A community-based lifestyle intervention program for adults with type 2 diabetes mellitus in a low socio-economic status community.

by
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Declaration

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Bradley James Fryer **March 2016**

Abstract

The prevalence, and associated burden of type-two diabetes mellitus (T2DM), is rapidly increasing globally, and in South Africa, with men and women of all ages being affected. While there has been an extensive research into the pathophysiological mechanisms, and to some extent, the management of T2DM, healthcare systems are still not able to adequately deal with the increasing number of patients being diagnosed with the disease. Professional- and community-led lifestyle interventions have recently showed the most promise in combating T2DM. There is however, a paucity of data on comprehensive lifestyle interventions in communities of low socio-economic status (SES), where the incidence of T2DM and its related complications is high.

The primary aim of this study was to determine the effectiveness of a community-based, 10-week lifestyle intervention on physiological, psychological and health-related outcomes in adults suffering with T2DM in a low SES community.

Forty-three participants completed the study (age 59.5 ± 12.2 years, 25 Women; 18 Men), of which 23 made up the experimental group (EXP; BMI: 33.8 ± 7.5; HbA1c: 8.8 ± 2.1) and 20 made up the control group (CON; BMI: 34.4 ± 9.7; HbA1c: 9.4 ± 2.3). The control group completed a pre- and post-testing session, while experimental completed an additional post-testing retention session. The experimental group participated in a 10-week comprehensive lifestyle intervention. A number of anthropometric, cardiovascular and functional measurements were carried out, and questionnaires related to health-related quality of life (HRQoL), social support, dietary habits and lifestyle behaviours, as well as health professional usage were also administered.

Following the 10-week comprehensive lifestyle intervention, there was a positive change in the outcome variables measured. There was a statistically significant decrease ($p < 0.05$) in body fat percentage, diastolic blood pressure and HbA1c, with a statistically significant increase in the total distance walked during the six-minute walk test (6MWT) ($p < 0.05$). Furthermore, there was a statistically significant improvement ($p < 0.05$) in all but three of the HRQoL domains. Dietary habits and lifestyle behaviours improved significantly ($p < 0.05$), with the exception of eating times where there was no change. The frequency at which the participants actively sought professional assistance with the management of their T2DM did not change significantly ($p > 0.05$). The results from the retention period, obtained 10-weeks after the conclusion of the intervention, suggest that

the changes as a result of the program were maintained, however, it is uncertain if those results can be attributed to the use of the post-intervention guide.

The findings of this study indicate that a 10-week comprehensive lifestyle intervention is effective in improving physiological, psychological and health-related outcomes in adults with T2DM living in a low SES community. The use of a post-intervention guide as an assistive device to maintain these improvements requires further investigation and revision. Furthermore, this study reveals the opportunity for community-based interventions to assist the primary healthcare sector in the management and prevention of T2DM.

Abstrak

Die toeneemende voorkoms en geassosieerde las van tipe-twee diabetes mellitus (T2DM), global en in Suid Afrika, affekteer beide mans en vrouens van alle ouderdomme. Alhoewel daar ekstensiewe navorsing gedoen is in patofisologiese meganismes en tot sekere mate die bestuur van T2DM, sukkel gesondheidsorg stestels nogsteeds met ‘n toename in pasïente gediagnoseerd met die siekte. Onlangs is dit bewys dat professionele- en geemeenskap begeleide leefstyl intervensies toon die hoogste potensiaal om T2DM teen te werk. Daar is egter min data oor volledige leefstyl intervensies in geemeenskappe van lae-ekonomiese status (LES) waar die voorkoms van T2DM en sy verwante komplikasies hoog is.

Die primêre doel van die studie was om die effektiwiteit van ‘n gemeenskap-gebaseerde 10-weke leefstyl intervensie op fisiologiese, sielkundige en gesonheids-verwante uitkomste in volwassenes met T2DM in LES gemeenskap te bepaal.

Drie en veertig deelnemers het die studie voltooi (ouderdom 59.5 ± 12.2 jaar, 25 Vrouens; 18 Mans). 23 deelnemers was deel van die eksperimentele groep (EKS; LMI: 33.8 ± 7.5; HbA1c: 8.8 ± 2.1) en 20 deelnemers het gedien as die kontrole groep (KON; LMI: 34.4 ± 9.7; HbA1c: 9.4 ± 2.3). Die kontrole groep het voor en na toetsing vooltooi, terwyl die eksperimentele groep ‘n addisionele toetsing na ‘n retensie periode afgelê het. Die eksperimentele groep het deelgeneem in ‘n 10-weke volledige leefstyl intervensie. Antropometriese, kardiovaskulêre en funksionele metings is geneem, en vraelyste aangaande gesondheids verwante lewens kwaliteit (HRQoL), sosiale bystand, dieet en leefstyl gewoontes, asook gebruik van mediese dienste was geadministreer.

Daar was positiewe uitkomsveranderlikes na die 10-weke volledige leefstyl intervensie. Daar was ‘n statistiese beduidende daling ($p < 0.05$) in liggaamsvet persentasie, diastoliese bloeddruk, en HbA1c, met ‘n statistiese beduidende toename ($p < 0.05$) in die totale afstand gestap gedurende die ses minute stap toets (6MST). Verder, was daar ‘n statistiese beduidende verbetering ($p < 0.05$) in almal behalwe drie van die HRQoL domeine. Dieet en leefstyle gewoontes het statisties beduidende verbeter ($p < 0.05$) met die uitsondering van etenstye waar geen verandering plaasgevind het nie. Daar was geen statistiese beduidende verandering ($p > 0.05$) in die gebruik van mediese dienste om T2DM te bestuur nie. Na gelang van die 10-weke retensie periode blyk dit dat die uitkomste van die

intervensie behoue gebly het, alhoewel dit onseker is of dit toegesryf kan word aan die oefenings handleiding.

Die bevindinge van die studie bewys dat ‘n 10-weke volledige leefstyl intervensie effektief is om fisiologiese, sielkundige en gesonheids-verwante uitkomste in volwassenes met T2DM in LES gemeenskappe te verbeter. Die oefenings handleiding as ‘n addisionele hulpbron om die verbetering te behou verg verdere ondersoek. Die studie toon die geleentheid vir verder gemeenskap gebasseerde intervensies om die primêre gesonheidsdiens sektor by te staan met die bestuur en voorkoms van T2DM.

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Abbreviations

$\bar{x}$	:	Mean
*	:	Statistically significant difference ($p < 0.05$)
**	:	Statistically significant difference ($p < 0.01$)
***	:	Statistically significant difference ($p < 0.001$)
%	:	Percent
®	:	Registered trademark
±	:	Plus or minus
>	:	Greater than
≥	:	Greater than or equal to
$	:	Dollar
β	:	Beta
μL	:	Microlitres
Σ	:	Sum of
6MWT	:	Six minute walk test
a	:	Statistically significant difference between EXP and CON
A	:	Abdominal skinfold
ACSM	:	American College of Sports Medicine
AMPK	:	AMP-activated protein kinase
ANOVA	:	Analysis of variance
ASIS	:	Anterior superior Iliac spine
b	:	Statistically significant difference between PreT2 and Post (EXP)
BGlc	:	Blood glucose
BIA	:	Bioelectrical impedance analysis
BMI	:	Body mass index
bpm	:	Beats per minute

c	:	Statistically significant difference between PreT2 and Post (CON)
Ca^{2+}	:	Calcium Ion
CAM	:	Complementary and alternative medicine
CAN	:	Cardiac autonomic neuropathy
CHW	:	Community health workers
CI	:	Confidence interval
cm	:	Centimetre
CON	:	Control group
CV	:	Cardiovascular
CVD	:	Cardiovascular disease
CVE	:	Cerebrovascular event
d	:	Statistically significant difference between PreT2 and Reten (EXP)
d	:	Cohen's effect size
D-39	:	Diabetes 39
D-CLIP	:	Diabetes Lifestyle Improvement Program
DBP	:	Diastolic blood pressure
DFBS	:	Diabetes Family Behaviour Scale
DNA	:	Deoxyribonucleic acid
DPP	:	Diabetes prevention program
DPP-4	:	Dipeptidyl peptidase 4
DRD	:	Diabetes-related distress
e	:	Statistically significant difference between Post and Reten (EXP)
ED	:	Erectile dysfunction
EDTA	:	Ethylenediaminetetraacetic acid
ES	:	Effect size
Etc	:	Etcetera

EXP	:	Experimental group
FFA	:	Free fatty acid
FSD	:	Female sexual dysfunction
Fwd	:	Forwards
GCK	:	Glucokinase
GCKR	:	Glucokinase regulator
GDM	:	Gestational diabetes mellitus
GI	:	Glycaemic index
GIP	:	Glucose-dependent insulinotropic polypeptide
GIT	:	Gastrointestinal tract
GLP-1	:	Glucagon-like peptide-1
GLUT4	:	Glucose transporter type 4
GP	:	General practitioner
HbA1c	:	Glycated haemoglobin
HDL-C	:	High-density lipoprotein cholesterol
HIIT	:	High-intensity interval training
HP	:	High-protein
HPA	:	Hypothalamic-pituitary-adrenal axis
HR	:	Heart rate
HR_{max}	:	Maximal heart rate
HRQoL	:	Health-related quality of life
I	:	Intensity
IFG	:	Impaired fasting glucose
IGF-1	:	Insulin-like growth factor 1
IGFBP-1	:	Insulin-like growth factor binding protein 1
IGFBP-2	:	Insulin-like growth factor binding protein 2

IGT	:	Impaired glucose tolerance
IL-1β	:	Interleukin 1 beta
IRS1	:	Insulin receptor substrate-1
ISAK	:	International Association for the Advancement of Kinanthropometry
K_{ATP}	:	ATP-dependent potassium channel
kg	:	Kilogram
$kg.m^{-2}$	:	Kilogram per metres squared
L	:	Large practically significant difference
LC	:	Low-carbohyrate
LDL-C	:	Low-density lipoprotein cholesterol
M	:	Moderate practically significant difference
mg/dL	:	Milligrams per decilitre
MI	:	Motivational interviewing
mL	:	Millilitres
mm	:	Millimetre
mmHg	:	Millimetres mercury
$mmol.L^{-1}$	:	Millimoles per litre
n	:	Number
N	:	Negligible practically significant difference
NCDs	:	Non-communicable diseases
NGF	:	Nerve growth factor
NGT	:	Normal glucose tolerance
NO	:	Nitric oxide
OGTT	:	Oral glucose tolerance test
p	:	Probability of statistical significance
PAD	:	Peripheral artery disease

Post	:	Post-testing session
PPAR- γ	:	Peroxisome proliferator-activated receptor γ
PPARG	:	Peroxisome proliferator-activated receptor gamma
PreT1	:	Pre-testing session 1
PreT2	:	Pre-testing session 2
PUFA	:	Polyunsaturated fatty acid
r	:	Correlation coefficient
R	:	Rand
Reten	:	Retention testing session
RHR	:	Resting heart rate
ROS	:	Reactive oxygen species
RPE	:	Rating of perceived exertion
rpm	:	Revolutions per minute
RT	:	Resistance training
S	:	Small practically significant difference
SAT	:	Subcutaneous adipose tissue
SBP	:	Systolic blood pressure
SD	:	Standard deviation
Sdw	:	Sideways
SEP	:	Socio-economic position
SES	:	Socio-economic status
SF-36	:	Short Form 36
SGLT-2	:	Sodium-glucose cotransporter-2
SNP	:	Single nucleotide polymorphism
SS	:	Subscapular skinfold
SSp	:	Supraspinale skinfold

SU	:	Sulfonylureas
T1DM	:	Type 1 diabetes mellitus
T2DM	:	Type 2 diabetes mellitus
Th	:	Anterior thigh skinfold
THR	:	Target heart rate
TIA	:	Transient ischemic attack
TNF-α	:	Tumour necrosis factor alpha
Tr	:	Triceps skinfold
TSC	:	Total serum cholesterol
TTM	:	Trans-theoretical model
TZD	:	Thiazolidinediones
USA	:	United States of America
UTI	:	Urinary tract infection
VAT	:	Visceral adipose tissue
VGK	:	Vrye Gereformeerde Kerk
VL	:	Very large practically significant difference
VO_{2max}	:	Maximal aerobic capacity
VO_2R	:	Reserve oxygen uptake
YLD	:	Years lost to disability

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Chapter 1
Introduction & Problem Statement

1.1. Introduction

Type 2 diabetes mellitus (T2DM) is a life-style related disease of catastrophic proportions and is one of the greatest burdens to healthcare systems and providers globally (Laakso & Kuusisto, 2007). Two clinical subtypes of diabetes exist, namely type 1 diabetes mellitus (T1DM) and T2DM. They are clinically different from each other in a number of ways, although they result in a common manifestation of high blood glucose levels known as hyperglycaemia. T1DM is characterised by insufficient insulin production by the beta cells of the pancreas due to auto-immune destruction of the cells. T2DM is characterised by decreased sensitivity to the action of insulin (insulin resistance) as a result of abnormally high levels of free fatty acids in the blood stream as well as sustained hyperglycaemia. T2DM is a lifestyle-related chronic disease, and while pharmacological action is most often utilised, it can be modulated through exercise and dietary interventions, whereas T1DM requires exogenous insulin as a treatment modality (Silverthorn, 2007; Srinivasan & Davies, 2014; Motahari-Tabari *et al*., 2015). Chronic hyperglycaemia has a number of associated complications, including renal failure (Nolan *et al*., 2011), neuropathies (Bertram *et al*., 2013) and the formation of atherosclerotic plaques (Laakso & Kuusisto, 2007).

While the cardiovascular and systemic complications of long-term diabetes have been well documented (Yood *et al.*, 2009; Liu *et al.*, 2010; Mcauliffe & Christein, 2013; Umamahesh *et al.*, 2013), a study by Matsha *et al.* (2012) also found that the highest cardiovascular disease (CVD) risk is in hyperglycaemic individuals. Interestingly, they also found a trend towards increased risk of CVD in individuals of normal weight and high glycaemic levels. A common technique of assessing a non-fatal disease burden is to calculate years lost to disability (YLD). In South Africa, it was found that in 2009, 50 496 YLD could be attributed to diabetes alone, with a further 28 404 YLD being attributed to complications that arise as a result of diabetes (Bertram *et al.*, 2013).

The rise in world-wide urbanisation and consequent changes in lifestyle, are considered a primary cause for an increase in diabetes, especially in sub-Saharan Africa (Mbanya *et al.*, 2010). Relative to other sub-Saharan countries, South Africa has the highest incidence of diabetes and obesity, with prevalence rates as high as 28 % and 45 %, respectively (Kengne *et al.*, 2013). Recent research has revealed that of all African countries, South Africa has the second highest incidence rate of diabetes, of which most reported cases are under the age of 60 years old (Peer *et al.*, 2014). When examining the provincial incidence rates, a study by Erasmus *et al.* (2012) revealed that in a

community with a low socio-economic status in the Western Cape, the prevalence of diabetes and the metabolic syndrome was higher than in a similar study conducted 15 years ago in the same community (Levitt *et al.*, 1999). These results may be partially attributed to low socioeconomic status, considering the link between socioeconomic status and incidence rate of T2DM has been well-established, with a lower socioeconomic status being associated with a higher incidence of diabetes (Krishnan *et al.*, 2010; Lysy *et al.*, 2013).

Implementing effective strategies to slow, and hopefully decrease the rise in diabetes prevalence are continuously recommended, however, a number of barriers have to be overcome in the process. Primary barriers identified are poor communication between the patients and the medical personnel, and the overall medical care provided in communities with a low socio-economic status (Pilkington *et al.*, 2011; Bhojani *et al.*, 2013; Webb *et al.*, 2014). A more recent approach, based on community- or peer-led interventions, has been found to be cost effective when compared to standard individualised care, especially in cases where the individuals cannot afford, or do not have access to private health care (Prezio *et al.*, 2014). Furthermore, this type of intervention has been shown to be globally successful in modulating the physiological, as well as psycho-social parameters associated with T2DM (Kontogianni *et al.*, 2012; Weber *et al.*, 2012; Tang *et al.*, 2014; Chen *et al.*, 2015; Simmons *et al.*, 2015). With more individuals facing financial hardships, the effect of community-based interventions on disease management in low-income populations has been the focus of recent research. In resource-limited settings, almost all studies showed improvements in a number of diabetes-related parameters, with results comparable to affluent research populations (Cleland *et al.*, 2012; Prezio *et al.*, 2013; Tucker *et al.*, 2014; Assah *et al.*, 2015; McDermott *et al.*, 2015).

While clinical diabetes research in South Africa is reasonably extensive, community-based research is very limited when compared to the volume of research on a global scale. Furthermore, studies on socially disadvantaged populations are even scarcer. Only eight community-based studies have been conducted to date globally, of which five took place in communities with a low socio-economic status. Van der Does & Mash (2013) found significant improvements in self-care activities after a four-week intervention period in a number of community clinics in a rural town in George, in the Western Cape. Katz *et al.* (2009) examined whether a structured program could assist primary health care nurses in accurately identifying and managing diabetic patients in a rural setting and once again found encouraging results. They also identified a definite need for proper education and even distribution of workload in the health care sector.

While there have been positive results coming from the respective studies with respect to overall management of the disease, there remain challenges with the community health workers and/or individuals who are tasked with implementing the programs. These challenges include language barriers, lack of funding, lack of resources and extremely long working hours (Katz *et al.*, 2009; Ndou *et al.*, 2013; Van der Does & Mash, 2013; Mash *et al.*, 2014, Mash *et al.*, 2015; Muchiri *et al.*, 2015).

A number of community interventions, both for the prevention and treatment of T2DM, have been conducted outside of South Africa. Data from a recent study have shown that a 12-week lifestyle intervention program for Arab-Americans was sufficient to cause physiological changes (e.g. weight loss) and promote participation in physical activity, which was maintained for at least 24 weeks following the intervention (Jaber *et al.*, 2011). Studies such as this, as well as additional studies examining the long-term effects of lifestyle interventions, formed the theoretical basis upon which this study was built (Keyserling *et al.*, 2002; Koniak-Griffin *et al.*, 2015; Pérez-Escamilla *et al.*, 2015), with studies examining only one aspect of chronic disease or T2DM management, not proving to be as effective (Casey *et al.*, 2010; Wycherley et al., 2012; Muchiri *et al.*, 2015).

Most T2DM prevention and treatment programs rely on nurses and community health workers for their implementation in the community (Gary *et al.*, 2004). Community intervention programs in low- to middle-income countries, and communities with a low socio-economic status, have also shown promise. For example, a recent study in uninsured Mexican-Americans illustrated that community health-workers were an integral component in a program aimed at reducing HbA1c, with significant improvements seen compared to usual care (Prezio *et al.*, 2013). Furthermore, Weber *et al.* (2012) showed that the Diabetes Lifestyle Improvement Program (D-CLIP) is an adequate model to use for prevention and treatment of T2DM, as well as other chronic diseases, in low- and middle-income countries.

Exercise interventions are the most widely reported in the literature for both the prevention and treatment of diabetes (De Lemos *et al.*, 2012). It has been reported that even in the absence of individual lifestyle counselling, exercise and dietary interventions can result in a 50 % reduction in the incidence of T2DM (Sanz *et al.*, 2010). While aerobic and resistance exercise have beneficial effects on a number of diabetes-related outcomes independently there are a number of studies which suggest that combined exercise has the most beneficial effects on glycaemic, lipid and cardiovascular parameters (Sigal *et al.*, 2007; Church *et al.*, 2010; Jorge *et al.*, 2011). Furthermore, along with exercise, dietary education has been demonstrated to have a positive effect on a number of physiological variables, indirectly and directly related to diabetes, such as fasting plasma glucose, total serum cholesterol and improved dietary habits (Kontogianni *et al.*, 2012).

A very much overlooked aspect of the burden of diabetes is the economic impact on the individuals, the community, and country as a whole. Research in this area is limited, and although there is general consensus that there is a cost saving associated with diabetes interventions, the magnitude thereof varies (Gaziano *et al.*, 2007).

1.2. Problem statement

To date, no known studies in South Africa have attempted to establish a comprehensive lifestyle intervention program, consisting of dietary, physical activity, and psychological components, in a low socio-economic community. Furthermore, although there are numerous prevention and treatment programs available, there is a lack of standardised intervention procedures and practices that prevent efficient implementation of these programs on a larger scale. While programs such as the Diabetes Prevention Program (DPP) have been successfully implemented in the United States and Europe, it is challenging to implement these and similar programs in resource-limited settings in other parts of the world. There are also a number of unique challenges which are faced by community health care workers in South Africa, with only minimal viable alternatives for T2DM patients to turn to, which include the costly use of private care, or the use of allied healthcare professionals for advice on the management of their disease. These challenges highlight the need for further research into structured programs to enhance primary healthcare influences and effects.

1.3. Potential benefits of the study

To the researcher's knowledge, this is the first study in South Africa on the effectiveness of a comprehensive lifestyle intervention program in the management of T2DM in a low socio-economic community. Through comprehensive assessment and intervention, this study hopes to make a significant contribution to the overall health and quality of life of individuals in Cloetesville, and if successful, persons in a number of low socio-economic communities in Stellenbosch and the greater Boland region. However, the results of this study may be applicable to low socio-economic communities globally, facing similar limitations in care and infrastructure for the prevention, management and treatment of T2DM. Furthermore, the study hopes to show that with a comprehensive approach to management of T2DM, it is possible to achieve a long-term reduction in the prevalence of T2DM and its associated complications.

1.4. Primary aim of the study

To assess the effects of a community-based lifestyle intervention program on the physiological, psychological and health-related outcomes of individuals with type 2 diabetes mellitus, in a low socio-economic status (SES) community.

1.4.1. Research Objective Hypotheses

- Objective One – A 10-week comprehensive lifestyle intervention will result in significant changes in anthropometric, cardiovascular, haematological and functional capacity outcome variables.
- Objective Two – A 10-week comprehensive lifestyle intervention will result in significant changes in dietary habits and lifestyle behaviours.
- Objective Three – A 10-week comprehensive lifestyle intervention will result in significant changes in health-related quality of life (HRQoL).
- Objective Four – A 10-week comprehensive lifestyle intervention will result in significant changes in health professional usage behaviour.
- Objective Five – A post-intervention guide provided following a 10-week comprehensive lifestyle intervention will ensure that the significant improvements obtained during the program, will be maintained.

Chapter 2

Literature Review

2.1. Introduction

This literature review aims to outline the literature that currently exists on T2DM in low socio-economic communities, as well as providing further information on the pathophysiology, risk factors and long-term complication of T2DM. The various management strategies and treatment options will then be discussed in further detail in order to highlight the necessity of the study in this very important field.

2.2. T2DM in Communities with a Low Socio-Economic Status

The association between socio economic status (SES) and non-communicable diseases (NCDs) such as cardiovascular disease (CVD) and T2DM are well-established, with dietary (Monteiro *et al.*, 2004; Shahar *et al.*, 2005) and physical activity behaviours (Boone-Heinonen *et al.*, 2011; Chen *et al.*, 2015; Tate *et al.*, 2015) playing the most significant role in adequate management of the disease.

Diet quality and dietary composition are negatively impacted by low SES due to limited access to higher quality foods (Inglis *et al.*, 2005), reduced levels of dietary-specific knowledge and education (Hiza *et al.*, 2013) and a propensity towards traditional eating-habits and customs (Shahar *et al.*, 2005). Irrespective of the reasoning, individuals in low SES communities tend to consume less fruits and vegetables (Ball *et al.*, 2015) and therefore have lower levels of vitamin and mineral intake (Raffensperger *et al.*, 2010). Furthermore, low SES communities consume higher levels of saturated fat, sodium and processed foods than their high SES counterparts (Inglis *et al.*, 2005; Shahar *et al.*, 2005; Hiza *et al.*, 2013). The implications for these unfavourable dietary choices were highlighted in a study by Salas-Salvadó *et al.* (2011) where it was reported that reduced consumption of vegetables was associated with an increase in inflammatory marker levels, while an increased consumption of saturated fat affected insulin action and subsequent sensitivity, both of which are hallmark features of T2DM.

The lower levels of physical activity reported in low SES communities are likely linked to low levels of knowledge, self-efficacy and a lack of adequate resources to allow for participation in structured physical activity (Chen *et al.*, 2015). These findings were reinforced by a recent study by Sundquist *et al.* (2015) who found an inverse relationship between neighbourhood deprivation, which is commonly found in low SES communities, and walkability, which strongly impacted on

T2DM prevalence. The same relationship was found between neighbourhood deprivation and physical activity in a study by Boone-Heinonen *et al.* (2011), where it was reported that high neighbourhood deprivation resulted in a 16 % decrease in physical activity levels. Considering the known link between physical inactivity and the risk of developing T2DM (Peer *et al.*, 2014), the findings of these two studies are understandable. Smalls *et al.* (2015) added further credence to this theory, showing that neighbourhood aesthetics significantly impacted on glycaemic control as well as self-care activities, with impairments in glycaemic control being secondary to reduced levels of self-care. The association between low SES and self-care behaviours have been reported in diabetic and non-diabetic populations, with a significant positive association seen in both (Castillo *et al.*, 2010; Rabie *et al.*, 2015). A recent study conducted in South Africa found that the low levels of self-care in low SES communities were related to a lack of adequate knowledge (Rabie *et al.*, 2015). This finding was also in line with Pampel *et al.* (2010) who found that knowledge on health behaviours and proper management of T2DM was lower in a low-SES group compared to a high SES group. However, a 10-week community health worker (CHW) led program in a low SES community showed that by providing knowledge, there was a significant improvement in self-care behaviours among participants (Castillo *et al.*, 2010).

Socio-economic status, or socio-economic position (SEP), seems to be an important predictor of T2DM risk, with low SES being associated with T2DM development (Agardh *et al.*, 2011; Lysy *et al.*, 2013; Espelt *et al.*, 2014; Felea *et al.*, 2014). However, the true relationship between SES and the incidence of T2DM is unclear. Most studies report a higher incidence of T2DM in low-socioeconomic communities (Connolly *et al.*, 2000; Robbins *et al.*, 2001; Maty *et al.*, 2005; Krishnan *et al.*, 2010; Agardh *et al.*, 2011; Lysy *et al.*, 2013; Siddiqui *et al.*, 2015). SES comprises of a number of difference components, namely, income, educational level and occupational social class. When investigating each of these components separately, an inverse relationship with T2DM prevalence and incidence was observed with each of the respective components (Maty *et al.*, 2005; Agardh *et al.*, 2011; Lee *et al.*, 2013). However, recent research indicates that this is not always the case, with some reports on greater incidence rates in higher socio-economic status communities (Peltzer, 2009; Peer *et al.*, 2014).

What is consistent amongst studies, however, is that urban lifestyle habits are increasing the incidence rates of T2DM irrespective of socio-economic status (Soria *et al.*, 2009; Oyebode *et al.*, 2015; Siddiqui *et al.*, 2015). These include reduced physical activity (Peer *et al.*, 2014) which would lead to increases in body mass index (BMI) (Sundquist & Johansson, 1998), and decreased glycaemic control (Assah *et al.*, 2011), as well as a higher consumption of refined, processed and

high saturated fat and carbohydrate foods, all of which impair insulin functioning (Mbanya *et al.*, 2010).

Mumu *et al.* (2014) found that level of education and employment status was significantly associated with an individual's awareness and understanding of the risks of T2DM, and the development thereof. This has a direct translational economic implication as was reported in a study by Mantwill & Schulz (2015), where low health literacy and awareness were associated with higher healthcare and medication costs, both to the state and the individual suffering from T2DM. Furthermore, by improving health literacy and increasing the number of T2DM patients who achieve their treatment targets, there is an approximate 70 % reduction in medical costs (Hunt *et al.*, 2015).

A number of constraints have been identified that impact on the management and clinical outcomes of T2DM in communities with a low SES, including financial constraints, poor communication and lack of confidence in healthcare providers, as well as cultural and gender differences (Bhojani *et al.*, 2013). These underlying constraints could possibly explain the higher incidence of T2DM complications in communities with low SES. Numerous studies have confirmed this, with diabetes-related complications occurring more frequently in communities with low-socioeconomic status, with women being more affected than men (Elgart *et al.*, 2014; Collier *et al.*, 2015; Islam *et al.*, 2015).

Relative to the number of studies conducted in more affluent communities, there is limited research available that examined the various components of managing T2DM in communities with low SES (Glazier *et al.*, 2006; Lepard *et al.*, 2015). Progress has been made, however, in identifying intervention areas that are different from the main-stream T2DM management programs, which include a greater focus on health-related quality of life (HRQoL) (Nejhad *et al.*, 2013), psychosocial factors (Walker *et al.*, 2014), behavioural change strategies (Lepard *et al.*, 2015) and a greater number of contact sessions between the patient and primary or allied health practitioners (Glazier *et al.*, 2006).

2.3. Basic Pathophysiology of T2DM

Impaired insulin sensitivity, or insulin resistance, together with pancreatic β-cell dysfunction are the hallmarks underlying the pathogenesis of T2DM (Unger, 2012; Kahn *et al.*, 2014; Cornell, 2015). There are numerous compounding events that ultimately lead to the above-mentioned cellular outcomes (Kahn *et al.*, 2014). Normal glucose homeostasis, or normoglycaemia, is maintained through the synergistic actions of a number of hormones and organs (Unger, 2012; Kahn *et al.* 2014; Cornell, 2015). For the purposes of this sub-section of the literature review, the integrated

processes in the pancreas, liver, brain, skeletal muscle and gastrointestinal tract (GIT), when a non-diabetic individual ingests food, will be discussed. These processes will then be compared to an individual who is suffering from T2DM in order to better understand the pathophysiology and progression of the disease.

When a person consumes food, the production of two hormones in the GIT is up-regulated within minutes of the food being ingested in order to start the processes of maintaining glucose homeostasis. These hormones, also known as incretins, are glucagon-like peptide-1 (GLP-1) and glucose dependent insulinotropic polypeptide (GIP) (Alsahli & Gerich, 2010; Nolan *et al.*, 2011; Unger, 2012; Kahn *et al.*, 2014; Cornell, 2015). GLP-1 and GIP up-regulation activates the release of insulin from the β-cells in the pancreas, and suppresses glycogenolysis and gluconeogenesis in the liver and slow gastric emptying. They also prevent the secretion of glucagon from the α-cells in the pancreas and promote the uptake of circulating glucose into adipose tissue and skeletal muscles, all in an effort to maintain blood glucose levels between 85 – 140 mg/dL (Alsahli & Gerich, 2010; Nolan *et al.*, 2011; Unger, 2012; Kahn *et al.*, 2014; Cornell, 2015). Amylin, leptin and ghrelin act on the brain by regulating satiety levels, which will reduce the likelihood of further food consumption, thereby aiding in the control of blood glucose levels (Unger, 2012; Cornell, 2015). As blood glucose levels drop over time after a meal, circulating levels of GLP-1 and GIP decrease, and the subsequent processes these hormones triggered, are down-regulated or up-regulated, thereby ensuring that the individual does not fall into a hypoglycaemic state (Alsahli & Gerich, 2010; Unger, 2012; Kahn *et al.*, 2014; Cornell, 2015).

Numerous studies acknowledged that T2DM is a progressive disease that develops over a number of years, and is preceded by a number of stages, which ultimately end in T2DM (Alsahli & Gerich, 2010; McKenney & Short, 2011; Unger, 2012; Cornell, 2015). The first of these stages is the boundary between normal glucose tolerance (NGT) and impaired glucose tolerance (IGT), or put more simply, the inability of the body to adequately metabolise glucose. In diagnostic settings, an oral glucose tolerance test (OGTT) is used to evaluate whether an individual is suffering from IGT.

As a result of unhealthy lifestyle choices and habits, there is a decrease in insulin sensitivity and β-cell function. Despite this reduced capacity, blood glucose homeostasis following a meal is maintained, as the β-cells are still able to secrete sufficient insulin to promote the uptake of glucose into the skeletal muscle and adipose tissue, as well as promoting the hepatic storage of glycogen (Alsahli & Gerich, 2010). Without appropriate treatment occurring at this point, there are further decreases in β-cell function and a concomitant decrease in insulin sensitivity. The β-cells of the pancreas are still able to maintain glucose homeostasis during a fasted state, however, their capacity to regulate blood glucose levels after a meal is significantly affected, thereby resulting in sustained

elevated levels of blood glucose. Once again, should no treatment regime be implemented at this point, there will be a further reduction in β-cell function as well as a further decrease in insulin sensitivity. At this stage, due to the reduced β-cell function, blood glucose homeostasis in both the fasted and non-fasted state, is disrupted, with sustained hyperglycaemia being reported, and the individual being diagnosed with impaired fasting glucose (IFG). The final stage of the disease progression is T2DM, which is characterised by further decreases in insulin sensitivity and a significant reduction in β-cell functioning. In most cases, by the time of diagnosis, individuals have lost 50 - 80 % of their β-cell numbers, thereby making the reversibility of T2DM so challenging, while also highlighting the need for early intervention (Alsahli & Gerich, 2010; McKenney & Short, 2011; Unger *et al.*, 2011; Cornell, 2015).

The physiological mechanisms behind the destruction of the β-cells of the pancreas are far-reaching and extremely complex, with some areas still under investigation. However, what has been well established is that sustained hyperglycaemia and increased levels of circulating free fatty acids cause β-cell apoptosis through reactive oxygen species (ROS) and altered gene expression. Furthermore, higher levels of pro-inflammatory cytokines, such as tumour necrosis factor α (TNF-α) and interleukin 1β (IL-1β), decrease β-cell proliferation and increase the rate of apoptosis. Interestingly, the incretins (GLP-1 and GIP), which usually facilitate proliferation of the β-cells, are less effective in persons with T2DM, and therefore an increase in β-cell apoptosis is seen (Alsahli & Gerich, 2010; McKenney & Short, 2011; Nolan *et al.*, 2011; Unger *et al.*, 2011; Cornell, 2015).

Insulin resistance is the end result of glucotoxicity (Cornell, 2015), in addition to having a large genetic component (Henninger *et al.*, 2015). As the name suggest, high levels of blood glucose has toxic effects on a number of organs and/or tissues, namely, the liver, muscle and adipose tissue. Sustained hyperglycaemia causes destruction and alterations in mitochondrial DNA, which would impact significantly on energy metabolism (Zheng *et al.*, 2015). Disruption to mitochondrial energy metabolism results in increased levels of free fatty acids (FFA) in the blood stream. These high levels of FFA's alter the intracellular mechanisms of skeletal muscles, which results in diminished activity of the glucose transporter type 4 (GLUT4), even when insulin levels are at a concentration that should ordinarily elicit a response. Less glucose is therefore taken into the muscle cell, with the end result of sustained hyperglycaemia (Yki-Järvinen, 2010; McKenney & Short, 2011; Nolan *et al.*, 2011; Unger *et al.*, 2011; Cornell, 2015). In response to this there is a further up-regulation of insulin production to combat the hyperglycaemia. This cycle is what results in insulin resistance and ultimately, in the latter stages of disease progression, to the destruction of pancreatic β-cells, which in turn results in lower insulin secretion and therefore the necessity to use exogenous insulin in

addition to oral anti-hyperglycaemic medication (Yki-Järvinen, 2010; McKenney & Short, 2011; Nolan *et al.*, 2011; Cornell, 2015).

Insulin resistance has also been associated with overweight and obesity, and specifically the presence of visceral adipose tissue (VAT) (Snel *et al.*, 2012). Insulin promotes the storage of fat, with high levels of VAT being associated with higher levels of circulating FFA's, thereby exacerbating the mechanisms described above.

The role of gene's cannot be ignored, with numerous studies reporting a familial link to T2DM, as well as genetic susceptibility to T2DM as a result of abnormalities in the mitochondrial DNA (Emerson *et al.*, 2009; Vaxillaire & Froguel, 2010; Nolan *et al.*, 2011; Rieusset, 2011; Schäfer *et al.*, 2011; Unger, 2012; Cheng & Almeida, 2014; Kahn *et al.*, 2014). The pathogenesis of T2DM in most individuals is polygenic in origin, with at least 18 single nucleotide polymorphisms (SNP) and countless more gene loci being identified that contribute to the development of T2DM through β-cell dysfunction and intracellular abnormalities, all triggered by environmental factors such as obesity, physical inactivity, and dietary habits, to name a few (Vaxillaire & Froguel, 2010; Nolan *et al.*, 2011; Rieusset, 2011; Unger, 2012; Cheng & Almeida, 2014; Kahn *et al.*, 2014). There is further evidence that in progeny of individuals who had T2DM, adipocyte hypertrophy and adipocyte dysfunction was present, in addition to higher measurements of insulin resistance (Henninger *et al.*, 2015).

2.4. Incidence Rates of T2DM

Type 2 diabetes mellitus is one of the most common NCDs worldwide, with an estimate global prevalence of approximately eight percent, or put more crudely, a total of approximately 382 million people (Ma & Tong, 2010; Wändell & Carlsson, 2013; Wang *et al.*, 2015). What is of greater concern, is the growing numbers of children and adolescents that are being diagnosed with T2DM (Craig, 2009; Benhalima *et al.*, 2011; Ke *et al.*, 2015). North America (including Canada, the United States of America, and Mexico) is collectively the region with the highest global prevalence of T2DM (between 10 – 12 %), whereas Saudi Arabia is the country with the highest prevalence of T2DM, with 19 % of its population being affected (Ma & Tong, 2010). A number of recent studies have also identified Asia as a region of concern, with an exponential rise in T2DM diagnoses being reported in both urban and rural populations (Nagaya *et al.*, 2006; Liu *et al.*, 2007; Ke *et al.*, 2015; Oyebode *et al.*, 2015; Wang *et al.*, 2015). Furthermore, the once apparent gap between urban and rural communities is rapidly diminishing, probably due to westernised influences on diet and lifestyle habits (Liu *et al.*, 2007; Motala *et al.*, 2008; Oyebode *et al.*, 2015; Siddiqui *et al.*, 2015).

In South Africa, the prevalence of T2DM was estimated to be between four and nine percent, and the overall prevalence amongst woman was higher than in men (Motala *et al.*, 2008; Peltzer, 2009; Peer *et al.*, 2014). In contrast, however, in Middle Africa (e.g. Angola, Cameroon, Congo) and Eastern Africa (E.g. Burundi, Ethiopia, Kenya) the prevalence rates of men were found to be higher than in women (Hilawe *et al.*, 2013). Possible reasons for these differences were related to lifestyle behaviour differences such as alcohol consumption and smoking, differences in the levels of physical activity, as well as differences in psychosocial stress (Motala *et al.*, 2008; Peltzer, 2009; Hilawe *et al.*, 2013; Peer *et al.*, 2014).

The economic cost of T2DM to both the affected individual, as well as the public and private medical sector, cannot be discounted. Some studies examining Sub-Saharan Africa have reported a cost per patient of approximately $ 2 000 - $ 3 000 (approximately R 27 000 – R 41 000) per year, which includes in-hospital care and medications, among other services (Kengne *et al.*, 2013; Peer *et al.*, 2014). Globally this figure is substantially higher with approximately $ 200 billion being spent in the United States of America (USA) alone and with the total global costs approaching $ 400 billion (Ali *et al.*, 2010). What is encouraging, however, is that a recent study conducted in the South African setting outlines a framework upon which a cost-effective prevention program can be built in order to combat the rising healthcare costs (Volmink *et al.*, 2014). This framework would enhance the working dynamic and cohesion between health professionals in the primary healthcare sector, which could result in more favourable patient outcomes.

2.5. Risk Factors for T2DM

There are a number of both non-modifiable and modifiable risk factors for the development of T2DM. Non-modifiable risk factors are inherent factors that cannot be manipulated to alter the risk of developing T2DM, whereas modifiable risk factors can be altered. A large proportion of the modifiable risk factors are lifestyle related, with improvements in each of the respective categories, resulting in a concomitant improvement in disease management parameters.

2.5.1. Non-Modifiable Risk Factors

2.5.1.1. Age

It has been well established that the risk for developing T2DM increases with advancing age, with the current peak incidence rate occurring between 40 and 59 years of age (Chege, 2010; Mbanya *et al.*, 2010; Bertram *et al.*, 2013; Peer *et al.*, 2014). This is no different in Southern and South Africa, with the highest incidence rate occurring in this age group. When examining the gender differences with respect to age, it was found that women tend to develop T2DM at a slightly younger age than

their male counterparts, with peak incidence occurring between 35 and 55 years of age (Fletcher *et al.*, 2002; Bertram *et al.*, 2013). One possible reason for this occurrence has been postulated to be gestational diabetes mellitus (GDM) which affects approximately 20 percent of pregnant women (Mohan & Chandrakumar, in press; Hod *et al.*, 2015) and increases the risk of developing T2DM following the pregnancy (Wang *et al.*, 2013; Hod *et al.*, 2015). While there is still a higher proportion of adults with T2DM relative to adolescents and children, youth onset T2DM is becoming more prevalent, with a substantial increase of approximately 35 % over the last decade (Peer *et al.*, 2014; Amed, 2015).

A number of factors contribute to the development of T2DM in later life. First and foremost is the effect of poor diet and physical activity habits, which are less prevalent in children and adolescents than in adults (Hiza *et al.*, 2013). Secondly, and very importantly, there is the presence of mitochondrial dysfunction which impacts on insulin action, increases the levels of ROS, and promotes the destruction of the β-cell of the pancreas (Pinkney *et al.*, 2012; Marzetti *et al.*, 2013; Lane *et al.*, 2015).

2.5.1.2. Gender

There is still no clear indication whether men or women have a higher incidence of T2DM, with a number of studies indicating differences by global region (Almdal *et al.*, 2008; Tuei *et al.*, 2010; Hilawe *et al.*, 2013). However, studies that have examined precursors to T2DM, namely IGT and IFG, found differences in the incidences of T2DM between men and women. In these instances, men were found to have a higher incidence of IFG, whereas women have a higher incidence of IGT (Hilawe *et al.*, 2013). Possible mechanisms for higher levels of IFG in men are related to lifestyle habits, where men are found to be more likely to smoke than women (Townsend *et al.*, 2006) and insulin sensitivity purportedly decreases with regular smoking (Nakanishi *et al.*, 2000; Rafalson *et al.*, 2009). Furthermore, it has been shown that the eating habits of men are generally poorer than that of women, with lower levels of vegetables and higher levels of fats and sugars being consumed by men (Hiza *et al.*, 2013). The higher instances of IGT in women are most likely hormonally-related, with increased levels of oestrogen and progesterone impairing insulin sensitivity (Van Genugten *et al.*, 2006).

2.5.1.3. Family History and Genetic Susceptibility

There is a growing body of evidence which suggests that a family history of T2DM predisposes an individual to developing the disease. This is apparent in a number of studies globally, as well as in Southern Africa (Kelestimur *et al.*, 1999; Motala *et al.*, 2008; Emerson *et al.*, 2009; Mbanya *et al.*, 2010; Nolan *et al.*, 2011; Peer *et al.*, 2014). It appears that underlying genetic predisposition is

already present, but is triggered by certain environmental stimuli such as obesity, physical inactivity and poor lifestyle habits (Emerson *et al.*, 2009; Nolan *et al.*, 2011).

A number of different loci have been identified that substantially increase the likelihood of developing T2DM in a lifetime, and can be separated into two categories. Firstly, there are loci that are implicated in the impairment of β-cell function (GCK and GCKR), while there are also loci that are implicated in impaired insulin sensitivity (PPARG and IRS1) (Nolan *et al.*, 2011; Kahn *et al.*, 2014). Glucokinase (GCK) and glucokinase regulator (GCKR) are two such gene loci that have been implicated in the β-cell dysfunction, with defects in these genes resulting in sustained hyperglycaemia and resultant β-cell destruction (Gloyn, 2003; Mohás *et al.*, 2010; Ling *et al.*, 2011). Peroxisome proliferator-activated receptor gamma (PPARG) and insulin receptor substrate-1 (IRS1) are genes responsible for fatty acid metabolism and insulin action, respectively, with mutations within these genes resulting in impaired insulin sensitivity (Rangwala & Lazar, 2004; Rung *et al.*, 2009; Bermúdez *et al.*, 2010).

2.5.1.4. Ethnicity

Those of Middle Eastern, and Indian descent appear to have the highest risk of developing T2DM, with Mexican-Americans having the next highest risk. People of European descent follows, while individuals of Black African descent have the lowest risk (Ma & Tong, 2010; Tuei *et al.*, 2010; Danaei *et al.*, 2011; Peer *et al.*, 2014; Oyebode *et al.*, 2015). Theories that have been postulated to explain these differences include genetic susceptibility, differing levels of urbanisation and differences in the various phases of epidemiological transition (Tuei *et al.*, 2010; Choukem & Mbanya, 2013; Assah *et al.*, 2015; Oyebode *et al.*, 2015). Recent research on a South African population portray a slightly different picture, in which they found that differences in subcutaneous adipose tissue (SAT) and VAT between black and white South African women, is the mitigating factor in metabolic risk. In a study by Goedecke *et al.* (2015) it was found that black women with ectopic fat distribution had reduced insulin sensitivity when compared to white women who presented with the same fat distribution pattern. Additional factors proposed to influence insulin resistance in women of African ancestry are differences in adipose glucocorticoid metabolism, and adipose tissue inflammation, although more research is needed to substantiate these claims (Goedecke *et al.*, 2013).

2.5.1.5. Uterine Environment

There is a definitive link between malnutrition during pregnancy and the incidence of T2DM in later life (Alsahli & Gerich, 2010; Peer *et al.*, 2014). In addition, sustained hyperglycaemia and gestational diabetes have been shown to increase the risk of T2DM in the offspring and future

generations (Alsahli & Gerich, 2010; Ma *et al.*, 2015). It is proposed that in both of these environments, β-cell development is in some way disrupted, as well as being conditioned to adapt should over nutrition occur at a later stage in life (Alsahli & Gerich, 2010; Peer *et al.*, 2014; Ma *et al.*, 2015).

2.5.2. Modifiable Risk Factors

2.5.2.1. Urbanisation

Over the last decade, there has been a slow but steady rise in the number of individuals who are transitioning from rural to urban areas as places of residence (Muthuri *et al.*, 2014). This change has resulted in a number of lifestyle-related challenges, such as reduced occupational and recreational physical activity and increased stress levels (Muthuri *et al.*, 2014). Furthermore, changes in nutritional habits to more refined and convenience foods are additional compounding factors that increase the likelihood of an individual developing T2DM. Interestingly, Mbanya *et al.* (2010) found that those individuals who moved from a rural environment into an urban environment were more likely to have a higher BMI than those who had lived in an urban environment for most of their life.

2.5.2.2. Sedentary Behaviour

While physical inactivity has in the past incorporated sedentary behaviour as part of its global definition, there is an overwhelming number of studies that have been published over the last five years that provide substantial evidence as to why sedentary behaviour should be considered an independent risk factor for the development of T2DM and other NCDs (Healy *et al.*, 2008; Owen *et al.*, 2010; Thorp *et al.*, 2011; King *et al.*, 2016). Sedentary behaviour is traditionally measured via the use of an accelerometer, and can be quantified depending on the type of activity a person engages in (Chastin & Granat, 2010; Quante *et al.*, 2015). These activities could range from sitting watching television, extended periods of driving in a vehicle, or sitting for extended periods of time as part of an individuals occupation (Owen *et al.*, 2010; Thorp *et al.*, 2011; King *et al.*, 2016). It is evident that intermittent bouts of sedentary behaviour are preferable to extended bouts, and have shown to be associated with a better metabolic and cardiovascular outcome (Healy *et al.*, 2008; Chastin & Granat, 2010). A number of studies have been conducted in T2DM populations, with lower levels of sedentary behaviour, in conjunction with increased levels of physical activity have shown to improve insulin sensitivity and weight loss over an extended period of time (Lahjibi *et al.*, 2013; Yates *et al.*, 2015). Furthermore, it was found that men and women with T2DM who had higher levels of sedentary behaviour, had significantly higher levels of inflammation compared to

those who were found to be less sedentary (Falconer *et al.*, 2014). Pedometer-based studies have also been utilised to measure the level of sedentary behaviour, as well as physical activity in T2DM populations, with encouraging short- and long-term results with respect to the reduction in sedentary behaviours reported (De Greef *et al.*, 2010; De Greef *et al.*, 2011), although increasing physical activity will not necessarily result in a concomitant decrease in sedentary behaviour (Wisse *et al.*, 2010).

2.5.2.3. Physical Activity

Habitual participation in some form of physical activity has been associated with a decreased risk of developing T2DM and in some cases up to 34 % reduction in risk was found (Kelestimur *et al.*, 1999; Bi *et al.*, 2012; Ding *et al.*, 2015). Lower levels of physical activity are further associated with higher levels of obesity, as well as a higher incidence of IGT (Mbanya *et al.*, 2010; Peer *et al.*, 2014). Aside from the impact of low levels of physical activity on the risk of developing T2DM, there is a significant increase in the risk of developing other cardiovascular and NCD's, with a higher all-cause mortality rate (Fletcher *et al.*, 2002; Bi *et al.*, 2012; Wu *et al.*, 2014). An important finding by Hu *et al.* (1999) showed that walking may reduce the risk of developing T2DM to the same extent as higher intensity exercise, which, considering the high levels of obesity in T2DM individuals is encouraging due to the decreased load on the joints, and therefore reduced risk of injury.

The question of whether exercise alone can reduce risk of T2DM when compared to diet and exercise combined, has been examined extensively (Pan *et al.*, 1997; Li *et al.*, 2008). In a large scale study conducted by Eriksson & Lindgiirde (1991) it was found that only 11 % of the participants who took part in the study and received supervised exercise training and dietary advice, were diagnosed with T2DM at the five-year follow-up testing, compared to 21 % in the control group. Two long-term studies by Tuomilehto *et al.* (2001) and Pan *et al.* (1997) found similar results. In the first study, participants diagnosed with IGT were randomised to a physical activity and dietary advice group with individualised advice, while the control group received the usual care. At a four year follow up, only 10 % of the experimental group had been diagnosed, while more than double from the control group were known to be diagnosed with T2DM (Tuomilehto *et al.*, 2001). A further follow-up of these participants an additional three years later and in the absence of any structured experimental program, found similar findings, with the experimental group faring far better than the control group, with an approximately 40 % lower T2DM incidence rate (Lindström *et al.*, 2006). In the second study, participants with IGT were randomised into one of four groups, control, diet only, exercise only, or combination diet and exercise. At the six-year follow up, all three of the experimental conditions resulted in significantly lower incidence rates of

T2DM, with the exercise only group showing the lowest incidence in this case (Pan *et al.*, 1997). Once again, at an extended follow-up 14 years after the cessation of the trial (i.e. 20 year follow-up), (Li *et al.*, 2008) found that the incidence rate of the combined intervention groups was 43 % lower than that of the control group, with no data provided on the exercise only group. Most of these studies worked on the principle adopted by the ACSM that requires individuals to participate in at least 150 minutes of moderate to vigorous physical activity per week (American College of Sports Medicine, 2014), and suggest that exercise in isolation can result in lowering the risk of T2DM. However, long-term follow up studies suggest that a combination of both dietary changes and regular physical activity achieves better results.

2.5.2.4. Adiposity

In this instance, adiposity refers to the BMI, waist circumference and fat distribution patterns of an individual. Obesity (BMI $\geq$ 30 kg.m^{-2}) has become one of the leading underlying causes of NCD world-wide with an estimated prevalence of approximately 30 % (Costanzo *et al.*, 2015). If considering individuals who are overweight, or whose waist circumference falls outside of the established norms, this prevalence rate increases to almost 70 % (Tuei *et al.*, 2010; McKenney & Short, 2011; Costanzo *et al.*, 2015). This is a grievous figure when it is considered that of the over 300 million people suffering from T2DM, only 15 % would be considered to have a normal weight (approximately 45 million people). What is of further concern, is that even at BMI values that are at the upper limit of the normal range (23.0 – 24.9 kg.m^{-2}), the risk for the development of T2DM is substantially increased (Hauner, 2010; Costanzo *et al.*, 2015). De Onis, *et al.* (2010) found that by 2020 almost 10 % of children would be classified as obese, with a prevalence rate of almost 13 % in Africa alone.

Fat distribution patterns are particularly important, considering that VAT has a strong positive correlation to the development of T2DM, whereas the correlation to subcutaneous adipose tissue (SAT) is smaller and less concrete (Fox *et al.*, 2007). A large-scale study conducted in a South African population found that 10 % of men, and almost 50 % of women have a waist circumference that is higher than the designated norm by the ACSM for reduced cardiovascular risk, thereby indicating a greater degree of VAT (Shisana *et al.*, 2014). This is particularly concerning considering that high levels of both VAT and SAT substantially increase the risk of adverse events in women more than in men (Fox *et al.*, 2007). In the Southern Africa region, levels of overweight and obesity are high, with the prevalence rates between 12 % and 60 % (Mbanya *et al.*, 2010).

2.5.2.5. Diet and Lifestyle Behaviours

Due to the low manufacturing cost associated with processed and refined foods, more and more individuals are changing their dietary and lifestyle behaviours in favour of convenience and cost-effectiveness, while sacrificing healthy choices in the process (Peer *et al.*, 2014). In the South African, as well as sub-Saharan African context, there has been a definite shift towards nutrition-related NCD, otherwise known as a nutrition transition (Abrahams *et al.*, 2011). This is evident in the increasing number of individuals classified as overweight or obese, compared to the limited number of children born which are classified as underweight. Furthermore, the lack of dietary variety and food diversity, as well as lower nutrient content provide further evidence indicating that rural South Africans are engaging in non-favourable dietary habits (Abrahams *et al.*, 2011; Steyn *et al.*, 2012). Numerous studies have found that high consumption of sugar, refined products, and trans-fats are associated with an increased risk of developing T2DM, while consumption of monounsaturated fats, fibre and fresh vegetables are associated with a decrease in risk (Itsiopoulos *et al.*, 2011; Bi *et al.*, 2012; Kontogianni *et al.*, 2012; Grosso *et al.*, 2014; Cornell, 2015). Relative to T2DM, further research should address binge eating as a recent study by Herbozo *et al.* (2015) found that individuals who practiced binge eating had a higher BMI, and were less likely to adhere to healthy eating plans.

Individuals who are diagnosed with IGT are recommended to decrease their total carbohydrate and saturated fat intake as a first-line measure to prevent progression to T2DM (Mann *et al.*, 2004; Feinman *et al.*, 2014). In most cases, it is the type and amount of carbohydrate consumed that is the issue in glycaemic control, and complete elimination of carbohydrate from the diet is not recommended (Mann *et al.*, 2004; American Diabetes Association *et al.*, 2008).

There are a number of variables that could affect glycaemic response and control when consuming carbohydrates. These include the type of starch, the manner in which food is prepared, the extent to which the food is processed, the macronutrient composition of the meal and whether or not insulin resistance is present (American Diabetes Association *et al.*, 2008). The glycaemic index (GI) of foods is particularly important for those at risk of developing T2DM, with low GI foods such as barley, lentils, legumes and rye bread having a more favourable glycaemic response than high GI foods (American Diabetes Association *et al.*, 2008). A lower glycaemic response would place less pressure on the pancreatic β-cells to produce insulin and would decrease the pro-inflammatory state that hyperglycaemia induces.

With regards to the consumption of dietary fat, low levels of trans-fat in the diet are associated with a better outcome and a lower likelihood of developing T2DM. These improvements would be secondary to the reduced levels of plasma low-density lipoprotein cholesterol (LDL-C) with a

concomitant increase in high-density lipoprotein cholesterol (HDL-C) concentration, both of which would improve insulin function (Howard, 2002; American Diabetes Association *et al.*, 2008; Jelinek *et al.*, 2013). Furthermore, consumption of monounsaturated and polyunsaturated fats, which are commonplace in the Mediterranean diet, have been shown to improve glycaemic control and insulin action through the same method of action as described above (Barnard *et al.*, 2009; Esposito *et al.*, 2010; Itsiopoulos *et al.*, 2011; Koloverou *et al.*, 2014).

The consumption of daily dietary protein, which is nutrient dense, should be approximately 15 % in individuals who are at risk of developing T2DM (American Diabetes Association *et al.*, 2008). The effect of protein on glycaemic control is related to the increase in serum insulin levels rather than the lower glycaemic response (Gannon *et al.*, 2001; Franz, 2002).

Regular consumption of alcohol, as well as smoking on a regular basis, have been implicated in the risk of developing T2DM, with an almost two-fold increase in risk (Kelestimur *et al.*, 1999; Molsted *et al.*, 2014; Ding *et al.*, 2015). Two recent studies have reported that those individuals who are exposed to passive or environmental smoke are also at risk for developing T2DM, when compared to those who are not exposed, providing the evidence that non-smokers are also at risk (Ko *et al.*, 2011; Wei *et al.*, 2015). One would expect that following the cessation of smoking there would be an improvement in T2DM related parameters. However, even the cessation of smoking does not immediately have a direct positive impact on glycaemic control in type 2 diabetics. It has been reported that a total of three years of complete abstinence from smoking is required, in order to see improvements in glycaemic control (Lycett *et al.*, 2015).

There seems to be a general consensus that moderate consumption of alcohol protects against the development of T2DM due to its ability to enhance insulin sensitivity. However, at high levels, and especially when beer and spirits are consumed, there is a substantial increase in the risk of developing T2DM (Carlsson *et al.*, 2000; Carlsson *et al.*, 2005; Baliunas *et al.*, 2009). Binge drinking is also associated with an increased risk of T2DM development due to the supposed damage to the α-cells of the pancreas, which would result in alcoholic ketoacidosis and high levels of blood glucose (Prevost *et al.*, 2012).

2.5.2.6. Psychological Stress

The presence of depression, and its resulting consequences, have been widely reported in diabetic patients, and in the last decade, have also been implicated as a possible risk factor for T2DM (Pibernik-Okanovic *et al.*, 2005; Knol *et al.*, 2006; Peer *et al.*, 2014; Ding *et al.*, 2015). The mechanism underlying this risk is still being widely debated, however, the hypothalamic-pituitary-adrenal axis (HPA) seems to play a central role in the pathogenic mechanism (Gragnoli, 2012).

Sleep duration, which is indirectly related to depressive symptoms, is also implicated in the risk of developing T2DM, with individuals sleeping more than nine hours, or less than six hours being equally at risk, while those who slept between seven and eight hours an occasion, had the lowest risk (Gutiérrez-Repiso *et al.*, 2014; Cooper *et al.*, 2015; Ding *et al.*, 2015).

2.6. Long Term-Complications of T2DM

The long-term effects of living with T2DM are well documented and vary in severity depending on the management and complexity of the disease. Some of the most common long-term complications, some microvascular and others macrovascular, are discussed in further detail below.

2.6.1. Peripheral Neuropathy

Peripheral neuropathy, in all its various forms, is an extremely debilitating complication of T2DM and occurs in between 14 and 30 % of type 2 diabetics, and appears to affect women to a greater extent than men (Sharma *et al.*, 2010; Ziegler, 2010; Bertram *et al.*, 2013). Only a small percentage of these individuals progress to the stage where limb amputations are necessary, however, foot ulcerations and neuropathic pain impact significantly on quality of life and increased morbidity (Liu *et al.*, 2010; Sharma *et al.*, 2010; Ziegler, 2010; Sobngwi *et al.*, 2012; Salvotelli *et al.*, 2015). The pathological mechanisms behind peripheral neuropathy are multifaceted and complex. Increased levels of ROS and up-regulation of pro-inflammatory cytokines, reduced expression of neuroprotective factors such as nerve growth factor (NGF) and neurotropin-3 and reduced axonal transport, as well as alterations to nerve membrane structures, all contribute to the development of peripheral neuropathy, as well as its progression (Ziegler, 2010; Tahrani *et al.*, 2012). There are a number of pharmacological and non-pharmacological treatment options to reduce the painful symptoms associated with peripheral neuropathy (Ziegler, 2010; Tuttle *et al.*, 2012; Shehab *et al.*, 2015). Vitamin D deficiency has been identified as an independent risk factor for the development of peripheral neuropathy (Shehab *et al.*, 2012), with extra supplementation resulting in an improvement in symptoms (Shehab *et al.*, 2015). Exercise has also been reported to be effective in reducing the progression of peripheral neuropathy, with an eight-week study by Dixit *et al.* (2014) finding significantly improved nerve conduction velocities, which would ultimately improve the individual's exercise capacity.

2.6.2. Retinopathy

The incidence of diabetic retinopathy is slightly lower than peripheral neuropathy, with an overall prevalence rate of between 14 and 20 % (Scanlon, 2010; Shaikh *et al.*, 2010). However, it appears that up to 50 % of individuals with T2DM suffer to some extent with a reduction in vision (Liu *et*

al., 2010; Scanlon, 2010; Sobngwi *et al.*, 2012). Similar to peripheral neuropathy, the risk of developing diabetic retinopathy increases with disease duration and severity (Scanlon, 2010; Shaikh *et al.*, 2010; Munch *et al.*, 2011), and is also influenced by plasma homocysteine levels (Looker *et al.*, 2003), blood pressure (Abougalambou & Abougalambou, 2015), serum lipid levels (Scanlon, 2010) and the presence of microalbuminuria (Boelter *et al.*, 2006).

There are a number of events that occur, some simultaneously, that lead to the eventual development of diabetic retinopathy and include endothelial dysfunction characterised by micro aneurysms of, and increased permeability of the retinal capillaries (Collier *et al.*, 1986; Joris *et al.*, 1987; Stitt *et al.*, 1995), smooth muscle death (Malecki *et al.*, 2008) and retinal ischemia secondary to capillary occlusion (Gardiner *et al.*, 2007; Scanlon, 2010). Diabetic retinopathy accounts for almost one quarter of the cases world-wide where individuals are classified as blind (Cunningham, 2001). Treatment options are extremely limited in these severe cases, with laser to target the micro aneurysms and pharmacological therapies being the only currently used modalities (Scanlon, 2010). The mechanism of action of the laser treatment, which is the most successful treatment strategy, is thought to be linked to positive histopathological and biochemical changes (Apple *et al.*, 1973; Ogata *et al.*, 2001), and an improvement in oxygen delivery to the affected area (Arnarsson & Stefánsson, 2000). These benefits have obvious implications on an individual's HRQoL, allowing them to participate in activities that they may not ordinarily consider.

2.6.3. Cardiovascular and Cerebrovascular Disease

Cardiovascular diseases such as hypertension and peripheral artery disease (PAD) often occur prior to, or following the development of T2DM, and in conjunction with other metabolic diseases (Nilsson, 2010). The risk of an adverse cardiac event and/or subsequent death, is increased by two to five times in individuals with T2DM, with conflicting evidence as to whether men or women are at a greater risk (Nilsson, 2010; Umamahesh *et al.*, 2013; Shah *et al.*, 2015). The incidence of CVD and cardiovascular (CV) events varies greatly depending on geographical location, ethnicity and socio-economic status (Umamahesh *et al.*, 2013). Lifestyle habits, and not diabetes duration, are the main predictors for the development of most CVD (Liu *et al.*, 2010; Sobngwi *et al.*, 2012; Umamahesh *et al.*, 2013; Padilla & Peters, 2015). A further cardiovascular complication, which occurs exclusively in diabetic patients, is cardiac autonomic neuropathy (CAN), which alters the synergistic action of the sympathetic and parasympathetic nervous system on the heart. Interestingly, cardiac irregularities are also found in T2DM patients who do not present with CAN (Schnell *et al.*, 2002).

The global prevalence of cerebrovascular events (CVE) in individuals with T2DM is between four and nine percent, despite having a two fold-increase in risk for a CVE when compared to non-diabetics (Amory & Weinberger, 2010; Liu *et al.*, 2010; Sobngwi *et al.*, 2012). Interestingly, the likelihood of a transient ischemic attack (TIA) is lower in persons with T2DM, although the progression to a serious CVE is substantially higher (Sobngwi *et al.*, 2012). Furthermore, the morbidity and mortality rates following a CVE are higher in type 2 diabetics than their non-diabetic counterparts (Weinberger *et al.*, 1983; Tuomilehto *et al.*, 1996; Johnston *et al.*, 2007). The pathophysiology underlying the development of cerebrovascular disease in type 2 diabetics is multifaceted in nature. Carotid intima-media thickening has been reported in T2DM, and is a marker for early stage endothelial dysfunction (Malecki *et al.*, 2008). A strong association between stroke risk and thickening of the carotid intima-media exists (Tsivgoulis *et al.*, 2006). This thickening, together with impaired nitric oxide (NO) action, and an increased coagulability, all predispose an individual to a CVE (Yamada *et al.*, 2000; Air & Kissela, 2007; Taffi *et al.*, 2008).

2.6.4. Cancer

There have been a number of studies over the last two decades which have implicated T2DM in the risk of developing cancer of the pancreas, colon, liver, bladder and breast (Yood *et al.*, 2009; Noto *et al.*, 2010; Krämer *et al.*, 2012; Mcauliffe & Christein, 2013; Gong *et al.*, 2015). The exact pathological mechanism behind development of the various cancers is still not completely understood, although two hypotheses exist. The first hypothesis is related to the effects insulin has on the insulin receptor, insulin-like growth factor 1 (IGF-1) and its respective binding proteins (IGFBP-1 and IGFBP-2). It is proposed that by inhibiting IGFBP-1 and IGFBP-2, there are increased levels of IGF-1, which would alter the balance of cell proliferation and apoptosis (Yood *et al.*, 2009; Gong *et al.*, 2015). A second hypothesis is that sustained hyperglycaemia results in the production of ROS, which in turn would damage cellular DNA, which is ultimately the primary carcinogenic step (Noto *et al.*, 2013; Gong *et al.*, 2015). Adequate management of T2DM disease progression is therefore imperative to reduce the risk of cancer developing.

2.6.5. Sexual Dysfunction

Erectile dysfunction (ED) and female sexual dysfunction (FSD) are common occurrences in individuals suffering from T2DM, with the prevalence of ED being significantly higher than FSD (Giugliano *et al.*, 2010; Giugliano, *et al.*, 2010a). The prevalence of ED in men is between 35 and 50 %, although in some cases it is as high as 60 %, whereas FSD is observed in approximately 20 % of women with T2DM (De Berardis *et al.*, 2007). The prevalence of ED increases with age and disease duration, independent of the age-related decrease in testosterone levels (Derosa *et al.*,

2015). The pathophysiology underlying ED in men with T2DM is related to failure of NO to induce smooth muscle relaxation, and endothelial dysfunction within the corpus cavernosum (Price, 2010). FSD is characterised by decreased arousal and lubrication, with a similar pathophysiology to ED, although there is still a paucity of data to verify these findings (Giugliano, *et al.*, 2010a; Price, 2010). Psychological well-being and health related quality of life are significantly affected by sexual dysfunction (Litwin *et al.*, 1998; Malavige *et al.*, 2014) and therefore any strategy to improve or reverse this complication would have wide-reaching effects into other areas of T2DM management.

2.7. Management of T2DM

Management of T2DM can be separated into two general categories, with several sub-categories. Pharmacological and non-pharmacological management of T2DM usually occur in conjunction with one another, although in some cases, one strategy is preferred over the other, and is used in isolation. There are a number of factors that ultimately affect the decision of the healthcare provider and these include disease severity, patient compliance and readiness to change, as well as resource availability.

2.7.1. Pharmacological Management of T2DM

The pharmacological management of T2DM is most often conducted through multiple pharmacological agents, although in some cases the use of one agent together with lifestyle modification is preferred (Chitre & Burke, 2006; Harper *et al.*, 2013; Srinivasan & Davies, 2014; He *et al.*, 2015). While there are a multitude of pharmacological agents available for use in T2DM patients, most relevant for this study are biguanides, exogenous insulin, sulfonylureas (SU) and thiazolidinediones (TZD) as the traditional options, with incretin mimetics and sodium-glucose cotransporter-2 (SGLT2) inhibitors as novel pharmacological strategies.

Of the biguanides, Metformin is the most commonly used first-line therapy in combination with lifestyle changes. It has been found to decrease hepatic glucose production, increase insulin sensitivity in skeletal muscle and adipose tissue, decrease GIT absorption of glucose, decrease fatty acid oxidation and up-regulate the production of GLP-1. The mechanism of action of Metformin is not completely understood, however, it is postulated that it acts via the AMP-activated protein kinase (AMPK) pathway as well as altering the metabolism of gut microbes (Chitre & Burke, 2006; Joshi & Joshi, 2009; Srinivasan & Davies, 2014; Eriksson & Nyström, 2015; He *et al.*, 2015).

The use of exogenous insulin, in combination with other oral anti-diabetic agents, is a matter of debate in the current literature (Harper *et al.*, 2013; Cefalu *et al.*, 2014; Srinivasan & Davies, 2014;

Eriksson & Nyström, 2015). The time from initial treatment to the introduction of exogenous insulin, varies greatly between two and five years (Machado-Alba *et al.*, 2015). The mechanism of action of insulin is well documented, and involves increasing the uptake of glucose into both skeletal muscle and adipose tissue cells through increased GLUT4 translocation, as well promoting the storage of FFA's. Through these actions, exogenous insulin is able to mediate hyperglycaemia (Srinivasan & Davies, 2014; Eriksson & Nyström, 2015).

Sulfonylureas exist in two generations, with the second generation SU being preferred due to its improved efficacy and safety. SU are insulin secretagogues (promote the secretion of insulin) and act by binding to the SU receptor on the pancreatic β-cells that are still functioning. This binding closes the ATP-dependent potassium channel (K_{ATP}), which in turn depolarises the β-cells, causing an influx of calcium (Ca^{2+}) into the cell and a subsequent secretion of insulin (Chitre & Burke, 2006; Joshi & Joshi, 2009; Cefalu *et al.*, 2014; Srinivasan & Davies, 2014; Eriksson & Nyström, 2015; He *et al.*, 2015). Due to the presence of K_{ATP} in other cells of the body (heart, brain, endothelium), the safety of first-generation SU were questioned, although the possible negative outcomes have been significantly decreased with the development of the second-generation SU (Eriksson & Nyström, 2015).

Thiazolidinediones are usually used in combination with other oral anti-diabetic agents, most commonly metformin or SU (Chitre & Burke, 2006; Srinivasan & Davies, 2014). The use of TZD is associated with an increase in insulin sensitivity (and therefore a decrease in insulin resistance), and a decrease in serum FFA levels. The mechanism of action is believed to occur through activation of the peroxisome proliferator-activated receptor γ (PPAR-γ), which is responsible for adipose tissue differentiation and insulin gene transcription (Joshi & Joshi, 2009; Srinivasan & Davies, 2014; Eriksson & Nyström, 2015; He *et al.*, 2015). Unfortunately, the safety of PPAR-γ full antagonists has come into question, therefore the development of PPAR- γ partial antagonists is receiving urgent attention. From the results of recent clinical trials, it appears that a number of the PPAR-γ partial antagonists have similar, and sometimes greater, efficacies than the full antagonists, and a significant reduction in the adverse side-effects associated with long-term use of the drug (Chigurupati *et al.*, 2015).

Incretins were first mentioned in the pathophysiology section above, and were defined as GLP-1 and GIP. With respect to the pharmacological use of incretin mimetics, GLP-1 receptor agonists and dipeptidyl peptidase 4 (DPP-4) inhibitors are novel pharmacological treatment agents used in T2DM patients, with improved efficacy and safety outcomes relative to the traditional agents discussed above (Nourparvar *et al.*, 2004; Joshi & Joshi, 2009; Cuny *et al.*, 2012). Under normal circumstances, GLP-1 and GIP have a very short half-life of two and seven minutes, respectively,

and are broken down by DPP-4. However, through the synergistic action of GLP-1 receptor agonists and DPP-4 inhibitors, the serum levels of GLP-1 remain elevated for a longer period of time, thereby allowing for the beneficial effects to last longer. These include increased insulin secretion and suppression of glucagon secretion, increased satiety levels, and delayed gastric emptying. Furthermore, pancreatic β-cell proliferation is increased (Nourparvar *et al.*, 2004; Joshi & Joshi, 2009; Cuny *et al.*, 2012; Cefalu *et al.*, 2014; Srinivasan & Davies, 2014; He *et al.*, 2015).

Finally, sodium-glucose cotransporter-2 inhibitors are an additional novel pharmacological treatment modality and act by lowering the renal threshold for the excretion of glucose, thereby increasing the amount and rate of glucose disposal in the urine. Consequentially there will be a decrease in plasma glucose levels and, together with the action of other pharmacological agents, there will be an improvement in insulin sensitivity and response (Nourparvar *et al.*, 2004; Cuny *et al.*, 2012; Cefalu *et al.*, 2014; Srinivasan & Davies, 2014; He *et al.*, 2015). One of the reported side effects, however, is an increase in the prevalence of urinary tract infections (UTIs) and genital mycotic infections, with second generation SGLT2 inhibitors being developed to mitigate these complications (Cefalu *et al.*, 2014; He *et al.*, 2015).

2.7.2. Non-Pharmacological Management of T2DM

Lifestyle changes comprise the non-pharmacological management of T2DM and include various forms of exercise modalities as well as dietary management. Comprehensive lifestyle interventions are less frequently reported on, although their contribution to the overall management of T2DM cannot be discounted.

2.7.2.1. Aerobic Exercise and the Management of T2DM

Participation in regular aerobic exercise, irrespective of intensity, has been reported to have beneficial outcomes on glycaemic control, diabetes-related complications and HRQoL (Sardar *et al.*, 2014; Emerenziani *et al.*, 2015; Motahari-Tabari *et al.*, 2015; Sari-Sarraf *et al.*, 2015). Tessier *et al.* (2000) found that following a 16-week aerobic exercise program of moderate intensity in elderly men and women, there was an improvement in overall glycaemia and physical fitness levels. These findings were similar to two recent studies conducted in older adults that, in addition to improvements in glucose metabolism, also reported improvements in insulin sensitivity and serum lipid levels (Lee *et al.*, 2015; Sari-Sarraf *et al.*, 2015). The extent to which exercise influences blood lipid levels has been debated, with a meta-analysis by Kelley & Kelley (2007) only showing improvements in LDL-C levels. The mechanisms behind these improvements are related to the increase in glucose uptake into the actively contracting skeletal muscles, which occurs during

exercise and the consequential down-stream effects on insulin action (Lee *et al.*, 2015; Motahari-Tabari *et al.*, 2015).

Aside from the benefits to glucose metabolism, aerobic exercise has also been found to have a positive influence on endothelial function, ROS and inflammatory processes (Yokoyama *et al.*, 2004; Nojima *et al.*, 2008; Iyalomhe *et al.*, 2015). An exercise program of moderate intensity and conducted over a period of three weeks in older men and women, was found to be sufficient to significantly reduce arterial stiffness, an indirect marker of endothelial function (Yokoyama *et al.*, 2004). However, it was noted that within two days following the cessation of the exercise program, the improvements were not present, which suggests that in individuals suffering with T2DM, endothelial function can only be improved with constant exercise, possibly due to the damage caused by the consistent hyperglycaemia. The relationship between exercise intensity and oxidative stress has also been well-documented, with high intensity exercise causing higher levels of oxidative stress (Goto *et al.*, 2003). Moderate intensity exercise, however, has been found to reduce ROS in type 2 diabetics, with a 12 month exercise program in older adults (men and women) showing significant reductions in urinary markers associated with oxidative stress (Nojima *et al.*, 2008). Chronic inflammation, which accompanies T2DM, is indirectly related to oxidative stress, and a recent study by Iyalomhe *et al.*(2015) found that a six-month exercise training program in older men and women of moderate intensity, significantly reduced the production of pro-inflammatory cytokines, with a subsequent increase in anti-inflammatory molecules, as well as up-regulation of the genes associated with neural growth and repair.

The popularity of high intensity interval training (HIIT) for the management of body weight has been well documented, however, its use in T2DM patients is scarcely reported (Earnest, 2008; Terada *et al.*, 2013; Cockcroft *et al.*, 2015). Terada *et al.* (2013) found that compared to the more traditional moderate exercise intensity regimes, a HIIT program in older men and women was a feasible and effective treatment strategy in the management of T2DM. These findings were corroborated by three other studies where HIIT resulted in improvements in glucose metabolism, insulin sensitivity and cardiovascular functioning (Earnest, 2008; Drigny *et al.*, 2013; Cockcroft *et al.*, 2015). These improvements are related to cardiovascular adaptations (Drigny *et al.*, 2013), improvements in mitochondrial enzyme functioning and an increase in beta oxidation (Earnest, 2008; Cockcroft *et al.*, 2015).

Peripheral neuropathy is one of the most common complications associated with T2DM as alluded to in an above section. Dixit *et al.* (2014) found that after eight weeks of moderate intensity exercise, there was significant improvement in nerve conduction velocity in a group of older men and women. The practical benefits thereof were reported by Morrison *et al.* (2014), where a 12

week exercise program for patients with peripheral neuropathy, and of a similar age group as the above-mentioned study, resulted in improvements in balance and reaction time, and favourable changes in gait directly related to fall risk. These improvements were linked to improvements in postural control and proprioceptive improvements (Morrison *et al.*, 2014), with the improvements in nerve conduction velocity being attributed to improvements in the action of NO on the endothelium and a decrease in the production of protein kinase C (Dixit *et al.*, 2014).

A ground-breaking study has recently published data which could explain why certain individuals with T2DM respond to exercise programs, while others do not, even when they are matched (Stephens *et al.*, 2015). The difference appears to be genetic in nature, with a form of "exercise resistance" found in the transcriptional profile of skeletal muscle in non-responders (Stephens *et al.*, 2015). Muscle fuel metabolism is what differentiates those who respond, versus those who don't, therefore, dietary modifications may be of more benefit in these individuals. Furthermore, gene therapy may be indicated in future cases where all forms of traditional treatment options are exhausted (Stephens *et al.*, 2015).

2.7.2.2. Resistance Exercise and the Management of T2DM

There is a paucity of data with respect to resistance exercise and the effects it has in managing T2DM outcomes, with aerobic exercise being researched far more often (Morais *et al.*, 2011; Yang *et al.*, 2014). The effects of both acute and chronic resistance training on blood pressure in T2DM patients have been studied extensively over the last decade, with conflicting results, although a number of authors suggest that methodological differences are to blame. However, it seems that resistance exercise exerts beneficial effects on both SBP and DBP, although not to the same extent as aerobic training (Morais *et al.*, 2011; Figueira *et al.*, 2014). There is contradictory evidence with respect to the effect of resistance training (RT) on insulin sensitivity, with some studies indicating that RT improves insulin sensitivity (Earnest *et al.*, 2014; Abouassi *et al.*, 2015), while others indicate that it has little or no effect (Jorge *et al.*, 2011; Yang *et al.*, 2014). Contrary to this, the effect that RT has on glycaemic control is reasonably clear cut, with a number of authors reporting decreases in HbA1c, fasting plasma glucose and a better glucose tolerance (Maiorana *et al.*, 2002; Sigal *et al.*, 2007; Church *et al.*, 2010). Similarly to blood pressure though, while resistance exercise appears to exert beneficial effects on these parameters, the magnitude of the effect is still greater with aerobic training (Sénéchal *et al.*, 2014; Yang *et al.*, 2014). Finally, resistance exercise has been found, in some cases, to improve the lipid profile of T2DM patients by up-regulating lipid metabolism.

As was the case with a number of the above-mentioned outcomes, results are conflicting and more research into the effects of resistance exercise on T2DM parameters are needed (Gavin *et al.*, 2010; Jorge *et al.*, 2011). These conflicting results seem to be due mostly to methodological differences, with large discrepancies in the intensity of exercise, the duration of the program and the overall-make up of the exercise sessions. However, irrespective of these differences, it appears that resistance training can be successful in managing the glycaemic parameters of T2DM.

2.7.2.3. Combination Exercise and the Management of T2DM

Recent research into the management of T2DM through exercise has shifted away from a unimodal exercise philosophy (only aerobic or resistance exercise) to one of combination exercise, with a number of studies showing promising results (Balducci *et al.*, 2010; Figueira *et al.*, 2014; Ades *et al.*, 2015). However, one of the potential drawbacks to combination exercise as reported by Earnest *et al.* (2014), is that the amount of time required to exercise is substantially more and may influence adherence to a structured exercise program.

Similarly to what was found with both aerobic and resistance exercise, combination exercise training has been found to have beneficial effects on endothelial function, and a subsequent improvement in both systolic and diastolic blood pressure. While the magnitude of the difference is in some cases greater than in either aerobic or resistance training alone, there are still conflicting reports, with some authors showing almost no change (Maiorana *et al.*, 2001; Jorge *et al.*, 2011; Figueira *et al.*, 2014). Once again, the conflicting reports seem to be due to the large methodological differences with respect to program design and duration, with no standardised programs set for combination exercise in T2DM individuals.

Combination exercise was found to significantly improve insulin signalling in skeletal muscle by up-regulating IRS-1 expression (Jorge *et al.*, 2011). The effect of combination exercise on insulin sensitivity is detailed in a study by AbouAssi *et al.* (2015), where it was found that an eight month combination (resistance and aerobic) training program was significantly more effective than either aerobic or resistance training alone. With respect to glycaemic control and lipid metabolism, combination exercise was found to be more effective than either aerobic or resistance training in isolation, which is hypothesised to occur due to the synergistic action of both training modalities (Balducci *et al.*, 2010; Balducci *et al.*, 2015; Ades *et al.*, 2015). Furthermore, cardiovascular fitness, as measured by VO_{2max} or time to exhaustion, was found to improve to a greater extent with combination exercise compared to either aerobic or resistance exercise alone (Maiorana *et al.*, 2002; Earnest *et al.*, 2014).

2.7.2.4. Role of Dietary Control in the Management of T2DM

Dietary management of T2DM is a contentious issue and has been debated extensively by researchers over the last 50 years (Feinman *et al.*, 2014; Moosheer *et al.*, 2014; Campbell & Rains, 2015). The first line of defence in dietary control has commonly been to reduce carbohydrate intake and is the most commonly used strategy in individuals recently diagnosed with T2DM today (Feinman *et al.*, 2014). However, a number of additional strategies have been implemented over the years, either in combination with a low carbohydrate diet, or as a stand-alone treatment (Barnard *et al.*, 2009; Hussain *et al.*, 2012; Campbell & Rains, 2015). A study by Von Bibra *et al.* (2014) that investigated the effects of a low-carbohydrate/high-protein (LC/HP) diet on cardiac function and metabolic outcomes in older adults with T2DM, indicated that a LC/HP diet had a significant positive impact on cardiac function, insulin resistance and the risk of developing cardiovascular and metabolic complications.

The effect of a high protein diet on glycaemic control, anthropometric outcomes and cardiovascular risk was reported in two studies conducted in older men and women by Moosheer *et al.* (2014) and Campbell & Rains (2015), where it was found that a high protein diet, supplemented with polyunsaturated fatty acids (PUFAs), significantly reduced HbA1c, waist circumference and fat mass, as well as inflammatory markers associated with CVD. Similar findings were reported by Jelinek *et al.* (2013) in an animal-model study, where a high-fat diet supplemented by fish oil resulted in significant improvements in glycaemic control and a reduction in inflammatory cytokines related to CVD risk. The use of the Mediterranean diet in the treatment regime of T2DM is not new, with a number of studies showing improvements in glycaemic control, insulin resistance and cardiovascular risk (Esposito *et al.*, 2010; Itsiopoulos *et al.*, 2011; Salas-Salvadó *et al.*, 2011; Grosso *et al.*, 2014).

Of interest, is the timing of meals, and when the most calorie intensive meal is eaten. Jakubowicz *et al.* (2015) reported significantly better glycaemic control and insulin sensitivity in individuals who ate a high-energy breakfast versus a high-energy supper. What was of further importance is that those who missed breakfast on a regular basis had a higher cardiovascular risk and poorer glycaemic control (Mekary *et al.*, 2012; Reutrakul *et al.*, 2014).

2.7.2.5. Lifestyle Interventions and the Management of T2DM

While there are a multitude of studies on lifestyle programs for the prevention of T2DM, comprehensive lifestyle programs for the management of individuals diagnosed with T2DM are few and far between, with only a handful of studies published to date (Aguiar *et al.*, 2014; Blackford *et al.*, 2015). Lifestyle programs are multi-faceted in nature and usually consist of exercise, dietary

and behavioural change components (Aguiar *et al.*, 2014). Most of the published studies indicate that the long-term benefits of lifestyle programs are sustained when compared to only exercise or diet-based programs, although in some cases the short-term improvements are comparable (Aguiar *et al.*, 2014; Evert & Riddell, 2015). That being said, improvements in glycaemic control, body composition, insulin sensitivity and lipid metabolism have been reported in a number of comprehensive lifestyle programs (Andrews *et al.*, 2011; Aguiar *et al.*, 2014; Blackford *et al.*, 2015; Evert & Riddell, 2015). In a four-month comprehensive intervention consisting of group exercise sessions as well as dietary advice and counselling, participants in the experimental group reported a clinically and statistically significant decrease in HbA1c, as well as improvement in a number of dietary behaviours related to favourable T2DM outcomes such as regular fruit and vegetable consumption, and the sparse consumption of refined carbohydrates (Speer *et al.*, 2008). In a slightly longer six-month study by (Vadstrup et al., 2011), a comprehensive lifestyle intervention resulted in significant improvements in HRQoL as well as the individuals perception of their health, which are important in the overall management of T2DM. A multi-centre study by Wing *et al.* (2010) added further evidence in support of comprehensive lifestyle intervention programs, with data collected over a four year period reporting statistically significant improvements in body weight, glycaemic control and lipid metabolism, as well as cardiovascular fitness, when compared to participants who made use of traditional care modalities.

2.8. Management Strategies for T2DM

Three chief management strategies have been identified in research, each with their own positives and drawbacks, and are discussed in further details below.

2.8.1. Telephonic/Correspondence Interventions

With the advent of technology, and the need for health professionals to reach more individuals to try and mitigate the increased incidence of T2DM, telephone-linked, or telecare interventions have been implemented globally (Coberley *et al.*, 2007; Walker *et al.*, 2011; Saffari *et al.*, 2014; Kaur *et al.*, 2015). The cost-effectiveness of these interventions has been extensively studied, with a number of authors suggesting that telephone-based programs are effective in reducing healthcare costs, and costs to the individual concerned, without compromising on the quality of care (Gordon *et al.*, 2014; McGloin *et al.*, 2015). Most studies related to telephonic interventions have examined the effects on glycaemic control and other haematological variables. Kaur *et al.* (2015) found that weekly telephonic consultations, together with regular clinic visits resulted in significant improvements in HbA1c as well as HDL-C compared to those participants who didn't receive telephonic consultations. Furthermore, this group also reported a higher HRQoL with respect to the

physical functioning domains. This finding was corroborated by Huang *et al.* (2015) who found similar improvements in HbA1c, as well as a reduction in fasting glucose and glucose tolerance following a meal.

The use of text messaging was investigated in a recent study, and was found to be as effective as a traditional telephonic intervention with respect to a reduction in HbA1c (Saffari *et al.*, 2014). Furthermore, when telephonic interventions were compared to print media such as manuals, booklets, etc., a significant reduction in HbA1c and an improvement in self-care activities were found in a low-income community, suggesting that the feedback given by telephonic interventions are more beneficial (Walker *et al.*, 2011). While the authors did not explicitly state what the possible reasoning was for this finding, it is plausible that the personal contact, together with the opportunity to ask questions or voice concerns, gave individuals with T2DM more confidence to adhere to self-care activities and healthy lifestyle behaviours.

The use of telephonic reinforcement following a structured program has been investigated over the last few years, with a number of studies reporting that while the reinforcement did not infer any additional benefits over and above the changes seen as a result of the initial program, the improvements were maintained at a follow up period some 12 – 18 months following the program (Lorig *et al.*, 2008; Dunbar *et al.*, 2010).

2.8.2. Health Professional-Led Interventions

Healthcare programs or intervention strategies conducted by a group of health professionals or healthcare providers, are the most common form of intervention strategy, although not always the most effective (Smith *et al.*, 2011; Daly *et al.*, 2014; Edelman *et al.*, 2015). The impact of professional led interventions on glycaemic control and other metabolic measures is well documented, with a recent study by Tomioka *et al.* (2014) in elderly men and women showing significant improvements in HbA1c, lower lipid levels and lower blood pressure. Interestingly, these findings were not corroborated by Edelman *et al.* (2015), where only small and insignificant improvements were found in a similar study population. A study by Smith *et al.* (2011) in a multi-ethnic population of older adults found improvements in a number of areas related to diabetes management including blood pressure and cholesterol, with the program being led by primary care workers. A similar study conducted in an older Yemeni population found comparable results, in addition to improvements in fasting blood glucose (Babelgaith *et al.*, 2015).

2.8.3. Community-Led Interventions

Recently, the advent of community- or peer-led interventions have taken centre stage as the medical professionals are no longer able to maintain the required level of care relative to the increase in the number of sick individuals. A recent cost-effectiveness study by Brown *et al.* (2012) found that lifestyle intervention programs implemented by community health workers (CHW) was extremely cost-effective in a community with low SES. Improvements in HbA1c seems to be mostly reported in the literature, with improvements in blood pressure and lipid profile being reported less frequently (Lorig *et al.*, 2009; Castillo *et al.*, 2010; Welch *et al.*, 2011; Simmons *et al.*, 2015). In addition to improvements in haematological parameters, a recent study in a low-income and elderly Hispanic population by Koniak-Griffin *et al.* (2015) found a significant improvement in levels of physical activity, waist circumference and dietary habits. Similar findings were reported in a 6-week study by Melkus *et al.* (2004), where appropriately trained CHW delivered an educational program to 25 community members. Statistically significant improvements in glycemic control, BMI and emotional distress related to T2DM were reported. A 12-week dance and peer support program achieved similar results, with improvements in HbA1c, body fat percentage and blood pressure being substantially greater compared to the participants in the study who received the traditional method of care for T2DM (Murrock *et al.*, 2009). An extensive 24 month program carried out by CHW with the explicit goal of reducing body weight in elderly patients with T2DM, was found to have wider-reaching effects, with decreased body weight, waist circumference and BMI reported, as well as improvements in metabolic control (Katula *et al.*, 2013). Interestingly, a much shorter study of six months resulted in similar changes, in addition to improvements in diabetes self-care activities, all of which are essential to adequate management of T2DM (Assah *et al.*, 2015). A similar study by Spencer *et al.* (2011) reported that a six month CHW intervention program resulted in a significant improvement in HbA1c, in addition to definitive modifications in behaviour towards better management and knowledge of T2DM. A culturally-tailored educational intervention conducted by CHW over a period of 12-months showed great promise, with the intervention group significantly improving their glycaemic control and blood lipid levels, as well as their quality of life and overall self-efficacy (Kim *et al.*, 2015).

2.9. Conclusion

Despite the extensive research into T2DM there are still a number of unanswered questions and controversy surrounding the pathophysiology and management of the disease. This is especially evident in communities of low socio-economic status where further research needs to be conducted. The use of comprehensive, community-based lifestyle interventions have been identified as a

possible solution to the increasing prevalence of T2DM by empowering communities to manage their disease, in conjunction with the primary healthcare providers. What is abundantly clear however is that if nothing is done to curb this global challenge, the ramifications thereof will continue for generations to come.

Chapter 3

Methodology

3.1. Study Design

This study followed an experimental randomised case-control study design. Three testing sessions comprised this study, namely a pre-testing session before the start of the intervention, the post-intervention testing session, and finally a retention testing session. The time period between each of the testing sessions was 10 weeks. (*Figure 3.1*). The 10-week intervention period consisted of structured group exercise sessions, group dietary advice and group motivational interviewing conducted by clinical psychologists, which was determined to be a sufficient intervention duration based on studies with similar methodologies (Melkus *et al.*, 2004; Kim *et al.*, 2009).

Figure 3.1. Schematic of study design with the time between the respective sessions shown in weeks.

3.2. Participants

The target study population was a group of adults in a low-socioeconomic community in Cloetesville in Stellenbosch. Participants were recruited through the local media outlets, the Cloetesville community clinic, local churches via word of mouth, and flyers that were distributed within the community (Appendix A). All volunteers underwent a comprehensive pre-participation screening to determine their eligibility to participate in the study. Volunteers who qualified to participate in the study were requested to provide a medical clearance form from their primary physician (Appendix B), which had to be completed before any testing was conducted. All participants were informed of the purpose of the study in their preferred home language (English and/or Afrikaans), and gave full consent to participate in the study. A total of 45 individuals volunteered to participate in the study and were randomised into an experimental (n = 24) and control (n = 21) group. Randomisation was conducted by assigning a number to each participant and then randomly drawing the numbers out of a concealed box. A total of 43 participants completed the study, of which 23 were in the experimental group and 20 were in the control group.

3.3. Inclusion and Exclusion Criteria

Participants were included in the study if they were diagnosed with type 2 diabetes mellitus (T2DM) for at least six months prior to enrolment in the study. Participants were required to be over 18 years of age, and classified as sedentary according to the criteria outlined by the American College of Sports Medicine (*Table 3.1*). Participants were excluded from the study if they presented with any pathologies that would prevent them from participating in any of the intervention sessions, if they had been following an individualised diet plan prescribed by a registered dietician for three months or longer, or if they were intending to, or confirmed to undergo, any surgical procedure during the intervention period. Furthermore, if participants attended less than 60 % of the respective intervention sessions, their data was excluded from analyses.

Table 3.1. Definition of sedentary lifestyle, adapted from ACSM's Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2014).

Atherosclerotic Cardiovascular Disease (CVD) Risk Factors and Defining Criteria	
Sedentary Lifestyle	Not participating in at least 30 minutes of moderate intensity, physical activity (40 % - 60 % VO_2R) on at least three days of the week for at least three months.

3.4. Place of Study

All testing and intervention sessions took place at the *Vrye Gereformeerde Kerk* (VGK) in Cloetesville, Western Cape, South Africa. Cloetesville was chosen as the preferred place for the study to be conducted due to the high incidence of T2DM in the region, and due to its classification as a low socio-economic status (SES) community, which was determined by the average monthly income of employed individuals, the highest level of education, and access to basic services (Bureau for Economic Research, 2013). Blood sample analyses were performed by *PathCare* pathology laboratories in Stellenbosch, South Africa, by a registered nurse and/or phlebotomist. For testing, participants were required to make three visits to the VGK Church. For the intervention period, participants were required to make 50 visits to the VGK Church, over a 10-week period. These 50 visits comprised of 30 exercise sessions with a registered biokineticist, 10 motivational interviewing sessions with a qualified community psychologist, and 10 dietary counselling sessions with a registered dietician.

3.5. Measurements and Instrumentation

The physical measurements included standing height, body mass, body composition, resting blood pressure, resting heart rate, random blood glucose, total serum cholesterol as well as glycated haemoglobin (HbA1c). Quality of life was measured through the Short Form 36 (SF-36) questionnaire (Appendix E), and the Diabetes-39 questionnaire (Appendix F). Additional questionnaires on the participants' dietary (Appendix G) and health professional usage habits (Appendix H), as well as family support (Appendix I) were also included.

3.5.1. Anthropometrical Measurements

All anthropometrical measurements were taken by an ISAK level 2 qualified anthropometrist, ensuring consistency and reliability of the measurements at every testing session.

3.5.1.1. Standing Height (Stature)

Standing height was measured according to the guidelines outlined by the *International Society for the Advancement of Kinanthropometry* (ISAK). Participants were instructed to wear loose-fitting, light-weight clothing, and to be barefoot. A sliding steel stadiometer (Siber-Hegner GPM, Switzerland) was used to obtain height, with participants standing upright, with their feet together, and heels, buttocks, upper back, and posterior aspect of the head touching the stadiometer. Participants were then placed in the Frankfort plane/position with the notch above the tragus of the ear (*Tragion*), and the lower edge of the eye socket (*Orbitale*), being in the same horizontal plane. Participants were then instructed to inhale maximally while the headboard was lowered to the highest point of the skull (*Vertex*). Measurements were taken to the nearest 0.1 centimetre (cm).

3.5.1.2. Body Mass

Body mass was also measured according to the guidelines outlined by ISAK. Participants wore loose-fitting, light-weight clothing and were barefoot. A Safeway household scale, checked for accuracy before each measurement with a 5 kilogram (kg) plate, was used, and participants were instructed to stand in the middle of the scale, weight-evenly distributed, and looking straight ahead for the entire duration of the measurement. Measurements of body mass were taken to the nearest 0.1 kilogram (kg).

3.5.1.3. Body Composition

Body composition was measured by skinfold thickness via the use of a skinfold calliper (get info on calliper), which was calibrated according to the manufacturers protocol. The sum of skinfolds was then converted to body fat percentage by the formula developed by Yuhasz in 1974. This formula is

recognised as the gold standard by ISAK and is the reason for its use in this study. The formulas, different for men and women, are detailed in *Equation 3.1* and *Equation 3.2* below.

$$Body\ Fat\ \% = (0.1051\ \times\ [\Sigma(Tr + SS + SSp + A + Th + C)] + 2.585$$

Equation 3.1. Equation developed by Yuhasz (1974) to calculate body fat percentage in men, where *Tr* is triceps skinfold, *SS* is subscapular skinfold, *SSp* is supraspinale skinfold, *A* is abdominal skinfold, *Th* is anterior thigh skinfold, and *C* is medial calf skinfold.

$$Body\ Fat\ \% = (0.1548\ \times\ [\Sigma(Tr + SS + SSp + A + Th + C)] + 3.580$$

Equation 3.2. Equation developed by Yuhasz (1974) to calculate body fat percentage in women, where *Tr* is triceps skinfold, *SS* is subscapular skinfold, *SSp* is supraspinale skinfold, *A* is abdominal skinfold, *Th* is anterior thigh skinfold, and *C* is medial calf skinfold.

All skinfolds were taken according to ISAK guidelines, on the right side of the body, and measurements were repeated twice. If the difference between two measurements of the same skinfold site exceeded two millimetres (mm), then the measurement was repeated for a third time. Prior to any skinfolds being measured, the various anatomical landmarks were marked with the use of a permanent marker. Each of these respective landmarks are explained in further detail together with their associated skinfold site.

3.5.1.3.1. Biceps Skinfold

The *Acromiale* ® landmark is the most lateral aspect of the acromion border on the scapula and is the first anatomical landmark necessary. The second landmark is the *Radiale* ®, and is the point at the most proximal and lateral border of the head of the radius bone in the forearm. A horizontal line is made midway between these two landmarks, known as the *Mid-acromiale-radiale* ®, with both the biceps and triceps skinfold making use of this landmark. The biceps skinfold is a vertical skinfold made parallel to the long axis of the arm, and at the most anterior aspect of the biceps at *Mid-acromiale-radiale* ® level.

3.5.1.3.2. Triceps Skinfold

The triceps skinfold is a vertical skinfold made parallel to the long axis of the arm, at the most posterior aspect of the *triceps brachii*, at *Mid-acromiale-radiale* ® level.

3.5.1.3.3. Subscapular Skinfold

The *Subscapular* ® landmark is located by palpating the tip of the most inferior angle of the scapula. From this point, the subscapular skinfold site is marked two centimetres laterally and diagonally at an angle of 45 degrees. The subscapular skinfold is taken with the natural fold of the skin.

3.5.1.3.4. Supraspinale Skinfold

The *Supraspinale* ® skinfold site is determined by the intersection of the horizontal line from the *Iliocristale* ®, taken at the most lateral aspect of the iliac crest, and the line between the anterior axillary border and the *Iliospinale* ®, the most inferior aspect of the anterior superior iliac spine (ASIS), where the *Sartorius* muscle has its insertion point. The skinfold is taken with the natural fold of the skin, as in the case of the subscapular skinfold.

3.5.1.3.5. Abdominal Skinfold

The abdominal skinfold site is located five centimetres to the right of the centre of the navel (omphalion), with the skinfold itself being a vertical skinfold.

3.5.1.3.6. Anterior Thigh Skinfold

The anterior thigh skinfold site is located midway between the *Inguinal fold* ® and the most anterior and superior aspect of the patella (*Anterior patella* ®). This skinfold is taken with the person seated, and the knee bent at 90 degrees. The vertical skinfold is taken parallel to the long axis of the limb.

3.5.1.3.7. Medial Calf Skinfold

The medial calf skinfold is taken at the most medial aspect of the calf, at the level where the greatest circumference is measured. It is a vertical fold taken parallel to the long axis of the lower limb, with the foot placed on a raised platform.

3.5.2. Cardiovascular Measurements

Resting measurements of blood pressure and heart rate were obtained after the participants had been allowed to sit, at rest with feet flat on the floor, for five minutes. All cardiovascular measurements were taken according to the guidelines recommended by the American College of Sport Medicine (American College of Sports Medicine, 2014) and by a fully qualified biokineticist with five years of clinical experience, ensuring consistency and reliability of the measurements.

3.5.2.1. Blood Pressure

Resting systolic blood pressure (SBP) and diastolic blood pressure (DBP) was measured with a hand-held aneroid sphygmomanometer (Just Sports, South Africa), which had been calibrated prior to its first use by the manufacturers. An adult size cuff was used (27.5 – 26.5 centimetre upper arm circumference) and positioned to ensure that at least 80 percent of the upper arm was encircled by the bladder of the cuff. The head of the stethoscope (Hi-Care, South Africa) was placed in the antecubital space of the elbow joint, while the cuff was inflated. The pressure was released at a rate of 2 – 5 millimetres mercury (mmHg), with the first and last Korotkoff sounds being used to determine the participants' systolic and diastolic blood pressures, respectively. Resting blood pressure was measured twice, with a two-minute gap between readings. The average of the two measurements was used as the final reading. In addition to the resting blood pressure measurements, blood pressure was also measured at the termination of the six-minute walk test (6MWT), to determine whether the participant presented with the expected haemodynamic response at the end of the exercise bout as outline by the ACSM (American College of Sports Medicine, 2014). Measurements of blood pressure were taken to the nearest 1 mmHg.

3.5.2.2. Heart Rate

Resting heart rate was measured via palpation of the radial artery on the lateral aspect of the forearm, while the forearm was supinated. The radial pulse was measured for 60 seconds with the participant seated and with both feet flat on the floor. Heart rate was also measured throughout the duration of the 6MWT via an electronic heart rate monitor and receiver (Suunto Team System, Vantaa, Finland). Heart rate measurements were measured in beats per minute (bpm).

3.5.3. Haematological Measurements

3.5.3.1. Random Blood Glucose

To obtain a measurement of random blood glucose, a finger prick test was used to draw a small amount of blood needed for analysis. The ring finger of the participants' non-dominant hand was cleaned with an alcohol swab (Dura-Surge, South Africa) to remove any dirt or substances that could have affected the accuracy of the results. A single-use Haemolance plus lancet (HaeMedic, Poland) was then used to puncture the skin to a depth of 1.8 mm and draw blood. The first sample of blood was wiped away using cotton wool, as is common practice for finger prick tests, with the second sample of approximately 10 μL being drawn into a micro cuvette via capillary action. This sample was analysed using a Glucose 201+ analyser (Hemocue, Sweden). In order to ensure accuracy of the measurements, the analyser performed an internal self-calibration procedure prior to

each measurement, as outlined in the manufacturers protocol. All random blood glucose measurements were recorded with mmol.L^{-1} as the unit of measurement. Due to the logistical difficulties with obtaining fasting blood glucose measurements, the time at which the participants random blood glucose was tested, was fixed for each testing session in an attempt to standardise the measurements. I.e. If person A's blood glucose was tested at 09h00 at the pre-testing session, it was tested at 09h00 at the post-testing and retention testing sessions.

3.5.3.2. Total Serum Cholesterol (TSC)

The same procedure described above for obtaining a blood sample for random blood glucose was used to obtain a blood sample for the analysis of total serum cholesterol. Approximately 15 μL of blood was drawn and placed on the required area on the Accutrend ® cholesterol testing strips (Roche Diagnostics, Germany) to ensure that the reading was accurate. The blood sample was analysed using an Accutrend ® Plus multifunction analyser (Roche Diagnostics, Mannheim, Germany) and all measurements were expressed in mmol.L^{-1}. In order to ensure accuracy of the measurements, the analyser performed an internal self-calibration procedure prior to each measurement, as outlined in the manufacturers protocol.

3.5.3.3. Glycated Haemoglobin (HbA1c)

All measurements for glycated haemoglobin (HbA1c) took place at the PathCare laboratory in Stellenbosch under the guidance of a registered nurse or phlebotomist. Blood was collected in 4 mL Ethylenediaminetetraacetic acid (EDTA) tubes to prevent coagulation of the blood sample. During analysis, 1 mL of blood was washed three times with 8 mL saline solution, followed by centrifugation at 15 000 rpm for 10 minutes. The sediment was then further analysed to give HbA1c as a percentage of total haemoglobin present, and rated according to their level, namely, normal (3.9 % - 6.1 %), low (< 3.9 %) or high (> 6.2 %) (Zemlin *et al.*, 2015).

3.5.4. Questionnaires

Participants were required to complete a total of five questionnaires (in their preferred language). There was no time limit imposed to complete the questionnaires, and if they were unsure of any of the questions being asked, it was rephrased by the researcher until it was established the question was properly understood.

3.5.4.1. Short Form 36 (SF-36)

The SF-36 was first developed by Ware & Sherbourne (1992) as a measure of health-related quality of life, and how a specific disease or a condition has an effect thereon. It is comprised of 36

questions, which are split into eight domains, namely, physical functioning, role limitations due to physical challenges and shortcomings, social functioning, body pain, overall mental health, role limitations as a result of emotional problems, vitality, as well as overall perception of health. Each domain is scored from zero to 100, with a higher score indicating a higher quality of life. In a number of different chronic disease populations, it has been demonstrated that the SF-36 is a valid and reliable measurement tool, even when translated from English to another foreign language (Jenkinson *et al.*, 1993; Aaronson *et al.*, 1998; Alonso *et al.*, 1998; Failde & Ramos, 2000; Martin *et al.*, 2011). The English version of the SF-36 can be seen in Appendix E. To assess the reliability of the SF-36, a reliability analysis was performed, with Cronbach's alpha being used as a determining factor. Across the various domains of the SF-36, the Cronbach's alpha scores varied from 0.53 to 0.91 (average of 0.76), indicating an acceptable to high reliability.

3.5.4.2. Diabetes-39

The Diabetes-39 (D-39) questionnaire is a health-related quality of life questionnaire that examines five areas that are traditionally affected by an individual with diabetes, as well as their perceived quality of life and perceived disease severity. The five areas are energy and mobility, sexual functioning, anxiety and worry, social burdens and diabetes control and management. Each of the 39 questions is ranked on a seven point Likert scale, with one representing "not affected at all", and seven representing "severely affected". It has been shown to be a valid questionnaire and correlates well with more generalised health-related quality of life questionnaires such as the SF-36 ($r = 0.71$) (Boyer & Earp, 1997). Similarly to the SF-36, the Diabetes-39 questionnaire has been reproduced in foreign languages, without compromising its reliability (Khader *et al.*, 2008). The English version of the Diabtes-39 questionnaire can be seen in Appendix F. A reliability analysis was performed on all the various domains of the D-39, with Cronbach alpha scores ranging from 0.79 to 0.95, indicating a high degree of reliability.

3.5.4.3. Eating Habits

The eating habits questionnaire (Appendix G) was developed by the researcher for use in this study, and included a number of questions regarding the frequency of eating, the detailed content of meal times, as well as questions regarding lifestyle behaviours such as smoking and alcohol consumption. A number of the questions were derived from studies conducted by Van Dam *et al.* (2002), Pisani *et al.* (1997) and Buzzard *et al.* (2001), which were all found to be reasonably reliable and valid ($r = 0.71$; $r = 0.73$; $r = 0.59$). The questionnaire was evaluated according to eating times and frequency, the content of the various meal times, as well as the lifestyle habits of the participants.

3.5.4.4. Health Professional Usage

The health professionals' usage questionnaire (Appendix H) was also developed by the researcher for use in this study and was based on similar questionnaires developed by Rim *et al.* (2011) and Schweikert *et al.* (2008), both of which were shown to have reasonable reliability and validity (r = 0.65 ; r = 0.70). The questionnaire was designed to determine the frequency of participants' use of various health professionals, whether or not they went for regular check-ups, and the location of where the participants consulted with their primary healthcare provider.

3.5.4.5. Modified Diabetes Family Behaviour Scale (DFBS)

The Diabetes Family Behaviour Scale (DFBS) was originally developed to assess familial support for children with type 1 diabetes mellitus (T1DM) (McKelvey *et al.*, 1993). The original document was modified to make it more appropriate for adults with T2DM, and the English version can be seen in Appendix I. The DFBS is scored according to two subscales: the guidance-control subscale and the warmth-caring subscale. Participants answered questions on a five-point scale, and when the scores of the two subscales were totalled, a higher score indicated greater familial support. Due to the questionnaire being adapted from the original, a reliability analysis was conducted with Cronbach's alpha scores being utilised to determine the internal consistency of the questionnaire. Overall the Cronbach's alpha scores for the two subscales were 0.60, thereby resulting in acceptable internal consistency.

3.5.5. Functional Measurements

3.5.5.1. Six Minute Walk Test (6MWT)

The six-minute walk test (6MWT) has been validated on a number of occasions as an accurate measure of determining functional capacity and overall exercise ability in diabetic populations (Lambers *et al.*, 2008; Geirsdottir *et al.*, 2012; Tuttle *et al.*, 2012; Awotidebe *et al.*, 2014). It has also been shown that impairments in the components of physical fitness, which are related to health (muscle strength and endurance, cardiorespiratory endurance), will result in an inferior performance on the 6MWT, thereby indirectly testing these components (Bade *et al.*, 2012; Özgen *et al.*, 2015). For this study, the participants were instructed to walk as fast as they could, without running, between two cones set five meters apart. The total distance walked in the six minutes was calculated by multiplying the number of laps with the distance between the cones. Participants were allowed to rest if necessary, although the time continued. All participants wore an electronic heart rate monitor (Suunto Team System, Vantaa, Finland) which measured their heart rate continuously throughout the test. Furthermore, participants were asked to provide a rating of perceived exertion (RPE) score

(Borg scale) at three minutes and at the termination of the test. An upper limit of 75 percent of the participants' maximum heart rate (HR_{max}) was set as a termination criterion for the test, in addition to the standardised termination criteria outlined by the American College of Sports Medicine (*Table 3.2*). The participant's target heart rate (75 percent of HR_{max}) was calculated using the Karvonen formula (*Equation 3.3*).

$$THR = [(220 - age - RHR) \times I] + RHR$$

Equation 3.3. Karvonen formula used to calculate target heart rate (THR) as a specific intensity (I), where RHR is resting heart rate.

In cases where the participant were taking medication that could affect their haemodynamic response (e.g. β-blockers), an RPE of 7 or 8 was noted as the end point as these scores corresponded with approximately 75 percent of the HR_{max} (American College of Sports Medicine, 2014). Blood pressure and heart rate were measured immediately at termination of the test, as well as three minutes after termination to ensure a normal haemodynamic recovery following a bout of exercise.

Table 3.2. General indications for stopping an exercise test, adapted from ACSM's Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2014).

Onset of angina or angina-like symptoms
Drop in systolic blood pressure (SBP) of ≥ 10 mmHg with an increase in work rate or if SBP decreases below the value obtained in the same position prior to testing
Excessive rise in blood pressure: systolic pressure > 250 mmHg and/or diastolic pressure > 115 mmHg
Shortness of breath, wheezing, leg cramps or claudication
Signs of poor perfusion: light-headedness, confusion, ataxia, pallor, cyanosis, nausea, or cold and clammy skin
Failure of heart rate to increase with increased exercise intensity
Noticeable changes in heart rhythm by palpation or auscultation
Subject requests to stop
Physical or verbal manifestations of severe fatigue
Failure of the testing equipment

3.6. Experimental Procedures

3.6.1. Testing Sessions

There were a total of three testing sessions that each participant attended, which varied in duration between 60 and 90 minutes. Before the start of each testing session, the participants were guided through the session in their preferred language, and any concerns or questions were addressed. The study documents (informed consent, questionnaires, etc.) were presented to the participants in their preferred language to eliminate any language related bias.

3.6.1.1. Testing Session One

During this testing session, the participant provided a comprehensive medical history, including a list of their current medications, frequency of use and dosage (Appendix D). The informed consent form (Appendix C) was also explained at this time, and any questions or concerns that arose were addressed before being signed. Participants' anthropometrical measurements of standing height, body mass, and skinfold thickness were obtained. Furthermore, resting systolic (SBP) and diastolic blood pressure (DBP), and resting heart rate (HR) were taken as measures of cardiovascular functioning. A finger prick test allowed for the measurement of blood glucose and total serum cholesterol (TSC). Following these measurements, participants were required to complete the six-minute walk test (6MWT). A number of questionnaires were provided to the participants following the physical testing and included the Short Form 36 (SF-36), Diabetes-39 Questionnaire, eating habits questionnaire, health professionals' usage questionnaire, and the Diabetes Family Behaviour Scale (DFBS). At the end of the testing session, participants were provided with a request form for *PathCare* pathology laboratories for blood-work analysis. Participants were instructed to fast at least eight hours prior to their blood test (Gaudet-Savard *et al.*, 2007). A pre-prepared SMS was sent to participants the evening before and the morning of their schedule *PathCare* testing appointments to ensure that they were in a completely fasted state for the blood tests.

3.6.1.2. Testing Session Two

During this testing session, participants were required to undergo the same procedures as outlined in testing session one. However, an additional response form was added to the documents in order to obtain feedback from the participants on the respective intervention sessions so that the necessary changes could be made to the program going forward (e.g. what they enjoyed or didn't enjoy in the sessions, what could be done differently or better, etc.) (Appendix K). Furthermore, the participants were provided with a post-intervention guide (Appendix L) incorporating all the aspects of the intervention program (three exercise programs, dietary guidelines and advice from the psychologists).

3.6.1.3. Testing Session Three

The last testing session took place 10 weeks after testing session two. The same procedures as outlined in testing session one and two were performed.

3.6.2. Intervention Sessions

The intervention program consisted of exercise, dietary and psychological sessions. The exercise sessions occurred three times a week, at two different time periods (one morning session and one evening session), and lasted between 30 and 60 minutes. The dietary and psychological sessions occurred once a week and at two different time slots (one morning session and one evening session), and lasted 45 to 60 minutes, respectively. All of the intervention sessions were conducted in groups. Participants were allowed to change the times that they attended the respective sessions according to their schedules, however, they were not allowed to attend more than three exercise sessions, or more than one of the dietary and psychological intervention sessions, per week.

3.6.2.1. Exercise Intervention Sessions

The exercise sessions consisted of a progressive, whole body, exercise program that lasted for 10 weeks. A detailed breakdown of what occurred in each of the exercise sessions (per week) can be found in Appendix J, although a summarised example of one day, with progressions is displayed in *Table 3.3* below. The exercise sessions were made increasingly difficult every week, and consisted of both aerobic and resistance exercises, as well as exercises for balance and proprioception. Each exercise session was preceded by a warm-up of approximately five minutes and ended with a cool-down stretch of the respective muscles, of approximately five minutes. In order to ensure that the exercise sessions were progressive in nature, the RPE scores, based on the category-ratio Borg scale (Borg, 1982) were obtained from each participant at the end of each exercise session.

Table 3.3. Example of an exercise session, with progressions for the following session included.

Exercise	Sets/Reps or Time	Progression
Fast feet over rope (fwd, sdw, fwd)	35 seconds each	Increase time by 10 seconds
Tri-Directional Torso Rotation with Discus	2 x 20 (10 per side)	Increase reps per side by 2
Sit-to-stand with isometric abduction (with band)	2 x 15	Increase reps by 2 or add in hold at the halfway point
Sumo Squats	2 x 10	Increase reps by 2
Fast feet over rope (fwd, sdw, fwd)	35 seconds each	Increase time by 10 seconds
Lunges	2 x 6	Increase reps by 2
Half Seated Holds (Hold for 15s)	2 x 6	Increase reps by 2 or time by 5 seconds
Fast feet over rope (fwd, sdw, fwd)	35 seconds each	Increase time by 10 seconds
Calf Raises and Calf Raise Holds with Bounces	2 x 10	Increase reps by 2
Stork Stand/Single Leg Balance	2 x 25 seconds	Increase time by 10 seconds

3.6.2.2. Dietary Intervention Sessions

The dietary intervention sessions consisted of group discussions led by a qualified dietician, specialising in T2DM, on a number of topics relating to nutritional management of T2DM, which have shown to be successful in the past (Kontogianni *et al.*, 2012). The session breakdown for the 10-week intervention period is indicated in *Table 3.4* below. Within the topics covered there were discussions on the following, which are pertinent to the study: The preferred switch from white-bread to low-GI bread, the reduction in consumption of carbohydrates, especially multiple carbohydrates during one meal, the use of extra sugar or sweetener in food or beverages, and the increased consumption of the correct type of vegetables.

Table 3.4. The main topics of the dietary intervention sessions.

Week Number	Topics Covered
1	Basics of diabetes Goals for the program
2	Different food groups and how they are digested
3	When/What to eat for snacks Portion sizes
4	Specifics of a diabetic diet (Part one)
5	Specific of a diabetic diet (Part two)
6	The Glycaemic Index (GI)
7	Alcohol and diabetes
8	Quiz on previous week's sessions
9	Monitoring of blood sugar levels
10	Medication and diet

3.6.2.3. Psychology Intervention Sessions

Each of the psychological sessions was conducted in the form of a psychological technique known as the motivational interviewing (MI), and were presented by clinical psychology masters students who were appropriately trained in the technique. The purpose of motivational interviewing is to encourage the participants to utilise intrinsic motivation to elicit a change in behaviour, and is a collaborative and person-centred approach (Miller & Rollnick, 2009). The benefits of this approach were demonstrated in recent research by Li *et al.* (2014). Each of the sessions covered a number of topics, including motivating factors to change, relapse and its challenges, coping styles and support systems, eating habits at social functions, and setting personal and health-related goals. The sessions were conducted in groups of approximately five to six people and involved a discussion on each of the relevant topics, in line with the MI techniques, and all participants were encouraged to contribute and to be as open and honest as possible.

3.7. Ethics

This study proposal was approved by the Ethics Committee for Human Research (Humanoria), Stellenbosch University (HS1029/2014). Participants were read the informed consent in their preferred language, and were given the opportunity to read the informed consent in their own time. A signed copy of the informed consent was given to each of the participants at the second testing session. Furthermore, participants were made aware of the risks associated with the testing sessions, intervention sessions or both (in the case of the experimental group). These include, discomfort as a result of the finger prick and venopuncture by *PathCare*, and discomfort and dizziness following a bout of exercise. The safety, privacy and interest of the participants were always maintained as the highest priority during the testing and intervention sessions. Furthermore, the researcher is a registered biokineticist with the Health Professionals Council of South Africa (BK0020109) and was fully qualified to perform the pre-test screenings.

3.8. Statistical Analyses

Statistical analysis of the data was performed using Statistica® (Version 10, Statsoft, USA). Descriptive statistics were reported as means ($\bar{x}$) and standard deviations ($\pm$ SD), unless otherwise stated. A multivariate analysis of variance (MANOVA) was used to analyse the data of the two groups across the various testing periods, with a Bonferroni post-test being used to determine between-group statistical significance, which was set at $p \leq 0.05$. Furthermore, in cases where the same construct was tested by multiple measures, a Šidák correction was performed in order to eliminate the likelihood of a type 1 error. A Chi squared test was used to analyse the questionnaire data that were reported as a percentage of observed frequencies. Cohen's effect sizes (ES) were also calculated to provide information on the practical significance of the results with an ES of 0 – 0.15, 0.16 – 0.40, 0.50 – 0.75, 0.76 – 1.10 and 1.11 – 1.45, being considered a negligible, small, moderate, large and very large practical effect, respectively (Thalheimer & Cook, 2002).

Chapter 4

Results

The sections below are representative of the changes that occurred between the experimental and control groups over the pre-testing, post-testing and retention testing sessions, and encompass all of the outcome variables outlined in the methodology chapter. All data are expressed as means ($\bar{x}$) and standard deviations (± SD), unless stated otherwise. In the graphs, the error bars for the control group are represented by the dotted line (---------), whereas the error bars for the experimental group are represented by the solid line (———).

4.1. Participants

Forty-five participants volunteered to participate in the study following screening to ensure that they met the inclusion and exclusion criteria. Participants were randomised into either an experimental or control group. Two participants, one each from the control and experimental group, were unable to complete the study, and their data have been removed from the final analysis. The remaining 43 participants (25 women and 18 men) completed the study and all attended more than 60 % of the respective intervention sessions. The baseline descriptive statistics of the participants are outlined in *Table 4.1* below, with the only statistically significant differences between the groups being standing height and total serum cholesterol.

Table 4.1. Baseline physical characteristics (mean ± SD) for the experimental (EXP) and control (CON) groups.

Characteristic	Experimental (EXP)		Control (CON)		p-value
	Mean ± SD	**Range**	**Mean** ± SD	**Range**	
Age (years)	61.3 ± 12.1	33 – 74	57.6 ± 12.3	40 – 80	> 0.05
Height (cm)	156.9 ± 10.2	143 – 175	164.2 ± 8.8	149 – 175	0.02 *
Body Mass (kg)	84.5 ± 19.0	55 – 133	89.3 ± 22.2	52 – 133	> 0.05
BMI ($kg.m^{-2}$)	33.8 ± 7.5	23 – 53	34.4 ± 9.7	20 – 53	> 0.05
Body Fat (%)	31.8 ± 14.1	11 – 60	29.5 ± 15.3	11 – 53	> 0.05
SBP (mmHg)	138.8 ± 21.8	100 – 190	143.9 ± 20.0	110 – 190	> 0.05
DBP (mmHg)	76.3 ± 12.0	58 – 110	82.8 ± 15.1	62 – 110	> 0.05
BGlc ($mmol.L^{-1}$)	14.3 ± 4.3	5 – 22	13.4 ± 5.0	6 – 22	> 0.05
TSC ($mmol.L^{-1}$)	4.97 ± 1.2	4 – 9	5.71 ± 1.1	5 – 9	0.02 *
HbA1c (%)	8.82 ± 2.1	6 – 14	9.47 ± 2.3	6 – 14	> 0.05

* ($p < 0.05$). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; BGlc, blood glucose; TSC, total serum cholesterol; HbA1c, glycated haemoglobin.

4.2. Anthropometric Variables

4.2.1. Body Mass Index

Figure 4.1 shows the differences in body mass index (BMI) between the experimental and control groups over the three testing sessions. No significant differences were observed throughout the intervention or retention period between groups, and there was no statistically significant interaction effect (group x time). The difference between the two groups at post-testing (Post) was not statistically significant ($p > 0.05$), nor practically significant (ES = 0.01, *Table 4.2*). The difference between the pre-testing (PreT) and the retention (Reten) testing in the experimental group was 8.75 %, with this change not being statistically significant ($p > 0.05$).

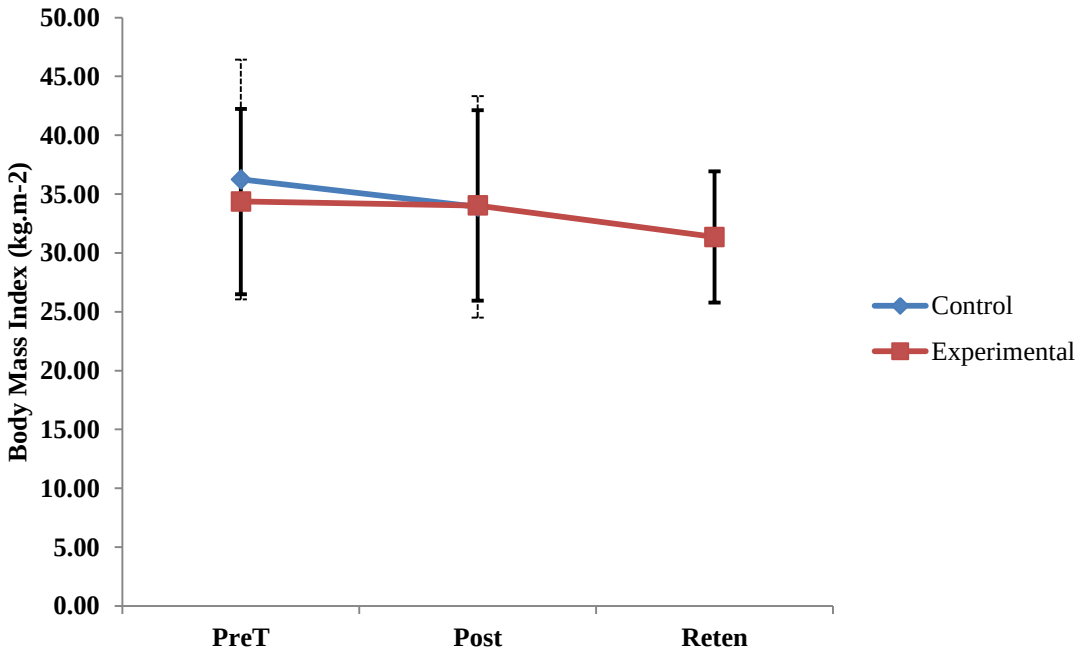

Figure 4.1. Changes in body mass index (BMI) over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing.

4.2.2. Body Fat Percentage

There were no statistically significant differences in body fat percentage between the two groups over time ($p > 0.05$), and no statistically significant interaction effect ($p > 0.05$) (*Figure 4.2*). The control group showed almost no change in body fat percentage from the pre-testing session (PreT) to the post-testing session, with an overall change of 0.8 % body fat, which was not statistically significant ($p > 0.05$). The experimental group, however, showed a statistically significant drop in body fat percentage of 3.4% ($p < 0.001$) from PreT to post-testing, and a 3.7 % decrease from PreT to the retention testing session ($p < 0.001$). While there was a decrease of 0.3 % from post-testing to retention testing in the experimental group, this difference was not statistically significant ($p >$

0.05). Furthermore, there were no statistically, nor practically significant differences (*Table 4.2*) between the groups at any of the testing sessions (p > 0.05).

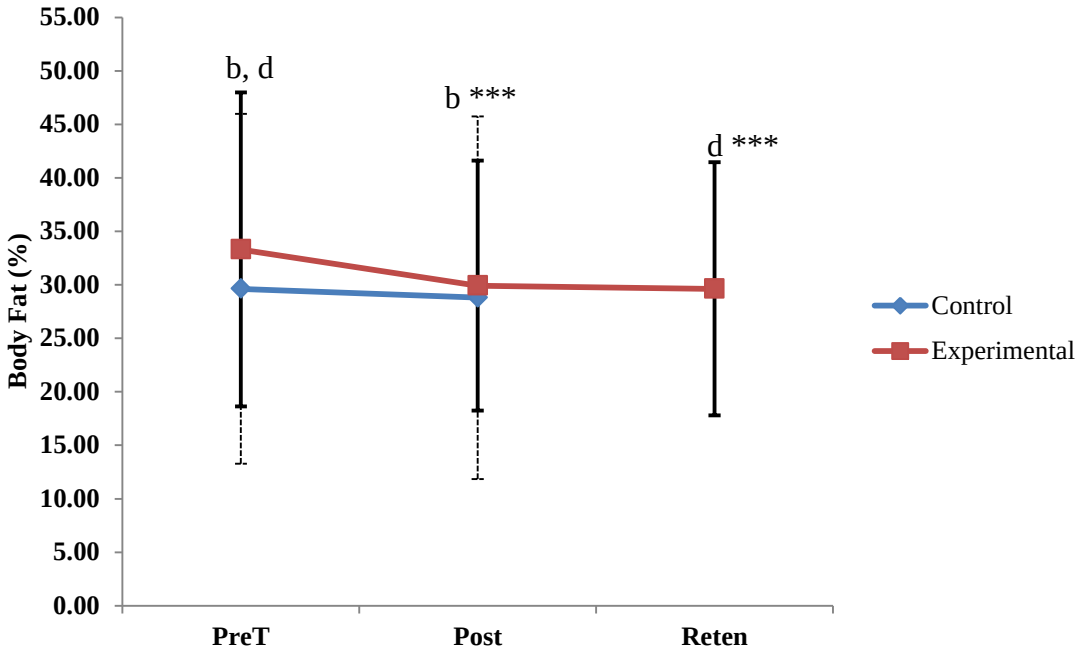

Figure 4.2. Changes in body fat percentage over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. ***, p < 0.001; b, statistically significant difference between PreT and Post (p < 0.05) for experimental group; d, statistically significant difference between PreT and Reten for the experimental group (p < 0.05).

Table 4.2. Effect sizes (ES) related to differences in anthropometric measurements between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	BMI	- 0.22	- 0.96 - 0.53	S
	Body Fat %	0.24	- 0.50 - 0.99	S
Post	BMI	0.01	- 0.61 - 0.64	N
	Body Fat %	0.08	- 0.55 - 0.71	N

PreT, pre-testing ; Post, post-testing ; N, negligible ; S, small.

4.3. Cardiovascular Variables

4.3.1. Systolic Blood Pressure

Changes in systolic blood pressure (SBP) between the two groups over the course of the study can be seen in *Figure 4.3* below. There were no statistically significant differences between the two groups over time ($p > 0.05$), nor was there a statistically significant interaction effect ($p > 0.05$). Between the pre-testing (PreT) session and the post-testing session, the control group on average had a four percent higher SBP. There was an approximate 2.0 mmHg increase in SBP in both groups at post-testing, signifying only a minor change from the pre-testing session (PreT), with no statistically significant or practically significant (*Table 4.3*) differences between the groups ($p > 0.05$). When comparing the retention testing session to both PreT and post-testing, there was a decrease of 2.40 % (3.3 mmHg) and 3.81 % (5.3 mmHg), respectively, neither of which were statistically significant ($p > 0.05$).

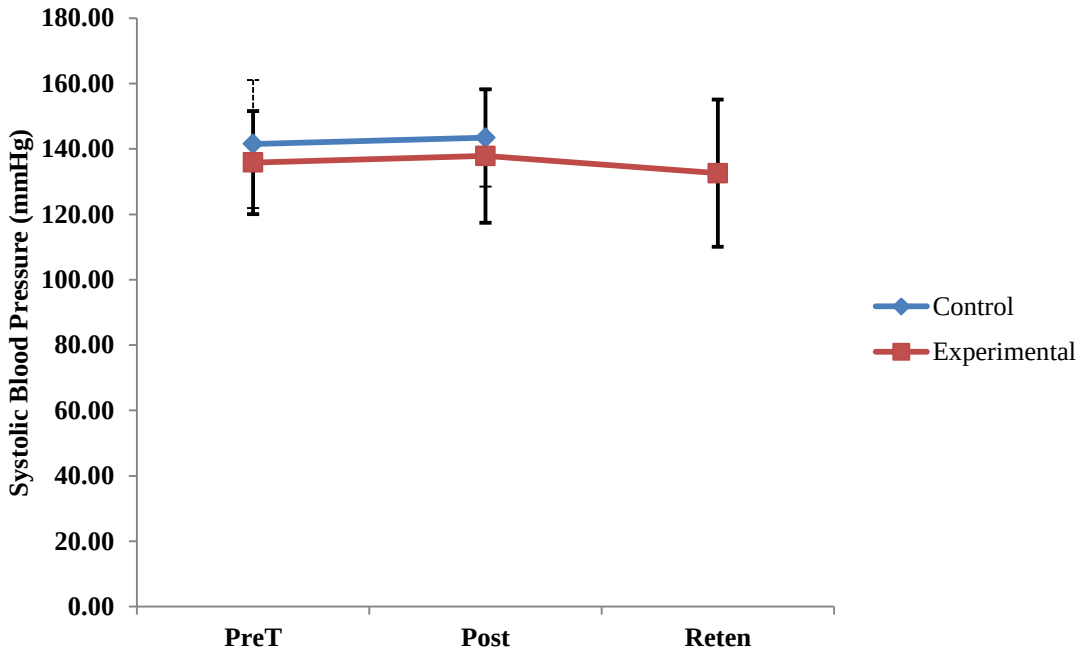

Figure 4.3. Changes in systolic blood pressure over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing.

4.3.2. Diastolic Blood Pressure

The changes in diastolic blood pressure (DBP) for the two groups are shown in *Figure 4.4* below, and show that the control group had on average a seven percent higher DBP than the experimental group over the first two testing sessions, although there were no statistically significant differences between the groups over time ($p > 0.05$), or any interaction effect ($p > 0.05$). The experimental group displayed statistically significant reductions in DBP of 5.4 % (4.2 mmHg) and 6.5 % (5.0 mmHg) at post-testing ($p = 0.04$) and retention ($p = 0.03$), respectively, when compared to PreT. This is further confirmed by the moderate practically significant difference between the control and experimental group seen at post-testing (ES = - 0.64, *Table 4.3*).

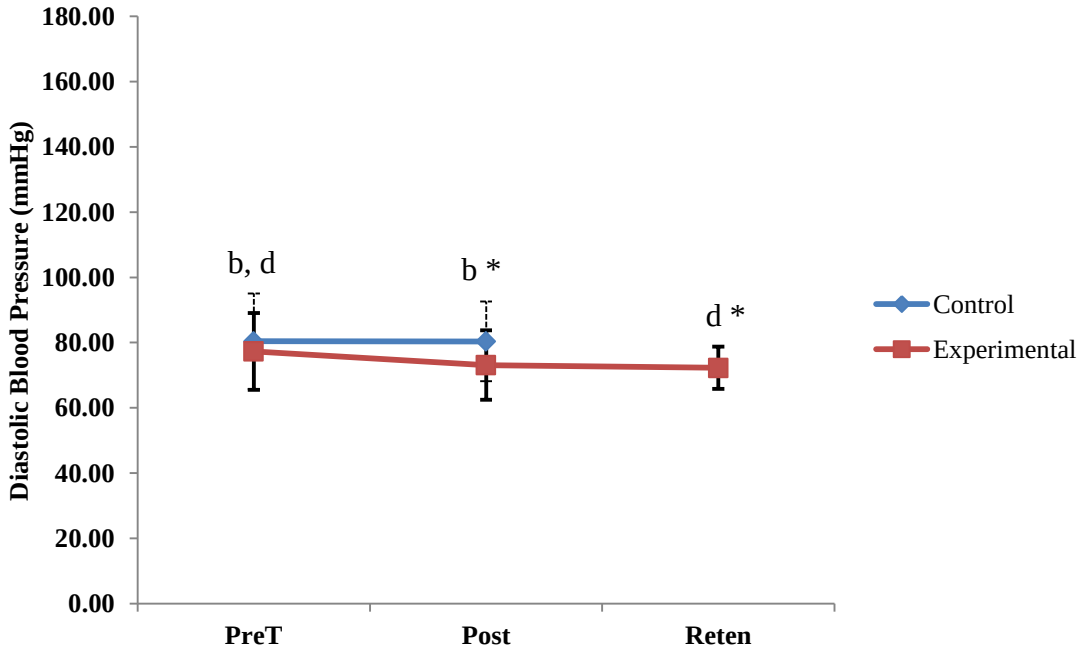

Figure 4.4. Changes in diastolic blood pressure over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing.*, $p < 0.05$; b, statistically significant difference between PreT and Post in experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten for the experimental group ($p < 0.05$).

Table 4.3. Effect sizes (ES) related to differences in systolic blood pressure (SBP) and diastolic blood pressure (DBP) between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	SBP	- 0.33	- 1.08 ; 0.41	S
	DBP	- 0.24	- 0.99 ; 0.50	S
Post	SBP	- 0.30	- 0.94 ; 0.33	S
	DBP	- 0.64	- 1.28 ; 0.01	M

PreT, pre-testing ; Post, post-testing ; SBP, systolic blood pressure ; DBP, diastolic blood pressure ; S, small ; M, moderate.

4.4. Haematological Variables

Due to their being two outcome variables related to blood glucose levels, a Šidák p-value adjustment was made, with the level of statistical significance for random blood glucose and glycated haemoglobin (HbA1c), being set at $p < 0.03$.

4.4.1. Random Blood Glucose

Figure 4.5 displays the change in random blood glucose over the three testing occasions with statistically significant differences between and within the groups, as well as a statistically significant interaction effect ($p = 0.02$). An increase of 14.1 % in blood glucose from the pre-testing session (PreT) to post-testing was reported in the control group although this increase was not found to be statistically significant ($p > 0.03$). On the other hand, there was a 12.8 % decrease from PreT to post-testing, and a further 4.97 % decrease from post-testing to retention testing in the experimental group, neither of which was statistically significant ($p > 0.03$). Similarly to this, the cumulative decrease of approximately 18.0 % from PreT to the retention testing session in the experimental group, was also not found to be statistically significant ($p > 0.03$). When examining the differences between the two groups, a statistically significant difference of 20.0 % was found at post-testing ($p = 0.03$) and this difference was also of moderate practical significance (ES = - 0.70, *Table 4.4*).

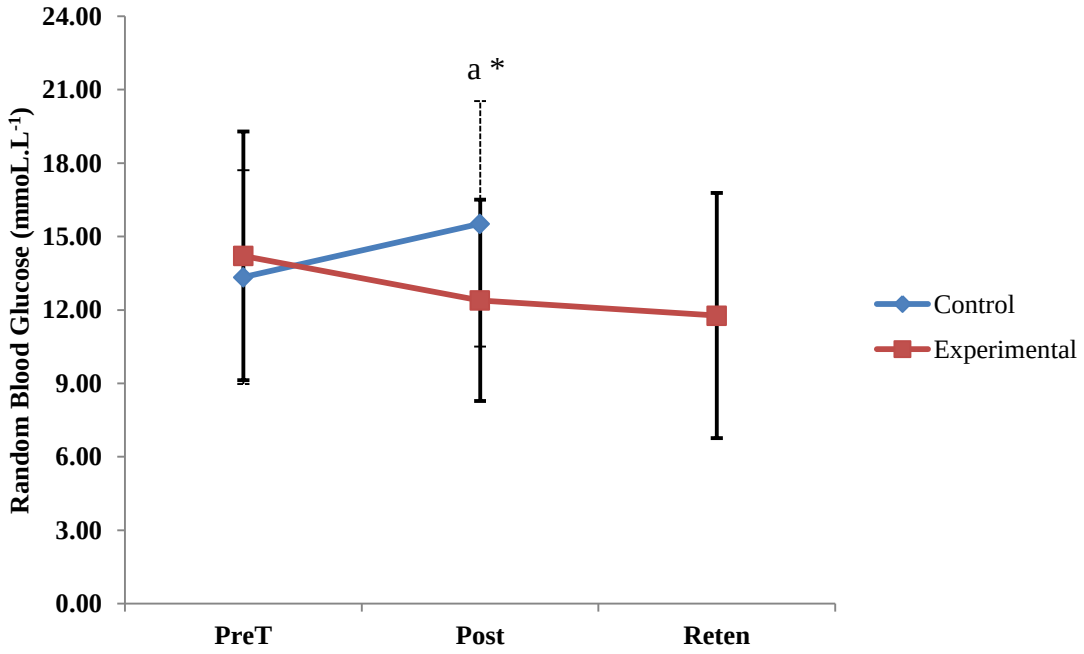

Figure 4.5. Changes in random blood glucose over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. *, $p < 0.03$; a, statistically significant difference between experimental and control group ($p < 0.03$).

4.4.2. Total Serum Cholesterol

Changes over the three testing sessions can be seen in *Figure 4.6*. There were statistically significant differences between the two groups over time, although no interaction effect was found ($p > 0.05$). The differences between the two groups at the pre-testing session (PreT) and post-testing were statistically significant (PreT, $p = 0.02$; Post, $p < 0.001$), with the difference of the greatest magnitude being at post-testing, namely a substantial difference of 23 %. These differences were also found to be of large and very large practical significance (PreT, ES = - 0.83; Post, ES = - 1.11), respectively, and are displayed in *Table 4.4*. Both groups saw an increase in their total serum cholesterol (TSC) from PreT to post-testing, although neither of the differences were statistically significant ($p > 0.05$). On average, the control group had a 19.9 % higher total serum cholesterol measurement than the experimental group. TSC levels increased from post-testing to the retention testing session in the experimental group by 0.83 %, and by 2.74% from PreT, with neither of these differences found to be statistically significant ($p > 0.05$).

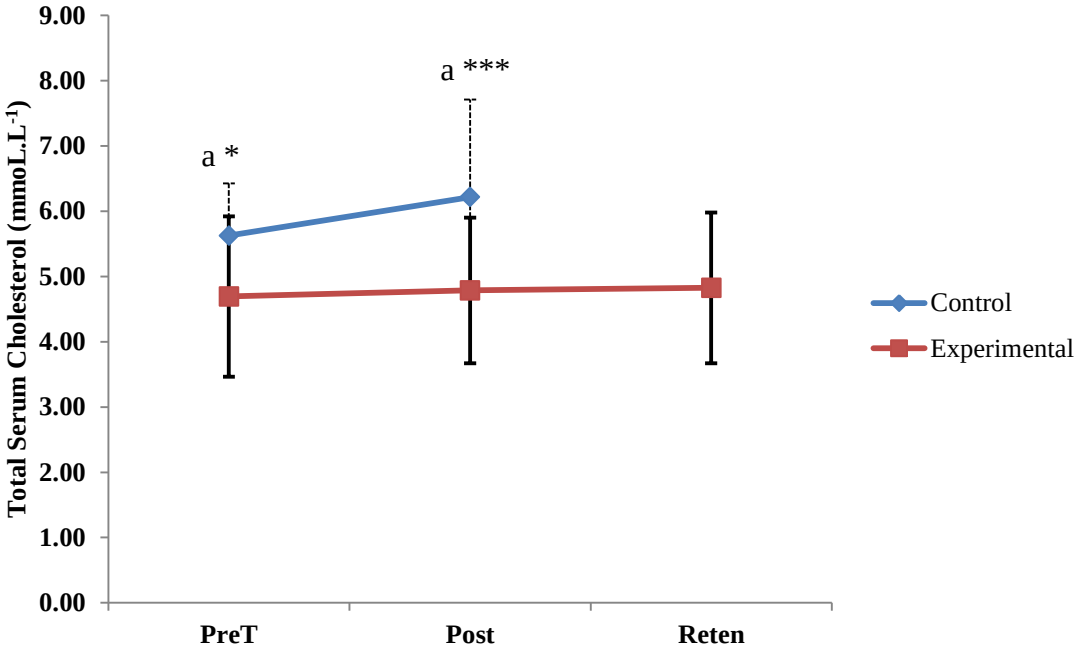

Figure 4.6. Changes in total serum cholesterol over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing.*, $p < 0.05$; ***, $p < 0.001$; a, statistically significant difference between experimental and control group ($p < 0.05$).

4.4.3. Glycated Haemoglobin

The final haematological variable measured was glycated haemoglobin (HbA1c), with differences between the two groups displayed in *Figure 4.7*. In this instance, there was a statistically significant interaction effect ($p = 0.01$), with differences between and within the groups being observed over time. The difference between the two groups at post-testing was 1.38 %, which was found to be statistically significant ($p = 0.03$) and practically significant (ES = - 0.64, *Table 4.4*). Statistically significant differences were also found between the pre-testing session (PreT) and post-testing in the experimental group ($p = 0.01$), as well as between PreT and the retention testing session ($p = 0.02$). Despite the 1.07 % increase in HbA1c from PreT to post-testing in the control group, the change was not statistically significant ($p > 0.05$).

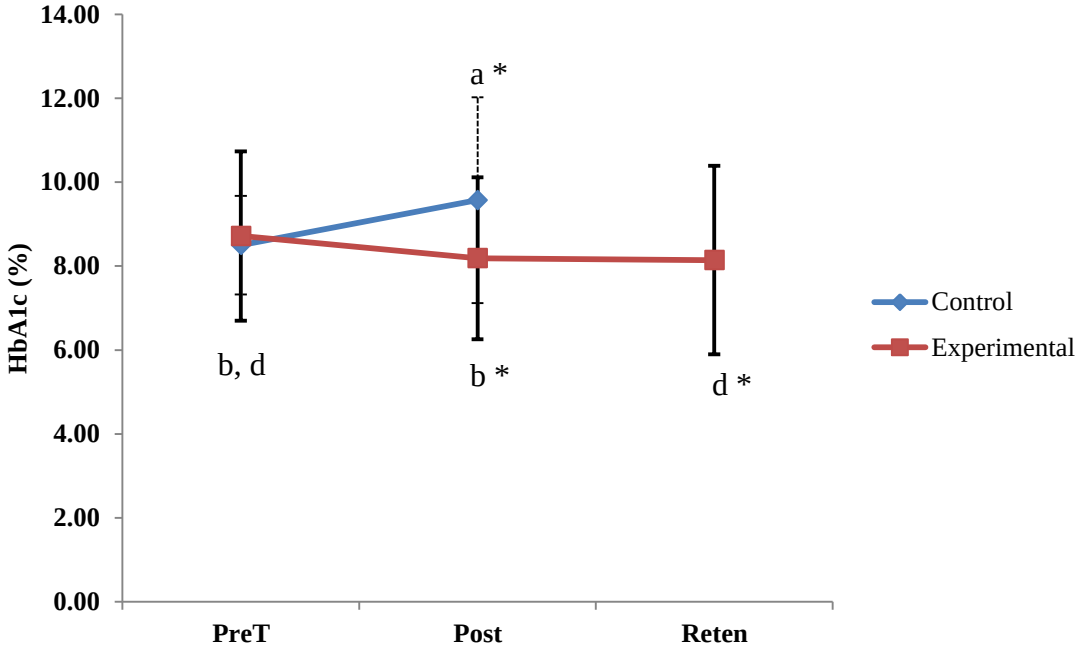

Figure 4.7. Changes in glycated haemoglobin (HbA1c) over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. *, $p < 0.05$; a, statistically significant difference between experimental and control group ($p < 0.05$); b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten ($p < 0.05$).

Table 4.4. Effect sizes (ES) related to differences in the haematological variables between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	BGlc	0.18	- 0.57 ; 0.92	S
	TSC	- 0.83	- 1.60 ; - 0.06	L
	HbA1c	0.12	- 0.62 ; 0.86	N
Post	BGlc	- 0.70	- 1.34 ; - 0.05	L
	TSC	- 1.11	- 1.78 ; - 0.44	VL
	HbA1c	- 0.64	- 1.28 ; 0.003	L

PreT, pre-testing ; Post, post-testing ; BGlc, blood glucose ; TSC, total serum cholesterol ; HbA1c, glycated haemoglobin ; N, negligible ; S, small ; L, large ; VL, very large.

4.5. Functional Capacity Variable

4.5.1. Six Minute Walk Test (6MWT)

Differences between the two groups, and changes over the three testing occasions are displayed in *Figure 4.8* below. There were no statistically significant differences ($p > 0.05$) between the groups over time, and no interaction effect. At the pre-testing session (PreT), both groups walked almost identical distances, with the control group walking 60 cm, or 0.2 % further. Both groups increased the total distance walked in six minutes at post-testing, with no statistically significant difference ($p > 0.05$) found between the two groups, although there was a small practically significant difference (ES = 0.38, *Table 4.5*). Statistically significant differences were found, however, when PreT ($p = 0.0001$) was compared to post-testing in the experimental group. Compared to post-testing, a slight decrease in the total distance walked of 3.89 % (14.7 m) was reported at the retention-testing occasion in the experimental group, with the difference not being statistically significant ($p > 0.05$). Despite the decrease compared to post-testing, the total distance walked at retention testing was still 11.0 % (39.8 m) further than PreT, which was found to be statistically significant ($p = 0.02$).

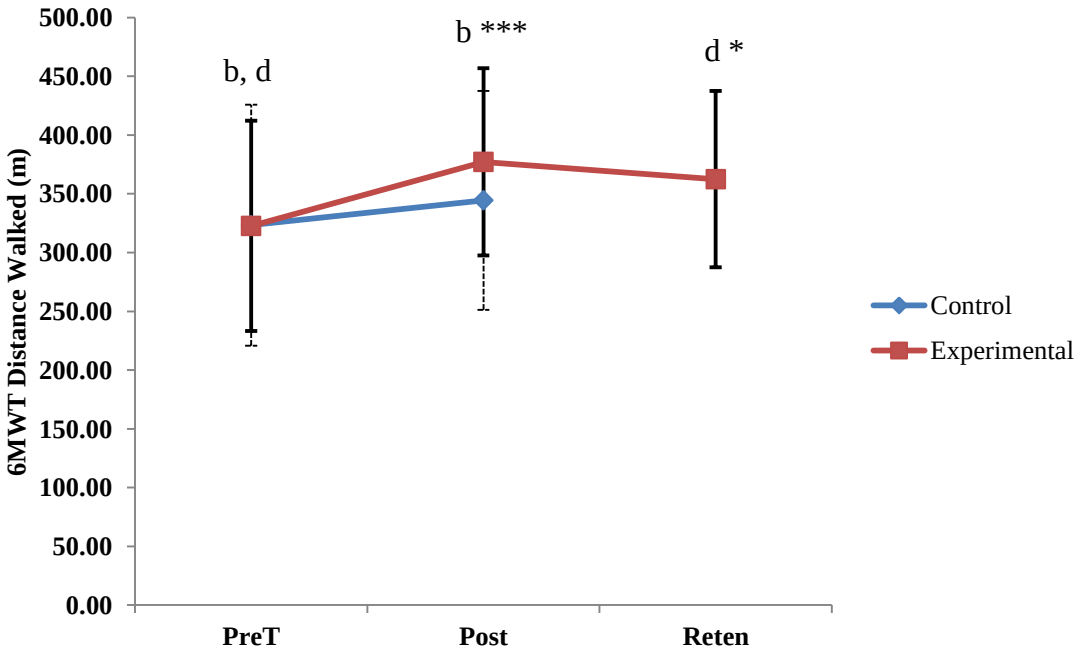

Figure 4.8. Changes in total distance walked in the six minute walk test (6MWT) over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. *, $p < 0.05$; ***, $p < 0.001$; b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten ($p < 0.05$).

Table 4.5. Effect sizes (ES) related to differences in the distance walked during the six minute walk test (6MWT) between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	6MWT	- 0.006	- 0.75 ; 0.74	N
Post	6MWT	0.38	- 0.25 ; 1.02	S

PreT, pre-testing ; Post, post-testing ; 6MWT, six minute walk test ; N, negligible ; S, small.

4.6. Health Related Quality of Life Questionnaires

Due to their being two questionnaires which objectively measured health-related quality of life (HRQoL), a Šidák p-value adjustment was made, with the level of statistical significance for each of the different domains of the two questionnaires, being set at $p < 0.03$.

4.6.1. Short-Form 36 (SF-36)

The SF-36 is a non-disease specific health-related quality of life (HRQoL) questionnaire and is scored according to the following domains which can be seen in *Figure 4.9* to *Figure 4.10* below: physical functioning, limitations in physical role functioning, bodily pain, social role functioning, mental health, limitations in emotional role functioning, vitality and general health perceptions. Each domain is scored from zero to 100, with zero being the least favourable outcome (i.e. HRQoL in the specific domain being scored is affected to the most severe extent), and 100 being the most favourable outcome (i.e. HRQoL in the specific domain being scored is not affected at all).

4.6.1.1. Physical Functioning

Changes in physical functioning scores between the two groups over the three testing occasions can be seen in *Figure 4.9* below. There were statistically significant differences between and within the groups over time, as well as a statistically significant interaction effect ($p < 0.001$). When the two groups were compared at post-testing, it was found that the experimental group scored substantially higher (34.3 %) than the control group, a difference that was found to be statistically significant ($p = 0.008$), as well as having a large practical significance (ES = 0.90, *Table 4.6*). Furthermore, the difference between post-testing and PreT (37.5%) in the experimental group was found to be statistically significant ($p < 0.001$). The change in physical functioning score between post-testing and the retention-testing occasion in the experimental group was hardly noticeable (0.18 %),

however, the difference between PreT and the retention-testing occasion was far more substantial. The difference of 27.4 % was found to be statistically significant ($p < 0.001$).

4.6.1.2. Limitations in Physical Role Functioning

Similarly to physical functioning, there were statistically significant differences between and within the groups over time, as well as a statistically significant interaction effect ($p = 0.002$) *(Figure 4.9)*. Once again, the control group scored on average 3.61 % higher than the experimental group at the pre-testing session (PreT), with the difference not being statistically significant ($p > 0.03$). At post-testing, the 23.6 % difference in score between the experimental and control group was found to be statistically significant ($p = 0.01$), as well as having a large practically significant difference (ES = 0.94, *Table 4.6*). Furthermore, within the experimental group, the difference between post-testing and PreT (19.6 %) was statistically significant ($p = 0.005$). Similar to what was seen in the above domain, there was a slight decrease (3.53 %) in physical role functioning score from post-testing to the retention testing session in the experimental group, although this difference was not statistically significant ($p > 0.03$). When the retention testing session is compared to PreT, the difference of 13.3 % was not statistically significant ($p > 0.03$).

4.6.1.3. Bodily Pain

As depicted in *Figure 4.9*, there were no statistically significant differences between the two groups over time ($p > 0.03$) and no interaction effect. The control group scored 13.8 % higher (and therefore a better outcome) than the experimental group at the second pre-testing occasion (PreT), which was not statistically significant ($p > 0.03$) or practically significant (*Table 4.6*). Both groups scored similarly at post-testing, and although there was an increase in score from PreT to post-testing of 10.6 % in the experimental group, it was not statistically significant ($p > 0.03$). Once again, it was found that at the retention-testing occasion, there was a change in bodily pain score of 7.51 % when compared to post-testing in the experimental group, a difference that was not statistically significant ($p > 0.03$). When compared to PreT, the difference of 17.3 % was not found to be statistically significant ($p > 0.03$).

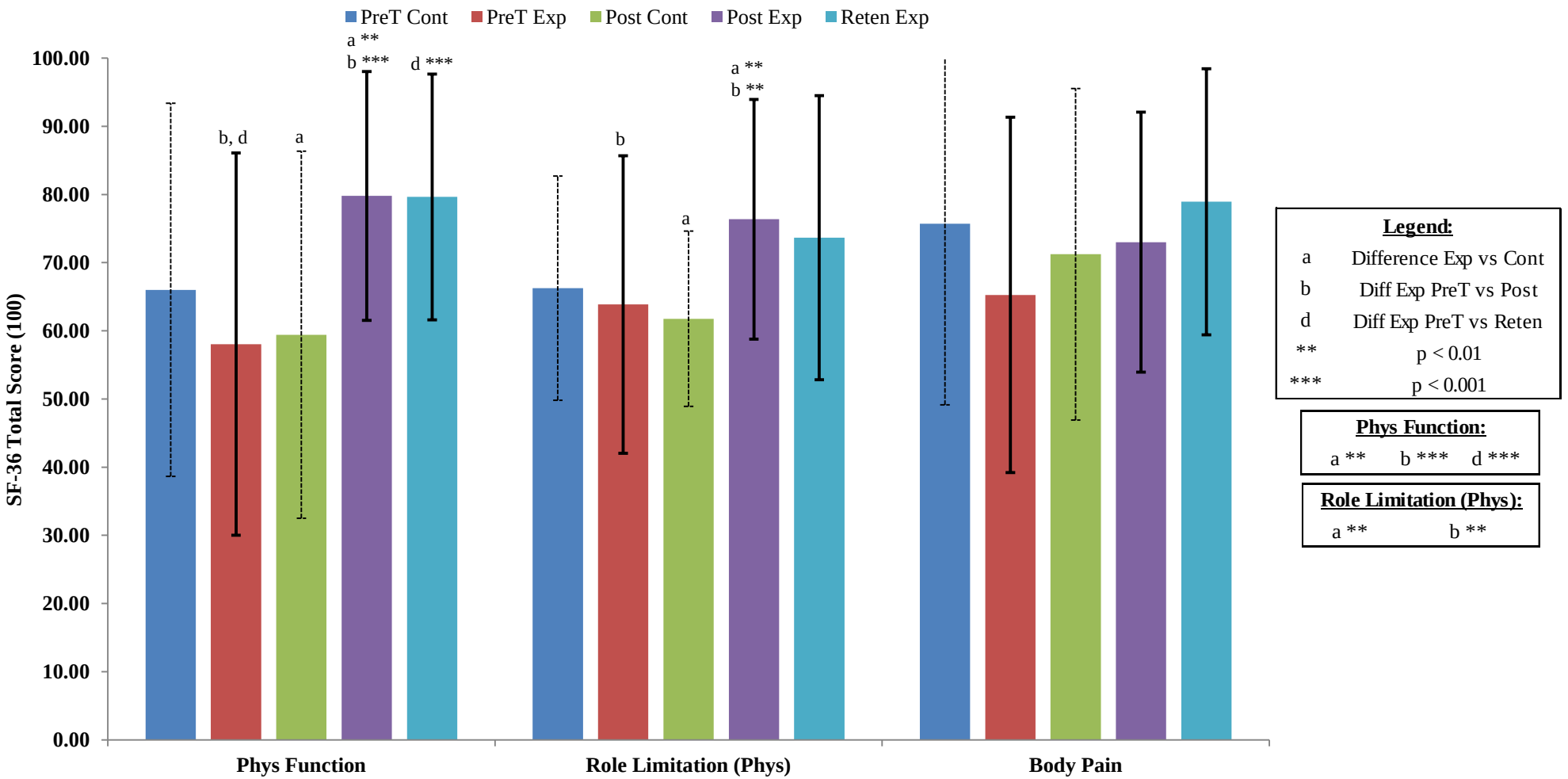

Figure 4.9. Changes in scores for the physical parameters of the short form-36 (SF-36) questionnaire, over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. The table inserts to the right of the graph indicates the statistically significant differences ($p < 0.03$) found for the three domains.

4.6.1.4. Social Role Functioning

Changes in social role functioning score between the two groups and across the three testing occasions, is graphically represented in *Figure 4.10* below. There were no statistically significant differences between the two groups over time ($p > 0.03$) and no interaction effect present. The difference between the two groups at the pre-testing session (PreT) was 9.1 % and although this difference was not statistically significant ($p > 0.03$), it was of moderate practical significance (ES = - 0.41, *Table 4.6*). At post-testing, the difference between the experimental and control group was 14.7 %, which was not statistically significant ($p > 0.03$), although it was a difference of moderate practical significance (ES = 0.65). The social role functioning score was highest at the retention testing occasion with differences of 13.4 % and 6.50 % when compared to PreT and post-testing, respectively. Neither of these differences was statistically significant ($p > 0.03$).

4.6.1.5. Mental Health

Figure 4.10 below is a graphical representation of the changes that occurred with respect to mental health between the two groups over the three testing sessions. There were statistically significant differences between and within the groups over time, although no interaction effect was found. Both the experimental and the control group had almost identical scores at the pre-testing session (PreT), with a non-significant overall difference ($p > 0.03$). At post-testing, the experimental group had a 14.1 % higher score compared to the control group, a difference that was not statistically significant ($p > 0.03$), although was of moderate practical significance (ES = 0.70, *Table 4.6*). At the retention-testing occasion, the mental health score decreased significantly ($p = 0.03$) when compared to post-testing in the experimental group, with a difference of 9.62 %. When compared to PreT, the score at the retention testing session was 4.99 % lower, although the difference was not statistically significant ($p > 0.03$).

4.6.1.6. Limitations in Emotional Role Functioning

The change in scores related to limitations in emotional role functioning between the two groups, over the three different testing occasions, is displayed in *Figure 4.10* below. There were no statistically significant differences between the two groups over time ($p > 0.03$), nor any interaction effect. The difference between the two groups at the pre-testing session (PreT) was a mere 2.9 %, which was not statistically significant ($p > 0.03$). Contrary to what was found at PreT, at post-testing the experimental group scored 6.5 % higher than the control group, although this difference was not statistically significant ($p > 0.03$) and was only of small practical significance (ES = 0.26, *Table 4.6*). Similarly to what was seen in a number of the above-mentioned domains, the difference between post-testing and PreT in the experimental group was statistically significant, and 13.4 % in

magnitude (p = 0.02). While there was an 8.82 % decrease in the retention testing score compared to post-testing, the score was still 5.04 % higher than PreT, with neither of these differences being statistically significant (p > 0.03).

4.6.1.7. Vitality

Figure 4.10 below is a graphical representation of the changes in vitality scores between the two groups over the three testing occasions. There were statistically significant differences between and within the two groups over time, although no interaction effect was found. Both the experimental and control group scored similarly at the pre-testing session (PreT), with the experimental group scoring 3.68 % higher than the control group, a non-statistically significant difference (p > 0.03). At post-testing, the 24.5 % difference between the experimental and control group was statistically significant (p = 0.004), as well as being of large practical significance (ES = 0.96, *Table 4.6*). Furthermore, the 15.1 % difference between post-testing and PreT in the experimental group was also statistically significant (p = 0.008). Contrary to what was seen in a number of the above-mentioned domains, there was a substantial decrease in vitality score from post-testing to the retention-testing occasion in the experimental group, with the score being only slightly higher than PreT (1.09 %). The decrease of 12.2 % between post-testing and the retention-testing occasion was statistically significant (p = 0.02).

4.6.1.8. General Health Perceptions

Changes in general health perceptions scores between the two groups, and across the three testing occasions, are displayed in *Figure 4.10* below. Similarly to the vitality domain, there were statistically significant differences between and within the two groups over time, although no interaction effect. There was a marginal difference (1.02 %) between the two groups at the pre-testing session (PreT), which was not statistically significant (p > 0.03). At post-testing however, the 24.8 % difference between the two groups was statistically significant (p = 0.004), and of large practical significance (ES = 0.86, *Table 4.6*). Similarly to what was reported above, the difference between post-testing and PreT (23.4 %) in the experimental group was statistically significant (p < 0.001). Scores at the retention-testing session were slightly lower when compared to post-testing in the experimental group, although the difference of 3.71 % was not statistically significant (p > 0.03). There was a statistically significant difference, however, between PreT (15.9 %, p = 0.02) and the retention-testing occasion.

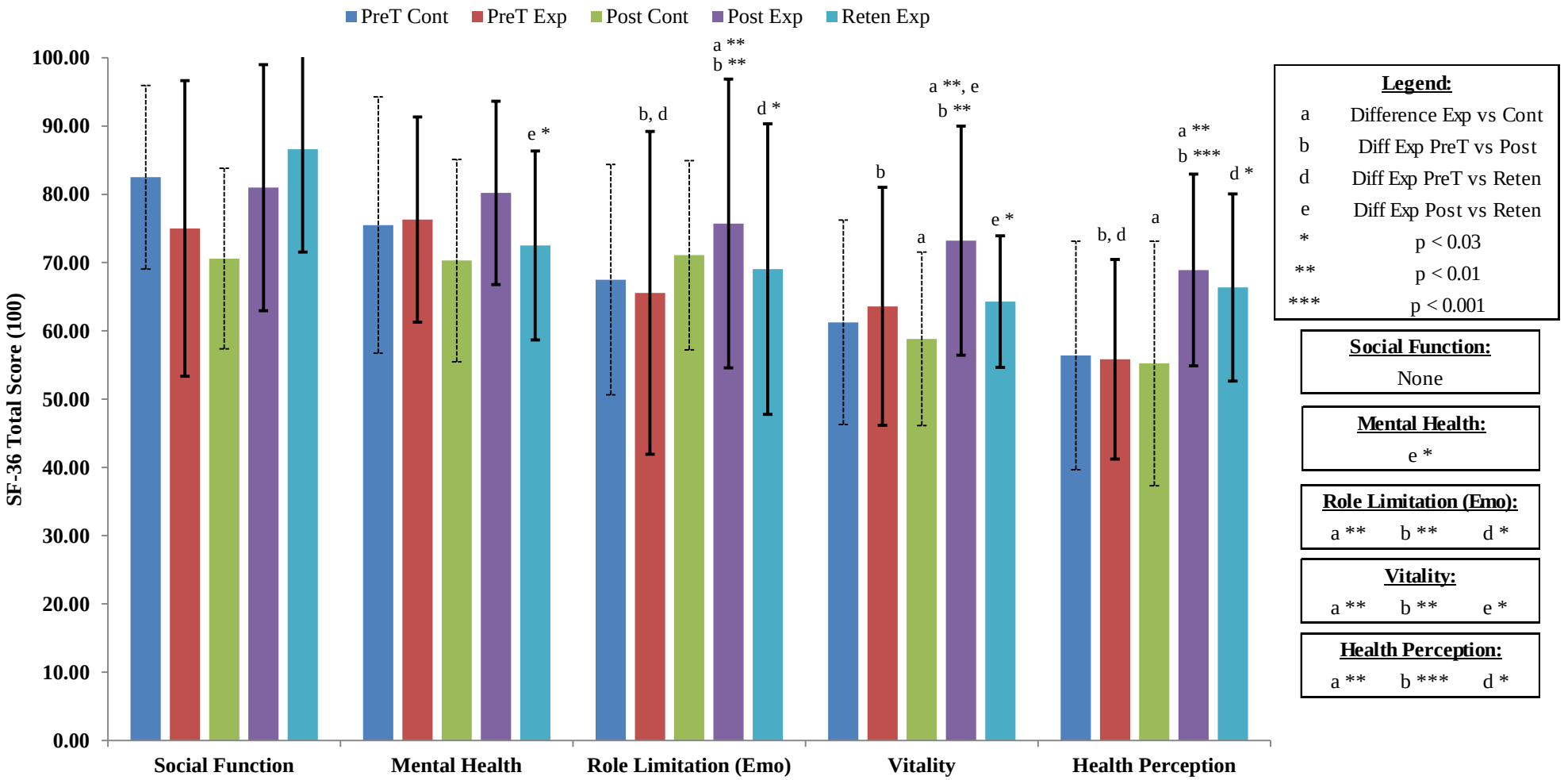

Figure 4.10. Changes in scores for the psychological parameters of the short form-36 (SF-36) questionnaire, over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. The table inserts to the right of the graph indicates the statistically significant differences ($p < 0.03$) found for the five domains.

Table 4.6. Effect sizes (ES) related to differences in the SF-36 domains between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	Physical Functioning	- 0.29	- 0.89 ; 0.32	S
	Role Physical	- 0.12	- 0.72 ; 0.48	N
	Role Social	- 0.41	- 1.02 ; 0.20	M
	Body Pain	- 0.40	- 1.00 ; 0.21	S
	Mental Health	0.05	- 0.55 ; 0.65	N
	Role Emotional	- 0.09	- 0.69 ; 0.51	N
	Vitality	0.14	- 0.46 ; 0.74	N
	Health Perception	- 0.04	- 0.64 ; 0.56	N
Post	Physical Functioning	0.90	0.27 ; 1.53	L
	Role Physical	0.94	0.31 ; 1.57	L
	Role Social	0.65	0.04 ; 1.27	M
	Body Pain	0.08	- 0.52 ; 0.68	N
	Mental Health	0.70	0.09 ; 1.32	M
	Role Emotional	0.26	- 0.35 ; 0.86	S
	Vitality	0.96	0.33 ; 1.59	L
	Health Perception	0.86	0.23 ; 1.48	L

PreT, pre-testing ; Post, post-testing ; N, negligible ; S, small ; M, moderate ; L, large.

4.6.2. Diabetes-39 Questionnaire (D-39)

The D-39 is a disease-specific health-related quality of life (HRQoL) questionnaire designed for use in diabetic populations. Similarly to the SF-36, it is scored according to a number of categories or domains that are relevant to a person suffering from diabetes and are graphically represented in *Figure 4.11* to *Figure 4.12*. The domains of diabetes specific HRQoL that are measured through this questionnaire are: energy and mobility, sexual functioning, diabetes management and control, anxiety and worry, social burdens, perceived quality of life and perceived diabetes severity. The lower the score, the less affected their HRQoL is, with a higher score indicating the persons HRQoL being affected to a greater extent.

4.6.2.1. Energy and Mobility

Figure 4.11 indicates the changes in energy and mobility, as determined by the D-39, over the three testing occasions and between the two groups. For this domain there were statistically significant differences between and within the two groups over time, and a statistically significant interaction effect ($p = 0.003$). At the pre-testing session (PreT), the control group scored 10.0 % higher than the experimental group, although this difference was not statistically significant ($p > 0.03$) and only showed a small degree of practical significance (ES = - 0.31, *Table 4.7*). At post-testing however, the experimental group scored 33.9 % lower than the control group, indicating an improvement in HRQoL related to energy and mobility, which was statistically significant ($p < 0.001$), as well as being a very large practically significant difference (ES = - 1.33). While the control group showed a general trend towards a lower score, and therefore a lower impact on their energy and mobility as a result of diabetes, the decrease was not statistically ($p > 0.03$), nor practically significant. On the contrary, the experimental group displayed a substantial 28.5% drop from PreT to post-testing, which was statistically significant ($p < 0.001$). There was a slight increase in score for the experimental group from post-testing to the retention testing session of 7.40 %, indicating that their HRQoL was once again being affected by their levels of energy and mobility, but the change was not statistically significant ($p > 0.03$). However, the 22.8 % difference between PreT and retention testing was statistically significant ($p = 0.003$).

4.6.2.2. Sexual Functioning

The changes in scores with respect to the sexual functioning domain of the D-39 over the three testing occasions can be seen in *Figure 4.11*. There were no statistically significant differences between the two groups over time ($p > 0.03$) and no interaction effect. At the pre-testing session (PreT), both the experimental and control group had similar scores, with the experimental group scoring 6.56 % higher, thereby indicating that their sexual functioning had a greater impact on their HRQoL. This difference was neither statistically nor practically significant ($p > 0.03$). The difference between the two groups at post-testing was 17.1 %, where the HRQoL of the experimental group was less affected by sexual function. This difference was not statistically significant ($p > 0.03$) and only of small practical significance (ES = - 0.27, *Table 4.7*). However, the difference between PreT and post-testing in the experimental group was statistically significant ($p = 0.02$), with a substantially improved HRQoL with respect to sexual functioning. The scores at the retention-testing occasion were almost identical to the score at post-testing, with the only statistically significant difference being found between PreT and retention testing ($p = 0.03$), where once again there was an improved HRQoL with respect to sexual functioning.

4.6.2.3. Diabetes Management and Control

Figure 4.11 below shows the changes in diabetes management and control scores between the two groups over the three testing occasions. Statistically significant differences between and within the groups were found over time ($p < 0.03$), although no interaction effect was found. The control group scored 8.1 % higher than the experimental group at the pre-testing session (PreT), indicating a greater impact of their HRQoL, although this difference was not statistically significant ($p > 0.05$) and only of small practical significance (ES = - 0.19, *Table 4.7*). Statistically significant differences between the two groups were, however, observed at post-testing, with a 25.2 % difference between the two groups ($p = 0.004$), which also resulted in a large practically significant difference (ES = - 0.85). Compared to PreT, the experimental group had a statistically significant change at post-testing of 16.2 % ($p = 0.01$). As has been a general trend for most of the above-mentioned domains, there was a slight increase in the score from post-testing to the retention testing session in the experimental group (2.47 %), although this difference was not statistically significant ($p > 0.03$). The 14.1 % decrease in score when compared to PreT was also not statistically significant ($p > 0.03$).

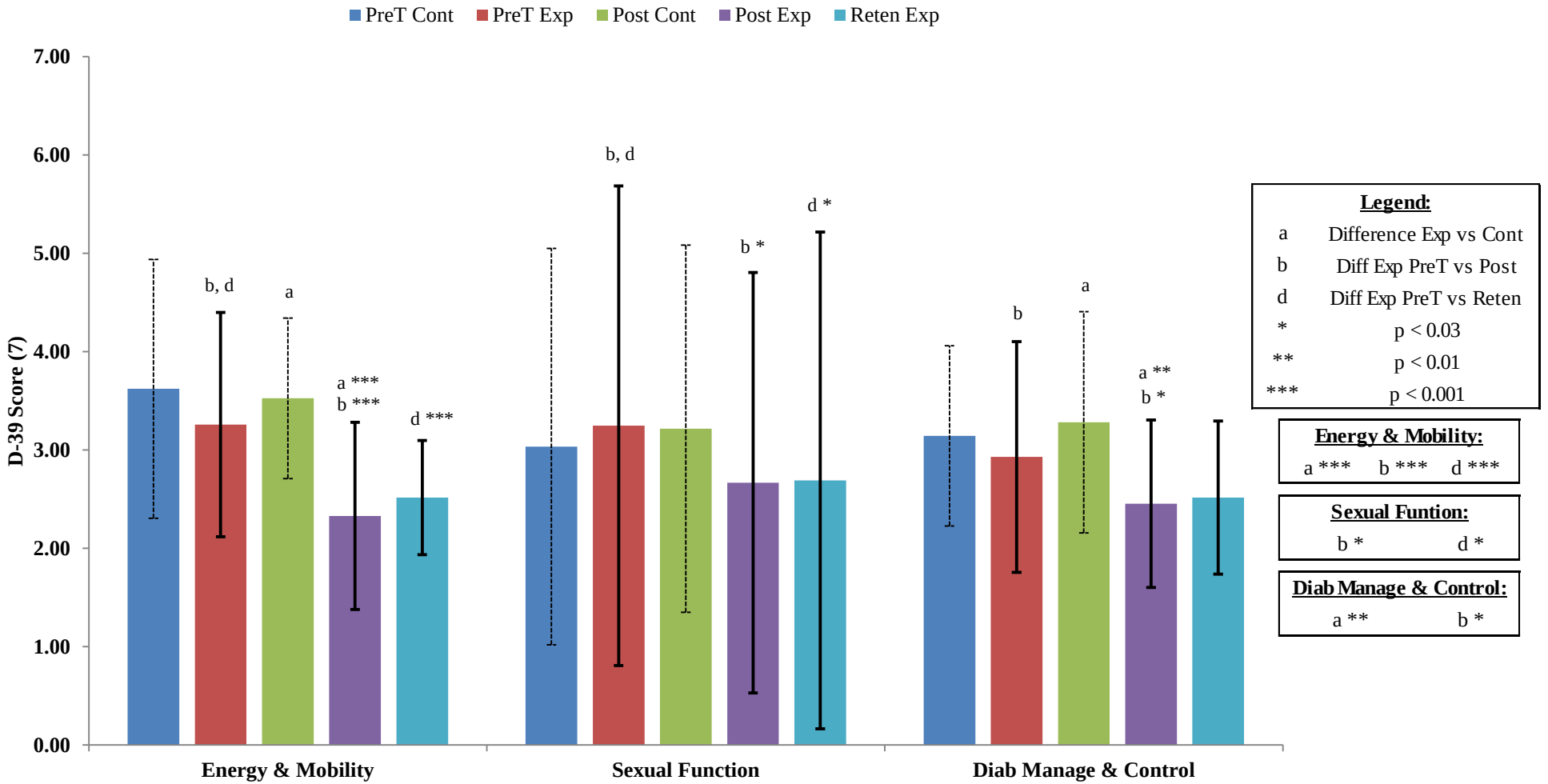

Figure 4.11. Changes in scores for the physical parameters of the diabetes-39 questionnaire (D-39) over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. The table inserts to the right of the graph indicates the statistically significant differences ($p < 0.03$) found for the three domains.

4.6.2.4. Social Burdens

The changes in social burdens score between the experimental and control group across the three testing occasions is displayed in *Figure 4.12* below. Statistically significant differences between and within the groups were found over time, however, no statistically significant interaction effect was found ($p > 0.03$). Similar to what has been observed in other D-39 domains, the control group scored 2.94 % higher than the experimental group in the pre-testing session (PreT), indicating that social burdens affected their HRQoL to a greater degree. This difference was not statistically or practically significant ($p > 0.03$). When the two groups were compared at post-testing, the difference of 33.1 % was statistically significant ($p = 0.003$), as well as having a large practical significance (ES = - 0.92, *Table 4.7*). Furthermore, the reduction in score from PreT to post-testing (21.7 %) in the experimental group, was also statistically significant ($p = 0.01$). At the retention-testing occasion it was found that the social burdens score increased marginally (4.27 %) when compared to post-testing in the experimental group, but was still 18.2 % lower than PreT; a difference that was not statistically significant ($p > 0.03$).

4.6.2.5. Anxiety and Worry

Figure 4.12 graphically depicts the change in score with respect to the anxiety and worry domain of the D-39, over the three testing occasions. There were no statistically significant differences found between and within the groups over time, nor any statistically significant interaction effect ($p > 0.03$). The control group scored 12.7 % higher than the experimental group at the pre-testing session (PreT), once again indicating that anxiety and worry affected their HRQoL to a greater degree. This difference was of small practical significance (ES = - 0.33, *Table 4.7*), although not statistically significant ($p > 0.03$). The difference between the two groups at post-testing (29.4 %), however, was statistically significant ($p = 0.006$). Aside from the statistically significant difference, there was also a moderate practically significant difference between the two groups (ES = - 0.74). The experimental group furthermore displayed a statistically significant difference between post-testing and PreT ($p = 0.006$), with a 20.6 % reduction in score. There was a non-statistically significant ($p > 0.03$) increase of 5.49 % from post-testing to the retention-testing occasion in the experimental group. Despite this increase, the anxiety and worry score at retention testing was still 15.9 % lower than PreT, which was not statistically significant ($p > 0.03$).

4.6.2.6. Perceived Quality of Life

Changes in perceived quality of life (QoL) scores between the two groups across the three testing occasions are displayed in *Figure 4.12* below. Statistically significant differences were found between and within the groups over time, with a significant interaction effect ($p = 0.02$). At post-

testing, the experimental group had a 22.7 % lower score than the control group, indicating that perceived quality of life affected their HRQoL to a lesser extent than the control group. This difference was found to be statistically significant (p = 0.02), as well as being of large practical significance (ES = - 0.82, *Table 4.7*). A statistically significant difference (22.7 %) was observed in the experimental group when the PreT (p = 0.008) score was compared to the post-testing score. When comparing the retention testing scores against the two preceding testing sessions in the experimental group, it was found that there was a non-significant (p > 0.03) 18.8 % increase compared to post-testing, and a non-significant (p > 0.03) 4.79 % decrease compared to PreT.

4.6.2.7. Perceived Diabetes Severity

Figure 4.12 below is a graphical representation of the changes in perceived diabetes severity score between the two groups over the course of the three testing occasions. Statistically significant differences between and within the groups over time were found, although on this occasion, no statistically significant interaction effect was reported (p > 0.03). The control group scored 6.83 % higher than the experimental group at the pre-testing session (PreT), a difference that was not statistically significant (p > 0.03), but was of small practical significance (ES = - 0.21, *Table 4.7*), and indicated that perceived diabetes severity affected their HRQoL to a greater degree than the experimental group. At post-testing, however, the difference of 20.4 % between the experimental and control group, was statistically significant (p = 0.03) and of moderate practical significance (ES = - 0.60). The decrease in score of 22.2 % from PreT to post-testing in the experimental group was statistically significant (p = 0.002). Once again, a similar pattern to the above-mentioned domains was found, with their being a slight, and not statistically significant (p > 0.03) 9.34 % increase in score from post-testing to the retention testing session in the experimental group. When compared to PreT, the retention testing occasion score was 14.2 % lower, which was not a statistically significant difference (p > 0.03).

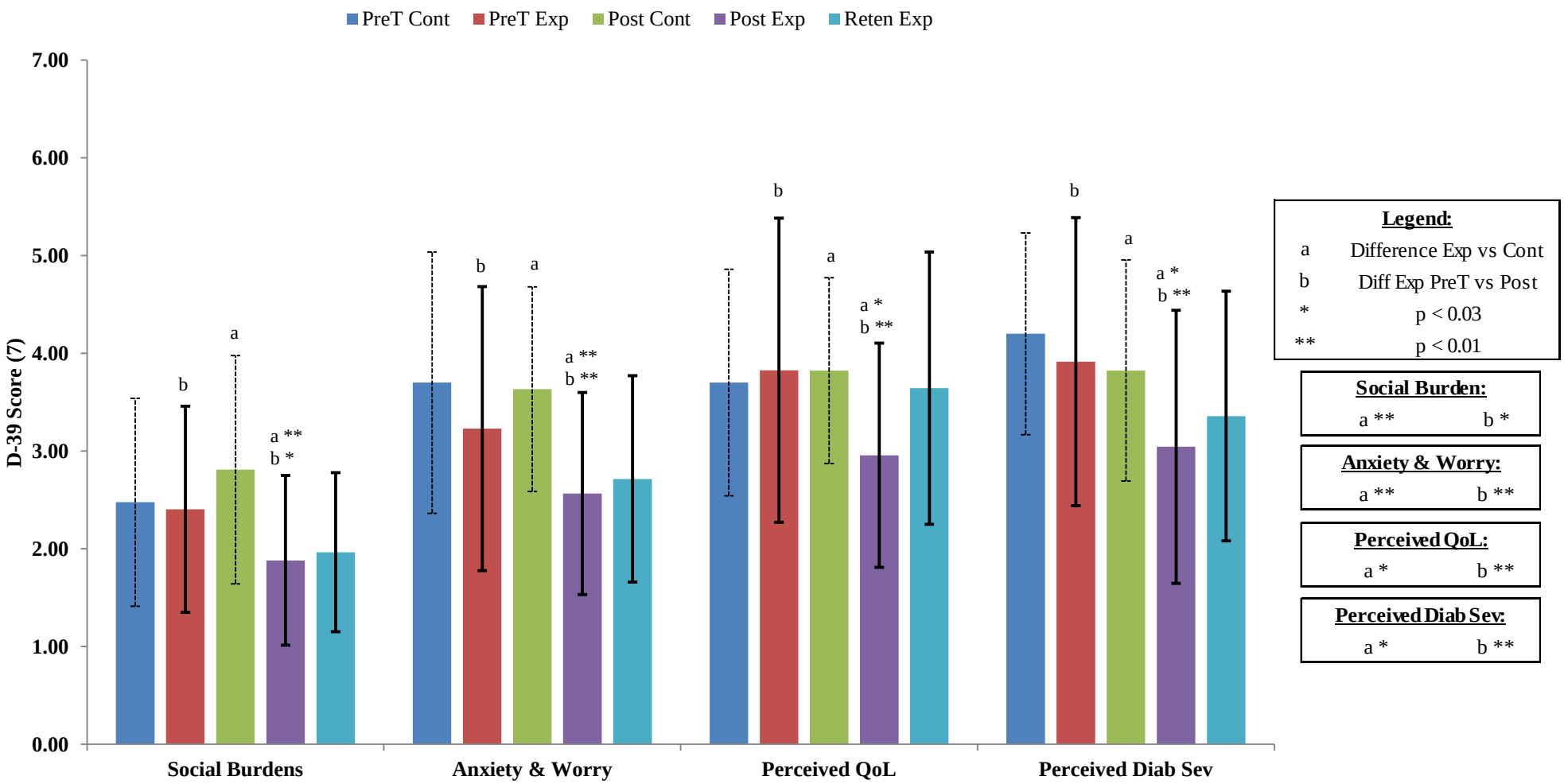

Figure 4.12. Changes in scores for the psychological parameters of the diabetes-39 questionnaire (D-39) over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing. The table insert to the right of the graph indicates the statistically significant differences ($p < 0.05$) found for the four domains.

Table 4.7. Effect sizes (ES) related to differences in the D-39 domains between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	Energy & Mobility	- 0.30	- 1.05 ; 0.44	S
	Sexual Functioning	0.09	- 0.65 ; 0.83	N
	Anxiety & Worry	- 0.33	- 1.08 ; 0.42	S
	Social Burdens	- 0.07	- 0.81 ; 0.67	N
	Diabetes Management & Control	- 0.19	- 0.94 ; 0.55	S
	Perceived QoL	0.09	- 0.66 ; 0.83	N
	Perceived Disease Severity	- 0.21	- 0.96 ; 0.53	S
Post	Energy & Mobility	- 1.33	- 2.03 ; - 0.64	VL
	Sexual Functioning	- 0.27	- 0.90 ; 0.36	S
	Anxiety & Worry	- 0.74	- 1.39 ; - 0.09	M
	Social Burdens	- 0.92	- 1.58 ; - 0.26	L
	Diabetes Management & Control	- 0.85	- 1.50 ; - 0.19	L
	Perceived QoL	- 0.81	- 1.46 ; - 0.16	L
	Perceived Disease Severity	- 0.60	- 1.24 ; 0.04	M

PreT, pre-testing ; Post, post-testing ; QoL, quality of life ; N, negligible ; S, small ; M, moderate ; L, large ; VL, very large.

4.7. Social Support Questionnaire

The Diabetes Family Behaviour Scale (DFBS), adapted for this study, was used to assess the degree of familial social support the participants received throughout the duration of the study. The DFBS is scored according to two subscales, namely the Guidance-Control subscale, and the Warmth-Caring subscale, with higher scores indicative of greater familial support.

4.7.1. Guidance-Control DFBS Subscale

Changes in the guidance-control scores between the two groups and across the three testing occasions are displayed in *Figure 4.13* below. There were no statistically significant differences between or within the groups over time ($p > 0.05$) and no interaction effect. The groups scored almost exactly the same for the pre-testing session (PreT), with the difference of 0.75 % not being statistically significant ($p > 0.05$) or practically significant. At post-testing, the control group scored 2.2 % higher than the experimental group, a difference that was neither statistically significant ($p > 0.05$), nor practically significant (*Table 4.8*). When compared to the retention-testing occasion, there were once again no statistically significant differences ($p > 0.05$), although the guidance-control subscale score for the experimental group was highest at this testing session, with differences of 1.07 % and 2.27 % when compared to PreT and post-testing, respectively.

4.7.2. Warmth-Caring DFBS Subscale

Figure 4.13 below is a graphical representation of the changes in warmth-caring scores between the experimental and control group over the three testing occasions. There were no statistically significant differences between or within the groups over time, and no interaction effect. The control group scored 1.3 % higher than the experimental group at the pre-testing session (PreT), although this difference was not statistically significant ($p > 0.05$) or practically significant. At post-testing, the magnitude of the difference between the two groups was larger (4.4 %), although this difference was not statistically significant ($p > 0.05$). The difference was, however, of small practical significance (ES = - 0.38, *Table 4.8*). When evaluating the warmth-caring subscale score at the retention testing session for the experimental group, once again no statistically significant differences were found compared to previous scores ($p > 0.05$), although the scores were highest during this testing period. The differences were a marginal 1.71 % and 0.09 % compared to PreT and post-testing, respectively

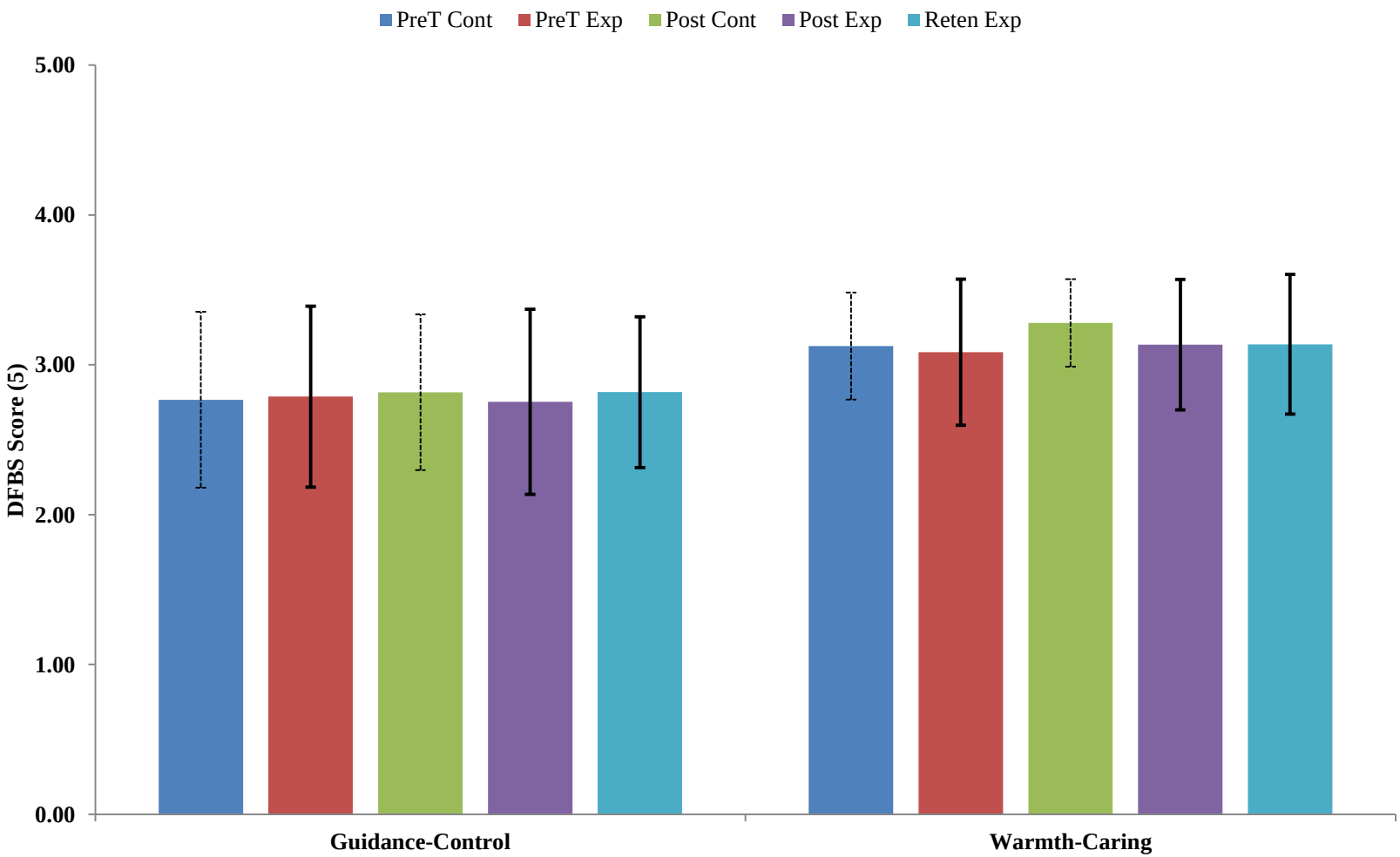

Figure 4.13. Changes in guidance-control and warmth-caring subscale scores from the diabetes family behaviour scale (DFBS), over the three testing periods. PreT, pre-testing; Post, post-testing; Reten, retention testing.

Table 4.8. Effect sizes (ES) related to differences in the DFBS Subscales between the two groups at the pre-testing session (PreT) and post-testing session.

Testing Phase	Variable	ES	95% CI	Qualitative Outcome
PreT	Guidance - Control	0.03	- 0.71 ; 0.78	N
	Warmth - Caring	- 0.09	- 0.83 ; 0.65	N
Post	Guidance - Control	- 0.11	- 0.74 ; 0.52	N
	Warmth - Caring	- 0.38	- 1.01 ; 0.25	S

PreT, pre-testing ; Post, post-testing ; N, negligible ; S, small.

4.8. Dietary Outcomes

4.8.1. Eating Times

There were a number of statistically significant differences between the experimental and control group with respect to eating times. For the most part, both groups ate at four occasions during the day (combination of breakfast, lunch, supper and snacks), with the experimental group reporting this eating pattern more frequently (73.6 %) compared to the control group (65.8 %). This figure increased to 85.7 % in the experimental group when the retention testing data was factored in. The remaining 26.4 % (14.3 % with retention data included) and 35.3 % in the experimental and control group, respectively, only reported eating on three occasions during the day (combination of breakfast, lunch, supper and snacks). Supper (*Figure 4.14c*) was the only constant between the two groups, with 100% of the experimental and control group reporting that they ate at supper time. Breakfast (*Figure 4.14a*) and lunch (*Figure 4.14b*) had similar frequencies, with snacks (*Figure 4.14d*) being consumed the least (76.9 % in the experimental group and 79.7 % in the control group) as displayed in *Figure 4.14* below. However, the incidence of participants in the experimental group eating snacks increased at retention testing (85.7 % versus 76.9 %).

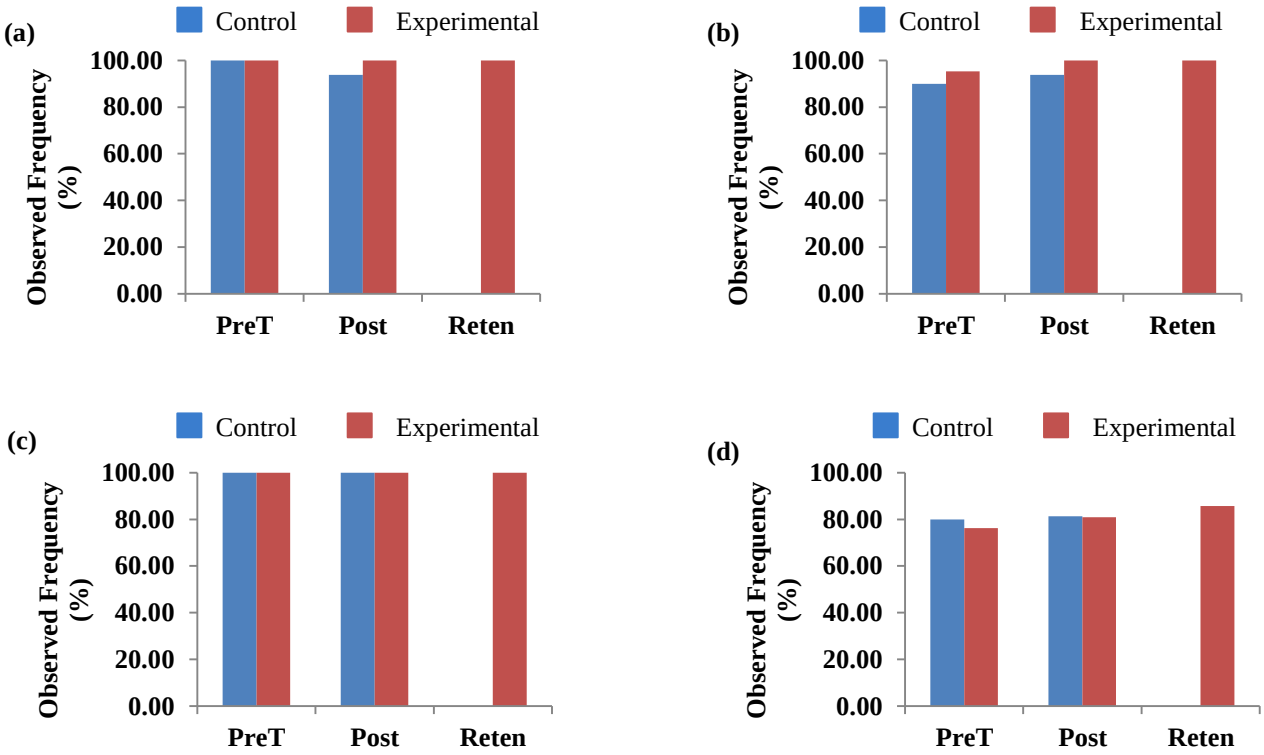

Figure 4.14. Differences between the experimental and control group at (a) breakfast, (b) lunch, (c) supper, and (d) snacks. PreT, pre-testing; Post, post-testing; Reten, retention testing.

4.8.2. Food Content

When looking at food content, the areas that were highlighted as clinically relevant for diabetics was sugar usage, the type of bread that was consumed, whether complex carbohydrates were eaten together during a single meal, and the frequency at which vegetables and/or salad were consumed per week.

With respect to extra sugar or sweeteners being used (*Figure 4.15*), the control group exhibited higher usage during the pre-testing session (PreT) compared to the experimental group, although the differences between the two groups was not statistically significant ($p > 0.05$). At post-testing, however, the 57.1 % difference between the two groups was statistically significant ($p = 0.002$). Furthermore, the experimental group exhibited a drop of 47.6 % in the use of extra sugar or sweeteners from PreT to post-testing, which was statistically significant ($p = 0.003$). However, there was no change in the number of participants who made use of extra sugar or sweeteners between post-testing and the retention testing session. The statistically significant difference of 47.6 % between PreT and retention testing ($p = 0.003$) was therefore seen once again.

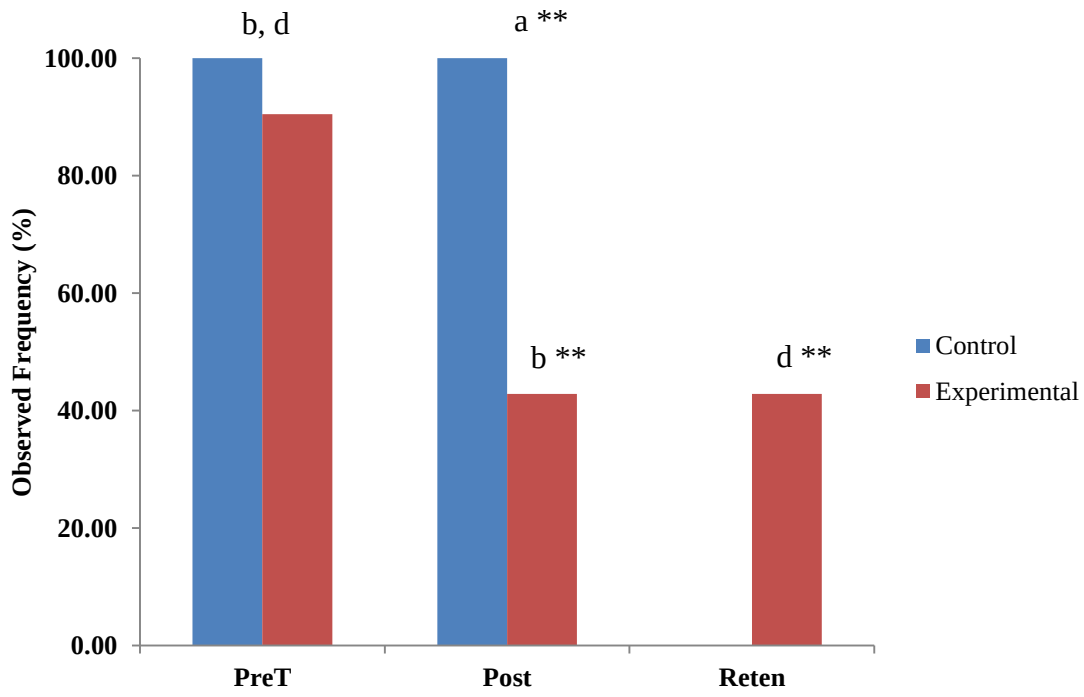

Figure 4.15. Differences between the two groups with respect to extra sugar and/or sweetener being used across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing. **, $p < 0.01$; a, statistically significant difference between experimental and control group ($p < 0.05$); b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten in the experimental group ($p < 0.05$).

The three types of bread consumed were white bread, brown bread and low glycaemic index (GI) / whole-wheat bread, with the differences being displayed in *Figure 4.16* below. White bread (*Figure 4.16a*) was the most commonly eaten bread by the control group across the first two testing occasions (61.2 %), whereas the experimental group most commonly ate low GI bread (*Figure 4.16c*) (52.4 %). None of the participants in the control group reported eating low GI bread, with brown bread (*Figure 4.28b*) only being eaten 38.8 % of the time. Statistically significant differences between the groups were found at the first two testing sessions with respect to white bread consumption ($p = 0.02$, PreT ; $p < 0.001$, Post), with the complete cessation of white bread consumption by the experimental group at post-testing and retention testing resulting in a statistically significant difference when compared to PreT ($p = 0.04$). While there was a difference of approximately one percent between the experimental and control group with respect to brown bread consumption, the difference was not statistically significant ($p > 0.05$). Considering the control group did not consume low GI or whole-wheat bread, the differences between the two groups at the first two testing sessions were statistically significant ($p = 0.01$, PreT ; $p < 0.001$,

Post). The increase in consumption of the experimental group between PreT and post-testing, was however, not statistically significant ($p > 0.05$). The experimental group reduced their low GI bread consumption at retention testing by 19.1 % when compared to post-testing, with a concomitant increase of the same magnitude in brown bread consumption. Neither of these changes was found to be statistically significant ($p > 0.05$).

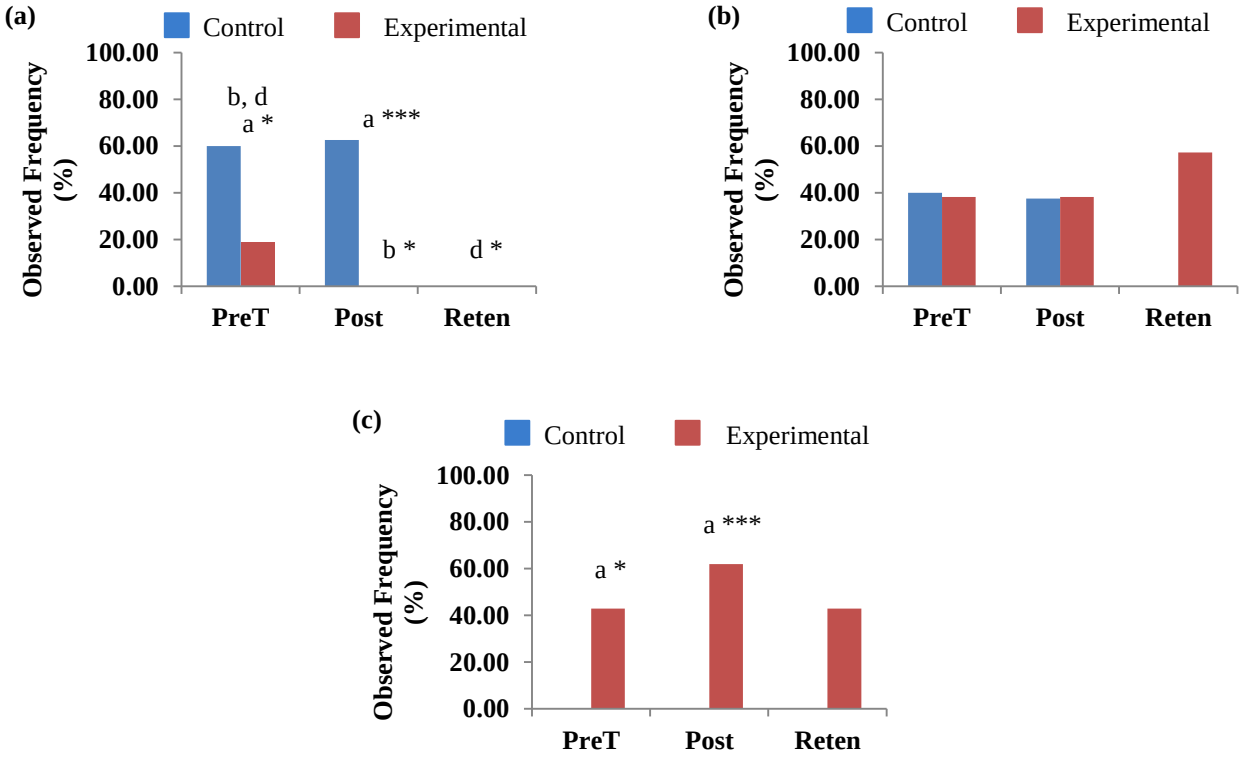

Figure 4.16. Differences between the experimental and control group with respect to (a) white bread consumption, (b) brown bread consumption, and (c) low GI or whole-wheat bread consumption. PreT, pre-testing; Post, post-testing; Reten, retention testing. *, $p < 0.05$; ***, $p < 0.001$; a, statistically significant difference between experimental and control group ($p < 0.05$); b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten in the experimental group ($p < 0.05$)

Figure 4.17 depicts the differences between the two groups with respect to the consumption of complex carbohydrates together during one sitting, across the three different testing occasions. Complex carbohydrates most commonly reported were rice, potatoes, maize meal and pasta. The control group consumed complex carbohydrates more frequently than the experimental group at the pre-testing session (4.3 %), but this difference was not statistically significant ($p > 0.05$).

However, at post-testing there was a substantial difference of 89.0 % between the two groups, which was statistically significant ($p < 0.001$). Furthermore, the 81.0 % reduction from PreT to post-testing in the experimental group, was also statistically significant ($p < 0.001$, PreT). At the retention-testing session, there was a small increase of 2.38 % from post-testing; however, this was still substantially lower than the reported incidence at PreT, with the difference of 78.6 % being statistically significant ($p < 0.001$).

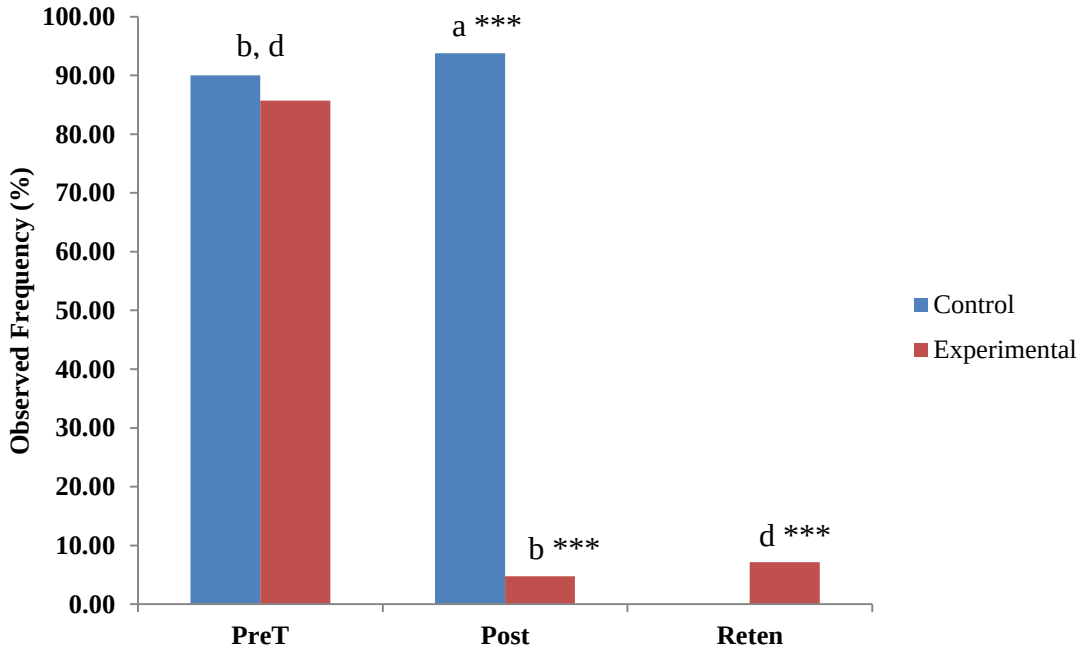

Figure 4.17. Differences between the experimental and control group with respect to the consumption of complex carbohydrates together during a single sitting, across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing. ***, $p < 0.001$; a, statistically significant difference between experimental and control group ($p < 0.05$); b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten in the experimental group ($p < 0.05$).

The frequency of vegetable and/or salad consumption per week for both groups across the three testing occasions is displayed in *Figure 4.18*. There were statistically significant differences between and within the groups over time, as well as a statistically significant interaction effect ($p < 0.001$). Marginal differences in consumption between the two groups were observed at the pre-testing session (PreT), with the experimental group on average, consuming vegetables and/or salads 2.7 times per week, compared to 2.4 times per week for the control group, a difference of 5.7 %. While this difference was not statistically significant ($p > 0.05$), the difference between the two

groups at post-testing was ($p < 0.001$). In this case the experimental group on average consumed vegetables and/or salads five times a week, compared to 2.4 times a week for the control group, a difference of 52.0 %. Furthermore, the 47.0 % increase from PreT to post-testing in the experimental group was also statistically significant ($p < 0.001$). A similar pattern was observed at the retention-testing occasion in the experimental group, with a large statistically significant difference when compared to PreT (44.6 %, $p < 0.001$). While there was a decrease of 4.29 % compared to post-testing, the difference between the two testing occasions was not statistically significant ($p > 0.05$).

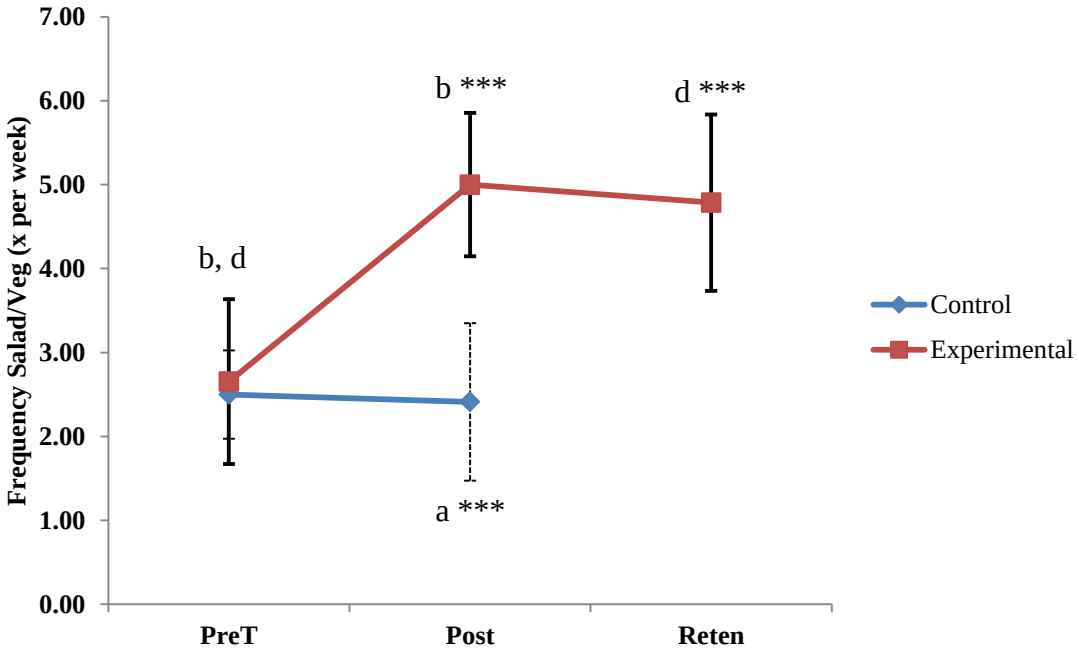

Figure 4.18. Differences between the experimental and control group with respect to the number of times per week vegetables and/or salad are consumed, across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing. ***, $p < 0.001$; a, statistically significant difference between experimental and control group ($p < 0.05$); b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten in the experimental group ($p < 0.05$).

When examining the total monthly food expenses (*Figure 4.19*), between the two groups across the three testing occasions, no statistically significant differences were found between the groups over time ($p > 0.05$), and no interaction effect was observed. At the pre-testing session (PreT), the control group had an average monthly expenditure of R 1 480.00, which was 9.81 % higher than the experimental group (R 1 334.78), although this difference was not statistically significant ($p >$

0.05). At post-testing, the experimental group had a 7.53 % (R 108.70) higher monthly expenditure, whereas the control group had a 3.62 % (R 53.53) lower monthly expenditure, with this difference not being statistically significant ($p > 0.05$). When looking at the differences within the groups between the first two testing sessions, a statistically significant difference between PreT and post-testing ($p = 0.03$) was found in the experimental group. However, no statistically significant difference was found between PreT and post-testing in the control group ($p > 0.05$). Monthly expenditure increased only marginally (R 6.52) for the experimental group at the retention testing session compared to post-testing, which was not statistically significant ($p > 0.05$). However, the difference of 7.94 % (R 115.22) between PreT and the retention-testing occasion was statistically significant ($p = 0.02$).

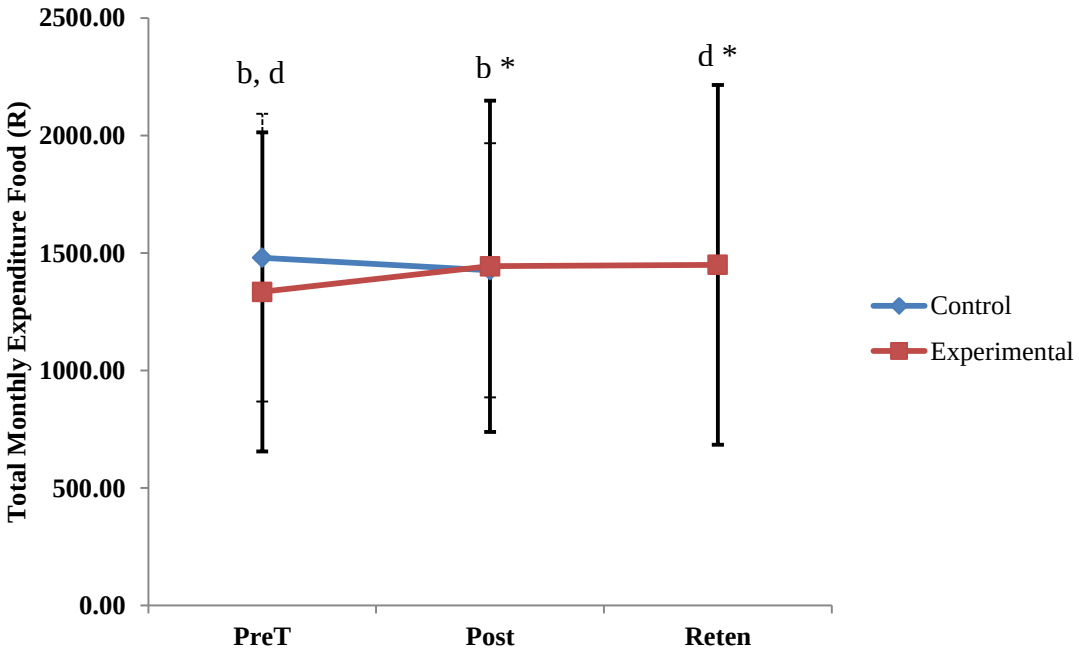

Figure 4.19. Differences in monthly expenditure on food between the experimental and control group across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing. *, $p < 0.05$; b, statistically significant difference between PreT and Post in the experimental group ($p < 0.05$); d, statistically significant difference between PreT and Reten in the experimental group ($p < 0.05$).

4.8.3. Lifestyle Habits

The smoking and drinking behaviours of the two groups formed the basis for the lifestyle habits analysis. On average, 19.4 % of the control group and 14.3 % of the experimental group indicated that they were regular smokers, with no statistically significant change ($p > 0.05$) in smoking behaviour observed in either group across the three testing occasions. The control group did, however, report a decreased number of smokers (6.25 %) at post-testing compared to the pre-testing session (PreT) as seen in *Figure 4.20* below.

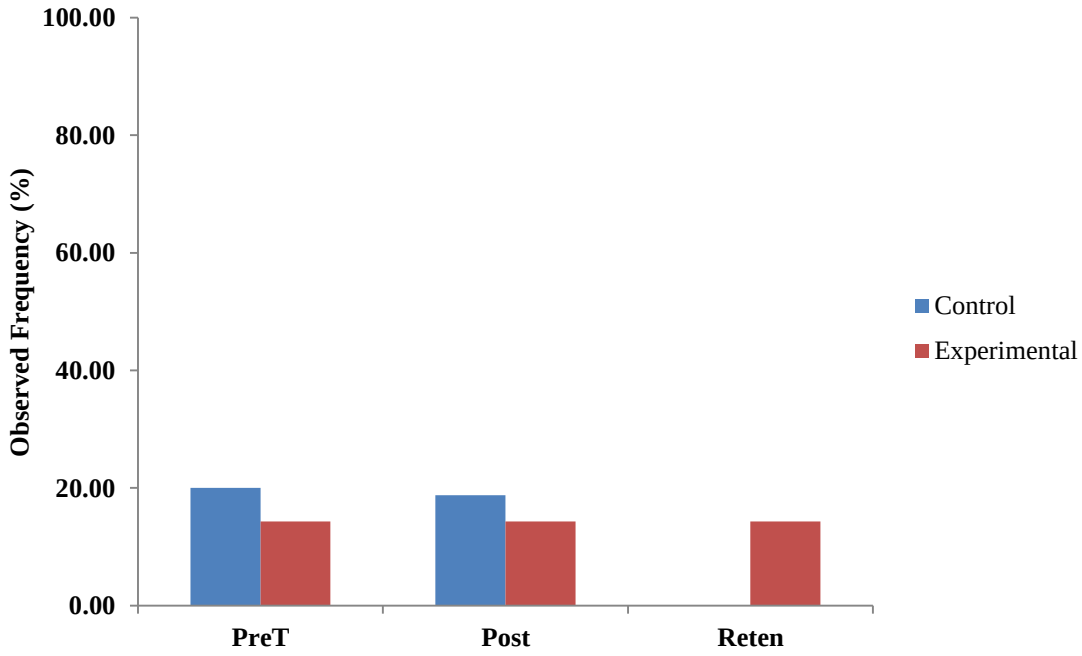

Figure 4.20. Differences in the number of smokers between the experimental and control group across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing.

The differences between the experimental and control group with respect to drinking behaviour are graphically represented in *Figure 4.21* to *Figure 4.25* below. For the first two testing sessions, there was a greater number of control group participants (22.5 %) who consumed alcoholic beverages (*Figure 4.21*) compared to the experimental group (14.3 %), although this difference was not statistically significant ($p > 0.05$). Compared to PreT, the experimental group displayed no change in the number of drinkers, whereas the control group displayed a slight increase (5.0 %) at post-testing, with the difference not being statistically significant ($p > 0.05$). Interestingly, at the retention testing session, there was a decrease of 7.14 % in the number of participants who consumed alcoholic beverages when compared to both post-testing and PreT. This decrease was not found to be statistically significant ($p > 0.05$).

The differences between the type of alcohol consumed by both groups is displayed in *Figure 4.22* below. The control group (*Figure 4.22a*) had a reasonably even distribution, with wine and beer being the most common type of drink consumed. Conversely, almost two thirds of the experimental group (*Figure 4.22b*) preferred spirits as their drink of choice, with wine being the next popular choice, and beer being the least consumed alcoholic beverage.

When looking at the quantity of alcohol consumed per week between the two groups (*Figure 4.23)*, no statistically significant differences between the groups were found, and no interaction effect was reported ($p > 0.05$). At the pre-testing session (PreT), the experimental group reported a 6.30 % higher alcohol intake than the control group which was not statistically significant ($p > 0.05$). In contrast to this, at post-testing, the experimental group decreased their alcohol consumption by 25 %, a non-statistically significant difference ($p > 0.05$). The control group did not change the quantity of alcohol consumed and were found to consume 20 % more alcohol than the experimental group at this testing period. A further reduction in the quantity of alcohol consumed by the experimental group was seen at the retention testing session, with non-statistically significant differences of 65 % and 50 % from PreT and post-testing, respectively.

With respect to the frequency of alcohol consumed per week (*Figure 4.24)*, no statistically significant differences between the groups were found, and no interaction effect was reported ($p > 0.05$). The control group engaged in drinking 42.9 % more frequently than the experimental group at the pre-testing session (PreT), a difference that was not statistically significant ($p > 0.05$). The control group reported a lower drinking frequency at post-testing when compared to PreT, with the decrease of 21.4 % not statistically significant ($p > 0.05$). The experimental group on the other hand did not change the frequency at which they consumed alcohol per week, although they did report a non-statistically significant ($p > 0.05$) decrease of 50 % at the retention testing session.

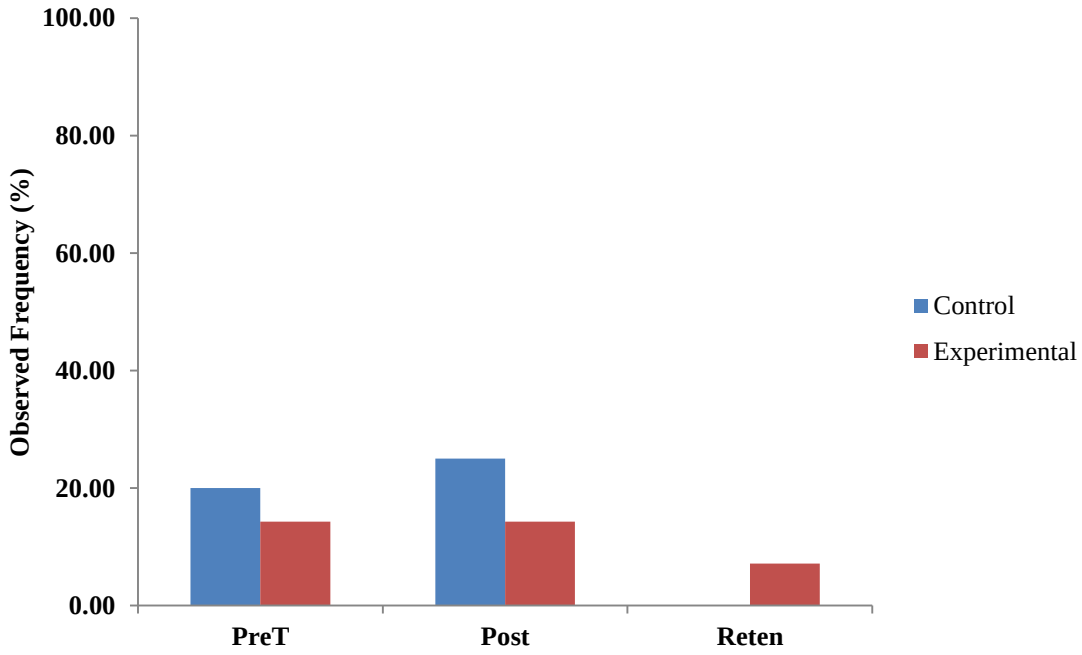

Figure 4.21. The frequency of participants in the experimental and control group who consumed alcoholic beverages across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing.

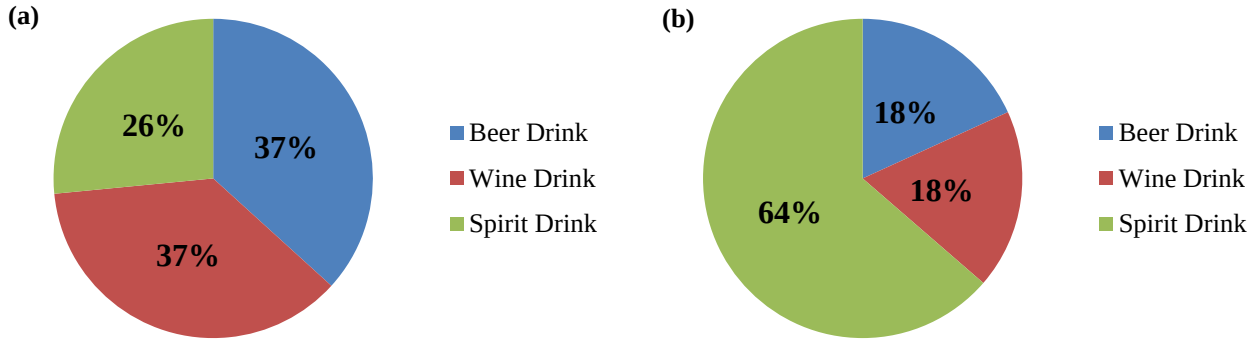

Figure 4.22. Differences in the type of alcoholic beverages consumed between the (a) control and (b) experimental group.

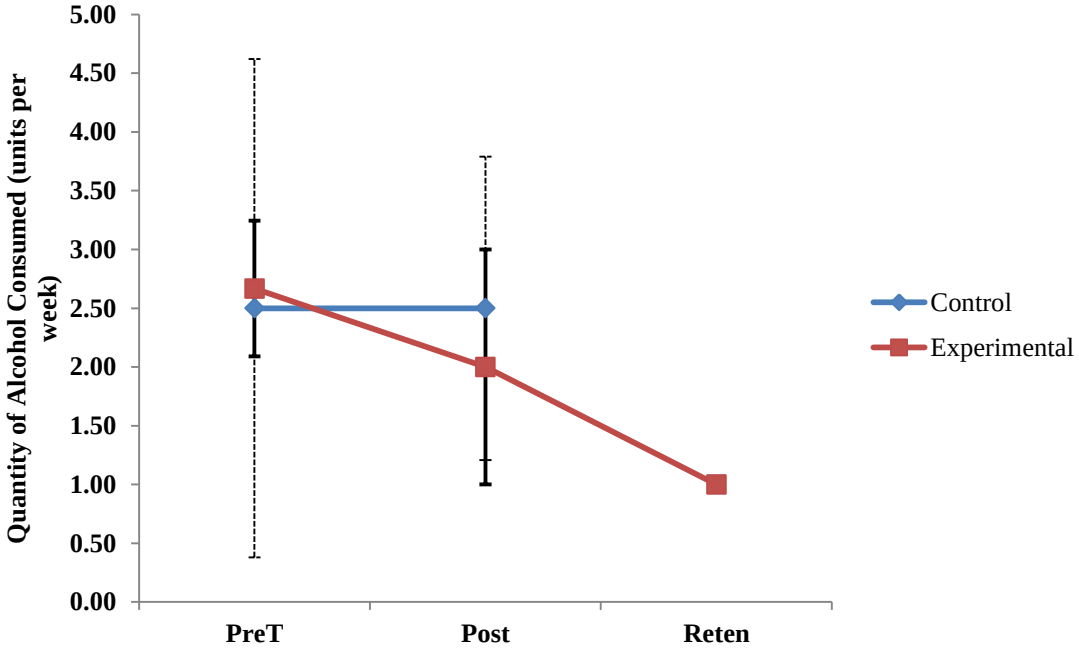

Figure 4.23. Differences in the quantity of alcohol consumed per week between the experimental and control group, across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing.

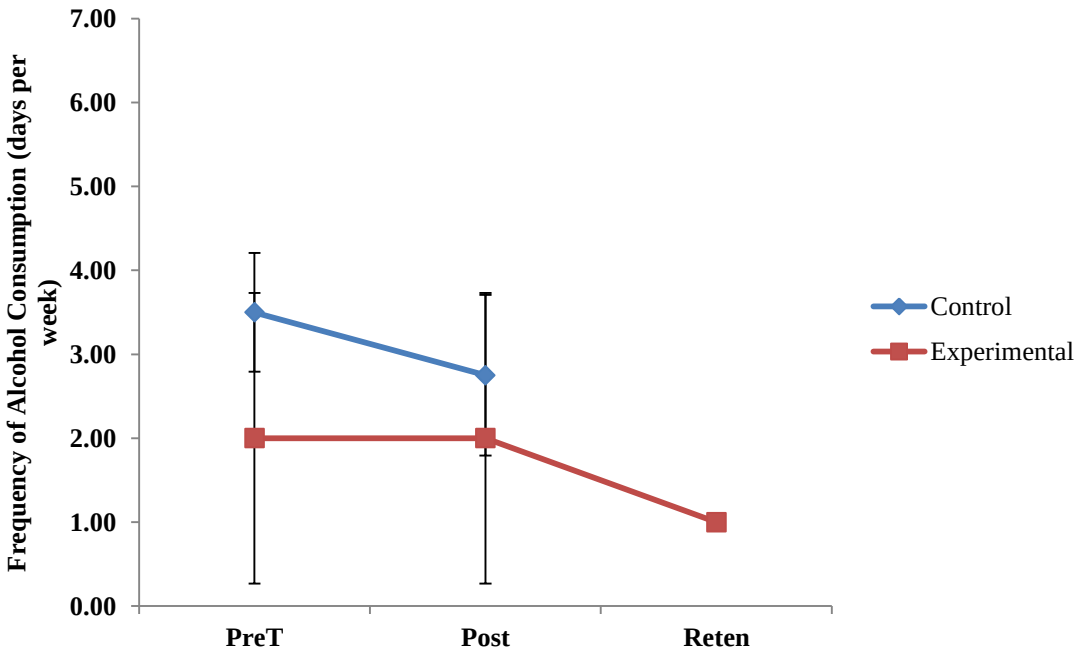

Figure 4.24. Differences in the frequency of alcohol consumed per week between the experimental and control group, across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing.

Figure 4.25 depicts the differences in monthly expenditure on alcohol and/or smoking products between the two groups. No statistically significant differences between the two groups were found over time ($p > 0.05$). On average the control group spent 33.3% more per month (R 100.00) than the experimental group, although this difference was not statistically significant ($p > 0.05$). There was no difference between the groups at post-testing compared to the pre-testing session (PreT).

Taken as a percentage relative to monthly food expenditure, the control group devoted 20.6 % of their funds towards alcohol and smoking products, with the experimental group apportioning 14.4 % of their funds towards alcohol and smoking products. The experimental group decreased their monthly spend on smoking and/or drinking activities by 50 % (R 100.00) at the retention testing session compared to post-testing and PreT, a difference that was not statistically significant ($p > 0.05$). However, when taken as a percentage of monthly food spend, only 6.90 % of their funds were allocated towards alcoholic and/or smoking products.

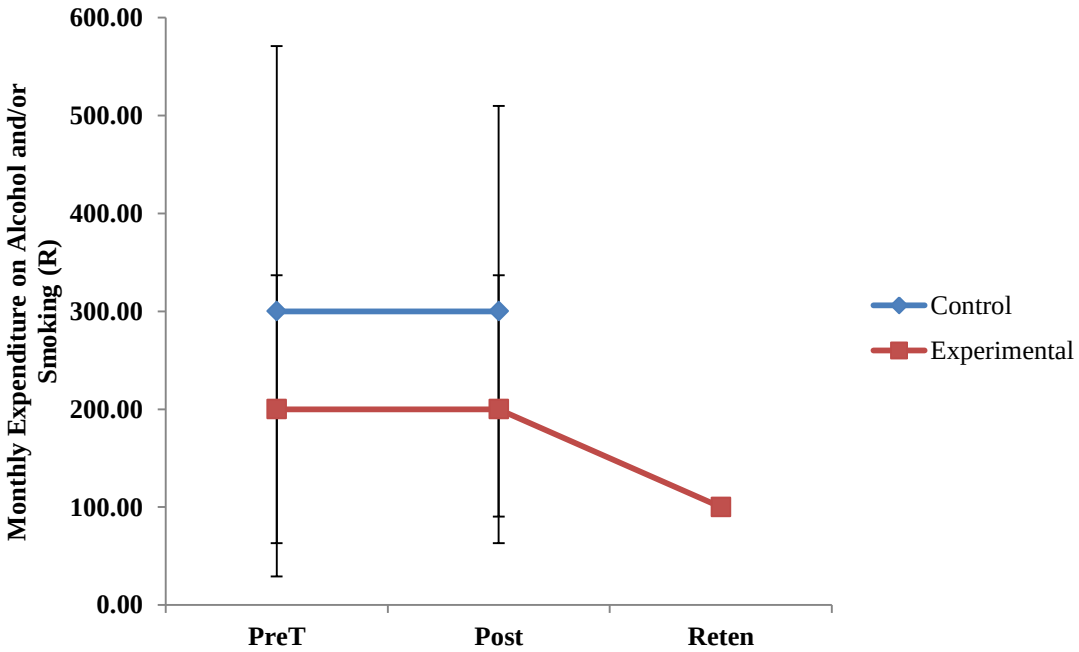

Figure 4.25. Differences in monthly expenditure on alcohol and/or smoking products between the experimental and control group across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing.

4.9. Health Professional Usage Outcomes

4.9.1. Location of Primary Healthcare Provider

Three locations were reported as places where the participants would visit their primary healthcare provider, namely, state hospital, community clinic, or private practice. *Figure 4.26* shows the differences between the two groups with respect to the above-mentioned locations. The control group (*Figure 4.26a*) most often consulted with their primary healthcare provider in private practice settings (63.0 %), both within and outside the community, with the community clinic being used by just under one quarter of the control participants. State hospital visits to consult with the participants' primary healthcare provider were the least favoured option. In contrast, the experimental group (*Figure 4.26b*) used both the community clinic (54 %) and private practice (46 %), in almost equal proportions, to consult with their primary healthcare providers, with none of the participants making use of the state hospitals for regular consultations.

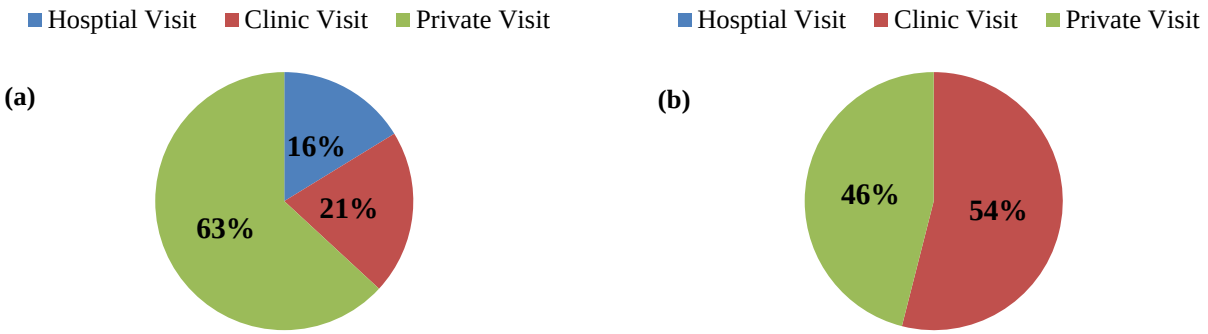

Figure 4.26. Differences in location for consulting with the primary healthcare provider between the (a) control and (b) experimental group.

Figure 4.27 below shows the different modes of transport used by the control (*Figure 4.27a*) and experimental (*Figure 4.27b*) group to travel to their respective primary healthcare provider. Almost two thirds of the control group made use of a vehicle (private or public transport) as their preferred mode of transport, with the remaining third walking to the location of their primary healthcare provider. The experimental group, however, favoured walking to the location of their primary healthcare provider, over the use of a vehicle as a mode of transport.

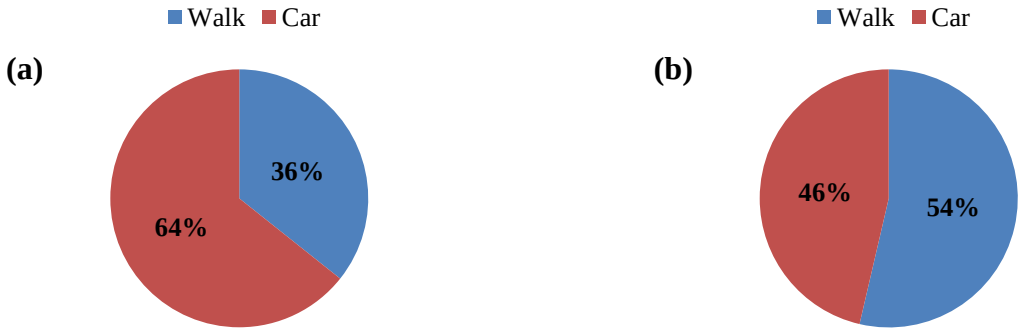

Figure 4.27. Differences in mode of transport to travel to the primary healthcare provider between the (a) control and (b) experimental group.

The differences between the two groups with respect to the distance needed to travel to consult with the primary healthcare provider are displayed in *Figure 4.28* below. The control group (*Figure 4.28a*) most often only had to travel five kilometres or less to reach the location of their primary healthcare provider, with 20.0 % of the participants travelling between six and 20 kilometres. Only a small proportion of participants travelled more than 20 kilometres to visit their primary healthcare provider. Similar proportions were found in the experimental group (*Figure 4.28b*), where almost three quarters of the participants were required to travel five kilometres or less, and only 28.0 % were required to travel between six and 20 kilometres.

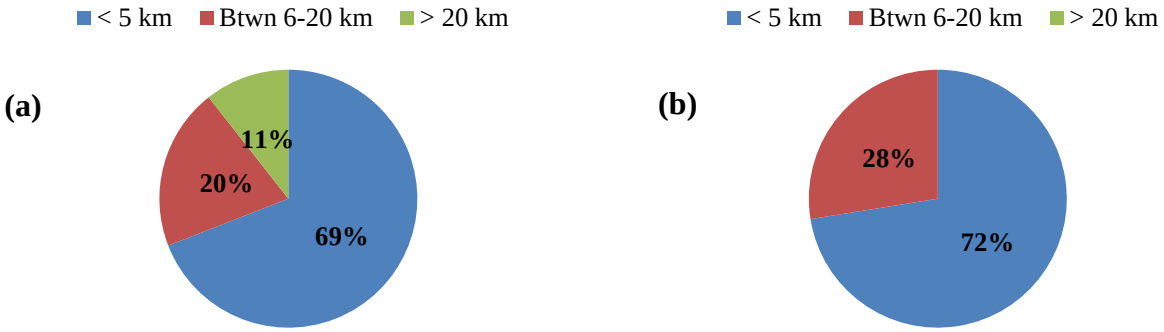

Figure 4.28. Differences in distances required to travel to the primary healthcare provider between the (a) control and (b) experimental group.

4.9.2. Use of Primary Healthcare Provider

The number of visits to the primary healthcare provider per year for the two groups is displayed in *Figure 4.29* below. The control group (*Figure 4.29a*) consulted with their primary healthcare provider far less frequently than the experimental group (*Figure 4.29b*), with only 44.0 % of the group visiting their primary healthcare provider between two and five times per year. In

comparison, 65.0 % of the experimental group visited their primary healthcare provider between two and five times per year, with six percent of the participants in the experimental group having monthly check-ups. Of concern is the 56.0 % and 29.0 % of the participants in the control and experimental group, respectively, who consulted with their primary healthcare provider once, or sometimes less, per year.

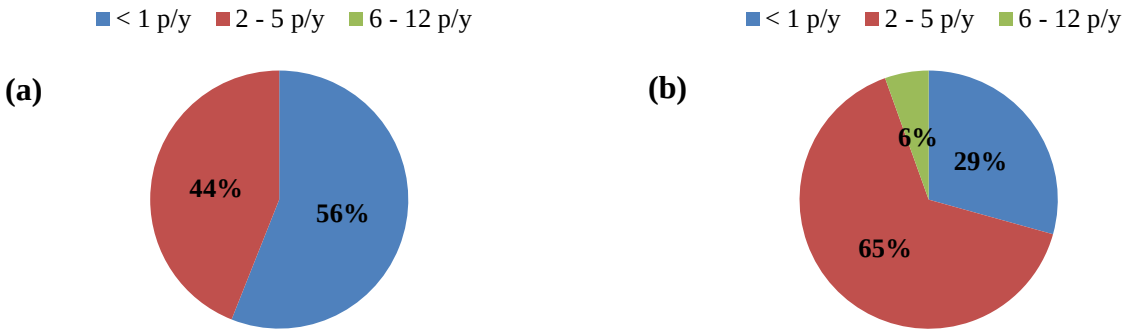

Figure 4.29. Differences in the number of visits per year to the primary healthcare provider between the (a) control and (b) experimental group.

Figure 4.30 further illustrates this point, where the number of participants who go for regular check-ups with their primary healthcare provider or other healthcare professional (nurse, etc), is surprising low in the control group. At the pre-testing session (PreT), the experimental group reported going for regular check-ups 17.6 % more frequently than the control group, a difference that was not statistically significant ($p > 0.05$). However, the difference of 81.3 % between the experimental and control group at post-testing, was statistically significant ($p = 0.003$). Encouragingly, the number of participants who reported regular check-ups at the retention-testing occasion, was similar to post-testing, with only a small non-significant ($p > 0.05$) decrease of 2.40 %.

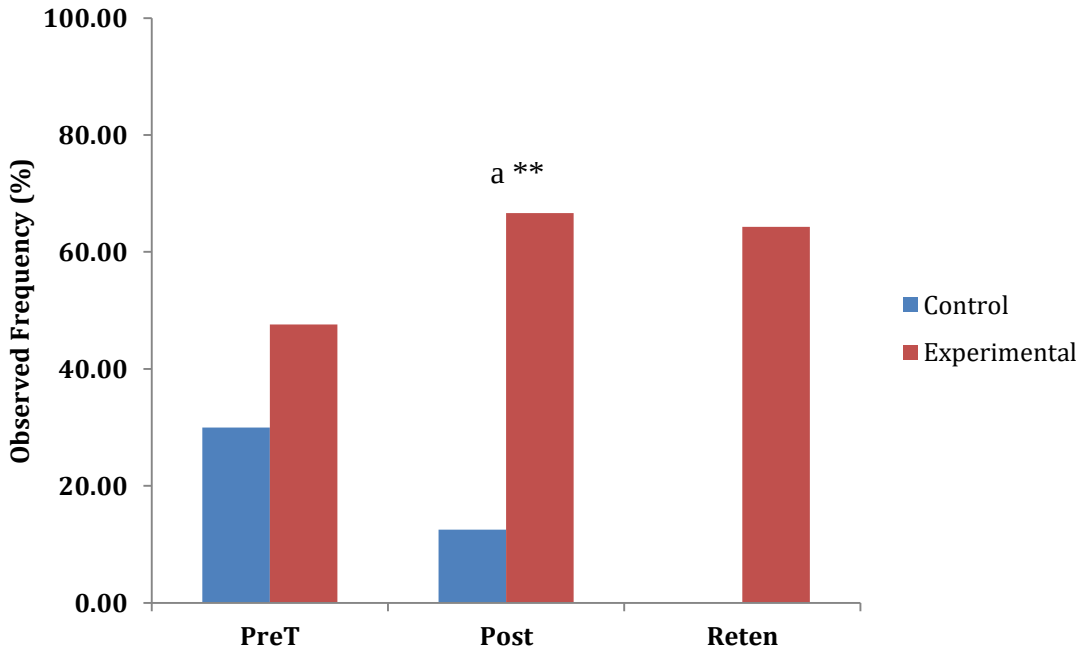

Figure 4.30. Differences between the experimental and control group with respect to regular check-ups with their primary healthcare provider and/or other healthcare professionals, across the three testing occasions. PreT, pre-testing; Post, post-testing; Reten, retention testing. **, $p < 0.01$; a, statistically significant difference between experimental and control group ($p < 0.05$).

Chapter 5

Discussion

5.1. Introduction

The main objective of this study was to determine the effectiveness of a community-based, 10-week lifestyle intervention on the physiological, psychological and health-related outcomes in adults suffering from T2DM in a low SES community. Furthermore, this study sought to determine whether a post-intervention guide containing information related to the different aspects of the study, was able to maintain the changes seen during the intervention period.

In the South African context, there are only a handful of studies conducted in low-socioeconomic communities, and only two community-based studies with similar methodologies to the current study, although not nearly as comprehensive in nature. This study is the first comprehensive lifestyle intervention in a low SES community in South Africa and will hopefully form the framework upon which further studies can be built. This study will also provide further insight into the barriers that exist to the development of and carrying out of comprehensive lifestyle intervention programs, specifically with respect to accounting for confounding variables, integrating the program with the primary healthcare sector and ensuring that each of the dimensions of the program work synergistically. The use of combination exercise in this specific community, with the focus on whole-body exercise is additionally an area that has not been extensively explored in low SES communities, despite the advantageous benefits over either aerobic or resistance exercise on their own, and is where the current study is contributing significantly to the paucity of data.

There were a number of encouraging findings in the study, with improvements seen in most of the physiological outcome variables, as well as a comprehensive improvement in HRQoL. Furthermore, there seemed to be an improvement in dietary habits, although minimal change to other potentially harmful lifestyle behaviours was observed. The use of the post-intervention guide and its ability to maintain the changes seen following the intervention was unclear and requires further investigation.

5.2. Descriptive Characteristics at Baseline

There are a multitude of studies that have been conducted over the last 30 years examining all the components of T2DM, and the management thereof. While there is a wide age-range of participants in T2DM studies, dependent on the specific goals of the study, the average age in recent studies

involving physical activity interventions, dietary interventions, or both is 57.2 ± 3.5 years (Itsiopoulos *et al.*, 2011; Yang & Oh, 2013; Ades *et al.*, 2015; Hosseinpour-Niazi *et al.*, 2015; Motahari-Tabari *et al.*, 2015), which is similar to the average age of this study of 59.5 ± 12.2 years. This is to be expected considering that T2DM is traditionally considered an adult-onset disease, although there is sufficient evidence to believe that this is changing, with the average age of onset for T2DM set to decrease substantially over the next decade if nothing is done to prevent it (Thunander *et al.*, 2008; Craig, 2009; De Onis *et al.*, 2010). While no specific information on income or education was explicitly asked from participants in the current study, 63 % of the participants were retired and receiving the state pension of approximately R 1 500 per month as their only form of income. Furthermore, 14 % of the remaining participants were nearing the age of retirement and would also be relying on the state pension as an income in the foreseeable future. The total income of approximately R 17 000 per year would place the majority of the participants in the low SES category. A number of other studies have found that annual income for low SES is approximately $ 15 000 per family (Krishnan *et al.*, 2010; Piccolo *et al.*, 2015) or approximately $ 1250 per month, placing the participants in this study well below the low socio-economic standard of living in the USA.

5.3. Outcome Parameters

5.3.1. Anthropometric Outcomes

The anthropometric profile of T2DM patients is of particular importance due to the link of android obesity with an increased risk of developing diabetes, and the complications that arise thereof (Fox *et al.*, 2007; American College of Sports Medicine, 2014). The average BMI of the participants in this study was 31.1 ± 8.6, which according to the ACSM, would classify them as obese (American College of Sports Medicine, 2014). Once again, the average BMI in related studies was similar to that of the present study, with only a marginally higher measurement of 32.3 ± 3.6 (Savoca *et al.*, 2004; Lambers *et al.*, 2008; Geirsdottir *et al.*, 2012; Yang & Oh, 2013; Ades *et al.*, 2015; Motahari-Tabari *et al.*, 2015). There is a well-established relationship between obesity and T2DM, which is why the high BMI measurements do not come as a surprise (Tuei *et al.*, 2010; McKenney & Short, 2011; Wu *et al.*, 2014; Costanzo *et al.*, 2015; Wang *et al.*, 2015).

Body fat percentage is not always reported in studies involving physical activity and/or diet as a treatment or intervention method, however, in the cases where it was reported, the average body fat percentage was 33.0 ± 5.3 % (Maiorana *et al.*, 2002; Geirsdottir *et al.*, 2012; Ades *et al.*, 2015; Emerenziani *et al.*, 2015; Sari-Sarraf *et al.*, 2015), which was slightly higher than the average body fat percentage of 30.7 ± 14.7 % of the participants in this study.

There was a slight decrease in BMI for both the experimental and control group over the 10-week period, although this difference was not statistically significant. There was, however, a substantial decrease of 3.4 % body fat in the experimental group (< 0.05). These findings are supported by Ades *et al.* (2015) who, in a group of obese/overweight individuals found a significant reduction in BMI and body fat percentage (3.5 %) following a six month weight loss program. Unfortunately, this study did not have a control group for comparison, however, in a similar, albeit slightly shorter study by Sari-Sarraf *et al.* (2015), they found the experimental group had a significant reduction in BMI and body fat percentage (3.1 %), with minimal changes in the control group for both BMI and body fat percentage. These changes in body fat percentage were similar to what was found in the current study of 10 weeks, providing evidence that a combination exercise program of reasonably short duration is effective in managing anthropometric outcomes. There were, however, distinct methodological differences between the two above-mentioned studies and the present study with respect to both the exercise and dietary programs. The exercise program of the current study continually progressed the exercises from week to week, whereas the studies by (Ades *et al.*, 2015) and (Sari-Sarraf *et al.*, 2015), used a set intensity for the duration of the intervention period. Furthermore, while the study by Ades *et al.* (2015) made use of a similar dietary intervention, none was used by Sari-Sarraf *et al.* (2015).

A 12 month study by Balducci *et al.* (2004) reported similar findings to the above-mentioned studies, with a combined aerobic and resistance training program resulting in a 10 % decrease in BMI and fat mass, respectively. Considering the exercise program methodology was similar to the current study, their results are probably due to the longer duration of their program. A six month home-based exercise program elicited similar results to the above-mentioned authors, with the intervention resulting in a significant decrease in BMI, although no information was provided with respect to changes in body fat percentage (Yang & Oh, 2013). In a recent study by Emerenziani *et al.* (2015), it was found that a 12-week aerobic exercise program resulted in a significant decrease in BMI and body fat percentage (2.0 %) in the experimental group and no change in the control group. Despite the experimental period being longer than the current study, the drop in body fat percentage was smaller, and could be as a result of the sole use of aerobic exercise as a training modality at a continuous intensity that may have been lower than the current study, the slightly older age of the participants in the study (67 years versus 60 years), or the lower baseline body fat percentage of the participants. These findings were corroborated by another recent study where there was a steady decrease in BMI over an eight week period during which an aerobic exercise program was presented, while the control group had minimal changes, even tending towards an increase (Motahari-Tabari *et al.*, 2015). This study did not explicitly measure body fat percentage,

however, considering the study population were obese, a decrease in waist circumference together with a decrease in BMI could suggest that there was a certain degree of fat mass loss as a result of the intervention (Meeuwsen *et al.*, 2010).

Contrary to these findings, Maiorana *et al.* (2002) found that following an eight week combined exercise program, there was no change in BMI in either the experimental or control group. However, there was a decrease in body fat percentage in the experimental group, which suggests that there was a concomitant increase in fat free mass to compensate. Considering that the absolute weight of fat free mass is higher than fat mass, this is a plausible reason for this finding. Another study which had similar findings was conducted by Tessier *et al.* (2000) and found no change in BMI following a 16-week progressive aerobic exercise program in either group, with no data on body fat percentage being reported. There are a number of plausible reasons for this finding. Firstly, it has been reported by Stephens *et al.* (2015) that individuals with T2DM exhibit a genetic predisposition towards a term known as "exercise resistance", whereby physical activity does not result in improvements in T2DM management and control. Muscle fuel metabolism is what differentiates those who respond, versus those who don't, therefore, dietary modifications may be of more benefit in these individuals. Secondly, the participants in this study were on multiple pharmacological agents for the management of their T2DM, with most of these participants being on these agents for three years or more. One of the well-established side-effects of certain medications is weight gain, and could explain why the BMI did not change, despite the increase in energy expenditure brought about by the exercise program (Neumiller & Setter, 2009; Harper *et al.*, 2013; He *et al.*, 2015). Finally, the possibility exists that the participants could have increased their food consumption due to the exercise sessions, with no data reported on dietary changes by the authors.

Aside from the effects of physical activity on anthropometric outcomes, dietary changes have been reported to impact on BMI and body fat percentage, in the absence of, and in conjunction with physical activity. Hosseinpour-Niazi *et al.* (2015) found that simply by substituting certain food types (substitution of red meat with legumes), eight weeks was sufficient to cause a decrease in BMI and waist circumference, which was not seen in the control group. The principle of substituting food groups was similar to what was observed in this study, and was part of the dietary intervention, with changes in the quality of carbohydrate consumed (e.g. substituting white bread for low GI bread, which causes a more sustained glycaemic response) possibly accounting for some of the changes in anthropometric outcomes. Encouraging research published earlier, found that after only three weeks of either a low-carbohydrate or low-fat diet, there was a marked reduction in BMI and waist circumference, although the low-carbohydrate diet seemed to be more effective (Von

Bibra *et al.*, 2014). Considering that the participants in this study were not prescribed a specific diet, it is difficult to directly compare these results to this study. Nevertheless the decrease in multiple carbohydrates being eaten in one meal, as well as a decrease in the use of extra sugar and sweeteners from the current study could account for the changes in body composition. With this consideration in mind, the decrease in body fat percentage, which is strongly associated with waist circumference (Meeuwsen *et al.*, 2010), shows that the exercise and diet intervention affected change.

A large percentage of studies investigating diet-related changes on T2DM outcomes are conducted over six months to one year, which is substantially longer than the current study, and could account for some of the differences seen between the present study and previous studies of longer duration. Andrews *et al.* (2011) examined the effects of a six-month program of diet only, a combination of diet and exercise and usual care given by healthcare professionals. It was found that diet alone and the combination of diet and exercise, both resulted in decreases in BMI, as well as decreases in resistance measured by bioelectrical impedance (BIA), while negligible differences were found between the diet only and combination group. BIA works on the principle that a micro-current emitted, will experience impedance based on the size and type of the various tissues it passes through, with lower levels of impedance indicating a greater degree of fat free mass, and higher levels of impedance indicating a greater degree of fat mass (Ryo *et al.*, 2005; Huang *et al.*, 2015; Mehlig *et al.*, 2015).

The negligible differences between the diet only group, and combination group could be due to a number of reasons. Firstly, the intensity of the activity may not have been high enough to elicit a response, with walking being used as the modality. Secondly, it is plausible that the participants increased their food intake in response to exercise participation, which would negate the caloric deficit that may have been present. Finally, most of the participants were at the early stages of disease progression, therefore the magnitude of improvement possible would be less. While the dietary components were similar between the current study and the study by Andrews *et al.* (2011), the exercise components were vastly different, which makes the two studies difficult to compare. However, the benefits of a combination intervention over usual care are comparable and illustrate the potential these types of programs have in managing T2DM. Kontogianni *et al.* (2012) found that a 12-month dietary intervention consisting of a reduction in sugars, saturated fat and refined foods, together with an increase in vegetable intake, resulted in a substantial decrease in BMI and a small decrease in waist circumference.

The similarities in the findings between the two studies is more than likely because the dietary component of the current study included similar dietary advice, with participants being encouraged

to reduce sugar intake, minimise the frequency at which they ate multiple carbohydrates during one meal, moderate portion sizes and increase the consumption of vegetables and healthy fats. Another long-term study conducted over 12 months by Pedersen *et al.* (2014), investigated the difference between a high-protein and standard-protein diet on a number of anthropometric and metabolic markers. Both the high- and standard-protein diets resulted in a decrease in BMI and body fat percentage, although the high-protein diet resulted in a greater, yet not significant reduction. The reasoning behind these types of diets is that protein, like fat, gives higher levels of satiety, and therefore an individual is more prone to decrease their food intake in subsequent meals, resulting in an energy deficiency and ultimately weight loss (Johnston *et al.*, 2004). Dietary protein in the form of fish and some vegetables were consumed in greater amounts following the 10-week intervention in this study which would confirm the findings of the study by Pedersen *et al.* (2014). A recent study conducted in a resource limited setting in South Africa found that, following a six-month program of dietary advice, BMI was moderately lower than at baseline, although was not maintained at the 12 month follow-up, suggesting that constant support and a structured program is necessary to maintain changes in anthropometric outcomes (Muchiri *et al.*, 2015). The findings of the present study contradict this, with an improvement in BMI being reported at the follow-up period 10-weeks after the intervention program

It is possible that the longer time period between the cessation of the intervention and the follow-up in the study by (Muchiri *et al.* (2015) could account for the failure to maintain the changes. Furthermore, the participants in the current study received a post-intervention guide to assist them with making healthy dietary choices, which the participants in the study by Muchiri *et al.* (2015) did not.

Mora-Rodriguez *et al.* (2014) found that following a four-month aerobic training program and in the absence of any further training (detraining) for one month, the improvements seen in insulin resistance and cardiorespiratory fitness fell to almost baseline levels, with only some blood pressure and body composition variables being maintained. Being cognoscente of these findings, it is clear that the results of this study (further decreases in BMI and body fat percentage) demonstrate that the participants remained active, albeit at a lower level than during the intervention, for the 10-week period following the completion of the program. This study highlights the importance of continued participation in physical activity, and healthy lifestyle behaviours, even after the cessation of a structured program.

It is also likely that the combination exercise program in the current study played a role. As mentioned previously, combination exercise incorporating both upper and lower body exercises, results in significant improvements in anthropometric outcomes by increasing the uptake of glucose

in the blood stream, thereby improving the sensitivity of insulin, as well as decreasing the likelihood of the storage of fat. Furthermore, improvements in dietary habits in combination with exercise would result in lower levels of ROS and less damage to pancreatic β-cells, thereby increasing serum insulin levels.

5.3.2. Cardiovascular Outcomes

Hypertension in most cases precedes the diagnosis of T2DM, although in some cases it may occur secondary to disease progression. The average systolic and diastolic blood pressure for this study population was 141.4 ± 20.9 mmHg and 79.6 ± 13.6 mmHg, respectively, with all of the participants being diagnosed with hypertension prior to participation in the study. While the range of blood pressure measurements in related studies varies greatly, the average SBP was 137.9 ± 18.7 mmHg, while the average DBP was 82.6 ± 9.0 mmHg (Geirsdottir *et al.*, 2012; Kontogianni *et al.*, 2012; Von Bibra *et al.*, 2014; Ades *et al.*, 2015; Muchiri *et al.*, 2015; Sari-Sarraf *et al.*, 2015). The ACSM recommends that SBP be lower than 120 mmHg and DBP lower than 80 mmHg under ideal circumstances. According to ACSM criteria, the participants in this study would be classified as having stage one hypertension, while the overall study population would be classified as pre-hypertensive (American College of Sports Medicine, 2014).

There was a slight, but not significant increase in systolic blood pressure (SBP) over the 10-week intervention period in both groups, combined with a decrease in diastolic blood pressure (DBP), which was significant in the experimental group compared to baseline. The general trend among almost all exercise- and diet-based intervention studies is that there is a reduction in SBP and DBP of varying degrees.

The increase in SBP following the intervention is an unexpected result, with no other study supporting this finding. There are two plausible reasons for this finding. Firstly, it is possible that the participants were not consistent with adhering to their anti-hypertensive medication, particularly on the day of post-testing, which has been previously reported (Saleh *et al.*, 2014). Secondly, it is possible that due to the participants' walking to the testing sessions, the five-minute rest period provided before taking the individual's resting blood pressure was not sufficient time to allow for the blood pressure to normalise. While the guidelines provided by the ACSM suggest that five minutes is sufficient (American College of Sports Medicine, 2014), it is possible that due to all of the participants having diagnosed hypertension, their SBP and DBP would be elevated to a greater degree after a bout of walking, than someone who was normotensive. The only study that found no change in blood pressure was by Edelman *et al.* (2015), where neither SBP nor DBP changed

following a 24 month behavioural intervention led by nurses, although the methodology and study design was vastly different to the current study and therefore makes it difficult to directly compare.

The statistically significant decrease in DBP in this study is corroborated by a number of authors. A recent study involving aerobic training over a 16-week period reported an almost 15 % decrease in DBP with a smaller, but still significant decrease in SBP (Sari-Sarraf *et al.*, 2015). Similar findings were reported in a six month study conducted by Ades *et al.* (2015), where there was a non-significant decrease in SBP, but a significant decrease in DBP (6.0 mmHg) following a exercise intervention aimed at weight loss, and was conducted in a group of elderly men and women. The concomitant decreases in body weight, fat mass and serum lipids, as well as an improvement in glycaemic control could all account for this improvement in blood pressure, due to their direct effect on vascular function (Selwyn *et al.*, 1997; Goldstein & Scalia, 2004). Despite the duration of the current study being slightly shorter than the above-mentioned studies, the mechanisms responsible for the lower DBP found in this study would be similar, with the additional anti-inflammatory benefits provided by healthy dietary choices.

In a longer 12-month intensive exercise program, Balducci *et al.* (2010) reported decreases in SBP and DBP compared to baseline in both the control and experimental groups, although the magnitude of the decrease was greater in the experimental group for both SBP and DBP. In this instance, changes to anthropometrical outcomes were only seen in the experimental group, which could account for the difference between the groups. However, both groups also experienced an improvement in VO_{2max}, and thus central adaptations such as improvements in mitochondrial enzyme activity, or a decrease in pre-load, could further account for the reduction in SBP and DBP in both groups (Balducci *et al.*, 2010). An earlier study by the same author, which also employed a 12-month combination aerobic and resistance exercise program, found similar results, with a clinically significant improvement of SBP and DBP by 5 mmHg and 4 mmHg, respectively in the experimental group (Balducci *et al.*, 2004).

Although there was no change in SBP in this study, the decrease in DBP of 4.2 mmHg in this study was comparable to the study by Balducci *et al.* (2004), and achieved in a shorter time period. A plausible reason for the more rapid decrease in DBP could be linked to the concomitant dietary intervention that was included in this study, where a 12-week dietary intervention study by Sasakabe *et al.* (2015) providing evidence of this. A study comparing the effects of aerobic, resistance and combined exercise found that following a 12-week intervention period, all three exercise modalities, as well as the control group, reported decreases in SBP and DBP (6.3 mmHg decrease on average) that were statistically significant (Jorge *et al.*, 2011). The authors did not explicitly measure dietary control, therefore it is possible that both the experimental and control

group made changes to their eating habits (e.g. reduced carbohydrate, increased vegetable consumption) which would have affected vascular function, and therefore their blood pressure. Furthermore, either adherence or non-adherence to medication could have influence the blood pressure measurements in the study by Jorge *et al.* (2011) and was combatted in the current study by requesting participants to not change their medication schedule unless medically advised to by their primary healthcare provider. Geirsdottir *et al.* (2012) found that a 12-week resistance training program resulted in reductions in SBP and DBP (2.9 mmHg), which were comparable to healthy elderly individuals. The decrease in this study was slightly higher than the abovementioned study and may be due to the combined effect of aerobic and resistance exercise on vascular function.

Similarly to exercise interventions, dietary interventions have been equally successful in reducing both SBP and DBP over a period of time by reducing plasma glucose levels, which was seen in this study. A 12-week study by Sasakabe *et al.* (2015), reported decreases in SBP and DBP (3.9 mmHg) that were both statistically significant and were as a result of adopting a low-carbohydrate diet. These findings are comparable to the current study, although it must be noted that these findings were from a diet-only intervention, whereas the present study made use of both dietary and exercise interventions. In another 12-week study that examined the impact of a traditional Mediterranean diet on blood pressure, there was no change in SBP and only a slight decrease in DBP (Itsiopoulos *et al.*, 2011). However, these results should be interpreted with caution, as the baseline blood pressures of the participants indicated that they were not classified as hypertensive (< 140/90 mmHg). In a similar, albeit shorter study to Sasakabe *et al.* (2015), a three week low-carbohydrate diet was found to significantly decrease SBP and DBP when compared to a low-fat diet, with a subsequent improvement in cardiac function (Von Bibra *et al.*, 2014). Kontogianni *et al.* (2012) reported similar findings, whereby reducing sugar, refined carbohydrate and saturated fat intake resulted in a significant decrease in SBP, but no change in DBP following a year of the specific diet.

These findings are contrary to what was found in the present study and could be due to the inclusion of exercise in the current study. On the other hand, a study conducted in a resource-limited setting found that, while there were improvements in SBP and DBP following a six-month nutritional education program, neither SBP nor DBP were maintained at the six month follow up, with levels returning to baseline values (Muchiri *et al.*, 2015). This is contrary to what was found in the present study, with decreases in both SBP and DBP being reported at the follow-up testing which occurred 10-weeks following the post-testing session. Continued involvement in some form of exercise, as well as health dietary behaviours, were more than likely responsible for these findings.

5.3.3. Haematological Outcomes

Considering that a large part of the pathology of T2DM arises due to sustained levels of elevated blood glucose (hyperglycaemia), it was deemed necessary to include three blood tests as part of the outcome variables, with glycated haemoglobin (HbA1c) being one of the most important indicators of blood glucose levels over a period of 10 to 12 weeks.

Fasting blood glucose is most often used as a measure of glycaemic control in conjunction with HbA1c. The range of blood glucose values among the participants in this study was large and could have been influenced by a number of factors such as treatment regime, time when tested, and diet. On average, fasting blood glucose in related studies was on average 7.9 ± 1.5 mmol.L^{-1} (Maiorana *et al.*, 2002; Lambers *et al.*, 2008; Geirsdottir *et al.*, 2012; Kontogianni *et al.*, 2012; Von Bibra *et al.*, 2014; Ades *et al.*, 2015), which considering that participants were diagnosed diabetics and for the most part on medication, is surprisingly high. This again highlights the need for more research into adequate management of the disease.

In resource-limited settings, it is not uncommon for random blood glucose to be used as a measure of glycaemic control and it has been shown to correlate well with HbA1c (Gill *et al.*, 1994; Rasmussen *et al.*, 2014). Furthermore, recent studies have indicated that the use of random blood glucose testing may be superior to predicting T2DM than the traditional methods and should be included as part of pre-diabetic screening (Kowall *et al.*, 2013; Bowen *et al.*, 2015). The average value in these studies was 7.0 ± 1.2 mmol.L^{-1}, which is substantially lower than the average of 13.9 ± 4.6 mmol.L^{-1} which was found in the current study. Possible reasons for such a large disparity in the measurements could be related to medication adherence, inadequate medication dosage due to disease progression that is not picked up by the primary healthcare provider, or the time of day the measurements were taken.

When examining HbA1c, however, there is a large degree of uniformity, partly due to the standardised procedures and methods for collecting and analysing the blood samples. Similarly to a number of the above-mentioned variables, there is a large degree of variation in the HbA1c measurements, which could be as a result of the study populations observed. When looking at similar studies to the current one, the average HbA1c was found to be 8.3 ± 1.2 % which is substantially higher than the usual clinical treatment target of 7.0 % (Peer *et al.*, 2014). Once again, the average HbA1c in this study was substantially higher (9.1 ± 2.2 %), although this is to be expected considering the high blood glucose levels. This finding also suggests that despite being on hyperglycaemic medication, the T2DM in this study population was still not under control.

Total serum cholesterol was found to be 7.7 ± 1.2 mmol.L^{-1} on average for a number of related studies (Maiorana *et al.*, 2002; Lambers *et al.*, 2008; Von Bibra *et al.*, 2014; Ades *et al.*, 2015; Emerenziani *et al.*, 2015; Hosseinpour-Niazi *et al.*, 2015). This is substantially higher than the guidelines of the ACSM which suggest that total serum cholesterol should be under 5.20 mmol.L^{-1} in order to reduce cardiovascular risk (American College of Sports Medicine, 2014). This high level could be explained by the findings of Taskinen & Borén (2015) who suggested that long-term T2DM results in unfavourable changes in lipid profiles. The total serum cholesterol measurement in the current study was substantially lower than the average of previous studies and the measurement of 5.3 ± 1.1 mmol.L^{-1} was only marginally higher than the ACSM guidelines.

In the current study, reductions in random blood glucose and HbA1c, of which the latter was statistically significant, and an increase in TSC were reported in the experimental group following the intervention. In contrast to the experimental group, there were increases in HbA1c, TSC and random blood glucose in the control group.

Most studies report either a decrease or no change in the respective variables over time, therefore the increase in cholesterol in the experimental group is surprising, although it could be explained by the development of dyslipidaemia found in T2DM patients (Taskinen & Borén, 2015). The decreases in HbA1c and glucose were confirmed in a recent study by Ades *et al.* (2015), where HbA1c was 0.6 % lower following a six month intervention, and fasting glucose decreased by over 20 %. These differences were similar to what was found in this study, albeit with a shorter intervention period. The mechanism behind this decrease is linked to the effect of exercise on GLUT-4 translocation, and therefore a decrease in serum glucose levels. Over time, consistently lower blood glucose levels would translate into a lower HbA1c. Considering that the individuals in both the study by Ades *et al.* (2015) and this study, exercised three times a week for approximately 60 minutes, this mechanism of action is highly probable.

A 12-month intensive exercise program elicited almost identical results with a substantial decrease in HbA1c, fasting glucose and cholesterol values, highlighting the positive effect that exercise has on glycaemic and lipid control (Balducci *et al.*, 2010). The longer time period could account for the larger magnitude of the improvements observed in this study, in addition to the individualised exercise sessions these participants received. In the present study, the exercise sessions were conducted in groups which has been shown to be less effective than individualised exercise sessions (Perri *et al.*, 1997), although there evidence contrary to this is presented by Church *et al.* (2010) who found that group exercise was more beneficial than individual exercise.

The time period needed to achieve glycaemic control, or at least clinical improvements in glycaemic control, is widely debated and is dependent on a number of factors such as disease severity, the presence of other co-morbidities, and medication adherence to name a few. However, Sari-Sarraf *et al.* (2015) found that eight weeks of training resulted in statistically significant changes in fasting plasma glucose, and by 16 weeks, the change in the eight week period was not significantly less, therefore strengthening the notion that extended programs are not always necessary to achieve glycaemic control. The findings of the present study, however, are contrary to this, in that both blood glucose and HbA1c decreased further following the 10-week period after the cessation of the structured program. A possible reason for this finding is that the exercise program by Sari-Sarraf *et al.* (2015) was not incremental in nature, with the same intensity of exercise in the first week and sixteenth week. This was not the case in the current study, and the constant need to adapt to the increased exercise demands may have resulted in the further improvements seen in this study. A noteworthy finding of the study by Sari-Sarraf *et al.* (2015) is that the decrease in fasting plasma glucose was accompanied by a decrease in insulin resistance and plasma insulin levels, a clear indication of the physiological changes induced by regular participation in exercise.

The general consensus regarding changes to haematological parameters seems to be that all modes of exercise (aerobic, resistance or a combination of the two) result in improvements in HbA1c, fasting plasma glucose and total serum cholesterol, confirmed in a 12-week study by Jorge *et al.* (2011). HbA1c and fasting plasma glucose improved the most in the resistance training group, whereas total serum cholesterol improved the most in the aerobic training group. The magnitude of the differences was smaller in the combination exercise group, although still significant, and could be due to the reduced volume and specificity of training when compared to the aerobic and resistance training groups. With the exception of total serum cholesterol, the findings of the current study suggest that combination exercise is effective in decreasing HbA1c and blood glucose levels. These findings were similar to what was reported by Balducci *et al.* (2004), who found that a 12-month combination exercise program resulted in significant reductions in HbA1c, total serum cholesterol, LDL-C and triglycerides, with a significant increase reported in HDL-C. The longer duration of the study by Balducci *et al.* (2004) is a plausible reason for the significant improvements seen in lipid metabolism, which weren't found in the present study. These improvements in lipid metabolism are linked to decreases in central adiposity, which may take longer than the 10-week intervention period used in the present study. In a significantly shorter study of four months, which also made use of combination training, similar findings to that of Balducci *et al.* (2004) were reported, although the magnitude of the changes were not as large, and

there was no apparent change in HDL-C (Cauza *et al.*, 2006). This finding provides further evidence that changes in HDL-C may only occur after prolonged participation in physical activity.

Conflicting evidence with regards to resistance training and its impact on glycaemic control was highlighted by Geirsdottir *et al.* (2012) where a 12-week resistance training program resulted in a slight increase in both HbA1c and fasting plasma glucose. This was an anomaly, which could be explained by dietary behaviours or a reduced adherence to medication in the T2DM participants. Further evidence that this finding was an anomaly was reported by Cauza *et al.* (2005) who found that four months of resistance training resulted in a 1.2 % decrease in HbA1c, which was not found with endurance training of the same duration. Furthermore, there were improvements in insulin sensitivity and serum lipid levels, most notably a decrease in TSC, LDL-C and triglycerides. Considering that the present study made use of combination training techniques, these findings only partially support the results seen in the current study.

The role of diet in glycaemic control and lipid metabolism cannot be underestimated, and was clearly demonstrated by Sasakabe *et al.* (2015). They found that by adopting a low carbohydrate diet for three months, significant decreases were found in HbA1c and fasting blood glucose. While the total serum cholesterol was not reported, there was a decrease in LDL-C and a significant increase in HDL-C, which is indicative of an improvement in health status and decreased cardiovascular risk. These findings were corroborated in the present study, with the decrease in carbohydrates consumed together, and an increase in the frequency of vegetable consumption possibly accounting for these improvements. This in agreement with a substantially shorter three-week study by Von Bibra *et al.* (2014) where a low-carbohydrate/high-protein diet resulted in comparable changes in HbA1c, fasting glucose and cholesterol.

Specific diets, which were not employed in the present study, seem to result in favourable changes in a shorter period of time when compared to dietary advice, although the exact difference remains unknown. In another study of three month duration, using the Mediterranean diet as the treatment diet of choice, reductions in HbA1c and fasting blood glucose were reported, although the changes were not statistically significant (Itsiopoulos *et al.*, 2011). These results may indicate that the use of a low-carbohydrate diet initially to achieve glycaemic control might be a more prudent approach, with a switch to a more balanced diet at a later stage for maintenance. Interestingly, a high protein diet, which was designed for weight-loss, resulted in significant decreases in HbA1c and fasting blood glucose at four months, although these decreases were not maintained at the 12-month testing period (Pedersen *et al.*, 2014). This once again highlights the need to adapt the dietary behaviours accordingly as improvements in glycaemic control and lipid metabolism are seen (Pedersen *et al.*, 2014). This balanced diet is potentially the reason why the results in the present study were

maintained at the follow-up period. Andrews *et al.* (2011) found that both diet alone, and in combination with exercise, result in favourable improvements in glycaemic control and the magnitude of the difference between the two groups is minimal when the two groups were compared. This would suggest that diet plays a greater role in glycaemic control than exercise, although it must be noted that the participants in the study by Andrews *et al.* (2011) were newly diagnosed T2DM patients, and therefore may be more susceptible to dietary changes that an individual who had been suffering with T2DM for a longer period of time.

When looking at the difference at a follow-up period at some point after the cessation of an intervention program, Lee *et al.* (2015) found that participants in both a structured aerobic training and a structured walking program were able to maintain their improvements in glycaemic control variables seen at post-testing, although the improvements in the walking group were more consistent. Considering that walking is a more convenient and less strenuous form of exercise, these results are understandable, especially considering that most individuals with T2DM are overweight or obese, and where running may predispose them to increased risk of injury. Two community or peer-led studies by Koniak-Griffin *et al.* (2015) and Pérez-Escamilla *et al.* (2015) found that glycaemic variables and serum lipid levels were maintained, and in some cases improved, at the follow-up periods when compared to their respective control groups. The strength of both studies lies in their comprehensive intervention design, which involved community health workers (CHW) making individual visits over the course of the follow-up period. While this was somewhat different to the present study, the support of fellow participants, which was advocated during the psychological arm of the intervention, may have contributed to the maintenance of the improvements at the follow-up testing session. Contrary to this, Houle *et al.* (2015) reported increased HbA1c levels at six and 12 months following a hospital-based intervention, which could be as a result of reduced levels of support following the intervention.

5.3.4. Functional Outcomes

There was an increase in the distance walked by both the control and experimental group following the 10-week intervention, although only the difference in the latter was found to be statistically significant. These improvements are likely to have occurred from a combination of increased muscle strength and improved cardiovascular capacity, which have been widely reported in the literature (Maiorana *et al.*, 2002; Lambers *et al.*, 2008; Balducci *et al.*, 2010; Jorge *et al.*, 2011; Geirsdottir *et al.*, 2012; Earnest *et al.*, 2014; Morrison *et al.*, 2014; Ades *et al.*, 2015).

Increases in muscle strength were found in a number of studies where either combination or resistance training were used. In a 12-week resistance training program, absolute and relative (to

lean body mass) quadriceps strength was significantly increased, which led to an increase in the distance walked during a 6MWT (Geirsdottir *et al.*, 2012). While the exercise program of the present study was not exclusively resistance training, many of the exercises included were targeting lower limb strength, which would include the quadriceps. It is therefore plausible that the findings of this study are comparable to the findings of the above-mentioned study, which would account for the increase in distance walked during the 6MWT. Similar findings were reported in a combination exercise program also conducted over 12-weeks where both upper and lower body strength improved, with a subsequent increase in distance walked during the six-minute walk test (Lambers *et al.*, 2008). While it is unlikely that upper body strength would have contributed directly to the improvement in the 6MWT, it is possible that an increase in postural stability, in combination with the increased lower-body strength would have caused the improvement. This mechanism is also a plausible reason for the improvement in 6MWT distance walked in the present study, with a number of exercises included to improve core strength and postural stability, a hallmark of combination exercise programs.

The contentious issue of whether or not resistance exercise influences cardiorespiratory fitness in T2DM patients was explored by two comprehensive studies by Jorge *et al.* (2011) and Yang *et al.* (2014), where aerobic, resistance and combination exercise were compared for their effects on these parameters. Both studies found that resistance exercise, while beneficial in other areas, did not result in any substantial improvement in aerobic capacity (VO_{2max}). Aerobic training on the other hand, has been found to significantly improve walking speed (Morrison *et al.*, 2014), VO_{2max} (Emerenziani *et al.*, 2015; Sari-Sarraf *et al.*, 2015), functional exercise capacity (Tessier *et al.*, 2000) and leg strength (Sari-Sarraf *et al.*, 2015), which all would ultimately lead to improved performance in the 6MWT. These findings corroborate what was found in the present study, and although VO_{2max} wasn't explicated measured, the estimate from the distance walked in the 6MWT would suggest that it did, together with an increase in walking speed. Combination exercise has demonstrated similar results to that of aerobic training, with Earnest *et al.* (2014) showing a significant improvement in VO_{2max} and time to exhaustion during a VO_{2max} test in elderly adults. Similar findings in an older adult population was reported by Ades *et al.* (2015), where a six-month exercise program designed for weight loss resulted in a 20 % improvement in VO_{2max}. Structured exercise of moderate intensity was used by Ades *et al.* (2015), which was similar to the current study. Balducci *et al.* (2010) presented similar findings to Sari-Sarraf *et al.* (2015), where they found that a 12-month intensive exercise program in older adults improved upper and lower body strength, flexibility and VO_{2max}. One of the benefits of the present study was the use of whole body,

combination exercise, which confers additional benefits in muscular strength and endurance, and subsequent performance, compared to isolated programs.

Aside from the improvements in VO_{2max}, an eight-week combination exercise program in older adults also resulted in significantly lower RPE values at set exercise workloads (Maiorana *et al.*, 2002). Once again, the present study reported similar findings, with the perceived level of work, or difficulty during the 6MWT being lower following the intervention than at baseline, indicating an improvement in strength and aerobic capacity.

The mechanisms behind these findings are complex and involve the synergistic actions of a number of systems. Both aerobic and resistance exercise increase the levels of shear stress which ultimately results in increased NO production and improved vascular function (Delbin & Trask, 2014). Furthermore, muscle contraction promotes GLUT-4 translocation, which would aid in lowering serum glucose levels. Down-stream effects of this would ultimately result in improved insulin sensitivity, an increase in fatty acid metabolism, and a reduction in inflammatory cytokines and molecules, all contributing to a favourable outcome with respect to glycaemic control and T2DM disease management (Jorge *et al.*, 2011; Yang *et al.*, 2014)

5.3.5. Dietary Habits Outcomes

Dietary control for diabetics is of particular importance with a number of studies investigating the content of the food, frequency of eating and/or snacking, and time of day eating took place, and in some cases correlating it with the levels of HbA1c (Savoca *et al.*, 2004; Mekary *et al.*, 2012; Castro-Sánchez & Ávila-Ortíz, 2013; Hood *et al.*, 2014). Furthermore, with recent reports emerging of skeletal muscle "exercise resistance" in T2DM, with muscle fuel metabolism differentiating between those who respond, versus those who don't, dietary habits may play the most important role in T2DM disease management in these individuals (Stephens *et al.*, 2015).

A number of studies have shown that there is a strong resistance to changing dietary behaviours that may stem from cultural beliefs and practices (Hempler *et al.*, 2015), as well as perceived goal difficulty and chances of attainment (Miller *et al.*, 2012). There appears to be general consensus that the process of adopting changes in dietary behaviours is modelled on the trans-theoretical model (TTM) of behaviour change first introduced by Prochaska & DiClemente (1983). The five stages of behavioural change are pre-contemplation, contemplation, preparation, action and maintenance, and are fluid stages of indeterminate time. The likelihood of a person diagnosed with T2DM adhering to a diet has been shown to correlate well with the TTM behavioural stage they are in (Uggiero & Reene, 2003; Castro-Sánchez & Ávila-Ortíz, 2013; Knight *et al.*, 2015). Miller *et al.* (2012) found that those people with a higher self-belief in change, and therefore at the latter stages

of the TTM, were more committed to the end goal, and perceived the goal to be substantially less difficult to achieve than those with a lower self-belief. These findings were confirmed to a certain degree by Knight *et al.* (2015) where it was found that the perceived barriers to dietary change were greater in the earlier stages in the TTM, with the barriers and actual goal of dietary change being less at the latter stages in the TTM. Interestingly, it was found that women were more likely to be in the last two stages of the TTM than men. A number of barriers to dietary adherence were identified by Hempler *et al.* (2015), which included a lack of social and familial support, low socio-economic status, the affordability of the required food and lack of appropriate knowledge from community health-care workers. Binge eating is a further challenge associated with adherence to a healthy diet required for T2DM patients, with a strong correlation found between stage of TTM and the likelihood of engaging in binge eating behaviour (Herbozo *et al.*, 2015).

There is a certain degree of ambiguity in the knowledge that T2DM patients have regarding the role of carbohydrates in the dietary management of their disease, with a large percentage only attributing carbohydrate to sugar in its basic form, and reasoning that by decreasing sugar intake, you are effectively controlling your blood sugar (Breen *et al.*, 2015). This could potentially account for the finding in this study that the control group did not significantly change their eating habits with respect to the type of bread consumed, or the consumption of complex carbohydrates together. The change in the experimental group towards a low-GI or whole-wheat bread consumption is consistent with what was found by England *et al.* (2014) where study participants decreased their consumption of white bread and high-energy food sources. These results indicated the beneficial effects of dietary advice on eating habits, as was the case with the present study. Furthermore, the ability of a non-specific dietary intervention to exact change over a period of time was highlighted by the continuation of healthy dietary behaviours, even after the cessation of a structured intervention. Similar findings were reported by Kontogianni *et al.* (2012) where the experimental group decreased their consumption of sugars, refined cereals and processed foods, while a concomitant increase in fruit and vegetables and high-fibre foods was seen. The findings of the present study are in concordance with the findings of the above-mentioned study, with the nature of the dietary interventions being very similar.

There have been several studies that have reported the benefits of consuming low-GI or whole-grain products, which include improved insulin sensitivity and lower fasting plasma glucose, as well as decreasing the risk of developing T2DM by 30 % (Gil *et al.*, 2011; Aune *et al.*, 2013; Tucker *et al.*, 2014). These findings are similar to a study by Chandalia *et al.* (2000) who found that consumption of a high fibre diet resulted in 10 % improvement in glycaemic control, 12 % improvement in insulin sensitivity and an approximately nine percent decrease in serum lipid levels. The

improvements in glycaemic control were also reported by Buyken *et al.* (1998) which found that higher consumption of dietary fibre was associated with a decrease in HbA1c levels and therefore better glycaemic control. The present study reported similar findings, with consumption of low GI or brown bread, as well as increased consumption of vegetables accounting for the increased dietary fibre intake. The physiological manifestations of these dietary changes were evident in the decreased levels of blood glucose and HbA1c at the completion of the intervention.

Similarly to what was seen in this study, where a large percentage of the study population consumed far more than the recommended number of starch servings per day, Medagama & Widanapathirana (2015) found that 70 % of their participants also consumed more than the recommended number of starch servings per day, which had a significant impact on the glycaemic response. Cultural beliefs and practices more than likely contributed to this finding in the present study as well as the study by Medagama & Widanapathirana (2015), where the staple food is comprised of starch. Furthermore, the relatively low cost of these foods predisposes an individual to consume them on a more regular basis and in larger quantities in order to achieve adequate levels of satiety. However, as has been demonstrated in the present study, the sustained consumption of large quantities of starch results in an unfavourable progression in T2DM and worsening glycaemic control.

A recent meta-analysis by Wu *et al.* (2015) provided strong evidence that regular consumption of vegetables significantly reduces the risk of developing T2DM. It was therefore no surprise that at the start of the current study, participants consumed less than two servings of vegetables per day. This finding was also in agreement with that of Medagama & Widanapathirana (2015). The increased levels of vegetable and/or salad consumption in the current study is in line with a number of studies that are based on the Mediterranean or prudent diet, which is characterised by a higher vegetable and legume intake (Salas-Salvadó *et al.*, 2011; Grosso *et al.*, 2014; Zad *et al.*, 2015). The present study reported a 52 % increase in vegetable consumption and most likely contributed to the improvements in glycaemic control being evident.

The decrease in the quantity of alcohol consumption reported in this study would have some question as to whether or not this is beneficial, considering there are a number of studies that indicate moderate alcohol consumption is associated with a decreased risk of T2DM which is loosely linked to improved insulin sensitivity (Carlsson *et al.*, 2000; Van de Wiel, 2004; Carlsson *et al.*, 2005; Baliunas *et al.*, 2009; Marques-Vidal *et al.*, 2015). However, what is important to note is that spirits were most often consumed by the experimental group, with a significant association found between spirit and beer consumption and impaired glycaemic control, as well as risk for developing T2DM (Carlsson *et al.*, 2000; Molsted *et al.*, 2014; Marques-Vidal *et al.*, 2015).

Therefore, by possibly changing the type of alcohol consumed, the experimental group would be reducing the likelihood of impaired glycaemic control as a result of spirit consumption. This finding is supported by Hausenblas *et al.*, (2015) who found that additional supplementation with resveratrol, one of the chief active ingredients in red wine, was successful in reducing HbA1c and SBP in older adults with T2DM.

5.3.6. Health-Related QoL Outcomes

The relationship between glycaemic control and HRQoL is one that has been explored by a number of authors, with conflicting results being found. Kuznetsov *et al.* (2014) found that those individuals who had a lower HRQoL at a five-year follow-up, had a higher HbA1c measurement. This is a plausible reason for the findings of the present study, which reported a substantially lower HRQoL in the control group, with a concomitant increase in HbA1c, whereas the experimental group reported a significantly higher HRQoL, together with a decrease in HbA1c following the intervention. These findings were highlighted in a study by Lambers *et al.* (2008) where a 12-week combined exercise-training program in older adults showed that a decrease in HbA1c resulted in small improvements in HRQoL. A study by Guldbrand *et al.* (2014) had a number of similarities, where it was reported that a low-carbohydrate diet improved HRQoL after 12 months. The mechanism behind this finding is two-fold. Firstly, there was a reduction in body weight, with the decrease in weight resulting in an improvement in HRQoL. Secondly, there was an improvement in glycaemic function, which has previously been shown to correlate with increased HRQoL (Shah *et al.*, 2015). Another similar study involving a low-calorie diet, with or without the addition of exercise, also reported an improvement in HRQoL that was once again attributable to weight loss (Snel *et al.*, 2012). While there was no significant weight loss in the present study, there was a significant decrease in body fat percentage, which would most certainly have a positive impact on HRQoL. It is understandable that embarrassment of physical appearance negatively impacts on social interactions and activities of daily living, therefore a decrease in body fat percentage resulted in an improvement in social function, which in turn positively impacted on HRQoL.

A ground-breaking study by Davis *et al.* (2012) found that both a low-carbohydrate and low-fat diet had beneficial effects on HRQoL, more specifically on energy and mobility, and sexual function, as assessed by the D-39 questionnaire. These findings were corroborated in the present study, albeit with dietary advice as opposed to a specific dietary plan. Furthermore, the effect of exercise cannot be negated, with improved vascular function as a result of exercise possibly accounting for the improvement in sexual function. However, it must be noted that higher consumption of vegetables and high-fibre food, together with a reduced intake of refined foods and sugars, as was the case

with the present study, have been shown to also positively impact sexual function. The mechanism responsible for this improvement is linked with decreased levels of oxidative stress and a subsequent improvement in vascular function (Giugliano *et al.*, 2010).

The impact of social support, from family, peers and healthcare professionals on HRQoL has been extensively reported. Chew *et al.* (2015) and Stopford *et al.* (2013) found that higher levels of social support resulted in greater glycaemic control, which in turn resulted in an improved HRQoL. The results of the present study reported no change in the levels of familial support, however, the group sessions for all the various intervention arms would have resulted in a significant increase in peer support, which would have positively impacted on HRQoL. Stopford *et al.* (2013) suggested that social support from family and close friends exerts greater benefits that the social support from a healthcare professional due to the more frequent interaction with the individual. Conversely, Chew *et al.* (2015) suggested that support from a healthcare professional or external social support group would offer greater benefits. The findings of the present study support the findings by Chew *et al.* (2015) with a slight decrease in HRQoL observed at the follow-up, 10-weeks after the cessation of the study. While it is possible that the continuous interaction with the healthcare professionals resulted in an improvement in HRQoL, a more plausible reason for the decline could be linked to a change in the routine or structure that the participants had become accustomed to in the preceding 10-weeks. Hilding *et al.* (2015) reported that higher levels of familial and social support, as well as social interaction, significantly decreased the risk of developing T2DM, however, it must be kept in mind that certain behaviours, while being socially active, may in turn increase the risk (e.g. high alcohol consumption, high refined food consumption, etc.). The role of spousal support is scarcely reported and is, to some extent, undervalued in the appropriate management of the disease. Choi *et al.* (2015) revealed the importance and beneficial effects of spousal support on quality of life, and highlighted the need for further research to be conducted in this area.

HRQoL and self-care activities are strongly associated with one another, with high levels in one, resulting in high levels in the other, a phenomenon which has been described by a number of authors (Walker *et al.*, 2014; Shayeghian *et al.*, 2015). Recent studies have all indicated that lower levels of self-care, with presumably lower levels of HRQoL, have resulted in poorer glycaemic control (Shayeghian *et al.*, 2015; Smalls *et al.*, 2015), poorer adherence to diet, and greater diabetic-related complications (Saleh *et al.*, 2014). The findings of the present study support these findings, with fewer check-ups with healthcare professionals to monitor blood glucose levels, decreased ability to fulfil physical and emotional roles and overall difficulty with managing T2DM seen in the control group. Conversely, the experimental group reported improvements in all of the above-mentioned areas, with a subsequent increase in HRQoL. Socio-economic status is another variable

that has been shown to indirectly impact on HRQoL through a number of different mechanisms; access to adequate care, self-efficacy and perceived stress being a few (Nejhad *et al.*, 2013; Walker *et al.*, 2014). This is an area that requires further research in the community investigated with the current study.

Diabetes-related distress (DRD) is another factor that has a significant impact on HRQoL and is very often associated with poor self-care, low self-efficacy and poor glycaemic control (Karlsen & Bru, 2014; Co *et al.*, 2015; Shallcross *et al.*, 2015). Karlsen & Bru (2014) revealed that DRD may be more challenging to combat than initially thought, with social support being the greatest predictor of whether an improvement would occur or not, and specifically support from healthcare providers was of more benefit than from family and peers. However, it is important to note that in most cases, and as was seen in this study, T2DM patients don't regularly visit either their primary or other health care provider(s), thereby highlighting the need for appropriate on-going support. A pilot study by Sabourin *et al.* (2011) did just that, with a very brief (six contact sessions) psychosocial intervention resulting in significantly lower DRD at the three-month follow-up session, which could have possibly translated into improved glycaemic control and HRQoL due to the link between DRD and HRQoL as described above. The present study made use of 10 psychological support contact sessions, with significant improvements in perceived QoL and perceived diabetes severity being attributed to a better HRQoL, and therefore lower DRD.

As alluded to in the previous paragraphs, HRQoL and glycaemic control go hand-in-hand, with a study by Co *et al.* (2015) confirming this, as well as suggesting that DRD is a mediator in the relationship between the two. The mechanism behind this mediated effect is thought to be related to the propensity of someone with DRD to engage in unfavourable lifestyle activities such as poor diet, low levels of physical activity and poor medication adherence, all of which would impact on physiological systems, thereby worsening glycaemic control and ultimately HRQoL. These findings, to a certain extent were confirmed by this study, with improvements in areas related to DRD as well as improved glycaemic control.

Overall the findings of this study were in concordance with the literature, although the improvements in HRQoL in this study appear to be more comprehensive that what is traditionally found. There are a number of possible reasons for this conclusion. Firstly, the community within which the intervention took place is a very close-knit community and a sense of togetherness throughout the different aspects of the intervention could have substantially impacted on HRQoL. Secondly, there was an improvement in glycaemic control, as well as an improvement in a number of the anthropometric outcomes, with a number of anecdotal reports of participants being extremely satisfied with their external appearance. The increase in confidence and self-efficacy that

accompanies these findings could also have played a role in the improved HRQoL. Thirdly, the improvements in strength and cardiorespiratory capacity would have afforded the participants the ability to partake in activities that family or friends participated in, that they may not have been able to do before, thereby reinforcing once again a feeling of togetherness and social coherence, which has been shown to significantly impact on HRQoL (Nilsen *et al.*, 2015).

5.3.7. Health Professionals Usage Outcomes

The findings of the current study showed that there was a small improvement in the number of people who regularly went for check-ups with their primary healthcare provider and/or associated healthcare provider, although of concern is the 56.0 % and 29.0 % of the participants in the control and experimental group, respectively, who consulted with their primary healthcare provider (doctor) once or less per year. There is, unfortunately, extremely limited data specifically looking at the use of primary care providers and the reasons for not consulting them on a regular basis. With that being said, Unger *et al.* (2011) went some way to shedding more light on this area by examining the pattern of primary care utilisation in urban and rural areas. One of the most important findings of their study was that those people living in an urban area most commonly made use of general practitioners (GPs) as their primary healthcare provider, with those in rural areas making use of allied health professionals, nurses and complementary and alternative medicine practitioners. Considering that the study population in the current study would be seen as urban, the findings seem to be in opposition to what is reported in the literature. However, the shortage of GPs in the area would have a significant impact on the participants' choices, thereby driving them towards the use of nurses and other allied health professionals out of necessity.

Sabale *et al.* (2015) painted a slightly different picture in that individuals with newly diagnosed T2DM generally made use of a GP for the first year of treatment, thereafter preferring to make use of nurses with diabetes-specific training. Given that the participants in the present study had been diagnosed with T2DM for longer than one year, the finding that participants chiefly made use of nurses for the management of their disease fits the result of Sabale *et al.* (2015). The use of nurses as an adjunct profession to treating T2DM was well-documented in a study by Lawton *et al.* (2005). The nurses' approachability and sound technical knowledge base were highlighted by Lawton *et al.* (2005) and both these qualities was also confirmed by the participants in the current study. The use of complementary and alternative medicine (CAM) practitioners in the treatment of T2DM has been around for a number of years and was brought about due to the failings of the traditional healthcare system, or so-called "Westernised medicine" (Atwine *et al.*, 2015; Kapongo *et al.*, 2015). While no explicit findings have been reported, a number of patients are still reluctant to discuss the use of

CAM with their primary healthcare provider, due to the stigma attached to its use (Chao *et al.*, 2015). The disparity between patients and primary healthcare professionals with respect to patients' perspectives on the management of their disease, the need to tightly control blood glucose levels and empowering patients to manage their disease, seem to be a number of the barriers identified (Clark & Hampson, 2003; Bhojani *et al.*, 2013).

On the other hand, a comprehensive and multi-disciplinary study by Fokkens *et al.* (2011) found that by developing a structured care program, involving GP's, diabetes-specialised and practice nurses and dieticians, clinical outcomes related to disease management (HbA1c, BMI, SBP, DBP, etc.) were significantly better, and better maintained over time, than the usual care reported in most studies. These types of programs, where patients are more likely to reach their clinical goals, has significant economic implications, as well as health-related implications such as reduced risk of death from CVD, which could possibly encourage individuals suffering from T2DM to engage with their primary healthcare providers and allied health professionals on a more regular basis (Hunt *et al.*, 2015). The framework of the present study was similar to that of Fokkens *et al.* (2011), whereby a collective of healthcare professionals (Biokineticist, dietician, clinical psychologists) working synergistically achieved the best possible outcomes for the respective participants.

The advent of community-based interventions or programs were developed to assist primary healthcare providers and allied healthcare professionals, as is depicted in a model developed by West (2014). It is a comprehensive multi-system model proposed to adequately address the management and prevention of T2DM. It involves the collaborative work of all levels of the healthcare system, as well as community engagement and input. Together the various stakeholders put strategies in place to evaluate measureable outcomes as set out in a guide published by the CDC regarding community disease management. Although there are a number of logistical and methodological challenges that need to be addressed in future studies, the results of community-based interventions speak for themselves, with a number of extremely promising results.

One of the first community-based studies was a randomised controlled trial by Lorig *et al.* (2009) which found that compared to usual care by primary healthcare providers, a peer-led diabetes self-management program resulted in significant improvements in some health indicators (hypoglycaemic events) and health behaviours (healthy eating and glucose monitoring), which were maintained at 12 months. While the current study presents evidence that health-care led programs are definitely beneficial, the impact of programs delivered by peers cannot be underestimated. There is a significantly higher level of understanding with respect to the barriers that exist in the community and the plausible solutions to these barriers, in peer-led interventions compared to healthcare professional led interventions. Similar findings were reported by Klug *et al.* (2008)

where they found improvements in dietary and physical activity behaviours, as well as improvements in self-efficacy following a four-month peer-led program. The findings at the four- and eight-month follow-up were however inconclusive, with the authors recommending the need for further research in this area.

While the two above-mentioned studies reported minimal changes in HbA1c and other glycaemic variables, studies by Castillo *et al.* (2010) and Assah *et al.* (2015) which were 10-weeks and six months in duration, respectively, both found improvements in HbA1c and SBP. Furthermore, Assah *et al.* (2015) also reported improvements in serum lipid levels and anthropometric outcomes (body fat percentage, BMI, waist circumference). In a substantially longer study of 24-months, split into two phases, Katula *et al.* (2013) found that a peer-led lifestyle intervention significantly improved all the anthropometric outcomes measured (body mass, BMI, waist circumference), as well as measures of glycaemic control (fasting plasma glucose and insulin, insulin resistance), when compared to usual care by primary healthcare providers. The intrinsic motivation and increased accountability, which is created through the use of peer-led interventions, would account for most of the improvements seen in the above-mentioned studies. Furthermore, by using appropriately trained people within the community to lead these programs, there is a decreased pressure on the primary and allied healthcare professionals in managing T2DM in the community. The next phase in this project will aim to achieve exactly this, by identifying and properly training individuals within the community, who will drive the program in collaboration with other allied health professionals (Biokineticist).

5.4. Use of Post-Intervention Guide

There has been no study conducted to date that has examined the effects of a post-intervention guide on maintaining the effects of a structured program over a long period of time. The theory behind the guide is that when participants are not involved in structured contact sessions with the respective health professionals, it provides an understandable reference to the various components of the program. Furthermore, it serves as a reminder to continue with the progress that was made during the intervention program, as well as motivating those in the household to indirectly assist with the management of their respective family members T2DM. The only two studies to make use of print media in an intervention were conducted by Walker *et al.* (2011) and Kim & Kang (2006). In the study by Walker *et al.* (2011), the study compared a telephone-based intervention to a information booklet, without any prior intervention program, therefore making it difficult to draw conclusions, although the study concluded that the telephone-intervention was more successful. In

contrast to this, the study by Kim & Kang (2006), found that web-based and print materials were equally effective in increasing physical activity levels, and improving glycaemic control.

When compared to the outcome measures at the post-testing session, the post-intervention guide did not confer any additional benefits, nor was it able to successfully maintain the improvements achieved during the intervention program. There are a number of plausible reasons for this finding. Firstly, the post-intervention guide did not provide sufficient motivation and accountability, as is the case with contact sessions, therefore the participants could revert back to unfavourable activities without any verbal recourse or reinforcement. Secondly, the follow-up period was conducted at the beginning of winter, when the weather conditions were not as favourable when compared to the summer or autumn months. Inclement weather conditions may have negatively impacted on the likelihood of the participants exercising, especially if they had incorporated walking into their exercise regime. Thirdly, the participants may not have taken the opportunity to clarify any questions they may have had regarding the post-intervention guide, and decided to rather continue with their habitual behaviours, which may have resulted in unfavourable outcomes.

Nevertheless it seems that the post-intervention guide may have helped the participants to do better at post-intervention compared to baseline. With the exception of BMI, SBP and TSC, all the remaining anthropometric, cardiovascular, haematological and functional outcome variables were still significantly better at the follow-up session compared to baseline. Furthermore, the physical components of HRQoL and general health perception were significantly higher than at baseline. Dietary and lifestyle behaviour changes were also significantly better at the follow-up session compared to baseline. While these improvements may not be directly attributable to the use of the post-intervention guide, it is plausible that having a frame of reference upon which to work assisted the participants with maintaining healthy lifestyle choices over the long-term.

5.5. Research Objectives Hypotheses

5.5.1. Objective One – A 10-week comprehensive lifestyle intervention will result in significant changes in anthropometric, cardiovascular, haematological and functional capacity outcome variables.

There were statistically significant decreases in body fat percentage ($p < 0.001$), diastolic blood pressure ($p = 0.04$) and HbA1c ($p = 0.01$), together with a statistically significant improvement in the total distance walked during the 6MWT ($p < 0.001$). However, there were no significant changes in BMI, SBP, blood glucose or TSC. The findings of this study suggest that for individuals suffering from T2DM, a 10-week comprehensive lifestyle intervention can cause clinically

significant changes in anthropometric, cardiovascular, haematological and functional capacity variables, and therefore the hypothesis is partially accepted.

5.5.2. Objective Two – A 10-week comprehensive lifestyle intervention will result in significant changes in dietary habits and lifestyle behaviours.

A significant reduction in the frequency of external sugar/sweetener usage ($p = 0.03$) and a reduction in the frequency of complex carbohydrates being eaten together in one sitting ($p < 0.001$) were two important findings. In addition, there was a significant increase in the frequency of vegetables and/or salad consumption on a weekly basis ($p < 0.001$), and a reduction in the consumption of white bread ($p = 0.04$). There was, however, no significant change in lifestyle behaviours related to smoking and drinking habits. The findings of this study suggest that in individuals suffering from T2DM, a 10-week comprehensive lifestyle intervention can cause significant changes in dietary habits, but not lifestyle behaviours, and therefore the hypothesis is partially accepted.

5.5.3. Objective Three – A 10-week comprehensive lifestyle intervention will result in significant changes in health-related quality of life (HRQoL).

Physical and psychological components related to HRQoL, both general and diabetes-specific, were substantially improved following the intervention period. With respect to the physical components, there was a significant improvement in physical functioning ($p < 0.001$), energy and mobility ($p < 0.001$), sexual functioning ($p = 0.02$) and diabetes management and control ($p = 0.01$), with a decrease in the number of limitations in physical role functioning ($p = 0.005$). With respect to the psychological components, there was a significant improvement in vitality ($p = 0.008$), health perceptions ($p < 0.001$), anxiety and worry ($p = 0.006$), social burdens ($p = 0.01$), perceived quality of life ($p = 0.008$) and perceived diabetes severity ($p = 0.002$). There was furthermore, a decrease in the number of limitations in emotional role functioning ($p = 0.02$). No significant change was observed in the HRQoL domains of social functioning, body pain or overall mental health. The findings of this study suggest that in individuals suffering from T2DM, a 10-week comprehensive lifestyle intervention can cause significant changes in HRQoL, and therefore the hypothesis is partially accepted.

5.5.4. Objective Four – A 10-week comprehensive lifestyle intervention will result in significant changes in health professional usage behaviour.

The findings of this study indicated that there was no significant change in the number of people who regularly went for check-ups with their primary healthcare provider and/or associated healthcare provider, and therefore the hypothesis is rejected.

5.5.5. Objective Five – A post-intervention guide provided following a 10-week comprehensive lifestyle intervention will ensure that the significant improvements obtained during the program, will be maintained.

The results of this study showed that a post-intervention guide was not effective in maintaining the improvements seen following participation in a 10-week comprehensive lifestyle intervention., However, it must be noted that all of the measured outcome variables were still better at the follow-up testing period compared to baseline. Furthermore, there was no means to investigate whether the results at the retention-testing session was due to the use of the post-intervention guide. The hypothesis is therefore rejected.

5.6. Conclusion

With the increased prevalence of T2DM and its associated complications globally, progressively more research is being devoted to prevention and improvement of management of the disease. The findings of this study demonstrated that as little as 10 –weeks of a community-based program can improve glycaemic control, HRQoL and lifestyle habits, contributing to the improved management of the disease in the specific community. While the economic impact of this study was not measured, previous research infers that the improvements in disease management would result in lower levels of morbidity and T2DM associated complications and lower years lost to disability or death. The improvements seen in glycaemic control should result in reductions in the dosage and frequency of medications usage, carefully controlled by the participants' primary healthcare providers, which in turn would lower the negative side effects associated with long-term medication usage. Furthermore, there is evidence to suggest that programs making use of both dietary and physical activity interventions achieve better long-term results.

To date, no study has been published which has examined the use of supplementary materials such as a post-intervention guide, in an attempt to maintain the changes resulting from a structured intervention program. It is highly probable that these studies don't yet exist due to the high costs associated with preparation of and manufacturing of the materials, especially in large-scale studies. The effect of post-intervention guides will need to be repeated in small-scale studies to determine

their effectiveness before a decision can be made on their large-scale application. There are however, a number of studies that used a follow-up period or periods after the completion of the respective intervention. What is of interest is that the number of published studies with a follow-up period pale in comparison to the studies that do not. This is particularly worrying considering that individuals suffering with T2DM often find it difficult to make the necessary changes to improve disease management, or to maintain the changes following a program. Once again, it is probable that this lack of data is due to limited resources and logistical challenges with respect to participant retention, medication adherence and the development of complications related to T2DM.

5.7. Study Limitations

Due to the comprehensive nature of the study there were a number of limitations. Firstly, the sample size was small and may have, in some cases, affected the statistical power of the analyses. Through G-power analysis it was calculated that a sample size of 60 would have been required to detect statistically significant differences between the two groups. Recruitment of the participants from this area proved extremely difficult due to the novelty of the study in the region. However, with that being said, a number of intervention studies with T2DM participants found statistically and clinically significant results with far fewer participants (Melkus *et al.*, 2004; Murrock *et al.*, 2009) Furthermore, there was a large degree of variability in some of the parameters related to HRQoL, as well as dietary and lifestyle habits. This could have been due to the validity and reliability of the self-developed questionnaires not being tested prior to their use, or the participants responding to questions based on what they perceived to be the correct answer, and not necessarily what was true in their case. Although participants were encouraged to answer as accurately and truthfully as possible, there are no tools that can control for the participants' responses.

In addition, there was no way to discriminate between the changes seen from the baseline to post-testing, and the respective contributions of each of the intervention methods (exercise, diet and psychology), with future research needing to be conducted in order to identify which, if any of the three, plays the most important role.

The use of the 6MWT as the only measurement of physical activity is a further limitation of this study, and although there is evidence to suggest that it indirectly assesses a number of the components of physical fitness, the use of an activity monitor, and additional testing in the form of the Seniors fitness test would have been preferable.

No data was collected on participants' exercise habits following the completion of the intervention, which could have explained some of the changes from post-testing to retention testing. The use of a physical activity questionnaire such as the EPIC physical activity questionnaire or global physical

activity questionnaire (GPAQ) would have been beneficial in this regard. It must be noted, that following 10-weeks of complete detraining, a number of the physiological variables would have returned to baseline levels (Narici *et al.*, 2008), which provides some evidence that the participants would have continued with some form of structured exercise and appropriate lifestyle behaviours.

Finally, not having two separate groups with respect to the post-intervention guide (one group who received the guide and another who did not), made drawing conclusions on its effectiveness very difficult, in addition to their being no published research in this area. Furthermore, the control group was not measured at the retention testing session, and while it is assumed that there would have been no statistically significant change, it would have been beneficial to test them. This is most certainly an area that requires further investigation considering that empowering individuals to manage their disease following a structured program, would allow community health workers to reach other people suffering from T2DM, thereby reducing overall prevalence of the disease.

The field of research into the management of T2DM is vast and diverse, with a number of areas yet to be properly explored and reported in research. What is known, however, is that more investigation into community or peer-led comprehensive lifestyle interventions is necessary in order to adequately tackle the medical catastrophe that is T2DM.

Chapter 6

Summary, Practical Application and Future Directions

6.1. Summary

With the prevalence of T2DM on the rise in communities with low SES there is a growing need for interventions driven by healthcare professionals within the community to continue to manage and prevent the medical catastrophe of T2DM from spreading further into a multi-generational disease. This study is the first comprehensive lifestyle intervention in a low SES community in the Stellenbosch region and South Africa and may assist in forming the framework upon which further low-cost and sustainable studies can be built, targeting T2DM and other prevalent NCDs. The results of this study demonstrate that a 10-week comprehensive lifestyle intervention program, incorporating physical activity, dietary advice and psychological behavioural change techniques, may significantly benefit T2DM related outcomes such as glycaemic control, HRQoL and lifestyle habits.

Improvements in anthropometric, cardiovascular, haematological and functional outcomes were found to be clinically significant in the experimental group. Furthermore, the improvements in self-care activities and diabetes-related distress add significant value, with higher levels of self-care being associated with better glycaemic control, and therefore better management of T2DM. By improving HRQoL, it significantly decreases the likelihood of unfavourable lifestyle behaviours such as binge eating and high levels of alcohol consumption, which themselves have been found to negatively impact of T2DM development and progression.

Considering the cultural beliefs and practices of the low SES community where the study was based in, which is characterised by a diet high in sugar, refined carbohydrates and low vegetable consumption, significant improvements in dietary habits, as well as a decrease in the quantity of alcohol consumed, demonstrates that education and access to information play a significant role in managing T2DM. Both dietary and lifestyle behaviours were maintained at the follow-up period, which, in conjunction with the haematological findings, indicate that participants were able to bring their T2DM under control.

The need for open and consistent communication and contact times between the patient with T2DM and healthcare professionals, whether it be their primary healthcare provider or allied health professionals, is essential to the proper management of T2DM. The more frequently the individual has their clinical status measured, the lower the incidence of diabetes-related complications and the

better an individual adheres to their medication schedule. This in combination, results in favourable outcomes and better management of the disease.

Considering the limitations, this study has shown that 10-weeks of a structured and comprehensive lifestyle intervention delivered by a multidisciplinary team, has the potential to significantly improve clinical outcomes, as well as overall management of T2DM in a community with a low SES.

6.2. Practical Application

One of the most important practical applications from this study is that community-based programs may prove useful for implementation by local clinics to manage the patients with T2DM. Furthermore, the knowledge gained by participating in these types of programs allows for the individuals suffering with T2DM to make informed choices regarding exercise, dietary habits and lifestyle behaviours, leading to better management and control of T2DM. These improvements are critical to the adequate management of T2DM, as prolonged uncontrolled T2DM has been linked to the development of CVD and other diabetes-related complications such as peripheral neuropathy and cancer. By empowering individuals with T2DM to take responsibility for their health, it has the potential to spread to family members who may also have T2DM, as well as friends who may be suffering from the disease. The potential impact this knowledge could have on other chronic diseases cannot be discounted, with the benefits of exercise and dietary interventions on hypertension and hypercholesterolemia being well documented. The financial costs needed to cover the testing and execution of the program were extremely low, which enables the program, or programmes similar to the one described in this study to be repeated a number of times, ultimately to reach a larger proportion of community members suffering with T2DM, or other NCDs. Furthermore, considering that the program was conducted in a low SES community, the low cost factor increases the likelihood of the program being sustained over an extended period of time. In addition to this, the need for further study in this and other similar communities is evident, with the current study providing valuable information to potential researchers regarding the development and execution of multi-faceted lifestyle interventions. Finally, the barriers to participation in this study were not investigated. Once again, this provides the opportunity for research into this specific community with regard to what those barriers may be. By identifying those barriers, possible solutions can be sought, which could improve the participation in, and adherence to programs that target the prevention and management of chronic lifestyle diseases.

6.3. Future Directions

Firstly, no study has previously differentiated between the three different intervention components (exercise, diet, psychology) and their individual contributions to change. This is especially important in a low SES community, where resources are limited and the need to optimise the programs at the lowest possible cost is necessary. By determining the relative contribution of each, future programs could be developed in relation to the overall benefit each component provides. Secondly, the impact of social support, especially in the follow-up period, should be investigated further considering that one of the barriers to positive lifestyle changes identified in the literature is low levels of social support. The success or impact of a post-intervention guide was not conclusive due to interaction of several parameters. Potential future studies could benefit from evaluating the effect of these guides on control and management of T2DM, in addition to the use of telephonic contact as an assistive aide. In principle, should this method be found to be effective, it would allow for community health workers to reach other people suffering with T2DM, thereby reducing overall prevalence of the disease, as well as the overall incidence of diabetes-related complications. There are, however, a number of logistical challenges that need to be overcome such as language preferences, provision of a central location where individuals can exercise as a group, and on-going support structures should they be needed. Considering that the overall running costs of the program were extremely low, the possibility to incorporate the program as part of preventative and on-going management of T2DM in the public health sector must be explored.

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Appendices

Appendix A – Flyer

Do you suffer from Type 2 Diabetes??

We are looking for men and women between the ages of **18 and 80 years** to take part in a **10 week lifestyle intervention** program to help better control their diabetes.

Participation in this program is **FREE** of charge!

If you are interested, call or message Bradley Fryer on **082 551 2318** or e-mail **bfryer@sun.ac.za.**

Appendix B – Medical Clearance Form

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I,_____, hereby give permission for **(Name of Participant)** to participate in the Type 2 Diabetes Lifestyle Intervention Program. Through consultation with him/her, I have no reason to believe that he/she will not be able to safely perform exercise of a moderate intensity (40-60% HR_{max}). This letter serves to clear **(Name of Participant)** for participation in the program.

Doctor Name:_____

Practice Number:_____

Signature:_____

Appendix C – Informed Consent

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STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

The implementation of a community-based lifestyle intervention program for adults with type 2 diabetes in Stellenbosch.

You are asked to participate in a research study conducted by Bradley James Fryer (M Sport Science), from the Department of Sport Science at Stellenbosch University. The results will be used as part of a PhD dissertation. You were selected as a possible participant in this study because you are older than 18 years and have been diagnosed with non-insulin dependent diabetes mellitus (Type 2 Diabetes) for at least six months.

PURPOSE OF THE STUDY

The purpose of this study is to implement a community-based intervention for individuals with type 2 diabetes in a socially disadvantaged community which can be managed and sustained by allied health professionals and local health care workers.

PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

Following screening for eligibility to participate in the study, you will need to visit the doctor(s) located at the Cloetesville clinic to clear you for participation, which will not cost you anything. You will be required to make two visits to the local community centre/church hall within a space of 4 weeks. Thereafter, you will make visits to the local community centre/church hall for the intervention period lasting a total of 10 weeks. The sessions will include teaching of lifestyle skills to manage your diabetes as well as advice on correct eating habits for your diabetes. You will also participate in an exercise session three times a week that will be about 60 minutes.

During the first visit, the outline and aims of the study will be explained in full to you, as well as the informed consent. During this first pre-testing session, basic measurements of height, body mass, blood pressure and body fat percentage will be taken, as well as glucose and cholesterol. Secondly, you will be asked to complete a few questionnaires on how being diagnosed with diabetes has affected you. Lastly, you will perform a short exercise test to test your fitness levels. You will then be given a form which you must take to a Pathcare clinic for blood to be drawn in order to measure your glycated haemoglobin (HbA_{1c}) levels. The testing procedures will take no longer than 90 minutes to complete. These procedures will be repeated on three other occasions over the next 6 months in order for us to assess your progress. The intervention will take place at the local community centre/church hall for under the guidance of the researcher and the assistance of allied-health professionals.

POTENTIAL RISKS AND DISCOMFORTS

During the testing sessions before the intervention begins, you will undergo a finger-prick test for blood glucose (sugar) and cholesterol. This may feel like a small sting and cause slight discomfort afterwards. You will also be required to give 5ml of blood so that your HbA1c levels (a blood marker for type 2 diabetes) can be measured. You will be performing moderate intensity exercise, therefore it is possible that you may experience some discomfort and dizziness following the exercise, and symptoms will be managed in this regard. You may also experience slight muscle soreness or fatigue 24- to 48-hours following exercise known as delayed onset muscle soreness (DOMS) which is a common side-effect following exercise and can be considered to be normal if it subsides over a 48-hour period. Some of the questions in the testing procedure(s) may be of a personal nature and all information will be kept strictly confidential. Furthermore, you may decide not to answer the question should you wish.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Participation in the study will help to improve with the management and control of your diabetes. It will also aid in the development of a structured and sustainable program for type two diabetics that could potentially be carried out as a community service initiative by the Stellenbosch Biokinetics Centre. It also has the potential to be carried out in other chronic disease population groups.

PAYMENT FOR PARTICIPATION

You will not receive any payment for participating in this study.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of special coding system for each participant. Data will be stored on a two password protected servers which only the researcher will have access to. Results of the study will be published in a reputable journal with no personal information being published. Any data published will be general and non-specific to the subjects.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. These circumstances include but are not limited to: significant decline in your health or inability to complete all the tests.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Bradley Fryer (Researcher) on 0825512318 (day), 021 889 5031 (day), or via e-mail bradleyjfryer@gmail.com. Prof. Elmarie Terblanche (Supervisor) may also be contacted on 021 8082742 (day) or via e-mail on et2@sun.ac.za. In the case of emergency you can contact Bradley Fryer on 0825512318 or 021 889 5031.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to *me* by Bradley James Fryer in *Afrikaans/English* and *I am* in command of this language or it was satisfactorily translated to *me*. *I* was given the opportunity to ask questions and these questions were answered to *my* satisfaction.

I hereby consent voluntarily to participate in this study I have been given a copy of this form.

_____

Name of Subject/Participant

_____

Name of Legal Representative (if applicable)

_____ _____

Signature of Subject/Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to _____ and/or [his/her] representative _____. *[H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English*].

_____ _____

Signature of Investigator **Date**

Appendix D – Medical History Form

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INITIAL SCREENING FORM

Name:_____ Contact Number:_____

Surname:_____ ID#:_____

Address:_____ DOB:_____

_____ Doctor:_____

_____ Next of Kin:_____

_____ Kin Cont #:_____

History:

_____

_____

_____

_____

_____

Family History:
Coronary Artery Disease
Myocardial Infarction
Stroke
Diabetes
Pulmonary Disease
Other Cardiovascular Disease
Other Metabolic Disease

Personal History:
Coronary Artery Disease
Myocardial Infarction
Stroke
Diabetes
Pulmonary Disease
Other Cardiovascular Disease
Other Metabolic Disease

Current Activity Levels

Type:_____ Duration:_____

Frequency:_____ Intensity:_____

Medications:

_____

_____

_____

Any Musculoskeletal or Joint Problems:

Yes:_____ No:_____

Specify:_____

Any Specific Eating Plan:

Yes:_____ No:_____

Specify and Duration:_____

Signature of Researcher:_____ Date:_____

Signature of Participant:_____ Date:_____

Appendix E – Short-Form 36 (SF-36) Questionnaire

Your Health and Well-Being

This questionnaire asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. ***Thank you for completing this survey!***

For each of the following questions, please mark an ☒ in the one box that best describes your answer.

1. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. <u>Compared to one week ago</u>, how would you rate your health in general <u>now</u>?

Much better now than one week ago	Somewhat better now than one week ago	About the same as one week ago	Somewhat worse now than one week ago	Much worse now than one week ago
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3. The following questions are about activities you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?

		Yes, limited a lot	Yes, limited a little	No, not limited at all
a	<u>Vigorous activities</u>, such as running, lifting heavy objects, participating in strenuous sports	☐ 1	☐ 2	☐ 3
b	<u>Moderate activities</u>, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	☐ 1	☐ 2	☐ 3
c	Lifting or carrying groceries	☐ 1	☐ 2	☐ 3
d	Climbing <u>several</u> flights of stairs	☐ 1	☐ 2	☐ 3
e	Climbing <u>one</u> flight of stairs	☐ 1	☐ 2	☐ 3
f	Bending, kneeling, or stooping	☐ 1	☐ 2	☐ 3
g	Walking <u>more than a kilometre</u>	☐ 1	☐ 2	☐ 3
h	Walking <u>several hundred metres</u>	☐ 1	☐ 2	☐ 3
i	Walking <u>one hundred metres</u>	☐ 1	☐ 2	☐ 3
j	Bathing or dressing yourself	☐ 1	☐ 2	☐ 3

4. During the past week, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Cut down on the amount of time you spent on work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Were limited in the kind of work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Had difficulty performing the work or other activities (for example, it took extra effort)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. During the past week, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Cut down on the amount of time you spent on work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Did work or other activities less carefully than usual	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. During the <u>past week</u>, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups?

Not at all	Slightly	Moderately	Quite a bit	Extremely
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. How much <u>bodily</u> pain have you had during the <u>past week</u>?

None	Very mild	Mild	Moderate	Severe	Very severe
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

8. During the <u>past week</u>, how much did <u>pain</u> interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9. These questions are about how you feel and how things have been with you during the past week. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past week…

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Have you felt full of life?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Have you been very nervous?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Have you felt so down in the dumps that nothing could cheer you up?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Have you felt calm and peaceful?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
e Have you had a lot of energy?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
f Have you felt downhearted and depressed?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
g Have you felt worn out?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
h Have you been happy?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
i Have you felt tired tired?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

10. During the past week, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

11. How TRUE or FALSE is <u>each</u> of the following statements for you?

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
a	I seem to get sick a little easier than other people	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b	I am as healthy as anybody I know	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c	I expect my health to get worse	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d	My health is excellent	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Thank you for completing these questions!

Appendix F – Diabetes -39 (D-39) Questionnaire

Diabetes-39

Quality of Life Survey

A person's quality of life is affected by many things. These things might include health, the opportunity for recreation and vacations, friends and family, and a job. This questionnaire is designed to help us learn about what affects the quality of life of people with diabetes.

Below are questions about your quality of life. For each factor listed, we ask you to place an "X" on the line to show whether that factor affects your quality of life "extremely". "not at all", or some place in the middle. An example is shown in the box below. For example, if you thought "having an automobile" affected your quality of life to some extent, but not extremely, you might mark the line as shown.

DURING THE PAST MONTH, HOW MUCH WAS THE QUALITY OF YOUR LIFE AFFECTED BY:

Having an automobile

1_____2_____3_____4_____5_____6_____7

Not Affected At all — Extremely Affected

DURING THE PAST MONTH, HOW MUCH WAS THE QUALITY OF YOUR LIFE AFFECTED BY:

1. Your diabetes medication schedule

1_____2_____3_____4_____5_____6_____7

Not Affected At all — Extremely Affected

2. Worries about money matters

1_____2_____3_____4_____5_____6_____7

Not Affected At all — Extremely Affected

3. Limited energy levels

1_____2_____3_____4_____5_____6_____7

Not Affected At all — Extremely Affected

4. Following your doctor's prescribed treatment plan for diabetes

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

5. Food restrictions required to control your diabetes

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

6. Concerns about your future

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

7. Other health problems besides diabetes

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

8. Stress or pressure in your life

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

9. Feelings of weakness

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

10. Restrictions on how far you can walk

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

11. Exercise requirements

1_____2_____3_____4_____5_____6_____7

Not Affected At all Extremely Affected

12. Loss or blurring of your vision

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

13. Not being able to do what you want

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

14. Having diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

15. Losing control of your sugar levels

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

16. Other illnesses besides diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

17. Testing your sugar (glucose) levels

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

18. The time required to control your diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

19. The restrictions your diabetes places of your family and friends

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

20. Being embarrassed because you have diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

21. Diabetes interfering with your sex life

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

22. Feeling blue or depressed

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

23. Problems with sexual functioning

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

24. Getting your diabetes well controlled

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

25. Complications from your diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

26. Doing things that your family or friends don't do

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

27. Keeping a record of your sugar levels

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

28. The need to eat at regular intervals

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

29. Not being able to do housework or other jobs around the house

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

30. A decreased interest in sex

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

31. Having your schedule centre around diabetes

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

32. Needing to rest often

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

33. Problems climbing steps

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

34. Having trouble caring for yourself (dressing, bathing, or using the toilet)

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

35. Restless sleep

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

36. Walking more slowly than others

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

37. Being labelled a diabetic

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

38. Having diabetes interfere with your family life

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

39. Diabetes in general

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

OVERALL RATINGS

1. Please place an "X" on the line below that indicates your rating of your overall quality of life.

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

2. Please place an "X" on the line below to show how severe you think your diabetes is.

1_____2_____3_____4_____5_____6_____7
Not Affected Extremely
At all Affected

Appendix G – Eating Habits Questionnaire

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EATING HABITS QUESTIONNAIRE

Subject Name & Surname:_____

Subject Code:_____ Group:_____

Date of Testing:_____ Time of Testing:_____

---

1. What time of the day do you eat (mark all that are applicable):

Breakfast ☐ Lunch ☐ Supper ☐ Snacks ☐

For the following questions, please be as specific as possible including the type of bread that you consume (if applicable), the type of fruit, salad or vegetables that you eat and the frequency at which you eat them. Also, if you add sugar or sweeteners to any meals please indicate where applicable, and if you eat more than one carbohydrate (e.g. rice, potato, pasta, etc.) in one mealtime specify where applicable.

2. What is your usual breakfast (if applicable):

_____

_____

_____

3. What is your usual lunch (if applicable):

_____

_____

_____

4. What is your usual supper (if applicable):

_____

_____

_____

5. What is your usual snack(s) (if applicable):

_____

_____

_____

6. Do you eat at least three meals a day?

Yes ☐ No ☐

7. Do you take any vitamin/herbal supplements and/or meal replacements?

Yes ☐ No ☐

8. What do you spend on average per month on food?

R_____

9. Do you drink alcohol?

Yes ☐ No ☐

10. Do you smoke, and if yes, how many cigarettes a day?

Yes ☐ No ☐ Number:_____

11. If yes, what type of alcohol do you consume?

Beer/Cider ☐ Wine ☐ Spirits ☐ Shooters ☐

12. What quantity and how many times per week do you consume alcohol?

Quantity (in units assuming that 250 ml = 1 unit):_____

Frequency (per week):_____

13. What do you spend on average per month on alcohol/cigarettes?

R_____

14. Have you ever had dietary counselling or advice from a dietician before?

Yes ☐ No ☐

Appendix H – Health Professionals Usage Questionnaire

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HEALTH PROFESSIONAL USE QUESTIONNAIRE

Subject Name & Surname:_____

Subject Code:_____ Group:_____

Date of Testing:_____ Time of Testing:_____

---

1. Have you ever been to a doctor (general practitioner, specialist, etc.):

Yes ☐ No ☐

2. Where do you go to normally see a doctor?

Hospital ☐ Clinic ☐ Private Practice ☐

3. How far do you have to travel to get to your doctor?

< 5 km ☐ 6 – 10 km ☐ 11 – 20 km ☐ > 20 km ☐

4. What is your mode of transportation?

Walk ☐ Bike ☐ Train ☐ Vehicle ☐

5. How often do you see your doctor per year (number of visits)?

≤ 1 per year ☐ 2 – 5 ☐ 6 - 11 ☐ ≥ 12 ☐

6. What do you normally see your doctor for?

_____

_____

_____

7. What other health professionals do you make use of?

Nurse ☐ Physio ☐ OT ☐ Other ☐

Other:_____

8. Do you take regular medication?

Yes ☐ No ☐

9. What do you spend on medication per month?

R_____

Appendix I – Adapted Diabetes Family Behaviour Scale (DFBS)

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STELLENBOSCH UNIVERSITY

ADAPTED DIABETES FAMILY BEHAVIOUR SCALE

Subject Name & Surname:_____

Subject Code:_____ Group:_____

Date of Testing:_____ Time of Testing:_____

Circle the answer that best tells how often these things happen or don't happen in your family. There are no right or wrong answers – if you are not certain, make your best guess.

Answer Legend: 1 = All the time ; 2 = Most of the time ; 3 = Sometimes ; 4 = Hardly ever ; 5 = Never

1. My family watches when I test for sugar .	1	2	3	4	5
2. When there is a problem with my Diabetes we call the doctor.	1	2	3	4	5
3. We know when there are problems with my Diabetes.	1	2	3	4	5
4. My family does thing for me that I could do myself in taking care of my Diabetes.	1	2	3	4	5
5. My family reads books about Diabetes.	1	2	3	4	5
6. My family reminds me to test my sugar.	1	2	3	4	5
7. My family encourages me to get some exercise every day.	1	2	3	4	5
8. My family buys sweets for everyone.	1	2	3	4	5
9. At home, my family eats food that is **NOT** on my Diabetic diet.	1	2	3	4	5
10. My Diabetes makes my family nervous.	1	2	3	4	5

11. We wait to call the doctor until I'm very sick because of my Diabetes.	1	2	3	4	5
12. I take care of my Diabetes myself.	1	2	3	4	5
13. My family listens to my ideas about taking care of my Diabetes.	1	2	3	4	5
14. If we're not sure what to do we call for help.	1	2	3	4	5
15. My family and I argue about whether I'm sticking to my Diabetes diet.	1	2	3	4	5
16. My family has regular meal times.	1	2	3	4	5
17. My family seems embarrassed that I have Diabetes.	1	2	3	4	5
18. My family listens to my problems about having Diabetes.	1	2	3	4	5
19. My family member(s) makes my snacks.	1	2	3	4	5
20. My family makes me feel good about taking care of my Diabetes.	1	2	3	4	5
21. My family embarrasses me by talking about Diabetes with other people.	1	2	3	4	5
22. When we go out to eat, I choose things from the menu that are in line with my Diabetic diet.	1	2	3	4	5
23. Other family members eat sweets in front of me.	1	2	3	4	5
24. I feel alone with my Diabetes.	1	2	3	4	5
25. My family is always ready to help with my Diabetes when I need it.	1	2	3	4	5
26. My family tells me to stop acting as if I am sick.	1	2	3	4	5
27. I don't worry about what my sugar test results unless I start feeling bad.	1	2	3	4	5
28. My family knows how well I am taking care of my Diabetes.	1	2	3	4	5
29. I have someone in my family to talk about Diabetes.	1	2	3	4	5
30. My family gets angry with me when I make a slip in taking care of my Diabetes.	1	2	3	4	5
31. My family talks about Diabetes.	1	2	3	4	5

Appendix J – Exercise Programs (Week 1 to Week 10)

Week 1:

Exercise	Sets	Reps	Notes
On the spot marching	1	20s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Arm circles – small to big			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	2 minutes		
SEATED EXERCISES			
Knee Extension with diagonal heel touch (alternating unilateral)	2	20	Alternate legs during the set
Hip Flexion (alternating unilateral)	2	20	Alternate legs during the set
Knee Extension with abduction (alternating unilateral)	2	14	Alternate legs during the set
Resisted clams (seated with band)	2	20	Use red bands around knees
Discuss shoulder press (unilateral)	Each side 2	10	Complete one arm before moving to the next
Sit-to-stand with handball raise	2	15	Handball must be held away from body with arms straight
REST	2 minutes		
Fast feet over rope (fwd, sdw, fwd)	Each 30s		Complete the three in succession
Half Seated Holds (Hold for 10s)	2	8	Start from standing position
Sit-to-stand with isometric abduction (with band)	2	12	Use red bands around knees
Calf Raises	2	12	Bilateral
REST	2 minutes		
Fast feet over rope (fwd, sdw, fwd)	Each 30s		Complete the three in

		succession
Stork Stand/Single Leg Balance (eyes open)	Each 30s	Can be assisted or not
Stork Stand/Single Leg Balance (eyes open)	Each 30s	Make sure to hold onto chair
Stretch - Hamstrings	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 2:

Exercise	Sets	Reps	Notes
On the spot marching	1	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Arm circles – small to big			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	1 minute		
SEATED EXERCISES			
Knee Extension with abduction (alternating unilateral)	2	20	Alternate legs during the set (10 each side)
Tri-Directional Torso Rotation with Discus	2	20	Make sure they sit up straight
Sit-to-stand with isometric abduction (with band)	2	12	Use red bands around knees
Wall Push Up with Twist	2	14	Make sure their backs remain straight
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
REST	2 minutes		
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
Half Seated Holds (Hold for 15s)	2	6	Start from standing position
Sumo Squats with Soccer Ball Extension	2	10	Hold soccer ball in front, wide stance
Calf Raises and Calf Raise Holds with Bounces	2	12	Bilateral
REST	1 minute		
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s		Complete the five in succession
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Can be assisted or not
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Make sure to hold onto chair

Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s	Complete the five in succession
Stretch - Hamstrings	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 3:

Exercise	Sets	Reps	Notes
On the spot marching	1	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Arm circles – small to big			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	1 minute		
SEATED EXERCISES			
Knee Extension with abduction (alternating unilateral)	2	20	Alternate legs during the set (10 each side)
Tri-Directional Torso Rotation with Discus	2	20	Make sure they sit up straight
Sit-to-stand with isometric abduction (with band)	2	12	Use red bands around knees
Wall Push Up with Twist	2	14	Make sure their backs remain straight
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
REST	2 minutes		
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
Half Seated Holds (Hold for 15s)	2	6	Start from standing position
Sumo Squats with Soccer Ball Extension	2	10	Hold soccer ball in front, wide stance
Calf Raises and Calf Raise Holds with Bounces	2	12	Bilateral
REST	1 minute		
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s		Complete the five in succession
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Can be assisted or not
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Make sure to hold onto chair

Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s	Complete the five in succession
Stretch - Hamstrings	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 4:

Exercise	Sets	Reps	Notes
On the spot marching	1	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Arm circles – small to big			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	1 minute		
SEATED EXERCISES			
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
Tri-Directional Torso Rotation with Discus	2	20	Make sure they sit up straight
Sit-to-stand with isometric abduction (with band)	2	15	Use red bands around knees
Sumo Squats with Soccer Ball Extension	2	15	Hold soccer ball in front, wide stance
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
REST	1 minute		
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
Half Seated Holds (Hold for 15s)	2	6	Start from standing position
Fast feet over rope (fwd, sdw, fwd)	Each 35s		Complete the three in succession
Calf Raises and Calf Raise Holds with Bounces	2	15	Bilateral
REST	1 minute		
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s		Complete the five in succession
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Can be assisted or not
Stork Stand/Single Leg Balance (eyes open)	Each 30s		Make sure to hold onto chair

Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s	Complete the five in succession
Stretch – Hamstrings and Gluts	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 5:

Exercise	Sets	Reps	Notes
On the spot marching	1	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Air Squat with Alternating Bum Kick			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	1 minute		
SEATED EXERCISES			
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 35s		Complete the five in succession
Shoulder Press into Forward Punch with Discus	2	10	Make sure they sit up straight
Sit-to-stand with isometric abduction (with band)	2	20	Use red bands around knees
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 35s		Complete the five in succession
REST	1 minute		
Stair Climbing (forward)	30s per leading foot		As quickly as possible
Stair Climbing (sideways)	30s per leading foot		As quickly as possible
Calf Raises and Calf Raise Holds with Bounces	2	15	Bilateral at Stairs
Half Seated Holds (Hold for 15s)	2	8	Start from standing position
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 35s		Complete the five in succession
Pelvic Tilt and Lift	2	15	Make sure they activate their core
Table Top	2	8	Make sure they activate their core
Cook Hip Lift	2	6	Make sure hips are stable
REST	1 minute		

Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 30s	Complete the five in succession
Step-touch (both ways)	2 x 30s	Complete as a superset
Step and Slide (both ways)	2 x 30s	Complete as a superset
Stretch – Hamstrings and Gluts	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 6:

Exercise	Sets	Reps	Notes
On the spot marching	1	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm Lifts (forward, side)			
Arm lifts and clap (front and back)			
Air Squat with Alternating Bum Kick			
On the spot marching			
Step-touch (both ways)			
Step and Slide (both ways)			
REST	1 minute		
SEATED EXERCISES			
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 45s		Complete the five in succession
Diagonal Sholuder Abduction with Discus	2	10	Make sure they sit up straight
Sit-to-stand with isometric abduction (with band) with holds (last 5 reps hold for 10sec)	2	20	Use red bands around knees
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 45s		Complete the five in succession
REST	1 minute		
Stair Climbing (forward)	2 x 45s per leading foot		As quickly as possible
Stair Climbing (sideways)	1 x 45s per leading foot		As quickly as possible
Calf Raises and Calf Raise Holds with Bounces	2	15	Bilateral at Stairs
Half Seated Holds (Hold for 15s)	2	10	Start from standing position
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 45s		Complete the five in succession
Pelvic Tilt and Lift	2	15	Make sure they activate their core
Table Top	2	10	Make sure they activate their core
Cook Hip Lift	2	8	Make sure hips are stable
Side-Lying Abduction	2	8	Make sure hips are

			stacked on top of each other
REST	1 minute		
Fast feet over rope (fwd, sdw, fwd, sdw, fwd)	Each 45s		Complete the five in succession
Step-touch (both ways)	2 x 30s		Complete as a superset
Step and Slide (both ways)	2 x 30s		Complete as a superset
Stretch – Hamstrings and Gluts	2 x 20s each leg		
GET RPE SCORES FROM EACH PERSON			

Week 7:

Exercise	Sets	Reps	Notes
On the spot marching	2	30s each	Warm-Up
Step-touch (both ways)			
Step and Slide (both ways)			
Arm lifts and clap (front and back)			
Air Squat with Alternating Bum Kick			
¼ Lunge (big step)			
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Sit-to-stand with Discuss Press	2	12	Make sure they sit up straight
Standing Hip Abduction and Hip Extension	2	10	From Hip Abd directly into Hip Ext
¼ Lunge (Big Step)	2	8	Complete 8 on each side
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Half Seated Holds (Hold for 15s)	2	10	Start from standing position
Stair Climbing (forward)	Pyramid Starting from 45 seconds, 10 seconds off until 25 seconds per foot		As quickly as possible
Stair Climbing (sideways)	Pyramid Starting from 45 seconds, 10 seconds off until 25 seconds per foot		As quickly as possible
Pelvic Tilt and Lift	2	15	Make sure they activate their core
Table Top	2	12	Make sure they activate their core
Cook Hip Lift	2	10	Make sure hips are stable
Small Crunches (slide hands on upper legs)	2	10	Make sure they don't pull on their neck
Side-Lying Abduction	2	10	Make sure hips are stacked on top of each other
REST	1 minute		

Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement	Complete the whole pyramid without a break
Step-touch (both ways)	2 x 30s	Complete as a superset
Step and Slide (both ways)	2 x 30s	Complete as a superset
Stretch – Hamstrings and Gluts	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 8:

Exercise	Sets	Reps	Notes
On the spot marching	3	30s each	Warm-Up (No rest between sets)
Step-touch (both ways)			
Step and Slide (both ways)			
Air Squat with Alternating Bum Kick			
½ Lunge (big step)			
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Standing Hip Abduction and Hip Extension	2	12	From Hip Abd directly into Hip Ext
½ Lunge (Big Step)	2	10	Complete 8 on each side
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 30 sec per movement		Complete the whole pyramid without a break
Sit-to-stands with abduction – into half seated holds at end of 15 repetitions	2	20	With red band around knees. 15 sit-to-stands, 5 half seated holds of 20s at end
Stair Climbing (forward)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (sideways)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (forward)	Pyramid Starting from 30 seconds, 5 seconds off until 15 seconds per foot		As quickly as possible
Standing Lateral Bend with Discus	2	20	20 each side, ensure back stays straight
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Step-touch (both ways)	2 x 30s		Complete as a superset
Step and Slide (both ways)	2 x 30s		Complete as a superset

Stretch – Hamstrings and Gluts	2 x 20s each leg
GET RPE SCORES FROM EACH PERSON	

Week 9:

Exercise	Sets	Reps	Notes
On the spot marching	3	30s each	Warm-Up (No rest between sets)
Step-touch (both ways)			
Step and Slide (both ways)			
Air Squat with Alternating Bum Kick			
½ Lunge (big step)			
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Standing Hip Abduction and Hip Extension	2	15	From Hip Abd directly into Hip Ext
Lunge (Big Step)	2	8	Complete 8 on each side
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 30 sec per movement		Complete the whole pyramid without a break
Sit-to-stands with abduction – into half seated holds at end of 15 repetitions	2	20	With red band around knees. 15 sit-to-stands, 5 half seated holds of 20s at end
Stair Climbing (forward)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (sideways)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (forward)	Pyramid Starting from 30 seconds, 5 seconds off until 15 seconds per foot		As quickly as possible
Seated Discus Torso Rotation with Press	2	20	20 each side, ensure back stays straight
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Step-touch (both ways)	1 x 30s		Complete as a superset
Step and Slide (both ways)	1 x 30s		Complete as a superset

Air Squat with Alternating Bum Kick	1 x 30s	Complete as a superset
Lunge (Big Step)	1 x 30s	Complete as a superset
Stretch – Hamstrings and Gluts	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Week 10:

Exercise	Sets	Reps	Notes
On the spot marching	3	30s each	Warm-Up (No rest between sets)
Step-touch (both ways)			
Step and Slide (both ways)			
Air Squat with Alternating Bum Kick			
½ Lunge (big step)			
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Standing Hip Abduction and Hip Extension	2	15	From Hip Abd directly into Hip Ext
Lunge (Big Step)	2	10	Complete 10 on each side
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 30 sec per movement		Complete the whole pyramid without a break
Sit-to-stands with abduction – into half seated holds at end of 15 repetitions	2	20	With red band around knees. 15 sit-to-stands, 5 half seated holds of 20s at end
Stair Climbing (forward)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (sideways)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (forward)	Pyramid Starting from 30 seconds, 5 seconds off until 15 seconds per foot		As quickly as possible
Stair Climbing (sideways)	Pyramid Starting from 45 seconds, 15 seconds off until 15 seconds per foot		As quickly as possible
Seated Discus Torso Rotation with Press	2	20	20 each side, ensure back stays straight
REST	1 minute		
Fast feet over rope (Fwd/Sdw Pyramid)	Start at 60s and work down by 10 sec until 20 sec per movement		Complete the whole pyramid without a break
Step-touch (both ways)	1 x 45s		Complete as a

		superset
Step and Slide (both ways)	1 x 45s	Complete as a superset
Air Squat with Alternating Bum Kick	1 x 45s	Complete as a superset
Lunge (Big Step)	1 x 45s	Complete as a superset
Stretch – Hamstrings and Gluts	2 x 20s each leg	
GET RPE SCORES FROM EACH PERSON		

Appendix K – Participant Feedback Form

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INTERVENTION FEEDBACK FORM

Subject Name & Surname:_____

Subject Code:_____ Group:_____

Date of Testing:_____ Time of Testing:_____

---

1. What did you enjoy most about the program?

_____

_____

_____

_____

_____

2. What were some of the barriers to participating in the program or improvements you could suggest?

_____

_____

_____

_____

_____

3. Would you recommend the program to friends and/or family that have Type 2 Diabetes?

Yes ☐ No ☐

4. Your comments/thoughts on the exercise sessions?

5. Your comments/thoughts on the dietician sessions?

6. Your comments/thoughts on the psychology sessions?

Appendix L – Participant Post-Intervention Guide

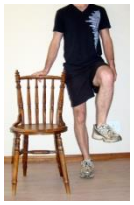
Type 2 Diabetes Lifestyle Intervention Program

Participant Guide

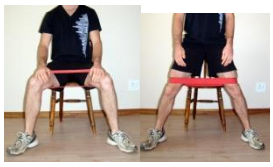
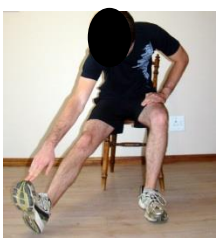
PART A – EXERCISE PROGRAMS

Perform any of the three programs below **at least 3 times per week**, either individually or in a group. The **first block** in the programs gives the **name of the exercise**, as well as a picture showing **how the exercise is performed**. The **second block** gives an indication of the **number of sets** (E.g. 2 or 3), and **repetitions** (E.g. 10 or 15) that need to be performed for the specific exercise. The **third block** gives a **short description** of the **most important aspects** of the specific exercise.

Easy Exercise Program

Warm Up	Do a brisk walk around the block for approximately 10 minutes.				
a) Knee Extension with Diagonal Heel Touch 	2 x 10	• Sit upright on the edge of a chair. • Straighten your one leg diagonally outward, touching the floor with your heel. • Return to the start and repeat on the opposite leg.	**b) Hip Flexion** 	2 x 10	• Sit upright on the edge of a chair. • Lift your one leg off the ground, keeping your knee bent. • Return to the start and repeat on the opposite leg.
c) Knee Extension with Abduction 	2 x 7	• Sit upright on the edge of a chair. • Straighten one leg, and then swing it out to the side while keeping it straight. • Return to the start and repeat on the opposite leg.	**d) Isometric Abduction** 	2 x 10	• Sit upright on the edge of a chair and place a band/rope around your knees. • Open your knees to tighten the band/rope and hold this position for 5 seconds.
e) Weighted Shoulder Press (± 1kg weight) 	2 x 10	• Sit upright on the edge of a chair with a weight in one hand. • Push the weight directly up above your head. • Complete the repetitions on the one arm before changing.	**f) Fast-Feet Rope Jumps** 	20 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways and forwards again for the required time.
g) Half Seated Holds 	2 x 6	• From a standing position, sit half-way towards a chair. • Hold this position for 10 seconds, ensuring that your back remains straight.	**h) Stork Stand** 	2 x 30 seconds	• Stand on one leg, either with or without assistance for the required time period. • Perform the exercise on each leg, with both eyes open and closed.

Moderate Exercise Program

Warm Up	Do a brisk walk around the block for approximately 15 minutes, incorporating some easy hills.				
a) Fast-Feet Rope Jumps 	35 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**b) Sit-to-Stand with Isometric Abduction** 	2 x 20	• Place a band or rope around your knees while seated and ensure that it remains taught throughout the exercise. • Perform standard sit-to-stands, while ensuring the band remains taught and does not fall down.
c) Fast-Feet Rope Jumps 	35 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**d) Stair Climbing** 	2 x 25 seconds	• Perform a step up/stair climbing on one step, both forward and sideways for the required time period. • Change the leading foot every 25 seconds.
e) Calf Raises with Holds 	2 x 15	• Perform 10 standard calf raises. • Hold the last 5 repetitions for 10 seconds each.	**f) Fast-Feet Rope Jumps** 	35 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.
g) Pelvic Tilt and Lift 	2 x 15	• Lie on your back with your knees bent and feet flat on the floor. • Slowly lift your hips towards the ceiling, and return to the ground.	**h) Table Top** 	2 x 8	• Lie on your back with your knees bent and feet flat on the floor. • Lift one leg, then the other in the air so that if forms a "table top" with your lower leg.
i) Cook Hip Lift 	2 x 6	• Lie on your back with your knees bent and feet flat on the floor. • Lift one leg to the table top position. • Push your hips up towards the ceiling using the foot that is on the ground.	**j) Hamstring Stretch** 	2 x 20 seconds	• Sit upright on the edge of a chair. • Straighten your one leg and try and touch your toes. • Hold this position for 20 seconds before performing the stretch on the opposite leg.

Difficult Exercise Program

Warm Up	Do a brisk walk around the block for approximately 15 minutes, incorporating a combination of easy and difficult hills.				
a) Fast-Feet Rope Jumps 	60 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**b) Standing Hip Abduction and Hip Extension** 	2 x 15	• Stand upright while supporting yourself on a chair. • While keeping your back straight, take the one leg out to the side, and then straight behind you. • Complete the 15 repetitions before changing to the opposite leg.
c)Lunge 	2 x 8	• Make sure that you take a big enough step that the knee doesn't pass over your toes. • Alternate between legs during this exercise.	**d) Stair Climbing** 	3 x 45 seconds	• Perform a step up/stair climbing on one step, both forward and sideways for the required time period. • Change the leading foot every 45 seconds.
e)Fast-Feet Rope Jumps 	60 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**f) Seated Torso Rotation with Press** 	2 x 10	• Sit upright on the edge of a chair. • While holding a weight, rotate your upper body to the one side, followed by and upward press, then rotation to the other side.
g) Fast-Feet Rope Jumps 	60 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**h) Table Top** 	2 x 12	• Lie on your back with your knees bent and feet flat on the floor. • Lift one leg, then the other in the air so that if forms a "table top" with your lower leg.
i) Fast-Feet Rope Jumps 	60 seconds per movement	• Place a rope on the floor in front of you. • Perform fast-feet jumps forward, sideways, forwards, sideways and forwards again for the required time.	**j) Hamstring Stretch** 	2 x 20 seconds	• Sit upright on the edge of a chair. • Straighten your one leg and try and touch your toes. • Hold this position for 20 seconds before performing the stretch on the opposite leg.

PART B – DIETARY GUIDELINES

What would you want your blood sugar to be approximately 2 hours after a meal?

Low:

< 4.0 mmol/L

Good:

4.0 – 7.0 mmol/L

Bad:

> 7.0 mmol/L

Food Group	Examples	Role in the Body	Portion Size
Carbohydrate	Rice, potato, bread, pasta, porridge, etc.	Provides energy for the body.	Size of a closed fist.
Protein	Beef, cheese, chicken, eggs, milk, etc.	Helps with building cells in the body.	Size of your palm.
Fat	Avocado, nuts, butter, etc.	Helps with thermoregulation and the transport of minerals and vitamins.	Size of your thumb.
Fruits	Apple, orange, pear, banana, kiwi, etc.	Provides us with vitamins and minerals to keep us healthy.	Size of a closed fist.
Vegetables	Carrots, broccoli, pumpkin, cabbage, etc.	Provides us with vitamins and minerals to keep us healthy.	Size of two palms.

What should your plate look like in the morning, afternoon and evening?

Morning

1 x Fruit

1 x Cup Oats

1 x Cup Low Fat Milk

Afternoon

1 x Palm Size Piece of Meat

1 x Slice Low GI Bread

1 x Cup Veg/Salad

Evening

1 x Palm Size Piece of Meat

½ Cup Rice

½ Cup Veg/Salad

PART C – LIFESTYLE TIPS

Our motivation to eat well and exercise regularly is linked to the way we think, our emotions, our stressors, and the support we get from those around us. Changing life-long habits of eating and exercising is a tough job! Congratulations for taking the first step by participating in the Type II Diabetes program. Here are some tips to help you when the going gets tough and you need some inspiration to carry on:

- Remember that social and emotional support is crucial!
  - Educate your family and friends about your Diabetes and ask them to help you stay on track.
  - Set up a regular meeting with others who have the same struggles as you, so that you can celebrate your achievements together, and laugh or cry about your struggles without judgement. We are social creatures – don't try to do it alone!
  - Stress contributes to illness and eats away at our motivation! Talking about our stresses and anxieties makes them easier to deal with.
  - Set up a regular schedule for exercise and ask others to exercise with you. Support each other by insisting that you all come to exercise sessions. You are more likely to do the exercise this way, and more likely to enjoy it!
  - Start up an informal gathering of people from the program. Meet for tea once a week or twice a month to support each other. Invite others who struggle with Diabetes to join you and inspire them to diet and exercise too.
- Remind yourself why you have taken the challenge to become healthier. Is it to live longer for your grandchildren, to keep your body as a temple, or to feel more comfortable? Use your answer to keep yourself motivated!
- Ask yourself, what is it that makes it difficult to control my sugar levels? How can I try to overcome this? What works for others may not work for you – you need to find your own unique plan.
- When you struggle to feel motivated to exercise, imagine how you know you will feel afterwards!
- Be kind to yourself. If you get off track with diet or exercise, don't be too hard on yourself. No one is perfect. Pat yourself on the shoulder for trying, and remember that change doesn't happen overnight. The fact that you are actively attempting to maintain healthy behaviors is a step in the right direction. It's okay to admit that it's hard - because it is. Carrying on in spite of the many difficulties you face it is what counts.
- Take a moment to ponder the following thoughts: Think about how hard it felt when you started the exercise routine. Think about how good it felt when you actually 'survived' it. Think about how, surprisingly, you felt positive change effects in your body as a result of your training. Moral of the story: it's not easy - but it's worth it.

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