Chapter 1

General Introduction

1.1 Background, Prevalence, Impact and Aetiology of Diabetes Mellitus

Diabetes mellitus is a chronic disorder of carbohydrate, fat and protein metabolism. Diabetes mellitus represents a heterogeneous group of disorders that have hyperglycemia as a common feature. There are two distinct forms of diabetes, termed type-1 diabetes mellitus formerly labelled as “insulin dependent” and type 2 diabetes mellitus previously known as “non-insulin dependent diabetes mellitus”. Type 2 diabetic patients need insulin for their wellbeing but not for survival. The value of this simple and useful classification relies on the recognition of the mechanisms underlying the development of the two types of diabetes mellitus. The identification of diabetes as type-1 diabetes mellitus is primarily achieved by clinical observation and simple investigations, although the condition can be further defined by genetic and immunological markers. Insulin dependence, the hallmark of type-1 diabetes, necessitates insulin injections in order to survive. Type-1 diabetes mellitus appears to be an auto-immune disease in which the body attacks and ultimately destroys insulin-producing pancreatic beta cells in an inflammatory reaction [1]. The pathogenesis in type 2 diabetes mellitus is such that although the pancreas produces insulin, the body does not utilise the insulin correctly. This is primarily due to insulin resistance in peripheral tissue, where the insulin-receptors within the body cells are insensitive to insulin resulting in glucose not readily entering the tissues [2], thus ultimately leading to hyperglycemia or elevated blood glucose concentrations [3]. This increase in blood glucose in turn stimulates the beta cells of the pancreas to secrete more insulin in an attempt to maintain a normal blood glucose concentration. Insulin resistance is often associated with hypertension, lipid disturbances and obesity [4]. Apart from genetic dispositions, diet and obesity, animal experiments as well as epidemiological data suggest that a lack of physical activity may contribute to insulin resistance [5].

In comparison to type-1 diabetes mellitus much less is known about the potential pathogenesis of type 2 diabetes mellitus, despite it being the most common type. There is no evidence that auto-immune mechanisms are involved. Lifestyle clearly plays a role and obesity has been identified as a co-morbidity of type 2 diabetes mellitus [6, 7]. Although considered to be a disease in adulthood, there has been an epidemic increase in the incidence of type 2 diabetes mellitus in obese children, particularly among Black Africans, Hispanics, Native Americans, and Asians [4]. Diabetes has been called the "new world syndrome" [8], a symptom of globalization with social, cultural, economic and political significance [9]. Apart from the impact on health, the economic cost of diabetes mellitus and its complications, the impact is enormous both in health-care and loss of productivity to society [9]. Diabetes mellitus will, in the future, constitute a heavy burden both for individuals affected and for the society in which they live [10].

Prevalence of Diabetes Mellitus

The incidence of type 2 diabetes mellitus is increasing markedly in adult populations around the world [11]. This is viewed as a growing chronic health problem, the complications of which cause significant morbidity and mortality [12]. Diabetes mellitus constitutes a growing global public health problem, with an increasing incidence from 30 million people ten years ago to about 135 million today [13] to an estimated 300 million in 2025 [14, 15]. As populations age and urbanize, and as obesity becomes more prevalent [16, 17], the incidence of type 2 diabetes mellitus increases proportionally.

The prevalence of type 2 diabetes mellitus is at its highest among the Pima Indians living in Arizona [18] and Polynesians. South Asians and West Africans are in the middle range, with European populations in the lowest range. Europeans could reflect a population predisposition to genetic susceptibility, and/or exposure to environmental factors [19]. The persistent elevated rates of type 2 mellitus among South Asian migrants several generations after migration to the UK, suggest that genetic factors play an important role [20].

A similar elevation in type 2 prevalence rates among urbanized Indian, Chinese and African migrants in Mauritius is testimony to the importance of environmental (lifestyle) factors [10], as does the five-fold difference in type 2 diabetes mellitus prevalence between rural and urban populations in Tamil Nadu in South India [20].

Care of diabetics in the African continent is fraught with numerous problems. The prevalence of diabetes mellitus among African adults appears to be lower than that reported in most industrial countries, however it has been estimated that at least one million people in Africa suffer from type 2 diabetes mellitus [21]. The continents identified with the largest potential future increase are Asia and Africa, where diabetes mellitus could increase two to three fold [13]. South Africa has diabetes mellitus prevalence of 4.5% and an impaired glucose tolerance prevalence of 51% [22]. Recent studies have indicated that the prevalence of type 2 diabetes mellitus is an increasing health concern among black South Africans. The age-adjusted prevalence of diabetes in urban settings in 2001 was found to be 8% in Cape Town and 5.3% in Durban [23]. Among peri-urban Xhosa speakers, the age-adjusted prevalence was found to be 4.5% [22] and in rural Kwa-Zulu Natal, 4.2% [24]. Diabetes care in South Africa is incongruent with the greatest need for care. From observation, highly trained health-care workers tend to be concentrated in metropolitan areas and render service to the affluent minority as opposed to rendering service in the rural, resource-poor areas of the country.

Aetiology of Type 2 Diabetes Mellitus

The main factors associated with the development of type 2 diabetes mellitus are genetic predisposition, increasing age, increasing body fat and environmental factors, such as urbanization and industrialization [25, 26]. Increased longevity and changes in lifestyle from a traditional healthy and active life to a modern, sedentary, stressful life coupled with the overconsumption of energy-dense food [11] [9], is also part of the aetiology.

Despite the variation in the prevalence of type 2 diabetes mellitus between populations and at the individual level, the most overt environmentally mediated epidemiological feature of type 2 diabetes mellitus is the strong positive correlation with relative body fat (Figure 1). Genetic factors exacerbate this condition and epidemiological studies indicate that type 2 diabetes mellitus appears to stem from a collection of multiple genetic defects, each contributing to its own pre-disposing risk and each modified by environmental factors. The two metabolic defects that characterize type 2 diabetes mellitus are a derangement in beta-cell secretion of insulin and an inability of peripheral tissue to respond to insulin (insulin resistance) [4].

Type 2 diabetes mellitus is generally viewed as a lifestyle disorder, most prevalent among populations with heightened genetic susceptibility [27]. Recent epidemiological evidence indicates that a majority of the world's population are prone to type 2 diabetes mellitus in the wake of increasing obesity [28], with Caucasians being a possible exception. This plausible evolutionary explanation relies on the old concept of hunter-gatherer genes that accounts for the rapid rise of type 2 diabetes in some populations. Neel (1962) postulated the theory of the existence of the "thrifty gene" [29]. According to Neel's theory early people lived in feast-famine cycles and the thrifty gene would have had selective advantages because it increased the ability of the body to store fat (energy) that could later be metabolized during periods of food shortage [30]. Accordingly, the 'thrifty" genotype would have been advantageous for hunter-gatherer populations, especially child-bearing women, because it would allow them to fatten more quickly during times of abundance. Individuals carrying the thrifty genes would thus better survive in times of food-scarcity. However, in modern societies with a constant abundance of food, this genotype efficiently prepares individuals for a famine that never comes. The result is widespread chronic obesity and predisposition to related health problems like diabetes.

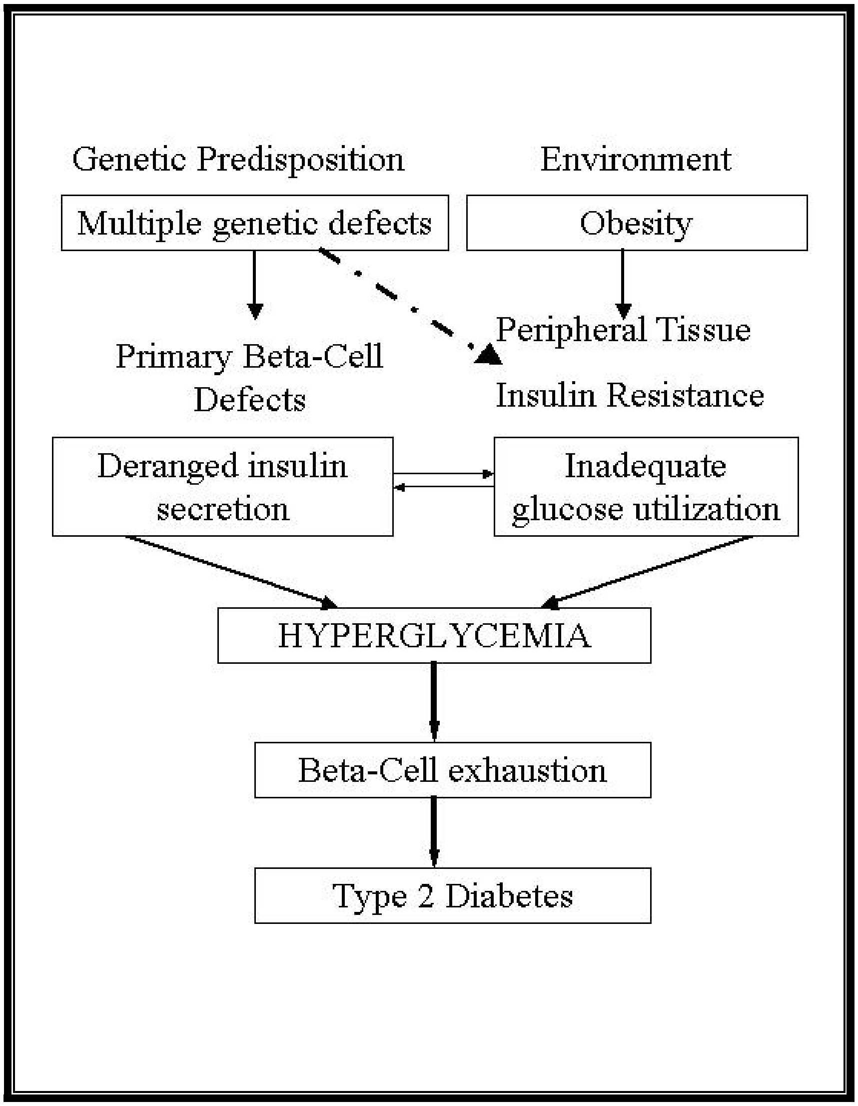

Figure 1: Pathogenesis of type 2 diabetes mellitus. Genetic predisposition and environmental influences converge to cause hyperglycemia and overt diabetes (Redrawn from Kumar, 2003)

In summary, type 2 diabetes mellitus has a heterogeneous and multi-genetic, complex aetiology [8, 31]. Most people who have type 2 diabetes mellitus are obese, have disturbances in lipid metabolism and suffer from hypertension [32, 33]. Diabetes mellitus needs to be treated using a holistic approach embracing dietary adjustments, physical activity and exercise, medication (if needed) and education.

1.2 General Exercise Guidelines in Type 2 Diabetes Mellitus

The therapeutic role of exercise in type 2 diabetes mellitus is different to that in type-1 diabetes. Approximately 80% of people with type 2 diabetes are obese and insulin resistant and only about 35% require insulin therapy. Physicians often prescribe exercise in combination with diet and oral antidiabetic agents to achieve and maintain weight reduction and improve glycaemic control. Research has proven that regular physical activity protects against the development of type 2 diabetes in high-risk populations [34, 35]. Together with the treatment and prevention of obesity by dietary restriction, increased physical activity is an important component of lifestyle modification for people with impaired glucose tolerance, with a family history of type 2 diabetes, or with other risk factors for its development [36]. Exercise induced hypoglycemia and acute regulation of blood glucose are less of a problem in type 2 diabetes than in type-1 diabetes, however cardiovascular disease and musculoskeletal injuries are generally greater. People with type 2 diabetes mellitus can develop the same diabetes complications as those with type-1 diabetes mellitus, including retinopathy, nephropathy, neuropathy, and macrovascular disease, and must be screened for conditions before starting an exercise program [36].

1.2.1 Guidelines for General Exercise Training and Prescription: Effects on the Exercise Response

Under normal circumstances, in people without diabetes there is coordination between the hormonal and metabolic events which results in the maintenance of glucose homeostasis. Insulin and counter-regulatory hormone concentrations in people with diabetes do not respond to exercise in the normal manner and the balance between peripheral glucose utilization and hepatic glucose production may be disturbed [37]. The effects of diabetes on a single exercise session is dependant on several factors, including: use and type of medication to lower blood glucose levels (oral or insulin hypoglycemic agents); timing of medication administration; blood glucose level prior to exercise; timing, amount, and type of previous food intake, presence and severity of diabetic complications; use of other medication secondary to diabetic complications and the intensity, duration and type of exercise [37].

1.2.2 General Recommendations for Exercise Prescription

Exercise prescription for people with diabetes must be individualized according to medication usage schedule, presence and severity of diabetes complications, and goals and expected benefits of the exercise program [37]. Physical activity for those without significant complications or limitations should include appropriate endurance and resistance exercise for developing and maintaining cardio-respiratory fitness, body composition, and muscular strength and endurance. In general, one hour of exercise requires an additional of 15g of carbohydrate either before or after exercise. If exercising is vigorous and of long duration, an additional 15 to 30g of carbohydrate is needed every hour. Exercise is a contraindication if: there is active retinal hemorrhage or there has been recent therapy for retinopathy; illness or infection is present; blood glucose is above 13.8mmol/l (250mg/dl) and ketones are present (blood glucose should be lowered before initiation of exercise); or blood glucose is 4.4 to 5.5 mmol/l (80 to 100 mg/dl) because the risk of hypoglycemia is great (in this situation, carbohydrate should be eaten and blood glucose allowed to increase before initiation of exercise). Exercise precautions includes the following: keeping a source of rapidly acting carbohydrate available during exercise; consuming adequate fluids before, during and after exercise; practicing good foot care by wearing proper shoes and cotton socks, and inspecting feet after exercise; and carrying medical identification [37].

1.3 General Effects of Acute Exercise in Patients with Type 2 Diabetes Mellitus

1.3.1 Blood Glucose Levels and Insulin Sensitivity

In healthy non-diabetic individuals, exercise has very little impact on blood glucose levels. In individuals with type 2 diabetes mellitus, exercise with either moderate or heavy intensity is associated with decreases in blood glucose levels. A single bout of exercise often decreases plasma glucose levels [38], which progresses into the post-exercise periods. The blood glucose lowering effect of exercise in individuals with type 2 diabetes mellitus can be explained by the insulin-dependent activation of glucose transportation by exercise [39], as well as increased insulin sensitivity.

1.3.2 Hormone Levels

Moderate to heavy exercise reduces insulin secretion and inversely the plasma insulin levels are reduced [38]. Glucagon and adrenaline levels increase during exercise. Glucose homeostasis is generally maintained during exercise because the increase in glucose utilization is matched by an increase in hepatic glucose production. The exercise-induced increase in glucagon and the fall in insulin levels can control the increase in glucose production. The important role of pancreatic hormones is the control of hepatic glucose production during exercise, the increase in glucose uptake in peripheral tissues is controlled primarily by insulin-independent mechanisms [4].

1.3.3 Glucose Transport

The total skeletal muscle glucose transporter protein (GLUT 4) levels are increased in exercise trained middle aged individuals with either normal glucose tolerance or in individuals with type 2 diabetes mellitus, compared to sedentary individuals [40]. These individuals have improved insulin sensitivity, which is explained by increased GLUT 4 expression. Exercise is also a stimulator of glucose transportation [39]. In humans, insulin sensitivity is related to the degree of physical activity [36]. Exercise also enhances insulin sensitivity in obese individuals and those with type 2 diabetes mellitus [41]. In patients with type 2 diabetes mellitus, regular exercise training may enhance cellular glucose uptake. This improvement in insulin sensitivity may overcome defects in the insulin signal transduction pathway, seen in muscle tissue taken from individuals with type 2 diabetes mellitus [42].

1.4 General Long Term Effects of Exercise in Patients with Type 2 Diabetes Mellitus

1.4.1 Metabolic Control and Insulin Sensitivity

Aerobic power is inversely related to modest, favorable changes in glycosylated haemoglobin and glucose tolerance [38, 43]. In certain studies [44-48], duration of physical activity ranged from 6 weeks to 12 months, and improved glucose tolerance was shown in early stages of type 2 diabetes [49]. Some studies also showed that mild-to-moderate physical activity ranging from 12 weeks up to 2 years did not improve glucose control in type 2 diabetic subjects [50, 51]. It was also noted that older diabetic individuals (e.g., over 55years) may not show the same exercise-induced blood glucose changes as usually seen in younger diabetic individuals [52]. Favorable changes in glucose tolerance usually deteriorates within 72 hours of the last exercise bout in those with type 2 diabetes [53] and are a reflection of the last individual exercise bout, rather than training per se [54]. Hence, regular physical activity is recommended for persons with type 2 diabetes to sustain glucose-lowering effects.

1.4.2 Body Weight

In individuals with type 2 diabetes mellitus and obesity a diet-induced decrease in body weight is associated with the beneficial effect of improved metabolic control and reduced risk of ischaemic heart disease [55]. Patient compliance with weight loss programmes is often low and diet therapy alone is generally not sufficient to maintain weight loss on a long term basis [56]. Programmes which combine diet therapy and exercise are more successful in achieving bodyweight reduction in participants [43, 57].

1.4.3 Cardiovascular Risk Factors

Exercise is associated with a decrease in serum triglycerides levels, particularly very low-density lipoproteins, and an increase in high density lipoprotein cholesterol [38]. Physical activity has also been reported to lower blood pressure in hypertensive individuals [38, 43]. The latter adaptation occurs independent of weight loss and changes in body composition. Physical training has also shown to increase cardiovascular fitness and physical working capacity in individuals with type 2 diabetes mellitus [58].

1.5 Resistance Training for the Management of Type 2 Diabetes Mellitus

Resistance training has been recognised as a useful therapeutic tool for the treatment of a number of chronic diseases [59-64], and has been demonstrated to be safe and efficacious for the elderly [65] and obese [66] individuals. Resistance training has been reported to enhance insulin sensitivity [67, 68], daily energy expenditure [68, 69], and quality of life [70]. Resistance training also has the potential for increasing muscle strength [69, 71], lean muscle mass [72], and bone mineral density [73] which could enhance functional status and glycaemic control and assist in the prevention of osteoporosis and sarcopenia. Resistance training requires equipment, knowledge of exercise techniques and initial instruction, unlike aerobic exercise, such as walking. Tesch et al. [74] demonstrated that muscle biopsy specimens form resistance-trained, non-diabetic men contained glycogen concentration 50-100% higher than those of physically inactive men in the general population. Certain exercise studies have shown that as little as 4 weeks of resistance training increases muscle glycogen synthesis in elderly, previously sedentary and healthy individuals [75]. Resistance training could help in the management of diabetes mellitus by increasing skeletal muscle mass, since muscle is the principal source of glucose disposal [76, 77]. In a cross-sectional study comparing healthy male athletes with sedentary control subjects, a significant correlation (r=0.54) was observed between muscle mass and insulin sensitivity [78]. Resistance training clearly produces significant skeletal muscle hypertrophy even in elderly individuals [79], with associated increases in insulin sensitivity [78].

1.6 Statement of the Problem

Disease prevention not only entails stopping the development of the disease before it occurs, but also includes measures aimed at slowing down the progression of the established disease. Primary prevention should focus on health promotion. Diabetes mellitus should be seen as an interacting occurrence between people and their environment. Thus the primary concern in prevention and treatment of type 2 diabetes mellitus should include changes in those structural, social and economic factors that are important determinants of lifestyle [80]. Exercise has long been a cornerstone in the management of diabetes based on its potential to improve metabolic control and diminish complications [81]. Presently the lack of understanding pertaining to exercise and its benefits, associated with type 2 diabetes mellitus as well as the absence of education and intervention programmes makes good diabetes management difficult to achieve [82]. Exercise is undervalued in the management of type 2 diabetes mellitus. This may be due to a lack of understanding and motivation on the part of the person with diabetes mellitus as well as the absence of clear recommendations, encouragement and follow-up actions by health-care workers. Health-care workers should address these issues because most people with type 2 diabetes mellitus have the potential to derive benefit from regular, moderate levels of exercise.

Despite evidence pointing to the benefits of exercise there is still a lack of participation among patients who are at risk of or who have type 2 diabetes mellitus. The reasons for the non-participation in regular exercise includes the patients' lack of knowledge about the benefits of exercise, a lack of motivation and the absence of clear guidelines from health-care professionals. Clinicians should view the need to encourage regular exercise as an essential part of diabetes management therefore specific instructions should be given to persons with type 2 diabetes mellitus rather than general advice, which does not encourage compliance. In most South African communities the rate of diabetes is on the increase and is becoming unmanageable due to a lack of education and proper interventional programmes. A study undertaken by Paul [83], investigated the knowledge, attitudes, beliefs and practices relating to exercise among type-1 diabetes mellitus patients in government hospitals in Kwa-Zulu Natal. The study showed that patients visiting government hospitals were provided with a basic check-up, including glucose capillary tests and blood pressure measurement and were very briefly advised on exercise, if at all. It was also noted that no education relating to diet or medication was provided. The results showed that even though many people were positive about exercising, they were unable to exercise due to the lack of knowledge on the appropriate type, duration and frequency. Furthermore there are no qualified exercise practitioners in public-sector government hospitals in South Africa, to recommend and monitor exercise programs for patients. It was also noted that when doctors and nurses recommended exercise in hospitals they very often referred to the use of sophisticated exercise apparatus, disregarding the fact that not all people were able to access gymnasia and commercial health programs. This misplaced counseling was the result of most of the global and local [23, 84] research on the benefits of exercise on diabetes management having focused on aerobic exercise in well-resourced settings. This study, however, has focused on progressive resistance training (PRT) utilizing basic affordable equipment and/or the use of own body weight in a resource-poor setting.

1.7 Significance of the Study

The research is interdisciplinary, involving experts from the field of epidemiology, exercise physiology, nutrition, as well as support from other academic institutions and industry. Previous diabetes related study in South Africa has been limited to risk profiles of various populations [24, 85, 86] and dietary habits [23] of diabetics. A more directly related intervention study [84] investigating diabetes and exercise focused on aerobic training and relaxation exercises in a resource poor setting but no study in South African has investigated the efficacy of resistance exercise on a diabetic patient. The desired outcome of this study was to observe a significant change (1%) in glycosylated haemoglobin and lipid profiles, and a significant potential improvement in morphological, musculoskeletal and cardio-respiratory health-related fitness. Ultimately all persons with diabetes, irrespective of geographic and/or socio-economic settings should have the opportunity to benefit from the many valuable therapeutic effects of exercise [87].

1.8 Aims of the Study

The study was designed to determine the effect of a community-based exercise (progressive resistance training) and lifestyle (dietary education) intervention on health outcomes in persons with type 2 diabetes mellitus, in a resource-poor setting.

1.9 Research Objectives

The following objectives were set out in accordance with the above stated aim of this study:

1. To describe the physical activity profile of subjects at baseline;
2. To investigate changes in glycosylated haemoglobin and lipid profiles of subjects;
3. To investigate changes in morphological, musculoskeletal and cardio-respiratory health-related fitness of subjects; and
4. To investigate the profile and changes in diabetes care activities among subjects.

1.10 Delimitations of the Research

As the study entailed a community-based trial undertaken in and confined to the under- resourced area of Mamelodi, in the city of Tshwane, Gauteng, South Africa, there was an ethnic focus on subjects of African heritage. Furthermore, only persons with type 2 diabetes mellitus on oral medication were included in the study.

1.11 Structure of the Thesis

In accordance with the aim and objectives of the study the chapters of the thesis are structured as follows:

Chapter 1:

General introduction

Chapter 2:

Habitual physical activity among an African cohort of persons with Type 2 Diabetes Mellitus in a South African resource-poor community setting.

Chapter 3:

Effects of progressive resistance exercise on glycosylated haemoglobin (HbA1c) and lipid profiles in participants with Type 2 Diabetes Mellitus.

Chapter 4:

The efficacy of a 20-week progressive resistance training programme on morphological, musculoskeletal and aerobic fitness in participants with Type 2 Diabetes Mellitus.

Chapter 5:

Influence of a dietary education programme on diabetes care, knowledge and activities among Type 2 Diabetics.

Chapter 6:

Summary, general conclusions and recommendations.

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Chapter 2

Habitual Physical Activity among an African Cohort of Persons with Type 2 Diabetes Mellitus in a South African Resource-Poor Community Setting

Abstract

Background: Despite positive evidence that physical activity (PA) can preserve mobility in older adults there is a trend for PA to decrease with advancing age. Therefore measuring the prevalence of inactivity has become increasingly pertinent in South African societies, particularly those affected by or at risk of chronic disease.

Aims: The purpose of the study was to describe the physical activity profile of a cohort of 80 male and female type 2 diabetics from ages 40-65 years. Participants were of African heritage and were recruited in a resource-poor setting from the outpatients' clinic at the Mamelodi hospital in Gauteng, South Africa.

Method: A cross-sectional baseline evaluation was done on a group of patients selected for a randomized controlled clinical trial using the short version of the International Physical Activity Questionnaire (IPAQ). This study reports on firstly: the physical activity profile in three exercising categories i.e. low, moderate and vigorous categories, secondly: their energy expenditure (METS) and lastly the sitting time (sedentary activity) on one weekday. The effect of age, gender and body mass index (BMI) on physical activity was also assessed.

Results: The cohort showed a distribution of 16 (20.0%) subjects in the low activity category, 49 (61.25%) in the moderate activity category and 15 (18.75%) in the vigorous activity category, respectively. The median baseline weekly energy expenditure (METS) was 2052.5 (p25 - p75; 677 - 2793). Gender had a differentiating effect on physical inactivity (sitting time) with males (median 180 minutes) spending significantly (p=0.02) more time sitting than females (median 120 minutes). However gender, age, and BMI had no significant differentiating effect on categories of physical activity or energy expenditure. Similarly age and BMI did not influence levels of physical inactivity (sitting time).

Conclusion: The prevalence of physical inactivity at baseline among the cohort of patients studied was moderately high. Most subjects reported doing physical activity of a moderate nature, with low energy expenditure. Males were more inactive than females. Efforts are needed to encourage active living and discourage sedentary habits, among patients with type-2 DM.

Keywords: International Physical Activity Questionnaire, Inactivity, Exercise, Health Promotion, IPAQ

2.1 Introduction

Physical activity is an important aspect of lifestyle with beneficial effects on well-being and health and, in particular, cardiovascular morbidity, mortality and longevity [1, 2]. As such, physical inactivity is a risk factor for cardiovascular disease and a variety of other chronic diseases [1-3]. Current advice recommends daily exercise to combat chronic disease. Studies done by Pate *et al.* [3], discussed these recommendations, focusing on the amount of activity needed to avoid the adverse health consequences of a sedentary lifestyle. Despite positive evidence that physical activity can preserve mobility in older adults there is a trend for physical activity to decrease with advancing age. This decline is more evident in women, low-income earners and in those with poor education [4, 5].

Recent cross-sectional studies in peri-urban communities of the Western Cape in South Africa highlighted that the most sedentary individuals were young women aged from 15-24 years and men and women over the age of 55 years [6]. Therefore measuring the prevalence of inactivity has become increasingly important in South African societies, particularly those affected by or at risk of chronic disease. South African data on the level of physical activity in older adults as obtained from the regional cross-sectional risk factor surveys suggest that persons over age 55 have the lowest levels of self-reported moderate and vigorous physical activity. In a study of older South African adults from historically disadvantaged backgrounds, the Yale Physical Activity Survey for Older Adults (YPAS) described patterns of weekly activity spent on housework, gardening and yard work, care-giving, exercise and recreation [7]. Results from this study suggested that South African seniors spent an average of 2583 kcal/wk (± 3027 kcal/wk) on physical activity, 65% less than reported in a sample of North Americans of the same age [8]. This has also been well documented in other developed countries [9]. In two studies conducted in South Africa on older adults from peri-urban communities [7, 10] current levels of physical activity were dissociated from various indicators of morbidity, such as blood pressure (BP), waist circumference and body mass index (BMI), as well as prevalence of hypertension, diabetes and hypercholesterolemia. This may be explained, in part, by a “healthy survivor" effect. On the other hand, moderate-lifetime occupational physical activity levels recalled for the ages from 14-49 years using a historical activity questionnaire, were significantly and inversely associated with current systolic blood pressure ($r=-0.24$, $p<0.05$) [11]. The inverse correlations between physical activity and cardiovascular disease (CVD) risk factors have been found in a number of cross-sectional studies [12, 13], and intervention studies have established that CVD risk factors can, to some extent, be modified through exercise [14, 15]. Physical inactivity is an independent CVD risk factor, since epidemiological studies find inverse relationships between physical activity level and cardiovascular as well as all cause mortality [16].

The purpose of the present paper is to report on the baseline data regarding the daily habitual physical activity among an African cohort of type-2 diabetics in a resource-poor community setting. This baseline analysis formed part of a clinical trial evaluating the efficacy of a physical activity and lifestyle intervention on health outcomes in persons with type 2 diabetes.

2.2 Materials and Methods

2.2.1 Participants

The study was undertaken in Mamelodi, a suburb in the city of Tshwane in the province of Gauteng, South Africa. The study participants (n=80) included black male and female participants between the ages 40-65 years with type-2 DM without complications and a known duration of the disease for at least one year. Most participants were recruited from the outpatient clinic at the Mamelodi government hospital as well as from local churches in the Mamelodi area. The following exclusion criteria were used: Cardiovascular contraindications Unstable angina, untreated severe left main coronary artery disease, angina, hypotension, or arrhythmias provoked by resistance training, acute myocardial infarction, end-stage congestive heart failure, severe valvular heart disease, malignant or unstable arrhythmias, large or expanding aortic aneurysm, known cerebral aneurysm, acute deep venous thrombosis, acute pulmonary embolism or infarction, and recent intracerebral or subdural hemorrhage; Musculoskeletal contraindications: Significant exacerbation of musculoskeletal pain with resistance training, unstable or acutely injured joints, tendons or ligaments, fracture within the last 6 months (delayed union), acute inflammatory joint disease; Other contraindications: Rapidly progressive or unstable neurological disease, failure to thrive, terminal illness, uncontrolled systemic disease, symptomatic or large abdominal or inguinal hernia, hemorrhoids, severe dementia/behavioral disturbance, acute alcohol or drug intoxication, acute retinal bleeding, detachment/severe proliferative diabetic retinopathy, recent ophthalmic surgery, severe cognitive impairment, uncontrolled chronic obstructive pulmonary disease, prosthesis instability, severe (systolic >160mmHg and diastolic >100mmHg) and malignant hypertension, and signs and symptoms suggestive of immuno-suppression.

2.2.2 Ethical Clearance

The protocol was approved by the Research Ethics Committees of the Faculties of Humanities and Health Sciences at University of Pretoria (Number 66/2004). The chief executive officer, superintendent and physician providing medical services as well as the health-care workers at the diabetes mellitus (DM) out-patient clinic of the Mamelodi Hospital also consented to the diabetes mellitus study being conducted.

2.3 Study Design

A descriptive survey was used with quantitative data captured by means of the International Physical Activity Questionnaire (IPAQ).

2.4 Instrumentation

In epidemiological studies, information about physical activity is often collected using questionnaires as this indirect method is a more feasible method in large studies [17]. The IPAQ (Appendix 1), which was designed by a multinational working group, is a standardized instrument that can be used internationally to obtain comparable population estimates of health-enhancing physical activity from surveillance system data [18]. IPAQ has 2 versions, namely a short (9-item) and a long (31-item) format. Both formats are designed to assess physical activity over a 7-day period or during a "typical week" and they can be administered by telephonic interviews or self-administered. The IPAQ was subjected to reliability and validity studies carried out in 14 centres' in 12 countries including South Africa during 2000. This demonstrated that the IPAQ instruments have acceptable measurements properties for monitoring population levels of physical activity among 18 to 65 year-old adults in diverse settings [18, 19]. It was reported that in South Africa, which was classified as a developing country, the reliability of the long and short IPAQ was 0.79 and 0.85 respectively [20]. The long and short version of the IPAQ questionnaire were further validated by Bohlmann *et al*. [21] among urban and peri-urban South Africans from various socio-economic backgrounds and divergent languages. The IPAQ was again cross validated among older adults in South Africa by Kolbe-Alexander *et al.* [20]. In this study physical activity was assessed using the English version of the short IPAQ available on www.ipaq.ki.se. The short version IPAQ deals with three specific types of activity undertaken in four domains namely: leisure activity, domestic and gardening activity, work related (occupational) activity and transport related physical activity. The specific types of activity assessed are walking, moderate-intensity activity and vigorous intensity activities. IPAQ defines moderate-physical activities as those that produce a moderate-increase in respiration rate, heart rate and sweating for at least 10 minute duration, which is equivalent to 3-6 metabolic equivalents (METS) based on the compendium of physical activity [22]. Vigorous physical activity is defined as those that produce a vigorous increase in respiration rate, heart rate and perspiration for at least 10 minutes duration where the metabolic equivalent value is above 6 METS [22]. Inactivity was also determined assessed using the IPAQ and is described as time spent sitting in an ordinary weekday.

Administration of the Questionnaire

A pilot study was conducted to pre-test the English version of the short IPAQ questionnaire. The questionnaires were administered by the primary researcher.

While most participants indicated their preference to have the questionnaire administered in English, where necessary, the resident hospital dietician was available during the administration to serve as a translator in case participants required clarity in a preferred African language.

2.5 Statistical Analysis

Data was checked for any outliers according to the guidelines from IPAQ (www.ipaq.ki.se). Data was screened for missing values and where the answers "don't know" or "not sure" appeared a "0" response was allocated to such answers. Data was analyzed using Stata 10 software programme [23]. Data was summarised using standard descriptive techniques of mean, median, frequency, percentage and range. The categories, baseline METS and sitting time in the group as a whole as well as in categories of age, gender and body mass index (BMI) (3 quantiles of BMI) were analysed. Groups were compared with either the Mann Whitney or Kruskal Wallis tests. A p value of ≤0.05 was regarded as statistically significant.

2.6 Results

The results are presented in the following order:
Pooled data of the entire cohort, categories of age, gender and BMI, pooled baseline METS, baseline METS by age, gender and BMI categories and pooled data regarding time spent sitting by the cohort and sitting time by age, gender and BMI categories.

Table 1: Overall Categories of Physical Activity

Category	Total Cohort (n=80)	
	N	%
Low (1)	16	20.0
Moderate (2)	49	61.25
Vigorous (3)	15	18.75

The total cohort of 80 subjects is shown in table 1. The categories 1, 2, and 3 represent the low, moderate and vigorous activity levels that the patients indicated on the IPAQ questionnaire. As seen in table 1, there were 16 (20.0%) subjects distributed in the low activity category, 49 (61.25%) subjects distributed in the moderate activity category and 15 (18.75%) subjects distributed in the vigorous activity category. The majority of subjects 49 (61.25%) were distributed in the moderate activity category.

Table 2: Categories of Physical Activity by Age

Age (Years)	Categories (n=80)							
	Low		Moderate		Vigorous		Total	
	N	%	N	%	N	%	N	%
40-50 years	6	35	8	47	3	17	17	21
51-60 years	5	15	22	66	6	18	33	41
61-70 years	5	16	19	63	6	20	30	38
Total	16	20	49	61	15	19	80	100
p-value	**0.54**							

Physical activity was further categorized in the different age categories of the cohort. As seen in table 2, 6 subjects within the age category 40-50 years, 5 subjects in the 51-60 years and 5 subjects in the 61-70 year age category, thus totaling to 16 subjects, fell into the low activity category. In the moderate category the were 8 subject in the 40-50 years, 22 subjects in the 51-60 years and 19 subjects in the 61-70 years category, thus totaling to 49 subjects in the moderate activity category. Similarly there were 3 subjects in the 40-50 years category that were classed as being vigorously active, 6 subjects in the 51-60 years category and 6 subjects in the 61-70 years category, thus totaling 15 subjects in the vigorous activity category. There was no-significant difference (p=0.54) when comparing the subjects physical activity within age categories.

Table 3: Categories of Physical Activity by Gender

Gender	Categories							
	Low		Moderate		Vigorous		Total	
	N	%	N	%	N	%	N	%
Males	4	24	11	65	2	12	17	21
Females	12	19	38	60	13	21	63	79
Total	16	20	49	61	15	19	80	100
p-value	**0.79**							

In the gender category highlighted in table 3 there were 4 males and 12 females in the low category, 11 males and 38 females in the moderate category and 2 males and 13 females in the vigorous category. There was no significant difference (p=0.79) in the gender category. As seen in table 3 the majority of females and males fell in the moderate physical activity category.

Table 4: Categories of Physical Activity by Body Mass Index

Quantiles of BMI	Categories							
	Low		Moderate		Vigorous		Total	
	N	%	N	%	N	%	N	%
Lowest (Mean 26.3)	4	14	19	68	5	18	28	35
Moderate (Mean 31.1)	5	18	17	65	4	15	26	33
Highest (Mean 39.6)	7	25	13	50	6	23	26	33
Total	16	20	49	61	15	19	80	100
p-value	**0.69**							

In the above BMI table the subjects are categorized according to the 3 quantiles of BMI ranging from lowest to highest quantile of BMI. As seen in the low activity level, 4 subjects fell within the lowest quantile, 5 subjects in the moderate quantile and seven subjects in the upper quantile. In the moderate activity levels, 19 subjects fell in the lowest quantile, 17 in the moderate quantile and 13 in the highest quantile. In the vigorous activity level, 5 subjects fell in the lowest, 4 in the moderate and 6 subjects fell in the highest quantile of BMI. There was no significant difference (p=0.69) when comparing the BMI to the categories of physical activity. A greater proportion of subjects in the highest quantile of BMI reported the lowest physical activity; however, as stated this was not statistically significant.

The distribution of baseline METS by category (i.e. age, gender and BMI) is shown in tables 5-8.

Table 5: Overall Energy Expenditure

METS	Total Cohort (n=80)		
	Median	**p25**	**p75**
Total METS	1392	677	2793

Table 5 shows the median in energy expenditure (METS) of the entire cohort of 80 subjects. The median METS was 1392 (p25=677) and (p75=2793). Most training studies [24] suggest that 150–400 kcal per day should be expended daily for those starting an exercise program. The lower end of range is considered the minimal threshold and should be considered an initial goal for persons initiating physical activity. If performed daily this should result in an energy expenditure of ±1000 kcal/week [24].

Table 6: Energy Expenditure by Age

Age (Years)	Pre-intervention METS (n=80)		
	Median	**p25**	**p75**
40-50 years	838	325	1674
51-60 years	1537.5	742.5	2970
61-70 years	1392	660	2844
p-value	**0.33**		

Table 6 shows the distribution of METS according to the age category. In the age range of 40-50 years the mean METS was 838 with p25=325 and p75=1674. In the 51-60 age range the total METS averaged 1537.5 with p25=742.5 and p75=2970 and in the age range 61-70 years the average total METS was 1392 with p25=660 and p75=2844. It is seen from the data that the average METS is higher in the age range 51-60 years, meaning that they are more physically active than the other two age ranges. However, among the entire cohort, there was no significant difference (p=0.33) when comparing the different age ranges at baseline.

Table 7: Energy Expenditure by Gender

Gender	Pre-intervention METS (n=80)		
	Median	**p25**	**p75**
Males	1155	462	1884
Females	1404	693	2970
p-value	**0.54**		

Table 7 shows the average baseline METS distribution among the males and females of the entire cohort of subjects. Based on the gender distribution the males averaged baseline METS of 1155 with p25=462 and p75=1884, while the females averaged a higher energy expenditure with a baseline METS of 1404 with p25=693 and p75=2970. There was, however, no significant differences (p=0.54) between the mean METS of males and females.

Table 8: Energy Expenditure by Body Mass Index

Quantiles of BMI	METS (n=80)		
	Median	p25	p75
Lowest (Mean 26.3)	1189.5	717.8	2658.5
Moderate (Mean 31.1)	1521.25	693	2970
Highest (Mean 39.6)	1536	325	2970
p-value	0.99		

The distribution of total METS at baseline into the quantiles of BMI showed that a total METS of 1189.5 fell in the lowest BMI quantile with p25=717.8 and p75=2658.5. However in the moderate BMI quantile the total METS averaged 1521.25 with p25=693 and p75=2970, and lastly in the highest BMI quantile category the total METS averaged 1536 with p25=325 and p75=2970. The differences observed were not statistically significant (p=0.99).

Table 9: Overall Levels of Physical Inactivity

Daily Time Spent Sitting (minutes)	Total Cohort (n=80)		
	Median	p25	p75
	129.3	90	180

The total time spent sitting on one weekday is shown for the overall cohort of 80 subjects in table 9. As observed, the average time sat was just over 2 hours (129 minutes with p25-75, 90-180 minutes). Thus the cohort basically sat for a minimum of 1.5 hrs which can be viewed as substantial sedentary activity, but is less when compared to other clerical office workers [18].

Table 10: Physical Inactivity by Age

Age (Years)	Time Spent Sitting (min) at Pre-intervention (n=80)		
	Median	**p25**	**p75**
40-50 years	100	90	180
51-60 years	150	90	180
61-70 years	120	80	180
p-value	**0.81**		

Physical inactivity among the cohort was further categorized into age ranges as shown in table 10. The proportion of inactive subjects was more or less equally distributed among the three age range groups with a median of 100min (p25=90min and p75=180min) in age range 40-50 years, a median of 150min (p25=90min and p75=180min) in age range 51-60 years and lastly with a median of 120min (p25=80 min and p75=180min) also in the age range 61-70 years. Inactivity seems to be higher in the age range 51-60 years with the median sitting time equaling to 150 minutes. There was no significant differences (p=0.81) by age category at baseline.

Table 11: Physical Inactivity by Gender

Gender	Time Spent Sitting (min) at Pre-intervention (n=80)		
	Median	**p25**	**p75**
Males	180	120	180
Females	120	90	180
p-value	**0.02**		

Table 11 shows the cohort of subjects distributed into gender categories regarding the time spent sitting at baseline on one specific weekday. From the data males spent more time sitting (180minutes) with a p25=120 min and p75=180 min, as compared to females who sat on average 120 minutes with a p25=90 min and p75=180 min. When comparing the males and females at baseline there was a significant difference (p=0.02) in the gender category, with males being more sedentary.

Table 12: Physical Inactivity by Body Mass Index

Quantiles of BMI	Time Spent Sitting (min) at Pre-intervention (n=80)		
	Median	p25	p75
Lowest (Mean 26.3)	180	90	180
Moderate (Mean 31.1)	120	100	180
Highest (Mean 39.6)	100	60	180
p-value	0.08		

Table 12 shows the 3 quantiles of BMI associated with the time spent sitting. In the 1st BMI quantile the median = 180 min with the p25= 90min and p75= 180 min, in the 2nd quantile the median=120 min with p25=100 min and p75= 180 min, and in the 3rd quantile the median = 100 with p25= 60 and p75= 180.

2.7 Discussion

The present study was a cross sectional evaluation done at the baseline of a clinical study to report on the physical activity profile of persons with type 2 DM in a resource-poor setting of South Africa using the internationally validated physical activity questionnaire (IPAQ - short version). The IPAQ is supported by many Health organizations including the World Health Organization, the US Centers for Disease Control and Prevention and the American College of Sports Medicine [18]. Regular participation is a key concept included in current public health guidelines for physical activity. This study reported on firstly: the overall physical activity profile of the pooled cohort of subjects in the 3 exercising categories i.e. low, moderate and vigorous categories as well as physical activity with respect to the age, gender and BMI. Energy expenditure (METS) as well as the baseline METS by categories age, gender and BMI was also reported and lastly physical inactivity reported by sitting time (sedentary activity) on one weekday, and the sitting time by categories i.e. age, gender and BMI was observed. The main significant finding in the baseline data was the amount of physical inactivity (time spent sitting) in the gender comparison. Although inactivity levels were high in both males and females the finding reflects that males spent more time (median of 180 minutes) sitting doing no physical activity on one weekday than the females, with a lower median of 120 minutes. In another recent study undertaken by Cook [25], the IPAQ was used to focus on the prevalence of cardiovascular risk factors and physical inactivity in a rural South African population. It was reported that most participants followed an inactive lifestyle.

The finding in the present report that females spent less time sitting than males deserves some comment. The IPAQ component also assessed components of physical activity including moderate intensity activities done at home such as carrying loads (e.g. babies, washing clothes) scrubbing floors and sweeping. These types of domestic activities are most likely to be performed by females. Cultural beliefs and practices of the subjects suffering with type 2 DM, also plays and important role in their participation in physical activity which could attribute to the more time spent sitting by males than females. According to Bopape [26], beliefs held by an individual may influence their decision to comply with preventative action. According to Tshabalala and Gill, 1997 [27], “older people are usually excluded from exercise by virtue of their senior status. They usually sit in the sun, while the young do the hard work”. This could thus be a possible explanation for the increased time spent sitting by the men, which was significantly greater ($p=0.02$) when comparing genders. One would have expected subjects with low BMI values to be less sedentary and vice-versa. The data shows the inverse but, essentially there was no statistical difference ($p=0.08$) in the sitting time between the quantiles of BMI.

Although there was no significant difference ($p=0.81$) in the sitting time and the age category, several reports have shown such a relationship [28]. Data from the Behavioral Risk Factors Surveillance System (BRFSS) study indicated that inactivity increased with advancing age from 18 to 29 years to 70+ in both sexes

[29]. A study done by Al-Hazzaa, (2007) [30], dealt with inactivity levels of Saudi males between ages 19 to 68 years and found a curvilinear relationship between inactivity prevalence and age [30]. This study showed an inactivity prevalence (sitting doing no physical activity) reaching its highest level in the age group of 30 to 49 years, and the lowest level in the age group 60 years and above. Again all the above studies assessed mainly leisure-type physical activity and this could explain the difference in results regarding inactivity levels.

A Brazilian survey using the IPAQ short version found an inactivity prevalence of 41% among Brazilian adults aged 20 years and above [31]. Data from the Behavioral Risk Factors Surveillance System (BRFSS) in the United States indicated that the majority (54%) of US adults were not physically active enough to meet the current recommendations of at least 30 minutes of moderate-intensity activity on most days of the week [32]. In another report analyzing 1988-2002 BRFSS data in the USA, it was revealed that leisure time physical inactivity had decreased especially after 1996 in both men and women [29]. However, the US national health objective for 2010 calls for a reduction in the prevalence of leisure time physical inactivity to 20% [29].

South Africa is a country undergoing rapid epidemiological transition, with a dual burden of infectious diseases and chronic diseases related to lifestyle. Results from the 1998 Demographic and Health Survey suggest that overweight and obesity affect more than 55% of South African women [33]. This high prevalence of overweight and obesity among South African women, particularly from the indigenous (black) population groups has dire health consequences, as it is associated with increased risk for chronic disease related to lifestyles. The relationship between Body Mass Index (BMI) and physical activity was investigated in 530 black women living in the North West Province as part of the 'Transition and Health during Urbanization of South Africans (THUSA) study [34]. Kruger *et al.* [34], reported that physical activity was significantly and inversely associated with BMI ($r= -0.14$; $p=0.001$) and waist circumference ($r=- 0.15$; $p\leq0.00001$). Furthermore, the women who were in the highest tertile for physical activity were 62% less likely to be obese compared to those who were the least active ($r=0.38$;

95% CI: 0.22 - 0.66). Similarly, the women in the second tertile for physical activity had approximately half the risk of obesity when compared to those who were least active (r=0.52; 95% CI: 0.31-0.86). These findings therefore underscore the importance of the role of physical activity in the prevention of obesity and overweight in women. This is particularly important since 54% of the women participating in the study were classified as either overweight (BMI >24.9 and <30) or obese (BMI >29.9) [34].

From the present study in table 1 we can observe that the majority (n=49; 61.25%) of the subjects were classified into the moderate activity category where physical activity was done for five or more days per week and walking activities for at least 30 minutes or more per day. It has to be noted that these activities were not structured and any type of movement would have generated METS which contributed to the "physical activity status".

In South Africa the Ministry of Health has initiated a consultative process to develop a series of guidelines for the prevention or management of chronic disease related to lifestyles (separate guidelines are available for the prevention and management of diabetes, hypertension, hyperlipidaemia, and overweight). The directorate has also recognized the need to encourage physical activity, in particular, among older adults and initiated guidelines for promoting "active" ageing [35]. More recently, in November 2004, the Directorate of Health Promotions, within the Department of Health, launched an inter-sectoral strategy aimed at the promotion of healthy lifestyles and change from high-risk behaviour, particularly among the youth. This forms part of the plan for comprehensive health care in South Africa, and is one of the strategic priorities for the period 2004 - 2009. The original successful initiative advocating physical activity in developing countries was the implementation of Agita Mundo in Brazil [36]. The Agita Mundo programme was formulated in response to the high prevalence of chronic diseases of lifestyle among Brazilian men and women. Agita Mundo translated means, "Move for Health", and the main aim of this campaign was to educate individuals on the health and fitness benefits of exercise and to promote the implementation of physical activity programmes. This programme, which started in Sao Paulo, spread to the rest of Brazil, and then to the rest of the Americas, has subsequently been recognised as a model to promote mass participation in physical activity programmes [37]. Consequently, the World Health Assembly has mandated its member states, of which South Africa is one, to celebrate "Move for Health" annually. The core message of "Move for Health" is to encourage individuals to accumulate 30 minutes of moderate-physical activity on most days (at least 5) of the week. The South African campaign has been named, "Vuka South Africa – Move for your Health", which means "Wake up South Africa, move for your health". The National Department of Health, together with its partners (National Departments of Education and Sport and Recreation South Africa; private companies, tertiary institutions and non-governmental organisations) launched the "Vuka" South Africa – Move for your Health campaign in May 2005. Since its inception, there have been numerous planning meetings, culminating in a stakeholders' workshop that was held in September 2005. This workshop served as a platform for the future implementation of the Move for Health programme, together with the monitoring and evaluation of the campaign [11].

In conclusion, while the short IPAQ provides reasonable specific measures of physical activity but its sensitivity to classify inactive people correctly, is limited. The present study is subject to the following potential limitations. Firstly the study used the short IPAQ. As is the case with any questionnaire, the respondents could have suffered from recall bias. Second limitation was that the sample of subjects to whom the IPAQ was administered to at baseline was not a random sample and there were small numbers in the analysis of age, gender and BMI specific outcomes.

From the findings of the current study we can conclude that the prevalence of physical inactivity at baseline among the cohort of patients studied was moderately high, but it is commonly acknowledged that inactivity increases with advancing age. This is reflected by the fact that majority of the participants were classified in the moderate physical activity category. Therefore health policies [38] in South Africa, should focus on active living and discourage sedentary habits. Health care workers should promote physical activity among the general population more, and in the context of this study, also among patients with type-2 DM. A limitation of this study is that the survey sample was small and inferring the results to a larger population should therefore be done with caution. There is a need for a national study with a representative sample to address the issue of physical activity in South Africans suffering from diabetes mellitus.

2.8 References

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