features of health-related fitness, namely body composition, cardiorespiratory fitness and muscular strength, and to a lesser extent, muscle endurance and flexibility. This can be seen in the paucity of research on these two components with chronic disease, particularly insulin resistance.

2.4.2.1 Cardiorespiratory fitness

Cardiorespiratory (CR) fitness is the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods (ACSM, 2010) and can be influenced by a number of factors including gender, age,

genetics (heredity) and medical status (Bouchard, Shephard & Stephens, 1994). Cardiorespiratory fitness is regarded as being health-related because an association exists between low levels of CR fitness and an increased risk of premature death from all causes. Similarly, increases in CR fitness are associated with a decrease in deaths from all causes. Concomitantly, greater levels of CR fitness have been correlated to higher levels of regular physical fitness, which in turn are associated with many health benefits (ACSM, 2010). It has recently been suggested that CR fitness should be used as a definitive marker for risk stratification and health outcomes (Dalleck & Dalleck, 2008).

The best measure of cardiorespiratory fitness is maximal oxygen uptake or aerobic power ($VO_{2\ max}$), referring to the highest rate at which oxygen can be taken up and consumed by the body during intense exercise (Dalleck & Dalleck, 2008). But this method is relatively expensive, time-consuming and requires the participant to exert maximal effort during the test, making it somewhat difficult to accomplish (U.S. Department of Health and Human Services, 1996). Therefore, submaximal tests have been developed, many of which utilise heart rate response to determine $VO_{2\ max}$, as heart rate during aerobic exercise is highly associated with the increase in oxygen uptake (ACSM, 2010). The advantage of submaximal tests is that it is cost-effective and large numbers of participants can be tested relatively quickly. However in certain tests, heart rate is not used to determine $VO_{2\ max}$, and a

participant's CR fitness is expressed as the heart rate at a set workload or at the workload required to reach a specific submaximal heart rate (Cooper, 1968).

Insulin resistance as well as insulin and glucose concentrations have been correlated to cardiorespiratory fitness in numerous studies. Messier, Malita, Rabasa-Lhoret, Brochu and Karelis (2008) found insulin resistance (classified by tertiles) to significantly correlate with cardiorespiratory fitness ($r = 0.25$, $p < 0.05$) using a submaximal cycle ergometer test in obese and overweight postmenopausal women. However, as cardiorespiratory fitness progressively increased from tertile one to tertile three, it was no longer significant after controlling for visceral adipose tissue and muscle strength, suggesting that these two factors may be potential mediators of this relationship. Similarly, Racette, Evans, Weiss, Hagberg & Holloszy (2006) identified that CR fitness, measured by a $VO_{2\ max}$ treadmill test, is a significant predictor of insulin sensitivity in old age ($p = 0.0001$). Abdominal obesity however was the most important single factor in predicting insulin sensitivity. When controlling for waist circumference however, they noted that only CR fitness remained significant ($p = 0.009$).

Further studies observing similar results were seen when the independent effects of high body fat and high cardiorespiratory fitness on insulin resistance was determined in 10 overweight and nine lean women with high cardiorespiratory fitness and 10 overweight women with low cardiorespiratory fitness (Gerson & Braun, 2006). Results showed that

fasting plasma glucose (p = 0.77), insulin (p = 0.23), and triacylglycerol (p = 0.99) concentrations were similar between the women with high cardiorespiratory fitness (lean weight and overweight), with mean values in both groups being lower than in the overweight women with low cardiorespiratory fitness. Insulin sensitivity was slightly but significantly lower in the overweight fit women compared with the lean fit women. When comparing the overweight fit to the lean fit women, the small difference in insulin sensitivity despite the twofold difference in body fat percentage suggests the importance of cardiorespiratory fitness independent of body weight.

Assah et al. (2008) also observed the importance of cardiorespiratory fitness when they aimed to identify the association between overall level and intensity of physical activity, measured by heart rate monitoring, and insulin resistance, using fasting insulin, in 643 individuals aged 50 to 75 years. Fasting insulin was shown to decrease progressively with an increase in physical activity energy expenditure from the first to the fourth quartiles in both men and women, showing a significant association (p = 0.006). Similarly, time spent 1.75 times above resting heart rate and two times above resting heart rate were also significantly associated with fasting insulin (p = 0.007 and p = 0.0001 respectively) after adjustment for age, gender and body fat percentage.

In a sub arctic Native Canadian population, Kriska, Hanley, Harris and Zinman (2001) examined the relationship between activity, fitness and

obesity and glucose concentrations using normal glucose tolerant, IGT, newly diagnosed diabetics and previously known diabetics. Both physical activity and physical fitness, using a physical activity questionnaire ($p = 0.014$) and cardiorespiratory step test ($p = 0.009$), were independently found to be significantly associated with fasting insulin concentrations after controlling for age, BMI or percent body fat and waist circumference in men but not women. This suggests a beneficial effect of physical activity and fitness on insulin sensitivity that is independent of any influence of physical activity on body composition.

2.4.2.2 Muscular strength

Muscle strength is defined as the ability of a muscle to exert an external force generated by a specific muscle or muscle group and can be achieved by completing either a dynamic (movement occurring in a muscle or limb) or static (no muscular or limb movement) contraction (ACSM, 2010; Wilmore 1989). The gold standard test predominantly used for measuring dynamic muscle strength is the one-repetition maximum (1-RM), which is the heaviest weight an individual can lift only one time through the full joint range of motion. The bench press and leg extension tests are two common tests used to determine dynamic strength (ACSM, 2010; U.S. Department of Health and Human Services, 1996) but can be somewhat time-consuming to complete and require large equipment. Field tests for static muscle strength include dynamometry such as handgrip dynamometry, and leg and back dynamometry (ACSM, 2010). Handgrip strength is a useful tool to measure body strength as it correlates well with elbow flexion

strength (r = 0.672), knee extension strength (r = 0.514) and trunk extension strength (r = 0.541) respectively, giving an estimate of total body strength. It is also a test that can be easily administered although it requires maximal effort from the participant. Handgrip strength has also been found to be a strong predictor of mortality in adults (Rantanen, et al., 2003).

Studies reveal an association between muscle strength activities and improved insulin sensitivity (Boule, Haddad, Kenny, Wells & Sigal, 2001; Dunstan et al., 2002; Cheng et al., 2007). In addition, its effects on insulin sensitivity have been implicated to reduce the risk of type 2 diabetes. To assess this relationship, Cheng tested 4 504 adults aged between 20 and 79 years with no diagnosed diabetes, surveyed as part of the National Health and Nutrition Examination Survey 1999-2004. Physical activity, in particular muscle strength, was assessed by a 30 day self-report recall questionnaire. Once the confounders were adjusted, results showed a significant positive correlation in both men (p = 0.008) and women (p = 0.009) between intensity of activity and insulin sensitivity, indicating that strength activities are independently associated with insulin sensitivity. Interestingly, results also showed that 84.7% of the study group performed strength activities for less than three days a week, with 76.9% of these engaging less than once a week. Those performing less than one day increased to 83% among participants aged 60 years or older, suggesting a decrease in muscle strength activity with increasing age. Further results showed that BMI in women progressively declined with increased activity

(p = 0.001). Importantly, higher strength activities correlated to higher insulin sensitivity, lower fasting insulin and lower fasting glucose for men (p = 0.001) and women (p = 0.001) (Cheng et al., 2007). Karelis et al. (2007) also found that insulin sensitivity correlated positively and significantly (*r* = 0.37, p = 0.001) with lower-body muscle strength in 82 overweight and obese sedentary postmenopausal women when quartiles of insulin sensitivity scores were compared with the muscle strength index.

In agreement with Cheng's findings, muscle strength has frequently been shown to decrease with age (Sayer et al., 2005). Chronic diseases such as coronary heart disease, stroke and diabetes mellitus are common conditions associated with advancing age which in turn are associated with decreased muscle strength, particularly type 2 diabetes (Sayer et al., 2007). Physical inactivity has been implicated as a risk factor for diminished muscle strength and could potentially be an indicator of disease severity (Rantanen et al., 2003). In those with type 2 diabetes, muscle strength has been shown to correlate with insulin sensitivity and enhanced glycemic control (Cheng et al., 2007). This was demonstrated by Sayer and colleagues (2007) where a decrease in grip strength was significantly associated with HOMA-IR (p = 0.008) and waist circumference (p = 0.001) in older adults aged 59 to 73 years.

Resistance training has shown to improve insulin sensitivity in older men and women. After a four month resistance training intervention program on moderately obese postmenopausal women, Ryan, Pratley, Goldberg & Elahi (1996) found an increase in insulin action with resistance training

alone and together with weight loss. This suggests that resistance training has the potential to improve and possibly prevent the development of insulin resistance.

2.4.2.3 Muscle endurance and flexibility

Muscle endurance is the ability of a muscle group to execute repeated contractions over an extended period of time sufficient to cause muscular fatigue, or maintain a percentage of maximum voluntary contraction for a prolonged period of time. When being tested, muscular endurance, like strength, is specific to a muscle or muscle group. Absolute muscle endurance is the term used when the total number of repetitions at a specific load of resistance is measured. Relative muscle endurance is measured when the number of repetitions is performed at a percentage of the 1-RM (ACSM, 2010). In the laboratory setting, endurance is predominantly measured by performing a number of muscle contractions at a given percentage of maximal strength and at a constant rate until the participant cannot perform any more contractions at that rate. The duration or total work performed is then used as a measure of muscular endurance (U.S. Department of Health and Human Services, 1996). In the field setting, muscular endurance is usually measured by performing a number of contractions for a fixed period of time at a percentage of 1RM, such as determining the number of crunches that can be performed in one minute. The most common field tests include the sit-up, or half sit-up (also known as the “crunch.”)

Flexibility is the ability to move a joint through its complete range of motion and is a vital component of health as it allows us to carry out activities of daily living by facilitating joint movement (ACSM, 2010). Flexibility is similar to strength and endurance as its measurement is also specific to the joint being tested therefore placing some difficulty in measuring a participant's overall flexibility. Laboratory measurement quantifies flexibility by means of range of motion expressed in degrees. A few common tests include goniometry and electrogoniometry and the use of tape measures. Field testing of flexibility is done predominantly by the sit-and-reach test, which is considered to be a measure of lower back and hamstring flexibility. However, these tests of flexibility may be an indicator of muscular lower back pain rather than metabolic disorders (ACSM, 2010; U.S. Department of Health and Human Services, 1996).

A dearth of information exists about the relationship between muscular endurance, flexibility and insulin resistance. A study by Chen et al. (2008) aimed to identify the ability of the components of fitness to predict insulin resistance. Their findings showed that muscle endurance (r = -0.14 for men and r = 0.31 for women), measured by half sit-up, and flexibility (r = -0.17 for men and r = -0.26, $p < 0.05$ for women), measured by sit-and-reach, had weak correlations with HOMA-IR, failing to be independent predictors of insulin resistance. These findings suggest that exercises improving hamstring muscle flexibility and abdominal muscle endurance may not effectively influence insulin resistance (ACSM, 2010).

2.5 AGE, PHYSICAL ACTIVITY AND INSULIN RESISTANCE

In 1986, Fink, Wallace and Olefsky assessed the effects of ageing on glucose-mediated glucose disposal and glucose transport in 11 elderly people, as insulin resistance was well known to be associated with ageing. They found that insulin resistance in ageing was due to a reduction in the capacity of the glucose uptake system. This supported the hypothesis that a reduction in glucose transport occurs with ageing.

Today, there is widespread evidence that ageing indeed leads to insulin resistance, in turn playing a vital role in the etiology and prevalence of type 2 diabetes in older adults (Amati et al., 2009). However, evidence supporting this association between age and insulin resistance somewhat demonstrates that insulin resistance may not be associated with ageing per se but rather with lifestyle linked with ageing, such as reduced physical activity and obesity (Amati et al., 2009). Thus, it is not clear whether insulin resistance is characteristic of ageing or, alternatively, whether obesity and/or physical inactivity underlie this “ageing” effect (Amati et al., 2009).

This was shown when Amati and colleagues (2009) compared insulin sensitivity in younger and older endurance-trained athletes, younger normal-weight and older normal-weight subjects and younger obese and older obese subjects, in which no difference was shown in any of the three groups. Regardless of age, athletes were more insulin sensitive than normal-weight sedentary subjects, who in turn were more insulin sensitive than obese subjects. Ferrannini and colleagues demonstrated this in 1996 when they concluded that the small effect age had on insulin action in

healthy Europeans could be explained by the age-related changes in body composition, suggesting that age is not a significant cause of insulin resistance (Ferrannini et al., 1996).

In addition to a decrease in insulin sensitivity, cardiorespiratory fitness has also shown to decrease with age (Fleg et al., 2005). In a cross-sectional study by Short and colleagues in 2003, baseline data showed a decline in CR fitness with increasing age from 22 to 87 years at a rate of 7.5% per decade. Concomitantly, insulin sensitivity declined with age at a rate of 8% per decade. After a 16-week moderate intensity aerobic exercise program, results showed an increase in insulin sensitivity only in young individuals (20 to 39 years), with no improvement in sensitivity in middle (40 to 59 years) and older age (≥ 60 years). Cardiorespiratory fitness increased significantly ($p < 0.05$) by 72% in the younger age group, by 20% in the middle age group and by five percent older age group (Short et al., 2003).

2.5.1 Age and Physical Activity Levels in South Africa

In South Africa, studies on physical activity, mortality and age were undertaken to identify if a relationship existed between these variables. One study indicated that levels of physical activity in the survivors of a 2-year follow-up study of historically disadvantaged, older South Africans residing in Cape Town were two-thirds lower than those reported in a North American sample of similar age indicating habitually low physical activity (Charlton, Lambert & Kreft, 1997). In a similar study, the International Physical Activity Questionnaire (IPAQ) was administered to older, previously disadvantaged South African adults (Lambert & Kolbe-

Alexander, 2006). Results indicated that on average this group utilized 65% less energy in physical activity (2583 kcal/week) than their North American counterparts. This highlights the extent of physical inactivity amongst our older population and that the amount of physical activity undertaken decreases with an increase in age.

2.6 CONCLUSION

Insulin resistance is associated with a number of lifestyle-related chronic diseases, including obesity and type 2 diabetes. It has been suggested that excess body fat plays a causative role in the development of insulin resistance. In turn, insulin resistance has been shown to precede the conditions of IGT, IFG and type 2 diabetes. Physical activity recall questionnaires have also been used to determine a correlation, many of which have shown to be significant while others have shown no significance. Similarly, health-related physical activity has also been correlated to insulin resistance. Studies reveal that cardiorespiratory fitness and muscular strength yield significant scores whereas fewer studies reveal significance with endurance and flexibility.

Both insulin sensitivity and physical activity has shown to decrease with age. In South Africa, this statement is supported as evidence reveals a decline in physical activity levels with age. Moreover, research has not only revealed this decline with age but also that physical activity levels are low across all ages.

CHAPTER THREE

METHODOLOGY

Within this chapter, the methods utilised to complete this study are explored and described. In particular, the chapter describes the setting of the study, followed by the design which was developed in order to achieve the aims and objectives. This chapter also describes the sample size and population selected and explains the methods of how data were collected and tests performed. In addition, the analysis of the data is explained and the ethical issues explored.

The key variables in this study are insulin resistance, body composition, physical activity, cardiorespiratory fitness, muscular fitness and flexibility. Insulin resistance was determined by the Homeostasis Model of Insulin Resistance (HOMA-IR). Height, weight (body mass index) and waist circumference were used to determine body composition, and the Global Physical Activity Questionnaire (GPAQ) was used to determine physical activity. The cardiorespiratory 3-minute step test, handgrip grip strength test, one-minute crunch test for muscular strength and endurance respectively and the sit-and-reach test for flexibility were used to determine physical fitness.

3.1 RESEARCH SETTING AND POPULATION

This research study was conducted in a low-income, previously disadvantaged mixed ancestry community within a northern suburb of Cape Town, Western Cape. The community consists of approximately 26,758 residents of which 46% is male and 54% is female. The predominant race is coloured (80.5%), the minority comprises of 15.1% black, 3.4% white and 1% Indian/Asian and the dominant language is Afrikaans (68%). Residents aged between 35 years and 65 years of age represent 27% of this community (7,225 residents). Of the 8,062 economically active employed residents (aged 15-65 years), 91% earn less than R6,400 per month, of which 42% earn under R1,600, making it a predominantly low income community (Statistics South Africa, 2001).

3.1.1 Overview of the Community-based Study

The Department of Biomedical Science, Cape Peninsula University of Technology and the Department of Chemical Pathology, Stellenbosch University (Tygerberg Hospital) have collaborated to form a community-based prospective observational study. This community was chosen as it represented a stable urban mixed ancestry community. The research protocol for this community study was approved by the Research and Ethics Committee of Cape Peninsula University of Technology, with reference number CPUT/HW-REC 2008/002. Permission was granted from relevant authorities, such as the City of Cape Town and community authorities to make use of the sample collecting venues.

3.2 DESIGN

3.2.1 Community Study Design

The overall aim of the community-based study was to determine the prevalence of type 2 diabetes mellitus and impaired glucose tolerance (IGT) as well as to identify certain predisposing factors leading to type 2 diabetes mellitus and IGT, such as family history, physical activity, high fat diet, cigarette smoking and alcohol consumption.

First phase

Residents aged between 35 and 65 years were recruited to participate in the first phase of the study using the stratified random sampling method of sample selection, in which the area (streets) was divided into six strata. From the selected streets, all household members meeting the selection criteria were invited to participate in the study. Biochemical tests were performed in this phase which included fasting blood glucose and insulin levels.

Second phase

The purpose of the second phase was to identify the predisposing factors contributing to the development of type 2 diabetes mellitus and impaired glucose tolerance. This phase of the study commenced in November 2008 and ended in December 2009 and the same residents who were recruited in the first were recruited to participate in the second phase. In this phase the following tests were performed:

Biochemical assessment:	Blood sample
Anthropometric measurements:	Height, weight, body mass index, waist circumference
Physical examination:	Blood pressure
Clinical assessment:	Resting electrocardiogram (ECG)
Dietary analysis:	Diet questionnaire
Physical activity assessment:	Physical activity questionnaire and physical fitness testing

The second phase of the study constituted the main part of the present study.

3.2.2 Phase Two Design

The current study was a quantitative cross-sectional, correlational study utilising descriptive data. A cross sectional study is one of several observational study designs. The design for this study was selected based on the feasibility, cost and length of time to complete and data was collected from participants at one point in time, relying on existing differences within the population, i.e., no conditions were altered (Katz, 2006; de Vaus, 2001; Drummond, 1996). Quantitative assessments utilising an interviewer-administered questionnaire was used to obtain physical activity and fitness tests were used to obtain physical fitness levels. Biochemical assessments, namely glucose and insulin values, were obtained from the first phase of the study.

In this study, physical activity and physical fitness levels were correlated to insulin resistant (quartile four) and non insulin resistant participants (quartiles one to three). Secondly, subjectively measured physical activity and objectively measured physical fitness levels between participants were compared and discrepancies identified (to determine the accuracy with which participants answered the quantitative physical activity questionnaire). In this method of sampling the population was separated into mutually exclusive categories, or strata (Drummond, 1996). Figure 2 provides an overview of all the tests conducted in this study. Originally, insulin resistance (IR) participants were to be separated into those with IR alone, those with IR and type 2 diabetes (newly diagnosed) and those with IR and impaired glucose tolerance (IGT) or impaired fasting glucose (IFG). However, too few participants were found to have diabetes, IGT and IFG. Therefore, only IR and non IR strata were analysed.

The sample size of this study was determined by the number of participants who participated in the second phase who formed part of the random sample selected in phase one of the community study and also satisfied the inclusion and exclusion criteria.

3.3 SAMPLE SIZE

A sample of 900 participants between the ages of 35-60 years old was tested in the first phase of the community diabetic study, of which 600 met the inclusion criteria.

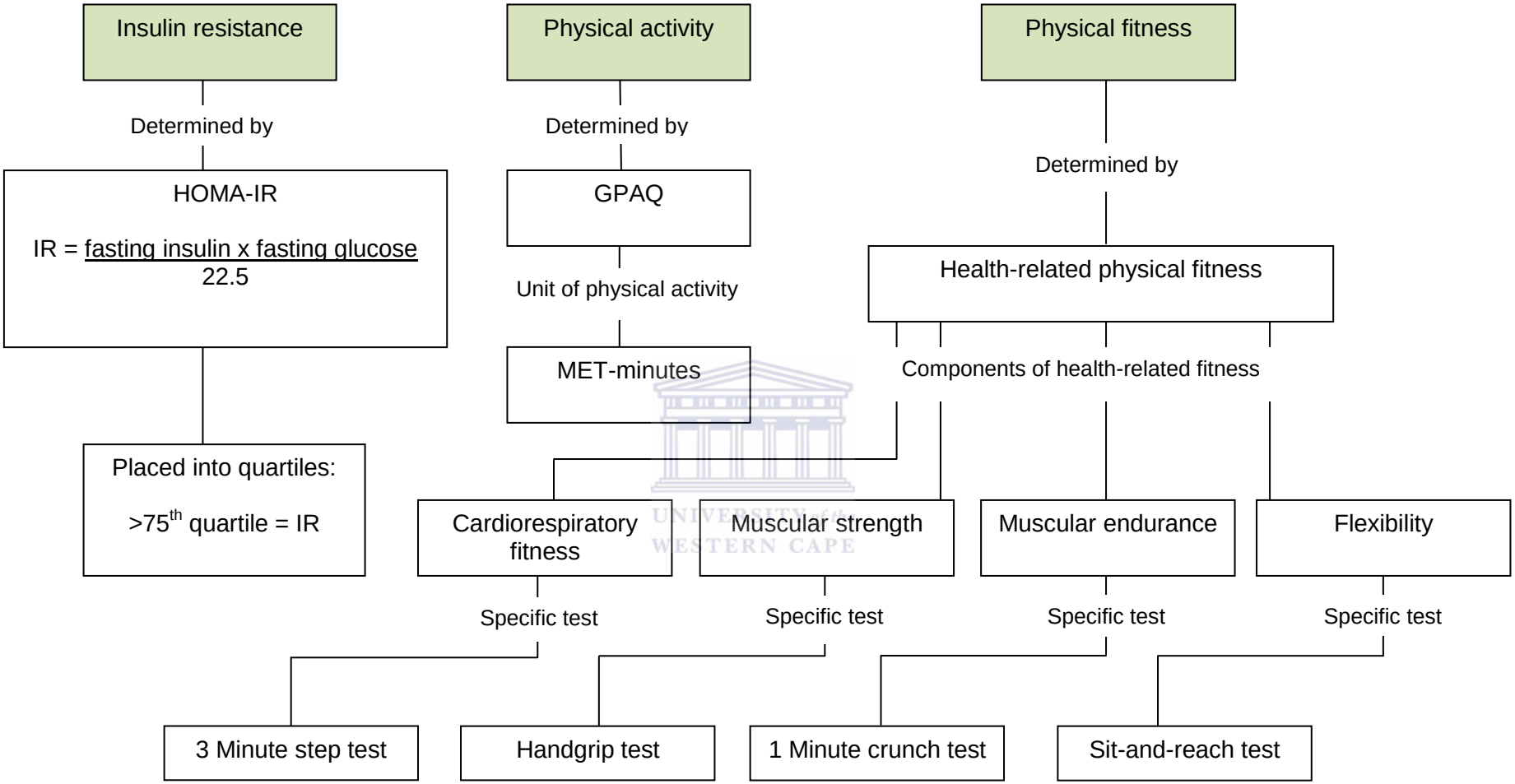

Figure 2. Tests Utilised in the Research Study

Using the following formula (Israel, 1992), with a level of precision of ±5% and a confidence level of 95%, the sample required for the current study was calculated as follows:

$$n = \frac{600}{1 + N(e)^2}$$

where n is the sample size, N is the population size and *e* is the level of precision. When the above formula is applied to the sample obtained in the first phase of the study, the following sample size was obtained for the current study:

$$n = \frac{600}{1 + N(e)^2} = \frac{600}{1 + N(0.05)^2} = 240 \text{ participants}$$

The sample number required for this study was therefore 240 participants.

3.4 METHODS AND PROCEDURES OF DATA COLLECTION

After the recruitment team had informed the participants of the second phase, participants were visited at their respective homes and given an information letter regarding the second phase of the study and its specific components. Recruiters also verbally informed participants of the study. Those willing to participate were sent an information letter containing the pre-test instructions and a consent form for them to read and complete (Appendices A and B respectively). The information letter contained information regarding all the areas that would be assessed. These forms were given to participants in their home language. As the majority of the participants (68%) were Afrikaans speaking, forms were translated into Afrikaans by an independent translator, then back-translated by a second

translator to ensure all information was correctly understood by the participant. The pre-test instructions pertained to the physical fitness tests which instructed all participants to prepare adequately for the tests.

3.4.1 Pilot Study

A pilot study was conducted to pre-test the physical activity questionnaire and test the feasibility of the fitness tests chosen in order to improve the quality and efficiency of the study. The pilot study provided vital information on the logistics and feasibility of the procedures and methods identified in the proposal. A total of 12 participants were identified to take place in the pilot study prior to the main study, the results of which were not included in the main study. During this time, the fitness tests and its procedures were assessed to identify if changes needed to be made. The testing assistant was also trained in the pilot study.

During the pilot study, the reliability of the testing equipment was also assessed. For the step test and curl-up test, the Technosport stopwatch was compared against two stop watches of different brands. For the step test, the metronome was tested against the actual number of steps counted – a total of 96 beats (24 steps) per minute and the heart rate monitor was tested against the number of beats per minute, measured manually on the brachial artery of the participant.

The questionnaire was interviewer-administered and was asked in the participant's home language; enabling participants to understand the

questions being asked (the questionnaire was not in their home language but was asked in Afrikaans and English). Descriptions of vigorous and moderate intensity activities and other terminology were described as per the instructions provided on the questionnaire. Outcomes of the pilot study found that the administrator needed to explore certain domains in more detail, particularly participants who gave very high or low responses. In addition, many participants were unsure of the time spent on a particular activity. Reference was therefore made to certain times of the day or television programs (although not part of the GPAQ administration procedure). This allowed for greater accuracy in the responses obtained.

Further outcomes of the questionnaire showed that it was suited for this population. Physical activity domains were in line with the activities performed by this population. For example, all participants performed work-related duties which included either vigorous- (five participants) or moderate-intensity (11 participants) work, predominantly as home-related work. For travelling, the majority of participants (eight participants) walked and none cycled as a form of transportation. Only two participants engaged in vigorous intensity leisure time physical activity and three participated in moderate intensity leisure time physical activity. When asked what other forms of physical activity they engaged in, participants all answered none.

With regards to the physical fitness tests, outcomes indicated that many participants could not complete the 3-minute step test. As the majority of participants reported to engage in walking activities, a walk test would have

been a suitable cardiorespiratory test. However, data collection took place within a classroom at a primary school and there were continuous activities during school hours. As a result, many participants would have completed the test during break times. Therefore a walk test was not feasible at this site. In addition, a cycle test was also considered, but as equipment needed to be moved to and from the school storeroom daily, it was not feasible to use the cycle ergometer. Time was also a factor as many participants queued for the tests. Therefore a cardiorespiratory test with the shortest duration was considered.

Participants who had earlier taken part in the pilot study were excluded from the study. On the day of testing participants were tested in the following order:

Station 1: Participants signed in, personal details were taken and consent forms were completed. Medical history was also assessed. Each participant was given a folder.

Station 2: Blood pressure

Station 3: Phlebotomy (blood sample)

Station 4: Electrocardiogram

Station 5: Physical activity, body composition and physical fitness testing

Station 6: Dietary analysis

A medical doctor was present in order to assess the results of the electrocardiogram and also to provide medical clearance to participate in the physical fitness tests.

3.4.2 Determining Insulin Resistance

Insulin resistance was measured by HOMA-IR according to the following equation: (Chen et al., 2008; Schmidt, Cleland, Thomson, Dwyer & Venn, 2008; Meigs et al., 2007; Bonora et al., 2007; Matthews et al., 1985)

$$\text{Insulin resistance} = \frac{[\text{fasting insulin } (\mu U \cdot mL^{-1}) * \text{fasting glucose } (mmol \cdot L^{-1})]}{22.5}$$

As no normative data exists for insulin resistance, HOMA-IR values are represented as quartiles and arranged in descending order. The twenty-fifth percentile is referred to as the first quartile (Q_1), the fiftieth percentile (P_{50}) is the median and is referred to as the second or middle quartile (Q_2) and the seventy-fifth percentile is referred to as the third quartile (Q_3). Participants in the top quartile (>75th percentile) of HOMA-IR distribution values were considered as insulin resistant (Bonora et al., 2007; Meigs et al, 2007, Bonora et al, 2004).

Quartiles were established using the following formulae:

$$Q_1 = \frac{n+1}{4} \quad \text{th}$$

$Q_2 = \frac{2(n+1)}{4}$ th $= \frac{n+1}{2}$ th

$Q_3 = \frac{3(n+1)}{4}$ th

3.4.3 Physical Activity Testing: The Global Physical Activity Questionnaire (GPAQ)

After completion of the previous four stations, the physical activity questionnaire and fitness tests were administered by one of two individuals: the researcher or an assistant. The Global Physical Activity Questionnaire (GPAQ) was first to be administered in the physical activity testing (Appendix C). The interview process began by explaining the concepts of the physical activity questionnaire and fitness tests. This took place in the participants' home language and allowed for orientation of the participant.

The questionnaire was designed to be a one-week recall to assess physical activity participation within a population. It contains 16 questions and is divided into three activity settings, also known as domains, as well as a fourth setting for sedentary behaviour. The three domains are activity at work, travelling to and from places and leisure-time activities. The questionnaire assesses the duration, frequency and intensity of each domain.

Prior to the start of testing, the GPAQ Question by Question Guide was reviewed (Appendix D). This section aims to guide the interviewer in asking

the questions and recording responses. Administration began with the participants being asked to think about all the physical activities they accomplished within the past week, followed by a description of the questionnaire and definition of intensity levels. The procedure and format of administering the questionnaire was strictly adhered to.

One important factor that was taken into account when administering the questionnaire was the perception of the intensity levels of vigorous-intensity and moderate-intensity activities. As fitness levels differed with each participant, it was emphasised that it was not the specific activity they performed but rather how the activity made them feel, and should be rated according to the physical symptoms, such as heavy breathing and heart rate. It was also emphasised that the vigorous- and moderate-intensity sections be seen as separate activities. If one participates in a vigorous activity, the same activity cannot be presented again in the domain referring to moderate activity. The importance of this was to prevent duplicated responses.

3.4.4 Health-Related Physical Fitness Testing

Health-related physical fitness was assessed by measuring body composition, cardiorespiratory fitness, muscular fitness (muscular strength and muscular endurance) and flexibility (U.S. Department of Health and Human Services, 1996). All instrumentation was calibrated according to the prescribed manufacturer's guidelines. A data record sheet was developed specifically for this study (Appendix E).

3.4.4.1 Body composition

Measures of body composition included height (stature), weight, body mass index and waist circumference. These measurements were taken with adequate space to allow for easy movement around the participant, assisting in the accuracy of measurements.

3.4.4.1.1 Measurement of stature

Height is defined as the perpendicular distance between the transverse plane of the vertex and the inferior aspects of the feet and is measured with a stadiometer (Marfell-Jones, Olds, Stewart & Carter, 2006). Four general techniques exist for the measurement of stature: free standing, stature against the wall, stretch stature and recumbent length. For this study, the stretch stature method was employed. The procedure is described as follows (Marfell-Jones et al., 2006):

- The participant was asked to remove their shoes and stand with their heels together, with the heel, buttocks and upper section of the back touching the scale.
- The head, placed in the Frankfurt plane, did not need to touch the back of the scale.
- The Frankfurt plane was achieved when the orbitale (lower edge of the eye socket) was in the same horizontal plane as the tragion (the notch superior to the tragus of the ear).
- This was accomplished by placing the tips of the thumbs on each orbitale and the index fingers on each tragion, then horizontally aligning the two.

- Once the head was positioned, the thumbs were repositioned posteriorly towards the participant's ears and far enough along the side of the jaw to ensure that upward pressure was transferred to the mastoid process.
- When the participant was aligned, the vertex was the highest point of the skull.
- The participant was then instructed to take and hold a deep breath, and while keeping the head in the Frankfurt plane, a gentle upward lift through the mastoid processes was applied.
- The head board was then placed firmly down on the vertex, compressing the hair as much as possible.
- The measurement was taken before the participant exhaled and was measured to the nearest 0.01cm.

3.4.4.1.2 Measurement of body mass

Mass is defined as the quantity of matter in the body and is calculated through the measurement of weight (the force matter exerts in a standard gravitational field) (Marfell-Jones et al., 2006). A weighting scale was used to quantify body mass (Beuer electronic scale, model GS 28). The scale was calibrated regularly against a calibrated Seca balance scale to ensure accuracy. This was accomplished by weighing various dumbbell weights ranging from 10 to 50kg on both the stadiometer and electronic scale. Ideally, body mass should be measured with the participant nude. However, it is accepted that the measurement be done with minimal

clothing in order to produce sufficient accuracy. The measurement was carried out as follows (Marfell-Jones et al., 2006):

- The participant was asked to remove all excess clothing as well as keys, cellular phones and any other objects.
- He/she then stood on the centre of the scale without support, with their weight evenly distributed on both feet.
- Body mass was measured to the nearest 0.01kg.

It is important to note that daily variation in body mass exists with a variation of 2kg being seen in adults. The most stable values are those obtained in the morning, twelve hours after food and after voiding (Marfell-Jones et al., 2006). In this study, weight measurement was taken between 08:00 and 10:00 and participants were informed to refrain from ingesting food prior to the measurement. For those on medication, participants were asked to have a light breakfast in order for them to take their medication.

3.4.4.1.3 Measurement of Body Mass Index (BMI)

Body mass index, or the Quetelet index, was used to assess weight relative to height and was calculated by dividing body weight in kilograms by height in meters squared ($kg \cdot m^{-2}$) (ACSM, 2010). In Table IV, disease risk is classified according to BMI.

3.4.4.1.4 Measurement of waist circumference

The pattern of body fat distribution is recognised as an important predictor of health risk and cardiovascular disease (ACSM, 2010). Waist

Table IV. Classification of Disease Risk According to Body Mass Index (ACSM, 2010)

Classification	BMI ($kg \cdot m^{-2}$)
Underweight	< 18.5
Normal	18.5 – 24.9
Overweight	25 – 29.9
Obesity class 1	30 – 34.9
Obesity class 2	35 – 35.9
Obesity class 3	≥ 40.0

circumference (circumference of the abdomen) is defined as the narrowest point between the lower costal border (tenth rib) and the top of the iliac crest, perpendicular to the long axis of the trunk (Marfell-Jones et al., 2006; ACSM, 2010). Table V describes the classification disease risk according to waist circumference. Table VI classifies disease risk based on BMI and waist circumference. Waist circumference was measured according to Marfell-Jones et al. (2006):

- The participant was asked to stand in a relaxed position with the arms folded across the thorax (chest).
- Standing in front of the participant, the stub of the tape was held in the left hand while at the back of the participant, the right hand adjusted the level of the tape to the adjusted level of the narrowest circumference.
- Then using the cross-hand technique, the tape was positioned in front of the specified level.
- The participant was asked to breathe normally and the measurement was taken at the end of normal expiration.
- If there was no obvious narrowing of the waist, the measurement was taken at the mid-point between the lower costal border and the iliac crest.

- Waist circumference was measured to the nearest 0.1 cm (Schmidt et al., 2008).

Table V. Classification of Coronary Artery Disease Risk According to Waist Circumference (ACSM, 2010)

Classification	Waist circumference	
	Male	Female
Normal	≤ 102 cm	≤ 88 cm
Increased risk	> 102 cm	> 88 cm

Table VI. Classification of Coronary Artery Disease Risk Based on BMI and Waist Circumference (ACSM, 2010)

BMI Classification	Waist circumference	
	Male ≤ 102 cm	**Male > 102 cm**
	Female ≤ 88 cm	**Female > 88 cm**
Underweight	……	……
Normal Weight	……	……..
Overweight	Increased risk	High risk
Obese class 1	High risk	Very high risk
Obese class 2	Very high risk	Very high risk
Obese class 3	Extremely high risk	Extremely high risk

3.4.4.2 Cardiorespiratory fitness

Aerobic capacity was determined by the YMCA 3-Minute step test. The test is a simple, inexpensive cardiovascular endurance test that can be easily administered to large groups of people. The test classifies fitness levels based on the post exercise heart rate response (ACSM, 2010; Earle & Baechle, 2004). A 30cm step box, metronome (Cherub WSM-003), stopwatch (Technosport stopwatch) and heart rate monitor (model K901B) were used for this test. The step box was specially designed to suit the requirements of the test. The test was performed as follows (Earle & Baechle, 2004):

- The chest transmitter of the heart rate monitor was placed around the chest of the participant, at the level of the heart.
- The transmitter is placed over the heart as it contains electrodes which detect heart rate. The electrodes then transmit the information to the wrist watch.
- Resting heart rate was recorded after the heart rate had stabilised. This was achieved by allowing the participant to sit motionless until the heart rate stabilised.
- The heart rate was then compared to the resting heart rate recorded from the electrocardiogram and the lowest measurement was chosen.
- A demonstration was performed for participants to familiarise themselves with the test.

- During the demonstration, the participant was instructed to step up and down to a set cadence of 96 beats per minute for three minutes.
- The stepping was described as follows:
    - “In time with the beat step up with one foot onto the box, either the left or right foot (first beat) followed by the opposite foot (second beat); then step down with the first foot (third beat), followed by the opposite foot (fourth beat).”
- The participant was allowed to practise and if they could keep the pace of the test, the test was started.
- Once the test was complete, the participant sat down immediately and remained still and within five seconds the heart rate was measured for one minute and recorded (Barnes & the American College of Sports Medicine, 2004).

Once a participant had started the test, the test-termination criteria were applied (ACSM, 2010). If the participant could not keep the pace of the metronome prior to the start of the test, the test was not executed. Similarly, if the participant failed to maintain the pace once started, the test was stopped.

3.4.4.3 Muscular strength

Handgrip strength was used to determine overall muscle strength, which requires a simple static muscle contraction utilising a handgrip dynamometer.

The handgrip dynamometer contains an adjustable handle to fit the size of the hand and a needle indicator for scoring on a dial marked off in kilograms from 0 to 100 (Johnson & Nelson, 1969). The test procedure was described to participants, as stated by Johnson and Nelson, 1969, as follows:

- The participant was instructed to stand erect, arms relaxed at the sides.
- The dynamometer was held parallel to the side with the dial facing away from the body.
- He/she was then asked to squeeze the dynamometer as hard as possible for two to three seconds without moving the arm.
- The participant was also instructed to keep the shoulders relaxed throughout the squeeze to ensure no accessory muscles assisted in action.
- Three alternating trials were allowed on each hand with a one minute rest between trials.
- The best score was then taken (Heyward, 1991).

3.4.4.4 Muscular endurance

The curl-up (crunch) was used to determine abdominal muscle endurance (ACSM, 2010). This test is simple to perform as it requires minimal effort and equipment and also allows large groups to be tested. Participants were required to perform as many curl-ups as possible within one minute. A

stopwatch (Technosport) and exercise mat were utilised for this test. The test was described as follows (ACSM, 2010):

- Prior to the start of the test, a demonstration was performed to familiarise the participant.
- The participant then lied on their back on the mat with their knees at ninety degrees and hands placed on their thighs.
- The curl-up was performed until the hands reached the knee caps and the trunk was elevated to a thirty degree position.

3.4.4.5 Flexibility

Flexibility was measured using the sit-and-reach test. This test is commonly used to measure lower back and hip joint flexibility and can be easily administered to large groups. Field testing of flexibility has frequently been limited to the sit-and-reach test therefore this test was used (Winter, 2006; U.S. Department of Health and Human Services, 1996). The test was conducted using a specially designed sit-and-reach box. The zero point was set at the 26 cm mark. The test procedure was performed according to ACSM, 2010:

- The participant was asked to remove their shoes and sit down on the mat with the legs extended. Facing the box, the soles of the feet were placed flat against the board; the feet held slightly apart.
- One hand was placed on top of the other and then on the measurement scale of the box.

- The participant was asked to take in a deep breath and as they exhaled, to relax completely.
- As the participant exhaled and relaxed, they were then instructed to slowly extend forward as far as possible, holding the position momentarily.
- Participants were told to refrain from fast, jerky movements as this may increase the possibility of injury.
- Throughout the test, it was ensured that the knees were held flat and the fingers remained parallel to each other.
- Three consecutive measurements were performed and the best score was taken.

3.4.5 Validity and Reliability of Tests

3.4.5.1 Measurement of insulin resistance

The gold-standard measurement of insulin resistance testing is the hyperinsulinemic- euglycemic clamp technique. In 2007, HOMA-IR was correlated to the clamp technique in hypertensive, type 2 diabetic adults. Results showed a strong, inverse relationship between HOMA-IR and the insulin sensitivity index from the clamp technique (r = -0.572, p = 0.001) (Sarafidis et al., 2007). In studies assessing reliability, Bonora and colleagues (2000) found a strong correlation between the clamp and HOMA-estimated insulin sensitivity (r = -0.820, p = 0.0001), with no substantial differences between men (r = -0.800) and women (r = -0.796), younger (aged

< 50 years, *r* = -0.832) and older (*r* = -0.800) participants, non-obese (BMI < 27 $kg \cdot m^{-2}$, *r* = -0.800) and obese (*r* = -0.765) participants, non-diabetic (*r* = -0.754) and diabetic (*r* = -0.695) participants and normotensive (*r* = -0.786) and hypertensive (*r* = -0.762) participants, concluding that the HOMA can be reliably used in large-scale or epidemiological studies when only a fasting blood sample is available to assess insulin sensitivity (Bonora et al., 2000). Fukushima et al. (1999) also reported a strong correlation between the clamp method and HOMA-IR (*r* = 0.603, p = 0.0001) as well as Katsuki et al. (2002) whose results showed a strong correlation in HOMA-IR and the clamp before and after a 6-week intervention with type 2 diabetics.

3.4.5.2 Physical activity testing: the Global Physical Activity Questionnaire (GPAQ)

Concurrent validity of the questionnaire was assessed by comparing the GPAQ with the International Physical Activity Questionnaire (IPAQ), which has already been validated (Craig et al., 2003). Validity between GPAQv1 and IPAQ produced a moderate-to-good correlation coefficient (*r* = 0.54). The concurrent validity of the sedentary questions was good (*r* = 0.65). Criterion validity (from pedometer studies) for total physical activity was fair (*r* = 0.31) as well as for time spent in sedentary activities (*r* = 0.26). Test-retest reliability data produced good-to-excellent results, indicating a high level of repeatability between administrations of GPAQ (0.67–0.81) (Armstrong & Bull, 2006).

3.4.5.3 Health-related physical fitness testing

The step test has shown to be valid and reliable measure of cardiorespiratory fitness (Shephard, 1966). The YMCA 3-minute step test originated from the Kasch Step Test which was validated in 1961 using a single-stage step with standard 30 cm height to assess cardiorespiratory fitness (Santo & Golding, 2003). In 1966, Kasch, Phillips, Ross, Carter & Boyle compared maximal oxygen uptake of treadmill and step test procedures. Scores showed a correlation coefficient of 0.95 for the difference between mean oxygen uptake for two tests, showing that they appear nearly identical.

Handgrip strength correlates with elbow flexion strength (r = 0.672), knee extension strength (r = 0.514) and trunk extension strength (r = 0.541). The test therefore provides an approximation of total body muscle strength (Rantanen et al., 2003). Grip strength is therefore commonly used to identify overall body strength because it has the highest correlate.

Testing for abdominal endurance showed high test-retest reliability (r = 0.98) using two testing instruments used to standardise the crunch test. The first instrument was designed to ensure that the correct crunch was counted only when the scapulae were raised from the exercise mat. The second instrument was designed specifically for field testing and was based on the criterion validity. A high correlation was found (r = 0.71) between the number of crunches performed using the 3.5 inch (8.75 cm) hand reach criterion and

the number performed using the second instrument (contact plate criterion) (Diener & Golding, 1995).

The sit-and-reach test was shown to be a reliable and valid test by Wells and Dillon in 1952. The test was shown to be a highly reliable test (r = 0.98) and a valid test (r = 0.90) of back and leg flexibility, measured by the Standing Bobbing test (Wells & Dillon, 1952).

3.5 DATA MANAGEMENT PROCESS

During the course of data collection, data was entered periodically to ensure that all information was captured soon after the end of the data collection process. Glucose and insulin values were obtained from the first phase of the diabetic study. During this process, a statistician advised on the appropriate format in which to capture the data.

Data were captured onto a Microsoft Office Excel spreadsheet which was cleaned by reviewing all the data a second time. The database was password protected at all times to ensure that only the data capturer and principal researchers of the study had access to the database. Once corrections were made, it was exported to the statistical package, Predictive Analytics Software (PASW), for data analysis.

3.6 DATA ANALYSIS

3.6.1 GPAQ analysis - calculation of MET-minutes

Physical activity can be described by both continuous and categorical indicators (Armstrong & Bull, 2006). In this study, physical activity was analysed as a continuous variable and represented by MET-minutes per week, which was used to express the community's median physical activity within a week. For the purposes of analysing GPAQ, the authors have identified two specific MET values to represent moderate-intensity and vigorous-intensity activities, namely four METs and eight METs respectively. The energy expenditure within each domain is calculated as follows:

Moderate-intensity: 4 METs x time spent in activity (minutes) x number of days

Vigorous-intensity: 8 METs x time spent in activity (minutes) x number of days

These two sections are added to represent the energy expenditure within a domain. To determine the total energy expenditure for one week, each domain is added together as follows:

Total energy expenditure = Activity at work (moderate-intensity + vigorous-intensity activities) + Travelling (moderate-intensity) + Recreational activities (moderate-intensity + vigorous-intensity activities)

3.6.2 Statistical Analysis

The study utilised both dependant variables, namely insulin resistance, (also a criterion variable) and independent variables, namely age, body composition, physical activity and physical fitness. The PASW statistics package was utilised for the statistical analysis. Once exported to PASW, the HOMA-IR was not logarithmically transformed but instead nonparametric tests were utilised. HOMA-IR was separated into two groups: the non insulin resistance group (quartiles 1-3) and the insulin resistance group (quartile 4). The Mann-Whitney test was used to examine sex-related differences as well as differences between participants involving the two insulin resistance groups. Descriptive data have been expressed as percentages, medians and interquartile ranges. Spearman correlation was used to assess associations between measures of physical activity and fitness. The alpha level was set at 0.05. A rho (ρ) value of -1.0 to -0.5 or 1.0 to 0.5 was considered a strong correlation, -0.5 to -0.3 or 0.3 to 0.5 a moderate correlation, -0.3 to -0.1 or 0.1 to 0.3 a weak correlation and -0.1 to 0.1 was seen as a very weak correlation or no correlation (Choudhury, 2009).

3.7 ETHICAL CONSIDERATIONS

Ethical clearance and permission was granted from the Senate Research Committee of the University of the Western Cape. Ethical clearance and permission for the community study was granted by the Research and Ethics Committee of Cape Peninsula University of Technology.

During the recruitment phase of this study, an information letter including the background and purpose of the study was given to all participants and their consent to participate requested. The information letter also included the benefits and risks of the study. The information letter, together with a physical activity checklist, and a consent form was administered in the participants' home language. All documents were translated by an independent translator then back-translated by a second translator to ensure that all the information was correctly understood by the participant.

On the day of testing, participants were given another explanation as to what tests would be done and requested to read and sign the consent form. At the physical activity testing station, tests were explained and the participant was given a consent form to read and complete in their home language. Participants were informed that participation in the study was voluntary and they could refuse to perform the tests or withdraw from the tests at any stage. A medical doctor was present to provide medical clearance to participate in the fitness tests and attend to any medical emergencies that might have arisen during the fitness testing. In addition, the researcher was trained to deal with unusual situations. All procedures of the physical fitness tests were described to the participants in their home language prior to the start of physical activity testing.

Confidentiality and anonymity was assured at all times. Each participant was allocated an identity code to protect participant identity. Once data was collected, only the researcher and principal researchers from the study had access to the participant files and database. Files were stored in a locked cabinet. The database containing participant information was protected by a password to which only the researcher and principal researchers had access.

CHAPTER FOUR

RESULTS

This chapter presents the results of the data collected in the study. Firstly, the sample size is discussed, followed by a description of the participant characteristics, which includes a description of the anthropometrical, metabolic and physical activity profiles. The correlation between physical activity and physical fitness is shown as well as their relationship with insulin resistance.

Results are presented as median and interquartile range, as data obtained were not normally distributed. In the data analysis, the outlying scores (outliers) were not excluded and thus the mean and standard deviation were not used as they would have been influenced by these extreme values. HOMA-IR was not logarithmically transformed in order to obtain a normal distribution and data is presented as quartiles of insulin resistance. However, due to the small numbers of the current data set, the first three quartiles have been combined and are described as non insulin resistant (NIR), with the fourth quartile being insulin resistant (IR).

4.1 PARTICIPANT CHARACTERISTICS

4.1.1 Morphological Characteristics

A total of 497 participants were tested in the current study. After exclusion criteria were applied, a total of 186 participants was included, which comprised of 145 females (78%) with a median age of 54 years, and 41 males (22%) with a median age of 53 years. Gender data are presented separately as a significant difference was found between males and females for insulin resistance, utilising the Mann-Whitney nonparametric test.

Median anthropometric and metabolic profiles for males and females are shown in Table VII for the study sample. Median BMI and waist circumference values for males were 24.0 $kg \cdot m^{-2}$ and 87 cm respectively, indicating the normal weight category whereas females showed median values of 31.4 $kg \cdot m^{-2}$ and 97 cm, indicating obesity. When placed into quartiles of HOMA-IR, females in both the IR and NIR groups had median BMI values that were in the obese category range (33 $kg \cdot m^{-2}$ and 31 $kg \cdot m^{-2}$, respectively). Median waist circumference was 18 cm less for females in the NIR group (92 cm) compared with those in the IR group (103 cm). For males, BMI median scores differed considerably, with those in the IR group having a BMI in the obese category (32 $kg \cdot m^{-2}$) and those without falling within the normal weight category (22 $kg \cdot m^{-2}$). Waist circumference showed a similar pattern, indicating that those in the IR group had a median score of 102 cm,

Table VII. Median (IQR) Anthropometric and Metabolic Profiles for the Study Sample

Variable	All	Males	Females
Age (years)	44.0 (6.5)	53.0 (16.0)	54.0 (17.0)
Height (m)	1.5 (6.5)	1.70 (0.1)	1.55 (0.1)
Weight (kg)	60.7 (6.5)	68.7 (25.4)	74.7 (25.3)
Body mass index ($kg \cdot m^{-2}$)	23.8 (6.5)	24.0 (7.4)	31.4 (8.6)
Waist circumference (cm)	83.0 (6.5)	87.0 (24)	97.0 (23)
Insulin resistance (HOMA-IR)	0.6 (1.8)	0.85 (1.7)	1.86 (2.8)
Fasting plasma glucose ($mmol \cdot L^{-1}$)	5.0 (0.7)	5.0 (2.0)	5.0 (1.0)
Fasting plasma insulin ($\mu U \cdot mL^{-1}$)	2.9 (6.5)	3.6 (6.3)	7.8 (10.4)
Physical activity (MET-minutes)	800.0 (6.5)	1120.0 (1560)	720.0 (1320)
Cardiovascular Endurance (heart rate)	78.0 (6.5)	87.0 (19)	102.0 (34)
Handgrip strength (kg)	12.0 (6.5)	30.0 (8)	15.0 (9)
Crunch test (number)	0.0 (6.5)	23.0 (11)	16.0 (23)
Sit-and-reach test (cm)	19.0 (6.5)	23.0 (13)	27.0 (11)

indicating obesity, and those in the NIR group had a score of 86 cm, indicating a normal weight.

4.1.2 Metabolic Characteristics

The median glucose value for all participants was 5.0 mmol·L^{-1} (IQR = 0.7), with median glucose showing the same values for both males and females (IQR = 2; IQR = 1, respectively). Insulin values for males was 3.60 (IQR = 6.3) whereas females showed a higher value of 7.8 (IQR = 10.4). Median HOMA-IR values was 0.6 (IQR = 1.78) for all participants, with 0.85 (IQR = 1.73) for males and 1.86 (IQR = 2.81) for females.

4.1.3 Physical Activity Characteristics

For the GPAQ, men showed a greater physical activity score than women, (1120 and 720 MET-minutes, respectively) indicating that they were more active than females. One minute recovery heart rates (3-minute step test) for males were 15 beats lower than the females (87 and 102 beats·min^{-1}); handgrip strength was greater in males (30 and 15 kg) and the men completed seven crunches more than the females (23 and 16 crunches per minute). Females had higher values for the sit-and-reach test (23 and 27 cm for males and females respectively). There was an indication of a slight decline in GPAQ scores within the three age groups of 35-44 years (1 973 MET-minutes), 45-55 years (1 445 MET-minutes) and 55-64 years (1 565 MET-minutes) and similar fitness scores for the fitness tests. Data has not

been compared to normative data as norms are expressed according to age groups.

Median physical activity and fitness levels of males in the non insulin resistance group depict greater GPAQ scores (1200 and 900 MET-minutes), cardiorespiratory fitness (85 and 89 beats·min^{-1}), muscular endurance (23 and 21 crunches per minute) and flexibility (23 and 17 cm) than participants in the insulin resistance group, although these differences were small. Handgrip strength was equal between the two groups. In females, GPAQ scores (720 and 790 MET-minutes) and cardiorespiratory fitness (105 and 98 beats·min^{-1}) were lower (poorer) in the non insulin resistance group, the number of crunches were higher (20 and 0 crunches per minute) and handgrip strength and sit-and-reach values equal in the two groups. However, both male and female groups had small numbers. Table VIII depicts the median physical activity and fitness levels of the study sample.

4.2 CORRELATION BETWEEN AGE, BODY COMPOSITION, PHYSICAL ACTIVITY AND FITNESS AND HOMA-IR

The following section presents the correlations between HOMA-IR, age and body composition as well as the correlations between HOMA-IR and physical activity and fitness (Table IX).

Table VIII. Median (IQR) Physical Activity and Fitness Levels in the Study Sample

Variable	Males			Females		
	All	NIR	IR	All	NIR	IR
Physical activity (MET-minutes)	1 120.0 (1560)	1 200.0 (1 920)	900.0 (1 140)	720.0 (1 320)	720.0 (1 440)	790.0 (1 190)
Cardiovascular Endurance (heart rate)	87.0 (19)	85.0 (19)	89.0 (0)	102.0 (34)	105.0 (35)	98.0 (0)
Handgrip strength (kg)	30.0 (8)	30.0 (8.8)	30.0 (-)	15.0 (9)	15.0 (8.5)	15.0 (9.2)
Crunch test (number)	23.0 (11)	23.0 (10)	21.0 (-)	16.0 (23)	20.0 (23)	0.0 (20)
Sit-and-reach test (cm)	23.0 (13)	23.0 (15.7)	17.5 (-)	27.0 (11)	27.0 (12.8)	27.8 (7.7)

Table IX. Spearman Correlations (significance) for HOMA-IR and Age, Body Composition, Physical Activity and Physical Fitness

Variables	All (p)			Males (p)			Females (p)		
	All	NIR	IR	All	NIR	IR	All	NIR	IR
A									
Age	**0.15 (0.025*)**	0.14 (0.051)	0.13 (0.206)	0.19 (0.121)	0.08 (0.305)	-0.54 (0.133)	0.11 (0.098)	0.12 (0.124)	0.20 (0.112)
Body mass index	**0.47 (0.000*)**	**0.43 (0.000*)**	0.17 (0.138)	**0.60 (0.000*)**	**0.48 (0.002*)**	**	**0.36 (0.000*)**	**0.35 (0.000*)**	0.14 (0.200)
Waist circumference	**0.44 (0.000*)**	**0.36 (0.000*)**	0.18 (0.121)	**0.52 (0.000*)**	**0.36 (0.016*)**	**0.64 (0.019*)**	**0.37 (0.000*)**	**0.30 (0.001*)**	0.14 (0.188)
B									
GPAQ	-0.04 (0.303)	-0.00 (0.496)	0.17 (0.130)	-0.09 (0.280)	0.02 (0.459)	-0.31 (0.272)	0.04 (0.322)	0.08 (0.219)	0.22 (0.089)
3-Minute step test	0.13 (0.249)	0.16 (0.280)	**	0.30 (0.151)	0.32 (0.144)	**	0.06 (0.419)	0.07 (0.405)	**
Handgrip strength	-0.15 (0.061)	-0.14 (0.089)	0.05 (0.418)	0.14 (0.247)	0.11 (0.299)	**	0.05 (0.314)	0.06 (0.318)	0.21 (0.211)
One-minute crunches	**-0.17 (0.031*)**	-0.01 (0.449)	0.01 (0.486)	0.11 (0.293)	0.20 (0.171)	**	-0.11 (0.143)	0.07 (0.271)	0.02 (0.471)
Sit-and-reach	0.03 (0.356)	0.06 (0.280)	-0.24 (0.146)	-0.30 (0.063)	-0.25 (0.117)	**	0.04 (0.343)	0.08 (0.250)	-0.29 (0.106)

* Significance level 0.05 (1-tailed)

** ≤ 5 data points therefore the statistic is not presented

4.2.1 HOMA-IR: Age, Body Composition and Physical Activity

Table IX-A shows the correlation between HOMA-IR, age and body composition. There was a significant correlation between HOMA-IR and age in all participants that was positive and weak (ρ = 0.15; p = 0.025). However this was not evident when males and females were analysed separately or in quartiles of HOMA-IR.

For BMI and waist circumference, there were significant positive correlations for all participants (ρ = 0.47 and 0.44 respectively), males (ρ = 0.60 and 0.52 respectively) and females (ρ = 0.36 and 0.37 respectively). All significance values for these correlations were 0.000. The strongest correlation was for the males' BMI (ρ = 0.60) and waist circumference (ρ = 0.52). When separated into non insulin resistance and insulin resistance, all the correlations for those in the NIR group were significant (ρ = 0.30-0.48). The only significant correlation for the IR group was for waist circumference (ρ = 0.64; p = 0.019). This was the highest correlation noted.

No significant correlation was found between age and physical activity in all participants, males or females, or in the quartile groups, except in the insulin resistance group (ρ = 0.28; p = 0.030). BMI was significantly correlated with cardiorespiratory fitness and muscle endurance in all participants (p < 0.05). In males, both BMI and waist circumference showed significance with GPAQ (p = 0.047) and strength and flexibility (p = 0.001) in females.

4.2.2 HOMA-IR: Physical Activity and Physical Fitness

4.2.2.1 HOMA-IR and GPAQ

No association was found to be significant between HOMA-IR and GPAQ in all participants, males and females (quartiles 1-4) as well as in males and females in the non insulin resistance and insulin resistance groups (Table IX-B).

4.2.2.2 HOMA-IR and physical fitness

For **cardiorespiratory fitness,** all participants were placed into four groups: “not cleared” (by the medical doctor); “could not do;” “did not complete” and “completed”. Sixty nine participants were not cleared as they presented a risk of a cardiac event during or after the test. Of those who were cleared, 12 were excluded due to medication, 19 could not keep pace with the metronome and dropped out, 55 could not complete the full three minutes and 30 participants completed the test. Only those who could complete the test were included in the analysis. The HOMA-IR group with the greatest number of participants not cleared to perform the fitness test were those in the IR group (n = 26). This group also had the greatest amount of participants who could not start the test and who could not complete the test. No significant association was identified between the 3-minute step test and HOMA-IR in all participants, males and females (quartiles 1-4) as well as in males and females in the NIR and IR groups.

Seventy three participants were either not cleared by the medical doctor or had a physical condition which prevented them from performing the **handgrip strength** test leaving 112 participants who completed the test. No significant association was identified between handgrip strength and any of the HOMA-IR groups. Similarly, no associations were found for **muscular endurance** (n = 124), except for the correlation for all participants (ρ = -0.17; p = 0.031). A total of 123 participants completed the **flexibility** test for which no significant associations with HOMA-IR were identified. Appendices F to I depict those who were not cleared, could not complete and completed the four fitness tests.

4.3 CORRELATION BETWEEN PHYSICAL ACTIVITY AND PHYSICAL FITNESS

The correlations between GPAQ scores and the four physical fitness tests were determined to identify the accuracy of the questionnaire, as the GPAQ is a subjective test and the fitness tests an objective one. The Spearman's nonparametric correlation test was performed with GPAQ against each fitness test to identify any correlations. Table X shows the correlations between the score of the questionnaire and each fitness test.

When all the participants were considered together, significant associations were noted for handgrip strength (ρ = 0.17; p = 0.039), one-minute crunches

Table X. Spearman Correlations (significance) for Physical Activity (GPAQ) and Physical Fitness

	GPAQ (MET-min per week)		
	All (p) (n)	Males (p) (n)	Females (p) (n)
3-Minute step test (recovery heart rate)	-0.29 (0.061)	-0.21 (0.239)	-0.17 (0.271)
Handgrip strength (kg)	**0.17 (0.039*)**	**0.33 (0.050*)**	0.06 (0.281)
One-minute crunch test (no. of crunches)	**0.18 (0.024*)**	0.18 (0.189)	0.12 (0.115)
Sit-and-reach test (cm)	**0.17 (0.034*)**	0.14 (0.245)	**0.22 (0.016*)**

* Significance level 0.05

** ≤ 5 data points therefore analysis not presented

(ρ = 0.18; p = 0.024) and sit-and-reach (ρ = 0.17; p = 0.034). When the males were considered, significant associations were identified for handgrip strength (ρ = 0.33; p < 0.05) and sit-and-reach (ρ = 0.22; p = 0.016) for the females. Although these correlations were all significant, they were positive and weak. No significant associations were seen with GPAQ and cardiorespiratory fitness.

4.4 PREDICTORS OF INSULIN RESISTANCE

Apart from the correlations with HOMA-IR, various other significant correlations were identified. Significant correlations were expected between body mass index and waist circumference as these are components of body composition, as well as between the physical fitness variables, as these are components of health-related physical fitness. However, these correlations were found to be mostly weak with some moderate correlations and one strong correlation, between BMI and waist circumference for all groups (ρ = 0.9; p = 0.000). Since any significant correlations observed may be influenced by confounders, a multivariate regression analysis was done to explore these effects. In the analysis, seven models were produced where HOMA-IR was the dependant variable. The independent variables were age, body mass index, waist circumference, handgrip strength, one-minute crunches and sit-and-reach flexibility. Cardiorespiratory fitness was excluded solely because of the small sample size (n = 30). As HOMA-IR was not

normally distributed, the square root of HOMA-IR was used with the outliers being excluded.

Stepwise backward regression was completed (Table XI) until only the predicting variables remained. Table XII represents the variables that predict HOMA-IR in males and females. In males, body mass index was the sole predictor of HOMA-IR (adjusted R^2 = 0.371) and in females, waist circumference was the only predictor (adjusted R^2 = 0.157).

4.5 SUMMARY OF RESULTS

To summarise the results of this chapter, it has been identified that the majority of females were obese (median = 31 $kg \cdot m^{-2}$ BMI and 97 cm for waist circumference) whereas males were normal weight (median = 24 $kg \cdot m^{-2}$ for BMI and 87 cm for waist circumference).

In males, GPAQ scores, cardiorespiratory fitness, one-minute crunch and sit-and-reach flexibility levels were higher in those in the NIR than in the IR group. In females, GPAQ scores and cardiorespiratory fitness was poorer and one-minute crunch scores higher in those in the NIR group than in the IR group. Handgrip strength and sit-and-reach flexibility were similar within the two groups.

Table XI. Summary of Backward Regression Analysis for HOMA-IR

Gender	Step	Variable removed	Model Adjusted R^2	p value
Male	1	None	0.35	0.037
	2	Waist circumference	0.38	0.018
	3	GPAQ	0.41	0.009
	4	Handgrip strength	0.42	0.004
	5	Age	0.41	0.003
	6	Sit-and-reach	0.38	0.002
	7	Crunch	0.37	0.001
Female	1	None	0.13	0.013
	2	GPAQ	0.14	0.007
	3	Body Mass Index	0.15	0.003
	4	Age	0.16	0.001
	5	Crunch	0.17	0.001
	6	Sit-and-reach	0.17	0.000
	7	Handgrip strength	0.16	0.000

* Significance level 0.05

Table XII. Predictors of HOMA-IR from Backward Regression Analysis in Males and Females

	Coefficients				
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	p-value
MALES					
HOMA-IR (Constant)	-0.719	0.437		-1.643	0.114
Body Mass Index	0.070	0.018	0.630	3.892	0.001*
FEMALES					
HOMA-IR (Constant)	-0.203	0.387		-0.523	0.602
Waist circumference	0.016	0.004	0.410	3.992	0.000*

* Significance level 0.05

Physical activity levels did not decrease but remained fairly stable with advancing age. No significant association was found between these two variables. The association between age and HOMA-IR was found to be significant in all participants but the correlation was weak, suggesting that HOMA-IR did not increase (or decrease) with age.

Only body composition (body mass index and waist circumference) had significant correlations with HOMA-IR within the NIR group. In the IR group, no significant correlations between HOMA-IR and the eight variables were identified, except for waist circumference in males. All HOMA-IR correlations with the physical activity and fitness in both males and females were weak, suggesting a poor relationship between these variables.

Significant correlations between physical activity (GPAQ) and physical fitness (four fitness tests) were found with GPAQ and handgrip strength in males and flexibility in females. In all participants, significant associations were found with handgrip strength, one-minute crunches and sit-and-reach flexibility. All the correlations were shown to be weak.

An interesting observation made was that participants in quartile four had the greatest number not cleared to participate in the fitness tests and were also not able to complete the tests, due to lack of fitness or ill health.

Regression analysis was performed in order to explore the relationships between HOMA-IR and the eight variables identified. BMI showed to be the only predictor of HOMA-IR in males while waist circumference was the only predictor of HOMA-IR in females.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The current study aimed to identify a relationship between physical activity, physical fitness and insulin resistance in an economically disadvantaged community residing in a northern suburb of Cape Town, South Africa. This study was undertaken as chronic diseases of lifestyle are steadily increasing globally, particularly in developing countries such as South Africa (WHO, 2009; Harlen & Harlen, 2009; Puoane et al, 2008; Roberts & Barnard, 2005; WHO, 2005). Insulin resistance has been implicated as an underlying factor in many chronic diseases, including type 2 diabetes and metabolic syndrome, and is highly associated with obesity (Danielsson et al., 2009; de Luca & Olefsky, 2008; Meigs et al., 2007; Abdul-Ghani et al., 2006c; Goodpaster & Wolf, 2004; Rizvi, 2004; Kahn, 2003; Stannard & Johnson, 2003). Physical activity has been shown to reduce the risk of chronic diseases by exerting various protective effects. In South Africa, a staggering 76% of women and 63% of men are insufficiently active to gain the health benefits associated with physical activity (Lambert & Kolbe-Alexander, 2006).

This chapter discusses the main trends, patterns and connections that have emerged in chapter four with reference to the research hypotheses. The

chapter firstly discusses the correlation between HOMA-IR and participant characteristics (age and body composition) then its relationship with physical activity and fitness. Lastly, the relationship between subjectively measured physical activity and objectively measured physical fitness is explored. The chapter ends with future recommendations and a conclusion, which summarizes the salient points.

5.1 CORRELATION BETWEEN AGE, BODY COMPOSITION, PHYSICAL ACTIVITY AND FITNESS AND HOMA-IR

5.1.1 HOMA-IR: Age, Body Composition and Physical Activity

Literature regarding the association between age and insulin resistance appears to be inconsistent. Over 20 years ago, Fink et al. (1986) found a reduction in glucose transport with ageing. A number of years later, Amati and colleagues (2009) suggested that age itself might not be associated with insulin resistance but rather physical inactivity and obesity. This is consistent with findings from other studies (Ferrara, Goldberg, Ortmeyer & Ryan, 2006; Goulet, Mélançon, Dionne & Aubertin-Leheudre, 2005; Ferrannini et al., 1996; Zachwieja, Toffolo, Cobelli, Bier, Yarasheski, 1996). In South Africa, Lambert and Kolbe-Alexander (2006), Kruger et al. (2002), Joubert et al. (2007) and Steyn et al. (2004) have all reported low physical activity levels in adults, including older adults.

In this study, it was hypothesised that with advancing age, physical activity levels would decline and HOMA-IR would increase. Associations between age and HOMA-IR were not significant when males and females were compared separately. However, when grouped together, a significantly positive but weak association was noted between these two variables. No significant association was found between physical activity and age for all participants, males or females, or in the quartile groups except for all participants in the IR group. In addition, these correlations were shown to be weak. Therefore the second hypothesis was not met in that with advancing age, there was no indication of declining levels of physical activity and progression to insulin resistance. This suggests that physical activity does not necessarily decline with age in this sample, and is supported by the observation of moderate to low physical activity levels in all the age ranges. Various studies done across South Africa support this association. Charlton, Lambert & Kreft, 1997 found that levels of physical activity in historically disadvantaged, older South Africans residing in Cape Town were two-thirds lower than those reported in a North American sample of similar age indicating habitually low physical activity. Lambert & Kolbe-Alexander (2006) in their study found that older South Africans utilized 65% less energy in physical activity (2583 kcal/week) than their North American counterparts but also reported that 70% of South Africans are insufficiently active (minimally active or inactive). Further cross-sectional studies indicated low levels of activity amongst both rural and urban women and only 50% amongst these

adults had sufficient activity levels to gain health benefits (Kruger, Venter, Vorster & Margetts, 2002). In 2004, Steyn et al. reported that only 49.7% of Mamre residents achieved the recommendation of 150 minutes of accrued moderate intensity physical activity weekly. Results also indicated 40% of those younger than 35 years of age were insufficiently active and those aged 55 to 64 and above 65 reported 66% and 76% insufficient activity, respectively. These studies indicate low levels of physical activity across all age groups. The weak correlation between age and HOMA-IR also suggests that insulin resistance does not increase with age, supporting numerous reports in the literature that age per se does not correlate with insulin resistance (Ferrara et al., 2006; Goulet et al., 2005; Ferrannini et al., 1996; Zachwieja et al., 1996).

Waist circumference, denoting central obesity, was shown to correlate significantly with age in male participants, males with insulin resistance and all participants without insulin resistance. Body mass index showed significant correlations with age in all participants as well as in females in the insulin resistance group. These findings, however, are not sufficient to suggest the effect of gender in terms of body composition and age. When separated into three age groups, BMI did not increase with advancing age, but instead remained fairly constant (29.8 $kg \cdot m^{-2}$, 28.5 $kg \cdot m^{-2}$ and 30.4 $kg \cdot m^{-2}$) for the respective age groups of 35 to 44 years, 45 to 55 years and 55 to 64 years.

Reports on body composition indicate that the prevalence of overweight and obesity is high in South Africans, particularly in females of mixed ancestry (52%). Males of mixed ancestry show opposing results, with the second lowest prevalence (31%) (Goedecke et al., 2006). These observations are supported in this study as the median values for both BMI and waist circumference in females was in the "obesity" range whilst they were normal in males. A significant moderate to strong positive association was hypothesised between body composition and HOMA-IR. The results indicated such an association, indicating that insulin resistance increases with an increase in BMI and waist circumference.

Literature supports these findings as an increased body weight impairs the ability to metabolise glucose, therefore playing a role in the development of insulin resistance (Goodpaster & Wolf, 2004; Kahn, 2003; Stannard & Johnson, 2003). Danielsson et al. (2009) also demonstrated that a high caloric diet led to the development of insulin resistance. Central fat accumulation has been shown to be associated more with insulin resistance than with peripheral fat due to the more metabolically active visceral adipocytes (Rosenberg et al., 2005; Kahn, 2003; Svedberg et al., 1992). In the current study, this was supported by the observation that waist circumference was the only predictor of insulin resistance, particularly in females. In addition, fat accumulation in the muscle and liver tissues has shown to be strongly associated with insulin resistance (Petersen & Shulman,

2006). Excess free fatty acids as a result of overweight and obesity also cause the secretion of adipocytokines, resulting in greater insulin resistance (Rosenberg et al., 2005).

In experimental studies, physical activity has shown to improve insulin sensitivity in obese individuals (Venables, 2009; Messier et al., 2008; Gerson & Braun, 2006) despite no changes in body composition. Short term intervention programs showed significant improvement in resistance in the absence of weight change (Kirwan, Solomon, Wojta, Staten & Holloszy, 2009; Venables, 2009). Interventions incorporating physical activity and diet have also shown to be successful in improving resistance to insulin. Arciero et al. (1999) showed a greater improvement in the exercise group versus the diet group. Perseghin and colleagues (2007) found that decreased intrahepatic fat content was found in the quartile with the greatest levels of physical activity and Berentzen et al. (2007) found that leisure-time physical activity decreased insulin resistance throughout the range of BMI. These studies highlight the correlation and effects of physical activity in reducing insulin resistance despite no weight change. As this study did not contain an intervention, it cannot be concluded that physical activity aided in reducing insulin resistance despite no weight change within this population. However, no significant correlation was seen between physical activity and HOMA-IR in men women, suggesting that regardless of weight, physical activity had no influence on HOMA-IR.

When placed into the four quartiles of HOMA-IR, a clear trend is seen in the categories of BMI (underweight, normal weight, overweight and obese) for both sexes, with a progressive decline in underweight and normal weight participants from quartile one to four. In contrast, the number of obese participants progressively increases from quartile one to four, with the largest percentage (22%) of participants (n = 40) within quartile four (Appendix J). A similar pattern is seen in the four quartiles for waist circumference for males and females respectively (Appendices K-L). This highlights the role body composition plays in insulin resistance, as it was the sole predictor of insulin resistance in the study sample. Decreasing body weight may be a mechanism through which physical activity increases insulin sensitivity (Balkau et al., 2008), as regular activity decreases the fat mass and builds lean mass, allowing the amount of muscle available for glucose absorption to increase (Perseghin, Ghosh, Gerow & Shulman, 1997).

5.1.2 HOMA-IR: Physical Activity and Physical Fitness

5.1.2.1 HOMA-IR and GPAQ

A significant inverse relationship between GPAQ and HOMA-IR was hypothesised for this study. However, no significant association was found between these variables in males and females as well as in the insulin resistance and non insulin resistance groups. In addition, all the correlations were shown to be weak, suggesting that either the questionnaire was answered inaccurately or engagement in physical activity in this sample does

not decrease resistance to insulin. This observation was unexpected, as physical activity, determined by a questionnaire, has been reported to significantly correlate with insulin resistance as well as insulin sensitivity and glucose tolerance in multiple population groups (Esteghamati et al., 2009; Balkau et al., 2008; Perseghin et al., 2007; Mayer-Davis et al., 1998). However, one study by Chen et al. (2008) found no significant correlation between these two variables. Physiologically, physical activity is shown to improve glucose transport (Geiger et al., 2006) as well as increase the metabolic action of insulin in healthy individuals and those in the insulin resistance state (Richter et al., 2001). Moreover, as the acute effect of exercise wears off, it is replaced by an increase in insulin sensitivity (Geiger et al., 2006). Therefore, one expects to see a relationship that is significant and moderate to strong in nature.

A possibility exists that participants did not answer the questionnaire accurately as a result of over reporting or under reporting, as participants might have struggled to remember the activities done in the prior week. Over- and under-reporting for both physical activity and food intake have been observed (Sun et al., 2009; Oppert, Laville & Basdevant, 2007). In the current study, it is likely that participants tended to over-report when answering the questionnaire, as physical fitness data revealed fairly low to moderate health-related fitness scores. Of the three domains and six sub-domains, travel-related activity and moderate-intensity work-related physical

activity were the most frequently reported activities with 70% and 49% reporting to engage in these activities respectively. Eighteen percent of participants reported to engage in moderate-intensity leisure-time physical activity, 10% in vigorous-intensity work-related activity and three percent in vigorous-intensity leisure-time physical activity. Due to these small numbers GPAQ was not analysed in these subdomains and correlated to HOMA-IR. The three areas where over-reporting could probably occur in these domains include:

- Participants did not fully comprehend the difference between vigorous-intensity and moderate-intensity physical activity.
- Participants lacked fitness and therefore activities usually regarded as moderate-intensity were interpreted as vigorous-intensity activities. Examples of these include walking and house cleaning. Concomitantly, activities usually regarded as light-intensity were interpreted as moderate-intensity activities. One example was the washing of clothes. Many female participants reported to do washing by hand which is regarded as a moderate-intensity activity. However, participants wanted to include hanging up the washing or going up and down one flight of stairs as one whole moderate-intensity activity, as a "carry-over effect" from the hand washing could have caused reporting these light-intensity activities as a moderate-intensity activity. Hanging up the washing and/or walking up and down a flight of stairs on its own

is not regarded as a moderate-intensity activity as well as the time period is not sufficient as the activity should be done for 10 minutes or more. In addition, the "travel to and from places" domain did not enquire as to whether the walking or cycling activity is moderate or vigorous, it only asks if the participant walks or cycles in order to travel. These walking, and to a lesser extent cycling activities, could have been a light-intensity activity, i.e. the individual could have walked slowly which therefore is regarded as light.

- According to Oppert et al. (2007) and Fogelholm et al. (2006), over-reporting can be found in obese individuals and those with a lower educational level. Half of this sample (49%) was regarded as obese and 22% overweight and this population has a low educational level, as mentioned in chapter three under Research Setting and Population.

Many participants could recall the number of days spent on an activity but many struggled to recall the time spent on the activity. Reference was therefore made to certain television programs. Prior to the start of questioning, the interviewer asked the participant to describe their week. The participant was asked to start recalling from the beginning of the week and to think of major or routine activities that were done, such as regular food shopping, cleaning the house, visiting a friend or relative, going to the doctor or watching a favourite television show. For the domain of sedentary behavior, the participant was asked to recall the activities of the entire day,

from the time they woke up to the time they went to bed. The interviewer found that participants could recall activities better if they recalled their week day-by-day, step-by-step. However most participants reported that they did not know exactly how much time they spent on activities as most participants did not follow a time schedule or even have a watch or clock. Therefore it was harder to gauge the amount of time spent on an activity and the actual activity itself when the individual does not have a structured routine throughout their day i.e. work and structured recreational activities. This was probably the predominant factor in the potential inaccuracy of the questionnaire, as most participants struggled to recall their activities. When participants need to be prompted to recall an activity and are unable to recall the duration of that activity, there is the potential to guess the amount of time spent on that activity. However, recall questionnaires are not designed to identify exact times and activities but instead an estimate of the activities done to obtain a general overview of what an individual is engaging in. Additionally, reconstructing the day in order to assist participants in recalling their activities does not form part of the actual GPAQ administration procedure and as a result, could have had an effect of double-counting or over-reporting.

5.1.2.2 HOMA-IR and physical fitness

Cardiorespiratory fitness has shown to be the fitness component most closely linked to health, and has been suggested it be used as a definitive

marker for risk stratification and health outcomes (Dalleck & Dalleck, 2008). Literature has shown the importance of cardiorespiratory fitness in maintaining insulin sensitivity, as demonstrated by Gerson and Braun (2006) when they investigated the effects of high body fat and high cardiorespiratory fitness on insulin resistance. Their results suggested that cardiorespiratory fitness maintained insulin sensitivity independent of body weight. This was also shown by Kriska et al. (2001) when both physical activity (via questionnaire) and the cardiorespiratory step test were independently found to be significantly associated with fasting insulin in men after controlling for age, BMI, percent body fat and waist circumference. This reiterates the beneficial effect of cardiorespiratory fitness on insulin sensitivity.

A moderate to strong positive association was hypothesised between HOMA-IR and cardiorespiratory fitness. Results, however, indicated no significant association between these two variables. In all participants, men and women, sample numbers were too small ($n \leq 5$) for statistical analysis. Numerous studies have observed that exercise stimulates the uptake of glucose into skeletal muscle cells by different signalling mechanisms and intracellular pathways (Plasqui & Westerterp, 2007; Geiger et al., 2006; Holloszy, 2005; Jessen & Goodyear, 2005; Bouché et al., 2004; LeRoith & Zick, 2001; Pessin & Saltiel, 2000). A number of contraction-stimulated pathways that augment GLUT 4 translocation have been proposed, including calcium signalling, 5'adenosine monophosphate-activated protein kinase

(AMPK), Akt and AS160, nitric oxide and bradykinin (Jessen & Goodyear, 2005). Detraining or cessation of exercise in contrast reverses the effects, as a decrease in insulin sensitivity and glucose tolerance after two weeks has been seen (Katz & Lowenthal, 1994).

Studies have demonstrated that muscle strength also correlates significantly with insulin sensitivity, in that increased muscle strength improved sensitivity to insulin. Cheng et al. (2007) assessed this relationship in the National Health and Nutrition Examination Survey 1999-2004 and found a significant positive correlation in both men and women. Their findings found that higher strength activities correlated to higher insulin sensitivity, lower fasting insulin and glucose in men ($p = 0.001$) and women ($p = 0.001$). Karelis et al. (2007) found similar results where muscular strength significantly and positively correlated with insulin sensitivity and Ryan et al. (1996) found that after a weight training program, insulin action improved with and without concomitant weight loss.

An inverse association was hypothesised between HOMA-IR and **handgrip strength**. This hypothesis was not confirmed as no significant correlation was identified in all the participants, males and females as well as in those in the insulin resistance or non insulin resistance groups. The sample size of men in the insulin resistance group was too small for statistical analysis and therefore was not presented.

Handgrip strength has been shown to correlate with elbow flexion strength, knee extension strength and trunk extension strength, suggesting it to be a useful measure of total body strength (Rantanen et al., 2003). Handgrip strength in this particular sample could not be an accurate reflection of total body strength or indeed, as the statistics suggest that the lack of association between handgrip strength and HOMA-IR exists due to the greater influence of body composition on insulin resistance.

A dearth of information exists about the relationship between **muscular endurance**, **flexibility** and insulin resistance. One-minute crunches and sit-and-reach flexibility was hypothesised to have an inverse correlation with HOMA-IR, as strength and flexibility improve, HOMA-IR decreases. A study by Chen et al. (2008) tested the association between both muscular endurance and flexibility and found no significance between these variables and HOMA-IR in men but found a significant association in females with the sit-and-reach test. In the current study, only muscle endurance in all participants was found to be significant, though with a weak negative correlation. Although flexibility is regarded as a component of health-related physical fitness, the sit-and-reach test is considered to be a measure of lower back and hamstring flexibility, which may instead be a contributing factor to muscular lower back pain rather than metabolic disorders such as insulin resistance (ACSM, 2010; U.S. Department of Health and Human Services, 1996). Muscular endurance and flexibility were included in the study as they

formed part of health-related physical fitness test battery although there is a lack of information concerning the biological effects of endurance and flexibility on metabolic disorders. The findings of the current study suggest that exercises improving muscular endurance, specifically abdominal endurance, and hamstring muscle flexibility may not effectively influence insulin resistance in this population.

The number of participants that completed each of the four fitness tests is also an interesting element. Out of 116 participants cleared to do the step test, only 42 completed the test (with 12 having to be excluded due to medication usage). When placed in quartiles of HOMA-IR, the number of participants in the insulin resistance group was very low (n = 2) when compared to the other three quartiles. This was due to quartile four having the greatest number of participants who were not cleared to perform the fitness tests (n = 26), whereas the other three quartiles had less participants who were not cleared. Those in the insulin resistance group also had the greatest amount of participants who could not start the test and who could not complete the test. Similar trends were seen with the handgrip, one-minute crunch and sit-and-reach tests in that those in the insulin resistance group had the greatest percent of participants not cleared to partake in the tests, with similar percentages completing the tests in all the quartiles.

Although no significant correlations were identified, this trend indicates that those in the insulin resistance group were the most “at risk” of a cardiac event during or after the test and presented with the greatest number of medical conditions (hence they were not cleared) and lacked fitness as they could not start the test and compete the full three minutes. The implications of these low participant numbers in the insulin resistance and non insulin resistance groups could have an effect on the statistical power, thereby rendering no significant associations. However this could suggest a trend towards a relationship between HOMA-IR and fitness as only those fit enough managed to complete the test and therefore were included in the analysis. Perhaps if a different test was chosen, such as a six-minute walk test, that all or most participants could complete, a stronger association may have been identified.

5.2 CORRELATION BETWEEN PHYSICAL ACTIVITY AND PHYSICAL FITNESS

The accuracy of the GPAQ was determined as it is a subjective measure of physical activity. The association between these two variables was hypothesised to be significant and positive and moderate to strong in nature. Significant associations were identified between GPAQ and handgrip strength, one-minute crunches and sit-and-reach flexibility in all participants, in handgrip strength in males and sit-and-reach flexibility in females. Though these relationships were shown to be positive they were fairly weak. No significant correlation was seen between GPAQ and cardiorespiratory fitness

in this study. This could be due to the small sample numbers (30 participants) who were then subdivided into the two quartile groups. Limited data exists on the association between subjective and objective measures of physical activity and fitness. An explanation for the weak correlations observed between GPAQ and the fitness tests could also be linked to the inaccuracy in the answering the questionnaire, such as over- and under-reporting when answering the questionnaire as well as remembering the activities in the week prior. Several reports have found that exercise can be over-reported (Bloomgarden, 2004a) and are subject to bias and measurement error (Sun et al., 2009). Further reports suggest that those with a low educational level (Fogelholm et al., 2006) and obese individuals (Oppert et al., 2007) tend to over-report. This was supported by Schmidt, Dwyer and Venn (2009) who found that higher levels of adiposity and poorer cardiorespiratory fitness were associated with potential over-reporting of walking activity in both men and women. They also found a relatively poor agreement between objective and subjective estimates of walking activity.

The weak and insignificant correlation observed between GPAQ and the fitness tests suggest that the accuracy of this subjective measure can be questioned in this population. This could be due to low sample numbers in the fitness tests, inaccuracy in answering the questionnaire or the participants not being able to remember all activities done in the previous week. Therefore, the fifth hypothesis was not completely satisfied in that although

three of the four correlations (in all participants) were significant, the relationships were all weak. This is also true for handgrip strength in males and sit-and-reach in females.

CONCLUSIONS

The current study aimed to identify a relationship between physical activity, physical fitness and insulin resistance within a northern suburb community in Cape Town, South Africa.

The main findings observed in this study have indicated that the physical activity and fitness data were not significantly correlated to HOMA-IR. In males, body mass index was the sole predictor of HOMA-IR and in females waist circumference was the only predictor. Associations between GPAQ and the four fitness tests indicated significance with handgrip strength, one-minute crunches and sit-and-reach flexibility.

These results of this study have important implications which indicate that body composition should be the main focus of attention in reducing the risk and managing insulin resistance in this population, thereby possibly reducing the risk for type 2 diabetes and a number of other chronic diseases. As physical activity was significantly correlated with body composition, it becomes important to encourage appropriate weight management in order to

help reduce the adverse consequences of excess body weight. It is important not only to educate community members but also those responsible for their health, such as medical practitioners and clinics. Interventions should be aimed at individuals of all ages, as body composition as well as physical activity levels remained fairly constant throughout the age ranges in this sample group.

LIMITATIONS

The limitations of the study included:

Insulin resistance values were determined from glucose and insulin testing completed in the first phase of a larger community-based study and fitness testing within the second phase. A time delay of between six to twelve months existed between these two measurements.

As physical activity and fitness testing for the second phase of the study took place within a school setting, fitness tests, particularly the cardiorespiratory test, which could be conducted within limited space were chosen. Therefore it was not specific to the usual activities performed by the participants, for example, walking.

A small sample was obtained in this study as the calculated number of 240 participants was not reached; thereby affecting the study power. In

addition, smaller sample numbers were found when the sample was divided into the quartile groups, particularly in the fourth (insulin resistance) quartile. This was also due in part to the many participants that were not medically cleared by the doctor to perform the fitness tests and others could not perform the test or complete the tests.

RECOMMENDATIONS

The recommendations for future research include larger sample numbers due to the division of the group into quartiles, and particularly to accommodate participants who are unable to do the fitness tests due to ill-health or lack of fitness. Further recommendations include the analysis of GPAQ in each domain of work-related, travel and leisure-time physical activity to gauge which domain has the greatest association with insulin resistance. In the current study, too few participants engaged in all domains and sub-domains to be included in the analysis, as participants engaged predominantly in moderate intensity work-related and travel-related physical activity. The selection of fitness tests should coincide as much as possible with the activities participants engage in (specificity). For example, a walk test is recommended for this population as this was the predominant form of activity in the majority of people.

Literature indicates a greater association between cardiorespiratory fitness and muscular fitness and chronic diseases of lifestyle such as metabolic disorders (Joubert et al., 2007; Armstrong & Bull, 2006; Booth et al., 2002b; Chakravarthy et al., 2002; U.S. Department of Health and Human Services, 1996). Flexibility has been correlated to conditions such as lower back pain, which affect Activities of Daily Living (ADL's) (ACSM, 2010). Therefore sit-and-reach flexibility can be excluded from testing if the study's focus is on health and chronic disease.

HOMA-IR and physical activity data can be compared to other mixed ancestry populations of similar and varying socio-economic status to gauge if similar associations exist within these populations. HOMA-IR and physical activity data can also be compared to other race groups. A physical activity intervention to determine the effects of physical activity on HOMA-IR and body composition is also recommended to determine initially (short term) if physical activity reduces insulin resistance and improves sensitivity in the absence of weight loss as well as over an extended period of time as weight loss occurs.

Body composition and physical activity levels have shown to be fairly poor within this sample group, particularly in females. More importantly, body composition has shown to be a predictor of insulin resistance. It is therefore recommended that participants aim to reduce excess body weight in order to

reduce the risk of further disease and disability. This can be achieved by increasing levels of physical activity as BMI correlates significantly with cardiorespiratory fitness and muscle endurance in all participants. In order to increase the levels of physical activity within the community, a social walk club can be established, with the goal of taking part in a local walk/run challenge. This promotes not only weight loss and physical activity but also socialising. There are also two known exercise groups that exist in this community. Community members are therefore encouraged to join one of these exercise groups as they are run indoors, especially during the winter months.

Engagement in physical activity as well as improving diet can be encouraged through medical practitioners and clinics, who can educate community members individually through reading material and verbal advice. Lastly, providing healthy meals in schools as well as providing safe and convenient means for walking and bicycling is also recommended to health planning authorities as well as education of community members at schools, worksites and faith communities.

In conclusion, as Eaton et al. (1988) stated, "*we should return to 'natural' activity - the kind for which our bodies are engineered and which facilitates the proper function of our biochemistry and physiology…"* As with our

ancestors, physical activity should return to being an obligatory and integral part of our existence.

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APPENDICES

Appendix A	Information letter including the pre-test instructions (English and Afrikaans)
Appendix B	Consent form (English and Afrikaans)
Appendix C	Global Physical Activity Questionnaire (GPAQ)
Appendix D	Global Physical Activity Questionnaire (GPAQ) Question by Question Guide
Appendix E	Data record form including the test termination criteria
Appendix F	3-minute step test “codes” (in percent) according to quartiles of HOMA-IR
Appendix G	Handgrip strength test “codes” (in percent) according to quartiles of HOMA-IR
Appendix H	One-minute crunch test “codes” (in percent) according to quartiles of HOMA-IR
Appendix I	Sit-and-reach flexibility test “codes” (in percent) according to quartiles of HOMA-IR
Appendix J	Body mass index (in percent) according to quartiles of HOMA-IR
Appendix K	Waist circumference for males (in percent) according to quartiles of HOMA-IR
Appendix L	Waist circumference for females (in percent) according to quartiles of HOMA-IR

Note: How to read the graphs in Appendices F-L:

Each %age within each quartile totals 100% therefore a % within one coloured block within a quartile represents the %age out of 100%. For example, the 22% seen in quartile four represents 22% of the total sample.

APPENDIX A

UNIVERSITY OF THE WESTERN CAPE

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BELLVILLE SOUTH DIABETES STUDY

PARTICIPANT INFORMATION SHEET

Dear participant

We would like to thank you for taking part in the first phase of the Bellville South Diabetes study. Your participation was appreciated and since then we have gained valuable information for our study. We would therefore like to invite you to take part in the second phase of this study. The study is a partnership between the Cape Peninsula University of Technology, Stellenbosch University and the University of the Western Cape.

What is the second phase about?

The first phase of this study aimed to find out if you have a condition such as diabetes, high blood pressure or a cardiovascular disease. In the second phase we want to find out what causes these conditions.

What will I need to do?

All data collection will take place at KASSELSVLEI PRIMERE SKOOL between 08:00 and 14:00 from Tuesday to Friday. Recruiters will discuss a date and time that is suitable for you. At the data collection site you will need to do four different tests. These include an ECG (a heart test), a blood sample, we will also check the types of food you eat and see how fit you are. The ECG records the function of the heart and to see if the heart is beating normally. During this test, tiny pads linked to the ECG machine will be placed on your chest. This test is not painful and quite easy to do. Height, weight and blood pressure will also be measured. All tests will be done by qualified health professionals. The ECG and blood test will be done by a nursing sister, the diet questionnaire will be done by a dietician and the fitness tests will be done by a physical activity therapist. The fitness testing has 2 sections, a short physical activity questionnaire, called the Global Physical Activity Questionnaire, and fitness tests.

Pre-test instructions

On the particular day of your tests, you will be required to follow the pre-test instructions. These instructions are important so that the tests are accurate.

- Eat a light breakfast as early as possible the morning of your testing
- If you are on medication, ensure you take them
- Do not use tobacco such as cigarettes (within 3 hours), drink alcohol (with 24 hours) or have caffeine, like coffee (within 24 hours) before testing.
- Make sure you get a good night's rest before the tests, therefore do not do heavy exercise on the day or the day before the assessment
- Wear clothing that is comfortable, such as a shorts or tracksuit, a loose sweater and takkies.
- Drink enough fluids such as water over the 24-hour period before the test.
- If you feel ill on the day of the testing or have an injury, let the researcher know, and if possible, we will set another appointment.

Please bring your medication with you on the day of your testing. We would like to see if it has changed since your first test.

Confidentiality, anonymity and withdrawal

All your personal information will be kept confidential. You will not be asked to write your names on the questionnaires. Codes will be used on data forms so that you stay unknown. The research team will take complete responsibility for storing all information and will make sure that these documents are locked in a secure storage place. Participation in this study is voluntary and you may choose not to participate. If you choose to participate you have the right to withdraw at any stage of the study.

Benefits and risks

The benefits of these tests are greater than any possible risk. The benefits include knowing your heart function, and receiving diet and physical activity advice. These tests will allow the health professionals to advise you on possible lifestyle changes that would delay or prevent the onset on diabetes. This advice and feedback you will receive once all the information has been checked and analysed. There is no known risk associated with the completion of the dietary and physical activity questionnaires.

For the fitness testing, there is a possibility that certain abnormal changes can occur during the tests. These include abnormal blood pressure, fainting and abnormal heart beat. Therefore, all participants will do screening before the

tests so that the researcher can tell you if there is a risk in doing the fitness tests. A medical doctor will be present if you need a doctors consent to participate. A paramedic will also be present at all times. In addition, the researcher is trained to deal with unusual situations that may occur. In the days following the fitness tests, your muscles might feel slightly stiff. This is normal for most individuals and the soreness will soon disappear as the muscle heals.

Queries and questions

If you have any queries or questions regarding the research study or your rights as a participant, please feel free to contact the following people **during office hours**:

Mr S Hassan……021 959 6274
Prof T Erasmus……...021 938 4107
Bianca…….072 958 1877
Sr Irene……....082 765 4163
Dr S Bassett…….021 959 2273

We thank you once again for participating in this study.

Principal researchers: Prof R Erasmus, Mr S Hassan and Dr T Matsha

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BELLVILLE SOUTH DIABETES STUDY

DEELNEMER INLIGTINGSBRIEF

Geagte deelnemer

Ons wil u graag bedank vir u deelname aan die eerste fase van die Bellville-Suid Diabetiese Studie. U deelname word opreg waardeer en ons het daardeur, waardevolle informasie verkry. Ons wil u uitnooi om verder aan die tweede fase deel te neem. Die studie is n vennootskap tussen KPUT (Kaapse Skiereilandse Universiteit van Tegnologie), US (Universiteit van Stellenbosch), en UWK (Universiteit van Wes-Kaapland).

WAAROOR GAAN DIE TWEEDE FASE?

Die eerste fase was om vas te stel of u wel Diabetes, Hipertensie (hoe bloeddruk) of n hartsiekte het. In die tweede fase, wil ons uitvind waardeur hierdie toestande veroorsaak word.

WAT MOET EK DOEN?

Al die toetse sal by KASSELSVLEI PRIMERE SKOOL gedoen word. Vanaf 08h00 tot 14h00. Op Dinsdae tot Vrydae. U kan, saam met die Werwer (" Recruiter"), op n gepaste dag en datum besluit. Op die dag van die toetse sal ons die volgende doen:

- EKG (n toets om die hartfunksie vas te stel- dis pynloos)
- Bloedtoets
- Bloeddruk
- Dieet
- n Fiksheidstoets
- U gewig, lengte en liggaams-omtrek.

Al die toetse sal deur gekwalifiseerde mediese personeel gedoen word. Dus, Verpleegkundiges, Dieetkundiges, n Biokinetikus, Dokter en Paramedici.

Die fiksheidstoets het twee afdelings:
- n Kort vraelys
- n Fiksheidstoets

Op die dag van die toets, moet u asseblief die voorafgaande instruksies volg. Dit is baie belangrik vir die akkuraatheid van die toets:

- Eet asseblief ’n lifte ontbyt so vroeg as moontlik
- As ’n op medikasie is, moet u u medikasie inneem
- Die inneem van alkohol (met 24 ure), caffeine (binne 24 ure) en
- Die gebruik van tabak produkte (binne 3 ure) is verbode voor die toets
- U behoort uitgerus te wees vir evaluaring. Om hierdie rede vermy uitputtende oefening.
- Maak seker u kry ’n goeie nagrus voor die die dag van die toets (6-8 ure)
- Gemaklike kleredrag en stapskoene word aanbeveel. Moet asseblief nie ’n jeans of rok/romp aantrek nie
- Drink genoeg vloeistowwe binne 24-uur om normale hidrasie voor die toets te verseker
- As jy enige beserings of siektes op die dag van die toets het, rapporteer dit onmiddellik aan die navorser en indien moontlik, skeduleer 'n ander afspraak.

Wanner u na die Kliniek toe gaan, kan u asselblief u medikasie saam bring, ons wil graag sien of dit verander het.

VERTROULIKHEID EN ONTTREKKING

Alle inligting sal hoogs vertroulik hanteer word. Die navorser sal alle verantwoordelikheid vir die berging van inligting verseker en sal ook die dokumente in 'n veilige plek toesluit. U kan ter eniger tyd van die studie onttrek, indien u dit sou verkies.

VOORDELE EN RISIKOS

Die voordele van die deelname is, dat u inligting sal kry oor die nodige verandering van lewenstyl, ten einde te voorkom dat u Diabetes ontwikkel, of indien alreeds gediagnoseer, dit te kontroleer. Daar is geen risiko's verbonde aan die EKG (harttoets) of vraelyste nie.

Die moontlikheid bestaan dat sekere abnormale veranderings gedurende die fisieke fiksheidstoetse kan voorkom. Dit sluit in abnormale bloeddruk, flou word, asook ongewone hartklopppings mag ondervind word. Om dié rede word alle deelnemers versoek om skermingtoetse te neem. Dit verseker dat net individule met ’n lae of geen risiko aan hierdie studie kan deelneem. ’n

Newe-effek is spierstyfheid. Dit is normaal vir die meeste mense en dié styfheid sal gou verdwyn. Daar is geen bekende newe-effekte ge-assosieer met die deelname in hierdie studie nie.

NAVRAE

Indien u enige navrae aangaande die studie of u regte as deelnemer, het, is u baie welkom om die navorsers te kontak, gedurende kantoor-ure:
Mr S Hassan……021 959 6274
Prof T Erasmus……...021 938 4107
Bianca…….072 958 1877
Sr Irene……....071 171 2099
Dr S Bassett…….021 959 2273

We thank you once again for participating in this study.

Principal researchers: Prof R Erasmus, Mr S Hassan and Dr T Matsha

APPENDIX B

UNIVERSITY OF THE WESTERN CAPE
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CONSENT FORM

Title of Research Project: The relationship between insulin resistance and physical activity in adults residing in Bellville South, Cape Town

The study has been described to me in language that I understand and I freely and voluntarily agree to participate. My questions about the study have been answered. I understand that my identity will not be disclosed and that I may withdraw from the study without giving a reason at any time and this will not negatively affect me in any way.

Participant's name…….

Participant's signature…….

Date……

Witness Name…….

Witness Signature…….

Date……

Should you have any questions regarding this study or wish to report any problems you have experienced related to the study, please contact the head of department:

Departmental Chairperson: Dr S Bassett
University of the Western Cape
Private Bag X17, Belville 7535
Telephone: (021)959-2273
Cell: 082 318 9454
Fax: (021)959- 3688
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TOESTEMMINGSVORM

Titel van navorsing projek: Die verhouding tussen insulin weerstand en fisieke aktiwiteit in volwassenes wie in Bellville Suid, Kaapstad gevestig is

Die studie was voorgelê in ’n taal wat ek verstaan en ek stem vrywillig saam om deel te neem. My vrae omtrent die studie was beantwoord. Ek verstaan dat my identiteit nie onthul sal word nie en dat ek op enige tyd van die studie mag onttrek sonder om 'n rede te gee en dit sal my op geen manier negatief affekteer nie.

Deelnemer se naam en van …….

Deelnemer handtekening…….

Datum……

Getuie se naam en van …….

Getuie handtekening…….

Datum……

Indien jy enige vrae aangaande hierdie studie het of enige probleme ervaar wat u wil rapporteer, kontak asseblief die Departementshoof:

Departementshoof: Dr S Bassett
Universiteit van Wes Kaapland
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APPENDIX C

Physical Activity

Next 1 am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these quest ons even if you do not consider yourself to be a physically active person.

Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking *employment [Insert other examples if needed].* In answering the following questions Vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

	Questions	Response	Code
	Activity at work		
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *{carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days |___|	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 1 0 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 If *No,gotoP7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days |___|	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P6 (a-b)
	Travel to and from places		
	The next questions exclude the physical activities at work that you have already mentioned. Now would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship, [insert other examples if needed]		
7	Do you walk or use a bicycle *(pedal cycle)* for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, g oto P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days |___|	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P9 (a-b)
	Recreational activities		
	The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].		

10	Do you do any vigorous-intensity sports, fitness or recreational *(leisure)* activities that cause large increases in breathing or heart rate like *[running or football.] tor* at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go toP13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational *(leisure)* activities?	Number of days |___|	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P12 (a-b)

Physical Activity (recreational activities) contd.			
Questions		Response	Code
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that causes a small increase in breathing or heart rate such as brisk walking, *(cycling, swimming, volleyball)tor* at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If 'No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational *(leisure)* activities?	Number of days |___|	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational *(leisure)* activities on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day?	|__|__|: |__||__| Hours : minutes hrs mins	P16 (a-b)

APPENDIX D

CORE: Physical Activity			
Next 1 am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. There are various domains of activity which need to be included; work, activities in and around the home and garden, to get from place-to-place (transport-related) and recreation (discretionary or leisure-time) exercise or sports activities. This opening statement should not be omitted. *The respondent will have to think first about the time she/he spends doing work. Work Includes things that he/she has to do such as paid or unpaid work, household chores, harvesting food, fishing or hunting for food, seeking employment {insert other examples if needed] In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities that require moderate physical effort and cause small increases in breathing or heart rate.*			
Questions		Response	Code
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *Activities are regarded as vigorous intensity if they cause a large increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work? *"Typical week" means a week when a person is doing vigorous intensity activities and not an average over a period* *Valid responses range from 1-7.*	Number of days |____|	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day? *Think of one day you can recall easily. Consider only those Activities undertaken continuously for 10 minutes or more. Probe very high responses (over 4 hrs) to verify*	|___|___| : |___|___| Hours : minutes hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 1 0 minutes continuously? *Activities* are *regarded as moderate intensity if they cause* a *small increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work? *Valid responses range from 1-7*	Number of days |____|	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day? *Think of one day you can recall easily. Consider only those activities undertaken continuously for 10 minutes or* more. *Probe very high responses (over 4hrs) to verify*	|___|___| : |___|___| Hours : minutes hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship, [insert other examples if needed] *The introductory statement to the following questions on transport-related physical activity is very important, it asks and helps, the participant to now think about how they travel around getting from place-to-place. This statement should not be omitted.*			
1	Do you walk or use a bicycle *(pedal cycle)* for at least 1 0 minutes continuously to get to and from places? *Circle the appropriate* response	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places? *Valid responses range from* 1-7	Number of days |___|	P8

9	How much time do you spend walking or bicycling for travel on a typical day? *Think of one day you can recall easily. Consider the total amount of time walking or bicycling for trips of 10 minutes or more. Probe very high responses (over 4 hrs) to verify*	|___|___|: |___||___| Hours : minutes hrs mins	9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now 1 would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms]. *This introductory statement directs the participant to think about recreational activities. This can also be called discretionary or leisure time. It includes spoils and* exercise *but is not limited to participation competitions. Activities* reported *should be done regularly and not just occasionally. It is important to focus on only recreational activities only not* to *include any activities already mentioned. This statement* should *not be omitted.*			
10	Do you do any vigorous-intensity sports, fitness or recreational *(leisure)* activities that cause large increases in breathing or heart rate like *[running or football]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)* *Activities* are *regarded as vigorous intensity If they* cause a large increase *in breathing and/or heart rate.*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational *(leisure)* activities?	Number of days |___|	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day? *Think of one day you can recall easily. Consider the total amount of time doing vigorous recreational activities for periods of 10 minutes or more. Probe very high responses (over 4 hrs).*	|___|___|: |___||___| Hours : minutes hrs mins	P12 (a-b)
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that causes a small increase in breathing or heart rate such as brisk walking,(cycling, *swimming, volleyball* at least 10 minutes continuously? *Activities are regarded as moderate intensity if they cause a small increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational *(leisure)* activities?	Number of days |___|	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational *(leisure)* activities on a typical day? *Think of one day you can recall easily. Consider the total amount of time doing moderate recreational activities for periods of 10 minutes or more. Probe very high responses (over 4 hrs).*	|___|___|: |___||___| Hours : minutes hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day? *Consider total time spent at work sitting, in an office, reading, watching television, using a computer doing hand craft like knitting, resting etc. Do not include time spent sleeping.*	|___|___|: |___||___| Hours : minutes hrs mins	P16 (a-b)

APPENDIX E

CARDIOVASCULAR DISEASE RISK FACTORS No. ……

Change in physical activity patterns in past 8m?	YES	NO
Change in medication that could affect your glucose, within past 3m?	YES	NO
Do you have a cardiovascular, metabolic or pulmonary disease	YES	NO

Medication: ……
Diabetic medication (incl dates): ……..
Diabetes diagnosis: ……

Family history	YES	NO (F<55y M<65y)
Smoking	YES	NO (current or quit in 6 m)
HDL	YES	NO
Hypertension	YES	NO
Dyslipidemia	YES	NO
Obesity	YES	NO
Sedentary	YES	NO

CHECKLIST

Did you have a light breakfast with the past 3 hours …….....	YES	NO
Did you smoke within the past 3 hours ……YES		NO
If on medication, have you taken it ……..	YES	NO
Did you bring your medication with you ……..	YES	NO
Did you drink alcohol within the past day (24hrs) ……..	YES	NO
Did you drink caffeine (coffee) within the past day (24 hours) …….	YES	NO
Did you get a good nights rest ……	YES	NO
Are you wearing comfortable clothing (shorts/tracksuit, sweater/top, takkies or barefoot).....YES		NO
Did you drink plenty of fluids (water) before the test ……YES		NO

APPENDIX E

DATA RECORD SHEET

Age …….. MHR 220- ……=……. HEIGHT ……m

WEIGHT ……..kg WAIST ……cm

AEROBIC STEP TEST:

RHR …… bpm immediately .....bpm

1 minute post HR …….. monitor / ……..actual

MUSCLE STRENGTH:

GRIP STRENGTH Dominant ……. ……... ……..kg

Non dominant …… …… ……..kg

Notes ……

MUSCLE ENDURANCE:

CURL UP …… 1 minute

Notes…….

FLEXIBILITY: SIT-AND-REACH …….. …… ……. cm

Notes .....

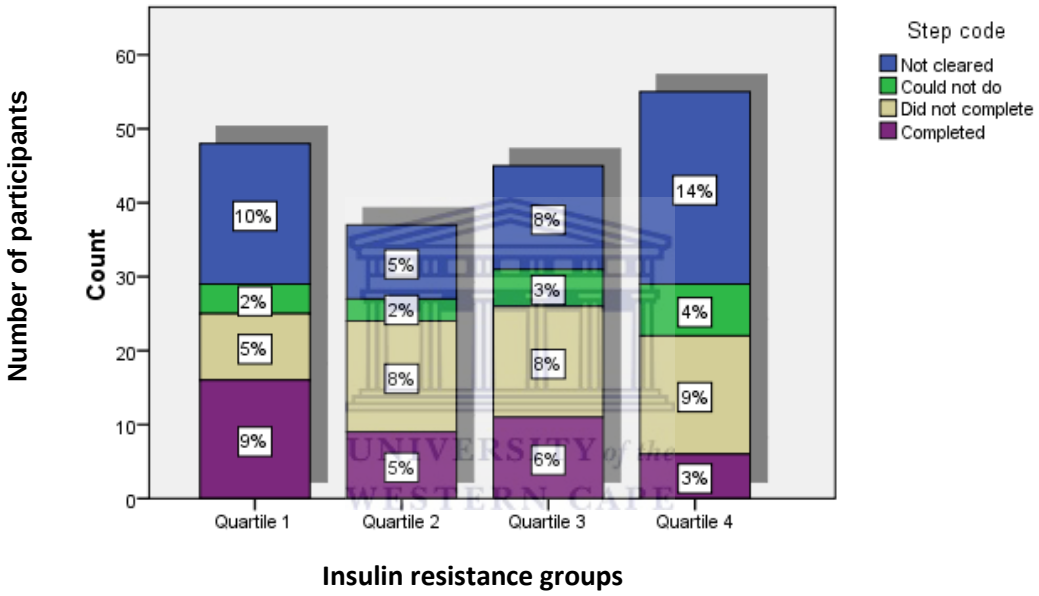
TEST TERMINATION CRITERIA

General indications for stopping an exercise test in low risk adults:

1. Onset of angina or angina-like symptoms
2. Shortness of breath, wheezing, leg cramps or claudication
3. Signs of poor perfusion: light-headedness, confusion, ataxia, pallor, cyanosis, nausea or cold and clammy skin
4. Failure of heart rate to increase with increased intensity
5. Noticeable change in heart rhythm
6. Subject requests to stop
7. Physical or verbal manifestations of severe fatigue
8. Failure of the testing equipment

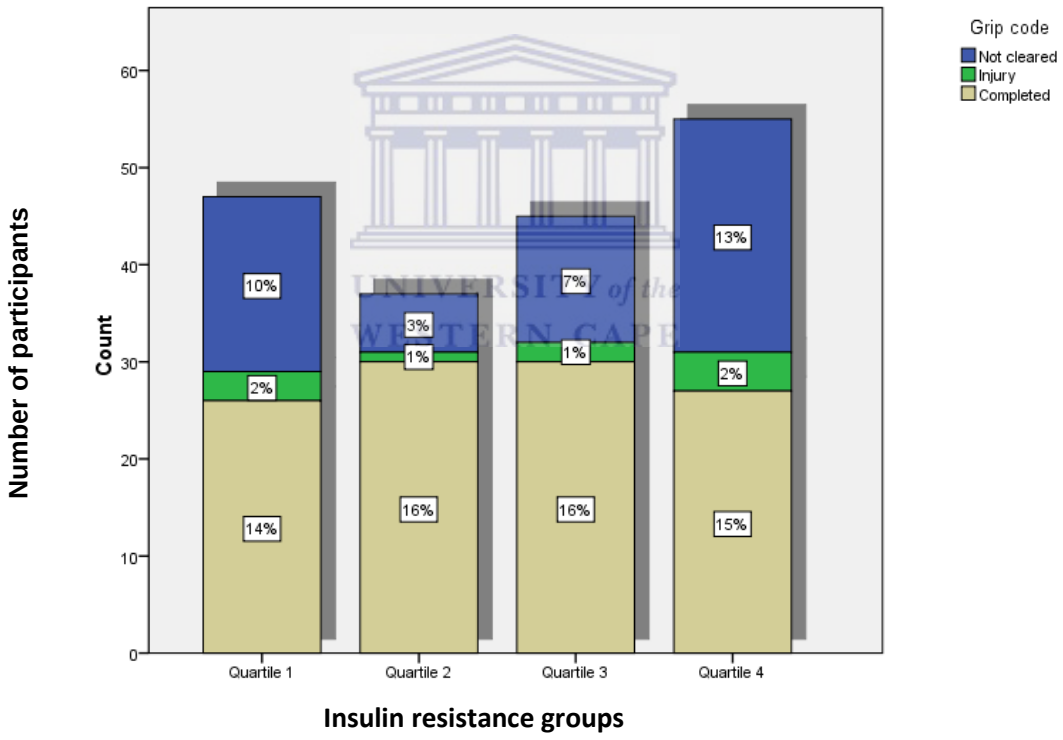
APPENDIX F

3-Minute step test "codes" (in %) according to the quartiles of HOMA-IR



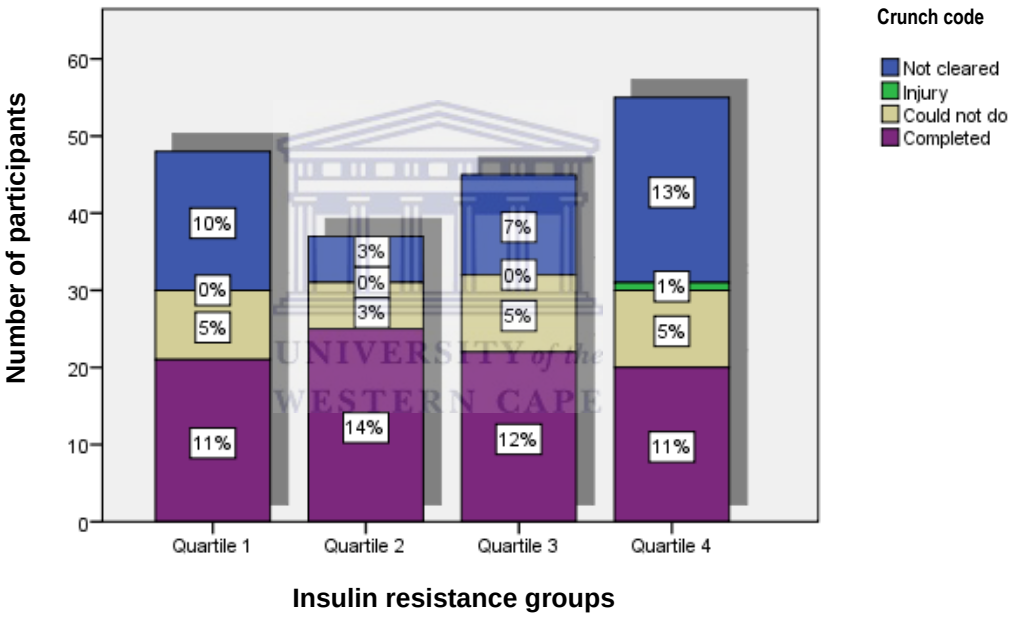
APPENDIX G

Handgrip strength test "codes" (in percent) according to quartiles of HOMA-IR



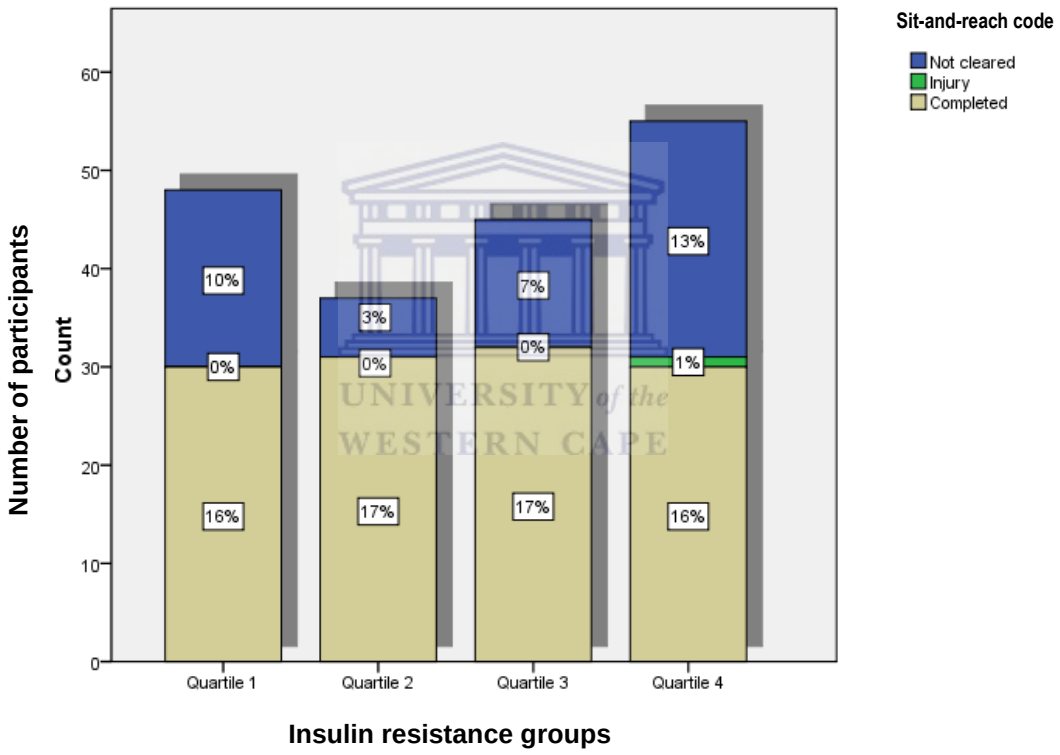
APPENDIX H

One-minute crunch test "codes" (in percent) according to quartiles of HOMA-IR



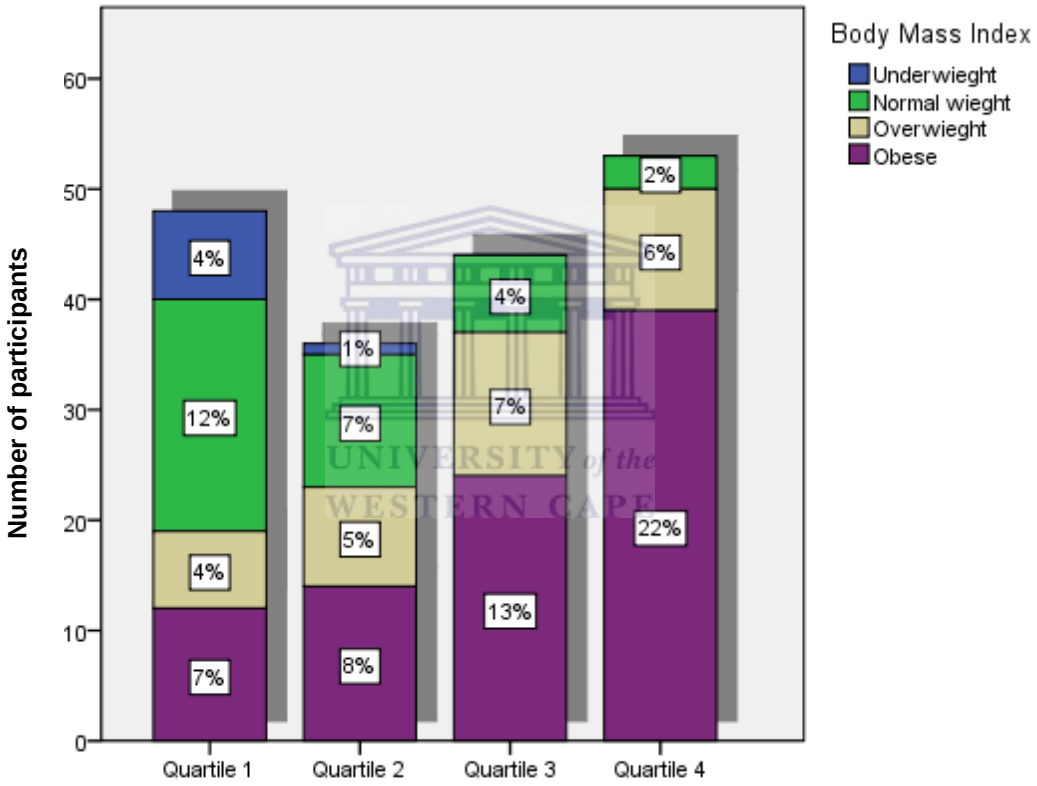
APPENDIX I

Sit-and-reach flexibility test "codes" (in percent) according to quartiles of HOMA-IR



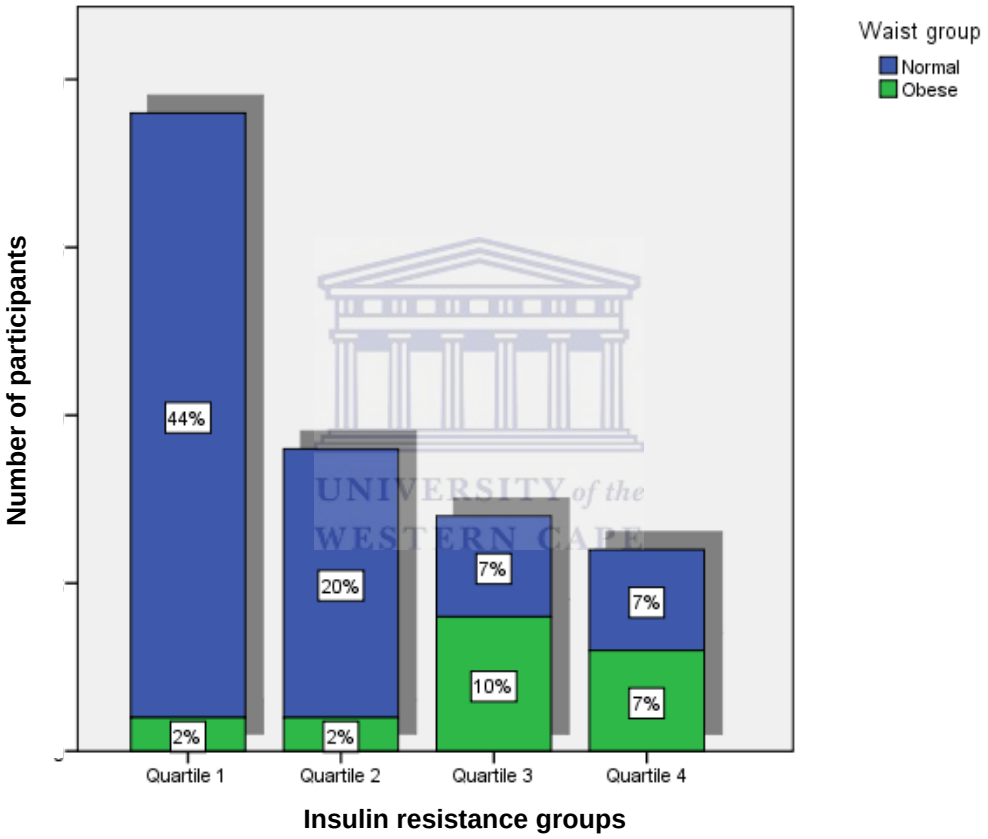
APPENDIX J

Body mass index (in percent) according to quartiles of HOMA-IR



APPENDIX K

Waist circumference (in percent) for males according to quartiles of HOMA-IR



APPENDIX L

Waist circumference (in percent) for females according to quartiles of HOMA-IR