Chapter 3

Effects of Progressive Resistance Training (PRT) on Glycosylated Haemoglobin (HbA_{1c}) and Lipid Profiles in Participants with Type 2 Diabetes Mellitus.

Abstract

Background: The influence on different types of exercise on risk factors for cardiovascular diseases have rarely been investigated in south African setting, however numerous trials worldwide have demonstrated that supervised resistance training may be a viable effective exercise modality for the improvement of glycaemic control and lipid profiles in persons type 2 diabetes mellitus.

Aims: The purpose of the study was to determine the efficacy of a 20 week progressive resistance training (PRT) and a dietary education programme on baseline blood glucose and lipid profiles in a cohort of 80 male and female type 2 diabetics from ages 40-65 years. Participants were of African heritage and were recruited in a resource-poor setting from the outpatients' clinic at the Mamelodi Hospital in Gauteng, South Africa.

Methods: A randomised controlled trial design was adopted for the study. Subjects were assigned to a PRT group (n=40) and control group (n=40). Participants in the PRT group were exposed to progressive resistance training and dietary education whilst the control group (CT) where only exposed to dietary education. The outcome measures entailed an assessment of glycosylated haemoglobin (HbA_{1c}), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides (TG) and total cholesterol (TC) count.

Results: The following pre-post intervention changes (mean (SD) were found for the PRT vs. CT for HbA_{1c} (PRT: pre 9.01 (3.1) vs. post 8.47 (2.4); p=0.04 vs. CT: pre 9.32 (2.3) vs. post 9.17 (2.5)%: p=0.72), TC (PRT: pre 4.92 (1.10) vs. post 4.69 (0.81); p=0.11 vs. CT: pre 5.08 (0.84) vs. post 5.04 (1.02) mmol/L: p=0.09), LDL (PRT: pre 3.05 (0.97) vs. post 2.89 (0.74); p=0.19 vs. CT: pre 3.17 (0.86) vs. post 3.11 (0.93) mmol/L: p=0.19), HDL (PRT: pre 1.05 (0.25) vs. post 1.09 (0.28); p=0.13 vs. CT: pre 1.27 (1.11) vs. post 1.09 (0.52) mmol/L: p=0.87), TG (PRT: pre 1.06

(0.84-1.74) vs. post 1.04 (0.79-1.52); p=0.16 vs. CT: pre 1.29 (1.1-1.9) vs. post 1.2 (0.95-2.03) mmol/L: p=0.73). However, none of these changes within the PRT group were significantly better (p>0.05) than that in the control (dietary intervention only) group.

Conclusion: The PRT and dietary education program combined failed to show a better improvement in metabolic parameters, than a dietary education program alone. Although this study failed to demonstrate a statistically significant change of at least 1% in the HbA_{1c} it is important to note that even the 0.5% difference achieved, can be considered as clinically significant. PRT needs to be of sufficient frequency and intensity to be effective as a treatment modality in persons with type 2 diabetes.

Keywords: Resistance training, glycosylated haemoglobin (HbA_{1c}), Lipid Profile, Type 2 diabetes mellitus, community setting.

3.1 Introduction

Diabetes Mellitus (DM) is a chronic disorder of carbohydrate, fat and protein metabolism. DM represents a heterogeneous group of disorders that have hyperglycemia as a common feature which is often associated with poor lifestyle and obesity [1, 2]. The incidence of type 2 DM is increasing markedly in adult populations around the world [3]. As populations age and become urbanised, and as obesity becomes more prevalent [4, 5], the incidence of type 2 DM rises. The striking epidemiological features of type 2 DM is the wide variation in population and individual prevalence and the strong positive correlation with relative body fat [6, 7] as well as socio-economic deprivation which, in turn, is associated with poor diet and other adverse lifestyle factors [8]. The main underlying factors associated with type 2 DM include genetic and environmental factors. These factors are urbanisation and industrialisation, increased longevity and changes in lifestyle from a traditional healthy and active way of life to a modern, sedentary and stressful life characterised by the overconsumption of energy-dense food [3].

The key factor in managing body weight is energy balance. When energy expenditure equates to energy intake, body weight is maintained, thus preventing initial weight gain or weight regain after weight loss. To promote weight loss it is necessary to create an energy imbalance that elicits an energy deficit. Structural physical activity contributes to energy deficit by increasing total energy expenditure, which thus promotes weight loss [9].

All patients with type 2 DM require active dietary management because this is an essential component of successful diabetic care [10, 11]. Dietary control involves balancing complex issues and needs, that are tailored to lifestyle, cultural and religious customs and to the overall diabetic management strategy of each individual patient [11]. There are three important goals related to dietary habits, i.e. essential nutrition, prevention of vascular complications and adaptation to metabolic problems. An optimal diet should provide all the essential nutrients bearing in mind that the person with type 2 DM needs the same essential nutrients as the general population. A balanced diet aims to reduce central obesity improve serum lipid

profile and lower blood pressure, all of which contribute to increased morbidity and mortality in a person with diabetes [12]. Food intake in type 2 DM patients must be balanced with exercise and hypoglycemic treatment [13], to avoid the twin perils of hypoglycemia and hyperglycemia. Most patients with type 2 DM are overweight; therefore they need to limit their energy intake.

Glycated haemoglobin provides an accurate and objective measure of glycaemic control over a period of weeks to months. Components of adult haemoglobin (HbA_1) can be separated from unmodified haemoglobin (HbA_0) by ion-exchange chromatography, and these haemoglobin moieties are increased in diabetes by the slow non-enzymatic covalent attachment of glucose and other sugars (glycation) [14]. The rate of formation of glycated haemoglobin is directly proportional to the ambient blood glucose concentration; a rise of 1% in glycated haemoglobin corresponds to an approximately 2 mmol/l increase in average blood glucose. Glycated haemoglobin concentration reflects integrated blood glucose control over the lifespan of the erythrocytes (120 days). Estimation is weighted by changes in glycaemic control occurring in the month before measurement (representing 50% of the glycated haemoglobin concentration). When initially diagnosed, type 2 DM can be controlled with diet and exercise because both contribute to weight loss. As weight is reduced insulin receptor numbers increase and insulin resistance is diminished. Exercise also contributes to weight loss by creating an increased demand for glucose in skeletal muscle and exercise promoting an increase in insulin receptors [15].

Strict blood glucose control in type 2 DM is essential because this is a critical factor in reducing the risk of chronic diabetic complications [13]. Research has suggested that in addition to good dietary habits, exercise is one of the cornerstones of DM management [16]. Exercise is often seen as a desirable means to manage excessive weight gain associated with type 2 DM and for its beneficial effect in increasing insulin sensitivity. Because muscle is a major site for insulin-induced glucose disposal and because muscle responds to exercise training, it is reasonable to assume that such changes in muscle tissue might contribute to reduced insulin resistance in people with type 2 diabetes [17-19]. Exercise can have

both long-term and short-term effects on insulin action. A strenuous session of exercise improves muscle glucose transport, which reverses rapidly when exercise is stopped [20]. This is then replaced by a marked increase in the sensitivity of the receptors to insulin [21]. The exercising muscle may increase the uptake of glucose by 7 to 20 fold during the first 30-40 minutes, depending on the intensity of the exercise session. Insulin receptors thus become more sensitive to the lower amount of insulin available during exercise. This improvement in insulin receptor sensitivity can last for many hours after the exercise bout is over, even for as long as 2 days if the exercise session was of sufficient intensity and duration [22].

Exercise and Insulin Sensitivity

Bjorntorp and colleagues [23], suggested the use of physical exercise to treat the insulin resistance associated with obesity and type 2 diabetes. They [23] have noted that active middle-aged men had significantly lower fasting insulin concentrations and lower insulin responses to oral glucose than untrained men of the same age and body weight. These findings suggested that regular physical activity is associated with increased insulin sensitivity which led them to study the effects of physical training in obese patients with normal glucose tolerance but insulin resistance. After 12 weeks of moderate intensity aerobic exercise (30-60 minutes, 5 days/week), there was no change in the subjects blood glucose responses but insulin levels were significantly lower, both fasting and following glucose administration [24]. The increase in insulin sensitivity and responsiveness associated with physical conditioning rapidly disappears when exercise is discontinued. Burstein *et al*. [25], found that much of the effect is gone within 60 hours; other researchers demonstrated that the effect is no longer present after 5 to 7 days without exercise.

Mikines and associates [26], observed that a single bout of aerobic exercise increased the sensitivity and responsiveness of insulin-stimulated glucose uptake in untrained individuals. The effect lasted 2 days but was not observed after 5 days. In addition, physically trained individuals (as compared to untrained individuals) had increased individual action 15 hours after their last training session. Five days after

their last training session, insulin responsiveness remained elevated compared with that of untrained subjects, suggesting that training results in a long-term adaptative increase in whole-body responsiveness to insulin [27]. Although the mechanism of this increase is not known, it may be related to increased capillary density in skeletal muscle, enhanced oxidative capacity or other adaptive capacity of skeletal muscle and to other adaptations to training such as elevated skeletal muscle GLUT 4 content [28]. An increase in insulin-stimulated glucose uptake can last 5 to 7 days following cessation of exercise in previously trained subjects, patients with type 2 DM do not have improved fasting blood glucose concentrations during this same period. Some researchers have observed that physical training is associated with lower glycosylated hemoglobin levels [29]. The cumulative result of decreased blood glucose concentrations during and after aerobic exercise rather than a specific effect of physical training is of importance. Since moderate-intensity aerobic exercise usually lowers blood glucose concentrations towards normal in hyperglycemic patients with type 2 diabetes, and since increased insulin-stimulated glucose disposal persists for many hours following a single bout of exercise, it is likely that regular exercise 4 to 7 days a week may decrease blood glucose and glycohemoglobin concentrations without a significant effect on fasting blood glucose or glucose response to meals. The net effect of exercise repeated on a regular basis would improve long-term glucose control in patients with type 2 diabetes [30].

Effects of Exercise on Lipid Control

Regular physical activity leads to reduced risks of cardiovascular disease [31, 32], an effect which is likely due to the beneficial effect on lipid metabolism [32]. Physical inactivity has adverse consequences on cardiovascular risk, due to the detrimental effects on serum lipoprotein concentrations. There are a number of studies that have considered the effects of exercise on lipid profile but there seems to be some uncertainty as to how much exercise is sufficient for health benefits and how much inactivity acts to worsen risk profiles [33]. Research done by Slentz *et al.* [32], referred to as the STRIDDE study (Studies Targeting Risk Reduction Interventions through Defined Exercise) examined one of many factors dealing with the effects of different amounts and intensities of exercise training on lipoproteins.

It was noted that many of the beneficial effects of exercise on lipids and lipoprotein was not observed in the typical lipid profile, but rather it was observed in the effects of exercise on the particle size and particle number. This was an important finding in that the concentrations of low density lipoprotein (LDL) particles, large high density lipoprotein (HDL) particles and large very low density lipoprotein (VLDL) particles are better indicators of cardiovascular risk than are the elements of the traditional lipid profile [34, 35]. In diabetes the plasma cholesterol level is usually elevated and this plays an important role in the development of atherosclerotic vascular disease which is a long term complication of diabetes in humans. The rise in plasma cholesterol level is due to an increase in the plasma concentration of VLDL and LDL [36]. The most common pattern of dyslipidaemia is hypertriglyceridemia and reduced HDL cholesterol levels. DM in itself does not increase levels of LDL, but the small dense LDL particles found in type 2 DM are more arterogenic because they are more easily glycated and susceptible to oxidation [37]. Physical training is associated with a decrease in serum triglycerides levels, particularly very low density lipoproteins, and an increase in high density lipoproteins-2 cholesterol [38].

The American College of Sports Medicine [39, 40] advises a combination of both aerobic and resistance training as part of an exercise regime. In general exercises with higher intensities are associated with poorer compliance [41]. Post-intervention compliance with lifestyle activity involving high intensity aerobic programmes is poor. Furthermore, aerobic training is not ideal for many type 2 patients because of advancing age, obesity and other co-morbid conditions [6, 42, 43]. On the other hand, resistance training leads to improved glycosylated haemoglobin (HbA_{1C}) levels [44] and increases in lean body mass [45-47]. Although this mode of exercise is generally safe, it is often erroneously neglected or absent from exercise programmes. Resistance training has additional benefits apart from improving glycaemic control and insulin sensitivity, such as building muscle mass, strength, endurance and mobility. Circuit-type resistance training thus appears to be a feasible and effective therapeutic modality in moderately obese, sedentary patients with type 2 DM [42].

3.2 Aims

The primary focus of this research was to establish the effectiveness of a progressive resistance exercise and dietary education intervention programme on baseline HbA_{1C} and lipid profiles in a cohort of African participants with type 2 DM.

3.3 Hypothesis

To implement a progressive resistance training intervention programme and to establish its efficacy based on the primary and secondary hypothesis.

3.3.1 Primary Hypothesis:

The implementation of a progressive resistance training programme would decrease the glycosylated haemoglobin (HbA_{1c}) by 1% given a standard deviation of 2.23% with α=0.05 and β=0.10 in a sample of 80 participants comprising of males and females with type 2 DM.

3.3.2 Secondary Hypothesis:

The implementation of a progressive resistance training programme would yield a significant change in lipid profile comprising low-density lipoprotein, high-density lipoprotein, total cholesterol and triglycerides.

3.4 Material and Methods

3.4.1 Participants

The study was undertaken in Mamelodi, a suburb in the City of Tshwane Metropolitan Municipality in the province of Gauteng, South Africa. The participants (n=80) included black male (6=control group and 11=exercise group) and female (34=control and 29=exercise group) participants from 40-65 years with type 2 DM without complications and a known duration of the disease for at least one year.

Most participants were recruited from the outpatient clinic at the Mamelodi government hospital whilst they were waiting to be seen by a doctor. Participants were also recruited from local churches in the Mamelodi area. Participants were excluded according to the following criteria: Cardiovascular contraindications: Unstable angina, untreated severe left main coronary artery disease, angina, hypotension or arrhythmias provoked by resistance training, acute myocardial infarction, end-stage congestive heart failure, severe valvular heart disease, malignant or unstable arrhythmias, large or expanding aortic aneurysm, known cerebral aneurysm, acute deep venous thrombosis, acute pulmonary embolism or infarction, and recent intracerebral or subdural hemorrhage; Musculoskeletal contra-indications: Significant exacerbation of musculoskeletal pain with resistance training as well as unstable or acutely injured joints, tendons or ligaments, fracture within the last 6 months (delayed union) and acute inflammatory joint disease; Other contra-indications: Rapidly progressive or unstable neurological disease, failure to thrive, terminal illness, uncontrolled systemic disease, symptomatic or large abdominal or inguinal hernia, hemorrhoids, severe dementia/behavioural disturbance, acute alcohol or drug intoxication, acute retinal bleeding, detachment/severe proliferative diabetic retinopathy, recent ophthalmic surgery, severe cognitive impairment, uncontrolled chronic obstructive pulmonary disease, prosthesis instability, severe (readings: systolic >160 mmHg and diastolic >100 mmHg) and malignant hypertension, as well as signs and symptoms suggestive of immuno-suppression.

3.4.2 Design, Randomization and Procedures

The experimental design comprised a pre-test post-test randomised controlled trial. The study comprised of two groups, a control group (no PRT with dietary education only) and an experimental group (received supervised PRT and dietary education). Participants who volunteered for baseline testing were randomised by means of block randomization, using a computerised programme (http:// www.randomization.com) [48]. However due to the relatively small sample size, important potential confounders such as age, gender and BMI were not matched or balanced and were adjusted for in the analysis.

The principal investigator was not blinded to the randomization of the participants, and trained university student assistants were recruited to assist in basic administrative work, however, the subjects were blinded to randomization. One hundred opaque sealed envelopes were used for the randomization process. Each envelope was numbered according to the randomization programme and a label was placed inside each one. The options were: (1=A=Exercise or 2=B=Control group). The letter A represented exercise and B represented control. On the appointed day, each of the participants who reported at the YMCA Hall at 08h30 was required to select an envelope indicating the group to which each had been assigned. At this session all participants were again briefed on the aim of the study. After being randomly assigned the participants were asked to fill out the consent forms.

3.5 Ethical Clearance

The protocol was approved by the Research Ethics Committees of the Faculties of Humanities and Health Sciences at University of Pretoria (Number 66/2004). The chief executive officer, superintendent and physician providing medical services as well as the health-care workers at the DM out-patient clinic of the Mamelodi Hospital, also consented. On reporting for baseline-testing participants received information on the study in their own language as well as in English and had the opportunity to ask questions. If they were sufficiently interested in the study the prospective participants provided their signed, written, informed consent. Before commencing with the programme individuals had to undergo a thorough medical evaluation by a specialist physician, to be screened for the presence of any contra-indications to exercise.

3.6 Intervention Programme

The duration of the study intervention programme was 20-weeks. Due to availability of subjects the study was staggered and therefore spanned over a period of 18 months in total (February 2004-June 2005), and was conducted in periods of 20 weeks until the targeted number of subjects were obtained. The

YMCA hall in Mamelodi was used to perform the weekly intervention exercise and dietary educational sessions.

3.6.1 Dietary Education

Research has suggested that both diet and exercise are cornerstones [16] which play pivotal roles in the control of type 2 DM. Participants who participated in this intervention programme were given dietary education, conducted in a community hall by the resident dietician at the Mamelodi Hospital with a view to educating participants on proper dietary habits. However no attempts were made to change their diet during the study. Before block randomization into exercise and control groups, all participants were given general information on lifestyle changes. The participants from the exercise and control groups had no contact or interaction with one another during the study. Dietary education for the control group was conducted twice a month for 20-weeks whilst the experimental group also received their dietary education twice a month following one of their exercise sessions. The PRT group and control group received their dietary education on different days of the week. Both groups received education in the form of dietary aids (food models), which the resident dieticians used to provide detailed information on portion sizes of food consumed. Educational aids such as pamphlets and diagrams were used to illustrate the preferred types of food selected and to explain the glycaemic indices of food groups. The instructions stressed the need for a reduction in the intake of total energy, total fat and cholesterol-rich foods. An ideal meal was served to all participants after the education sessions to enlighten them on the types of food to be consumed while stressing the preparation methods and portion sizes.

3.6.2 Exercise Intervention

Exercise sessions took the form of progressive resistance training (PRT) using equipment such as dumbells, elasticized bands, exercise balls and own body weight. The exercise intensities increased on a monthly basis using 5 differently coloured elastised therabands of varying resistance. The colours of the elasticized therabands were yellow (1.5 kg), red (2.0 kg), green (2.7 kg), blue (3.5 kg) and

black (4.5 kg). A bench-press and leg press 1RM test was determined by trial using a sub-sample of 10 subjects (6 females and 4 males) at the physiotherapy gymnasium in the Mamelodi hospital. This was done primarily to determine the initial repetitions per set of exercises than the resistance, as the elasticised tensile resistance (colour) of the theraband was constant for all subjects during each month of the study, with a different theraband (increased resistance) thus being used for each month (X5) of the 20 week program. Dumbells and ankle weights of 2 kg resistance were used, with the repetitions per exercise progressively increasing from 3 sets of 6 repetitions in month 1 to 3 sets of 12 repetitions in month 5. For the first 4 months there was an increase of 2 repetitions each month and in the 5th month the repetitions (12 reps) were the same as the fourth month. Between each station the subjects were given 30 seconds rest to move from one station to the other, and repetition of each exercise was done every 4 seconds. In certain instance chairs were substituted for the exercise gym balls. Tables were improvised for exercise benches and door knobs as well as railings in the hall were used to fasten the elastic bands. Participants performed supervised PRT on two non-consecutive days per week (Appendix 5: Exercises). The exercise programme commenced with 30 minute-sessions, progressing to 60 minute-sessions towards the end of the study. Before and after each exercise session blood pressure and glucose levels were measured to ensure that none of the participants was hypoglycaemic (<3.7 mmol/L) prior to exercising or had high blood pressure readings (increase in systolic blood pressure >170 mmHg) that would be contra-indicative to exercise. If any patients indicated that they did not consume prescribed medication they were not allowed to participate in the days activities. All exercise participants congregated in the community hall where they had to do a general warm up and stretching exercises for 20 minutes. The exercising participants which comprised of forty people were divided into four groups with ten participants in each group. The groups then did a circuit workout for the remaining 40 minutes, rotating at each station of the circuit. The groups were then given a further 10-15 minutes which was used as a cool-down period as well as to perform few basic stretching exercises. All the exercises were supervised by qualified exercise science students. An attendance register was kept for each exercise session.

3.6.3 Clinical Parameters

A qualified nurse as well as a general medical practitioner at Tshwane District Hospital took blood samples for HbA_{1c} and lipid-profile analyses. These samples were taken at baseline and at the end of the study. Blood samples were taken after an overnight fast and collected in EDTA tubes and were transported in ice to a pathology laboratory within six hours of being drawn. The HbA_{1c} and lipid profiles were analysed using reagent kits in conjunction with a SYNCHRON® and SYNCHRON LX® System Lipid Calibrator. The system utilises two unique cartridges Hb and $A1_C$ to determine the haemoglobin A1c concentration as a percentage of total haemoglobin.

Physical activity/energy expenditure was assessed using the English version of the short International Physical Activity Questionnaire available on www.ipaq.ki.se [49, 50]. The specific types of activity assessed were walking, moderate-intensity activity and vigorous intensity activities. IPAQ defines moderate-physical activities as those that produce a moderate-increase in respiration rate, heart rate and sweating for at least 10 minute duration, which is equivalent to 3-6 metabolic equivalents (METS) based on the compendium of physical activity [51].

Circumferences that were measured with an anthropometric tape measure, were used to determine the derived measures of waist-to-hip ratio (WHR) i.e. ratio of the minimum circumference of the abdomen to the circumference of the buttock at the maximum protuberance. Body mass index (BMI) was calculated from weight in kilogram divided by height in metres squared.

3.7 Sample Size

The initial sample consisted of 91 participants, with a subsequent dropout of 11 participants, leaving forty participants in an experimental group (6 males and 34 females) and forty participants in a control group (11 males and 29 females). Progress through the various stages of this study is highlighted in figure 1. The discontinuation of participants as highlighted in figure 1 was due to personal

problem experienced, non-compliance and amputation. Follow–up was done by means of telephone calls and letters that were posted to participants homes or hand delivered while they waited at the diabetes outpatient clinic. Socio-economic problems, psychosocial problems, death in the family and illnesses were given reasons for not attending the exercise and dietary sessions. No adverse effects or side effects were reported in either group.

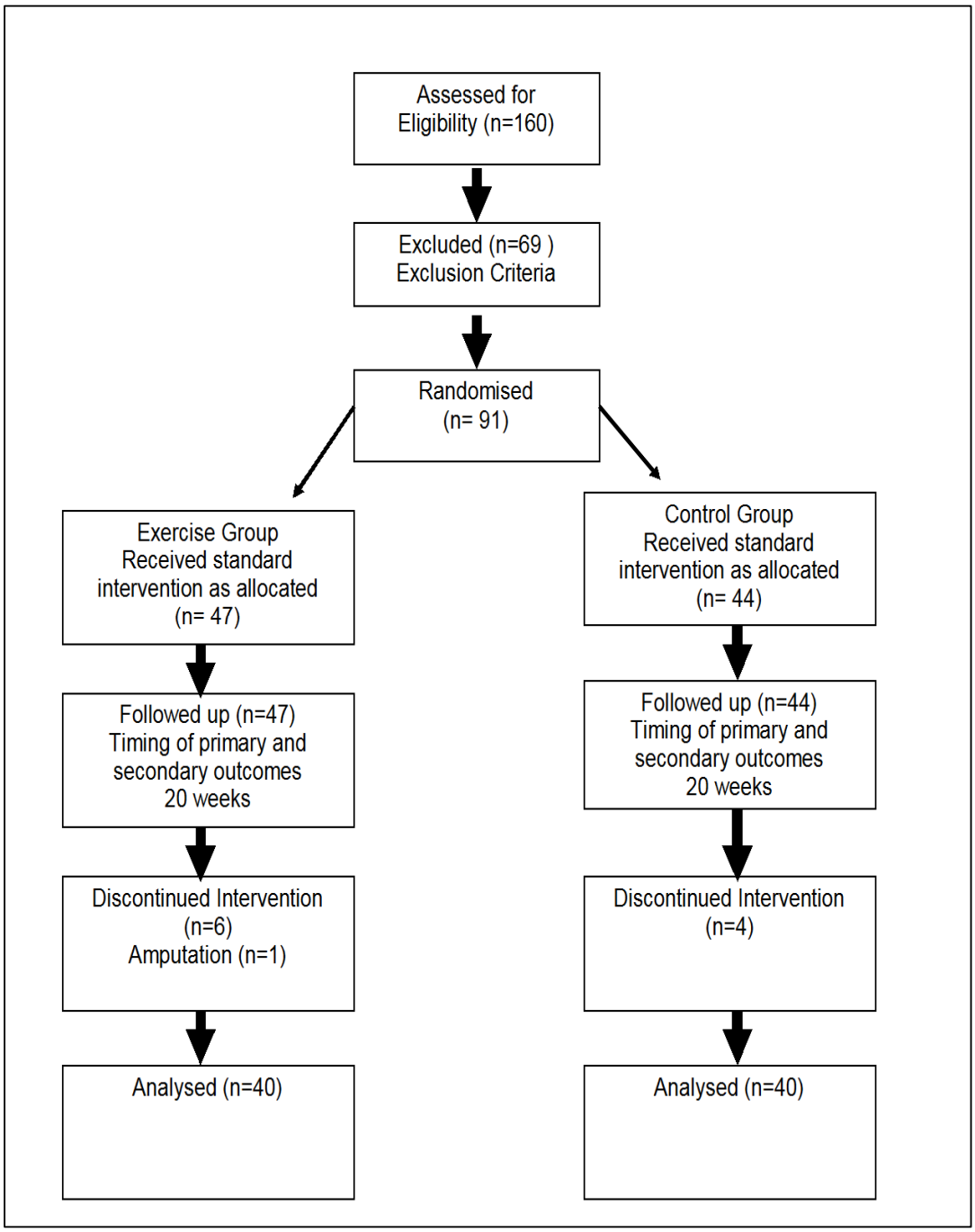

Figure 1: Diagram Showing the Flow of Participants through Each Stage of the Randomized Controlled Trial.

3.8 Statistical Analysis

The analysis of data was done using Stata 10® [52]. Analysis of co-variance was used to assess the post values adjusting for baseline value as well as age, gender and baseline body mass index (age and gender when assessing post body mass index and post waist to hip ratio). Comparison of the pre-post values within groups over time was done using the paired t-test or the Wilcoxon signed-rank test (for triglyceride values). For comparisons between groups over the 20-week period, analysis of co-variance (ANCOVA) was used adjusting for baseline values (using log transformation in the case of the triglycerides) as well as body mass index, gender and age. A p-value ≤ 0.05 was regarded as statistically significant.

3.9 Results

The demographics of the sample by gender, age, educational level and employment status are given in Table 1. The sample size consisted of 17 males and 63 females. The ages of the participants ranged from 40-65 years. The majority (52.50%) of the exercise group had passed standard 7 (grade 9) whilst the majority (40%) of the control group had passed standard 10 (grade 12). The employment status indicated that majority (52.5%) in the exercise group were unemployed, whilst the majority (40%) in the control group were pensioners. Formal statistical testing and matching of groups at baseline was not done and such post randomization differences observed were thus due to chance. However, age and gender appear not to have been balanced between the two groups and were thus adjusted for in subsequent analyses.

Table 1: Frequency Distribution of Demographic Variable

DEMOGRAPHIC VARIABLES		Exercise (N=40)		Control (N=40)	
		N	%	N	%
GENDER	Males	6	15.00	11	27.50
	Females	34	85.00	29	72.50
AGE (Years)	40-50	11	27.50	6	15.00
	51-60	16	40.00	17	42.50
	61-70	13	32.50	17	42.50
EDUCATIONAL LEVEL	St 1-4	7	17.50	8	20.00
	St 5-7	21	52.50	12	30.00
	St 8-10	11	27.50	16	40.00
	NONE	1	2.50	4	10.00
EMPLOYMENT STATUS	Part-time	1	2.50	4	10.00
	Full time	1	2.50	5	12.50
	Pensioner	17	42.50	16	40.00
	Unemployed	21	52.50	15	37.50

Table 2 highlights the clinical baseline characteristics of participants in the exercise and control groups. The mean values reflect the control and exercise group to be more or less homogeneous (based on randomization), except for BMI (which was subsequently adjusted for).

Table 2: Baseline Clinical Data

Variable	Exercise (N=40)		Control (N=40)	
	Mean	**SD**	**Mean**	**SD**
Glycosylated Haemoglobin (%)	9.01	3.11	9.32	2.32
Systolic blood pressure (mmHg)	142	28.55	133	20.66
Diastolic blood pressure (mmHg)	101	25.61	88	14.01
High-density lipoprotein (mmol/L)	1.05	0.25	1.27	1.11
Low-density lipoprotein (mmol/L) **Exercise: n=37** **Control: n=39**	3.05	0.97	3.17	0.85
Total cholesterol (mmol/L)	4.92	1.10	5.08	0.84
Triglycerides* (mmol/L)	1.57 *(0.38-11.78)	1.81	1.66 (0.47-5.00)	1.03
Body Mass Index (kg/m^2)	33.53	6.93	30.84	5.36
Waist to Hip Ratio	0.86	0.08	0.88	0.11
Energy expenditure (METS)* **(Pre-intervention)**	1662	343-3525	1347	714-2578.5

*Median (min-max)

SD= Standard deviation

N= Number of patients

BMI adjusted at baseline

Table 3: HbA_{1c} Values in Exercise and Control Groups

HbA_{1c} (%)	Exercise (N=40)		Control (N=40)	
	Mean	SD	Mean	SD
Pre-intervention	9.01	3.1	9.32	2.3
Post-intervention	8.47	2.4	9.17	2.5
Change within group	-0.54	1.6	-0.15	2.6
p- value at 20 weeks	0.04*		0.72*	
Difference at 20 weeks between exercise and control group	-0.59 (95% CI -1.45 to 0.27, p=0.18)**			

* p for change within group

** adjusted for BMI, age, gender as well as pre-test values

When comparing changes in glycosylated haemoglobin (HbA_{1c}) between exercise and control group over the intervention period, a non-significant difference (p=0.18) was observed. A 0.59% reduction in HbA_{1c} levels was seen between groups over the 20 week period (95% CI -1.45 to 0.27). A non-significant (p=0.72) mean (SD) HbA_{1c} reduction of 0.15% (2.6) was observed in the control group and whilst a significant (p=0.04) reduction of 0.54% (1.6) was observed in the exercise group.

Table 4: High-Density Lipoprotein Values in Exercise and Control Groups

HDL (mmol/L)	Exercise (N=40)		Control (N=40)	
	Mean	SD	Mean	SD
Pre-intervention	1.05	0.25	1.27	1.11
Post-intervention	1.09	0.28	1.09	0.52
Change within group	0.04	0.16	-0.18	1.04
p-value at 20 weeks	0.13*		0.28*	
Difference at 20 weeks between exercise and control group	0.01 (95% CI -0.16 to 0.19, p=0.87)**			

* p for change within group

** adjusted for BMI, age, gender as well as pre-test values

When comparing high-density lipoprotein (HDL) between exercise and control group over the intervention period, a non-significant difference (p=0.87) was observed. A 0.01 mmol/L (95% CI -0.16 to 0.19) difference in HDL levels was seen between groups over the 20 week period. A non-significant difference was observed in the exercise group (p=0.13) with an increase of 0.04mmol/L (0.16), a non-significant (p=0.28) mean HDL reduction of 0.18 mmol/L (1.04) was observed in the control group.

Table 5: Low Density Lipoprotein Values in the Exercise and Control Groups

LDL (mmol/L)	Exercise (N=40)		Control (N=40)	
	Mean	SD	Mean	SD
Pre-intervention	3.05	0.97	3.17	0.86
Post-intervention	2.89	0.74	3.11	0.93
Change within group	-0.16	0.78	-0.04	0.81
p-value at 20 weeks	0.22*		0.77*	
Difference at 20 weeks between exercise and control group	-0.22 (95% CI -0.55 to 0.11, p=0.19)**			

* p for change within group

** adjusted for BMI, age, gender and baseline value

When comparing low density lipoprotein (LDL) between the exercise and control group over the intervention period, a non-significant difference (p=0.19) was observed. A 0.22 mmol/L (95% CI -0.55 to 0.11) reduction in LDL levels was seen between groups over the 20 week period. A non-significant decrease, was observed in the exercise group (p=0.22) with a decrease of 0.16mmol/L (0.78), similar trends i.e. a non-significant (p=0.77) adjusted-for-baseline change with a mean LDL reduction of 0.04mmol/L (0.81) was observed in the control group.

Table 6: Total Cholesterol Values in the Exercise and Control Groups

Total Cholesterol (mmol/L)	Exercise (N=40)		Control (N=40)	
	Mean	SD	Mean	SD
Pre-intervention	4.92	1.10	5.08	0.84
Post-intervention	4.69	0.81	5.04	1.02
Change within group	-0.23	0.88	-0.03	0.88
p-value at 20 weeks	0.11*		0.81*	
Difference at 20 weeks between exercise and control group	-0.30 (95% CI -0.66 to 0.04, p=0.09)**			

* p for change within group

** adjusted BMI, age, gender and baseline value

When comparing total cholesterol (TC) between exercise and control group over the intervention period, a non-significant difference (p=0.09) was observed. A 0.30 mmol\L (95% CI -0.66 to 0.04) reduction in TC levels was seen between groups over the 20 week period. A non-significant (p=0.11) difference was yielded in the exercise group with a decrease of 0.23mmol/L (0.88) as well as in the control group (p=0.81) with a mean TC reduction of 0.03mmol/L (0.88).

Table 7: Triglyceride Values in the Exercise and Control Groups

Triglycerides (mmol/L)	Exercise (N=40)		Control (N=40)	
	Median	Min-Max	Median	Min-Max
Pre-intervention	1.06	0.84-1.74	1.29	1.1-1.9
Post-intervetnion	1.04	0.79-1.52	1.2	0.95-2.03
p-value at 20 weeks	0.16*		0.73*	
Difference at 20 week between exercise and control group	-0.05 (95% CI -0.25 to 0.14, p=0.57)**			

Median (25^{th}/75^{th}) minutes- max values.

* p for difference over time within groups

** Differences in log triglycerides adjusted for BMI, age, gender and baseline value

When comparing triglycerides (TG) between the exercise and control group over the intervention period, a non-significant difference (p=0.57) was observed. A 0.05 mmol/L (95% CI -0.25 to 0.14) reduction in TG levels was seen between groups over the 20 week period. A non-significant (p=0.16), was found in the exercise group. A similar trend was observed in the control group, with a non-significant (p=0.73) change.

3.10 Discussion

The primary aim of this paper was to establish the effectiveness of a resistance exercise and dietary education intervention programme on baseline HbA_{1C} and lipid profiles in a cohort of African participants with type 2 DM. This study failed to demonstrate a difference (statistically significant) of at least 1% in the HbA_{1c} after the intervention. The secondary hypothesis was also rejected as the implementation of the PRT programme did not show a significant change in lipid profile comprising low-density lipoprotein, high-density lipoprotein, total cholesterol and triglycerides.

This study did not show that supervised progressive resistance exercise and dietary education decreases HbA_{1c} and lipid profiles more than dietary education alone. Although the baseline energy expenditure (METS) of both groups were similar (table 2), interpretation of the results was complicated by the fact that participants having both poorly controlled (greater than 7 percent) and well-controlled HbA_{1c} were included in the study at baseline. This may have modified the effect of the exercise modality. The main focus was to achieve a significant reduction in the HbA_{1c} by 1%, given a standard deviation of 2.23%. Within the exercise group there was a significant reduction (p=0.04), but no significant difference in HbA_{1c} was observed between groups, over time (p>0.05) when adjusted for age, gender, BMI and baseline values.

The present study is in accordance with the results reported by Keyserling *et al.* [53] and Dunstan *et al.* [45] they reported minimal changes in HbA_{1c} in all groups for both studies. The improvement in the HbA_{1c} levels of 0.54% in the exercise group

is also in line with the results obtained by Dunstan *et al*. [46] who reported a reduction of 0.39% in their exercise group. The study done by Keyserling *et al*. [53] apportioned the minimal improvement in glycaemic control to the fact that the study did not address medication adherence, which to an extent is also a shortcoming in the current study. In contrast to the above studies research done by Goldhaber-Fiebert and Collegues [54] found a more substantial reduction of 1.8 + 2.3% in HbA_{1c} in a 12-week lifestyle intervention. Their study was based on 11 weekly nutrition classes and supervised walking groups three times per week. The frequent contact hours and direct supervision of exercise may have contributed to the success of the study. Previous investigations conducted involving resistance exercise in adults with type 2 diabetes in a supervised setting, have shown a reduction in the HbA_{1c} from baseline levels ranging between 0.5 to 1.2% [55].

While older persons may need a longer adaptation period to become accustomed to an exercise routine, the 20-week (5 month) study period was long enough to induce some positive, but statistically insignificant, changes in both the primary (HbA_{1c}) and secondary (lipid profile) outcomes. The improvement in the in both groups may be attributed to the Hawthorne effect [56]. The subject's participation in the trial and interest portrayed by the field workers and health care workers and exercise trainers may have contributed to the improvement in both groups rather than the exercise per se. It is recommended, however, that the duration, intensity and, most importantly, frequency of the programme be taken into consideration in exercise prescription for type 2 diabetics to achieve optimal benefits.

Having type 2 DM increases the incidence of cardiovascular disease two to four-fold [57]. The beneficial effect of physical activity on cardiovascular risk is related to an increase in insulin sensitivity [58]. Insulin resistance is an important contributor to premature coronary disease, particularly when associated with hypertension, hyperinsulinaemia, central obesity and an overlap of metabolic abnormalities. The risk factors for coronary heart disease in type 2 DM are increased LDL cholesterol, decreased HDL cholesterol, hypertension, hyperglycaemia and smoking [13]. It is also noted that intra-abdominal obesity is associated with insulin resistance type 2 DM, hypertension, dyslipidaemia and cardiovascular disease. The metabolic

syndrome is a cluster of these abnormalities. Hypertriglyceridaemia, low HDL, altered LDL cholesterol and elevated free fatty acids are strong risk factors of cardiovascular disease [59]. A study undertaken by Dattilo and Kris-Etherton [60] , has shown that weight-loss of 1 kg decreases serum cholesterol by 1%, triglycerides by 1.9% and fasting plasma glucose values by 3.6mg/dL (0.2mmol/L).

The beneficial effects of regular exercise on lipid and lipoprotein are well documented [61]. Many studies published demonstrated that regular exercise results in widespread beneficial effect on the lipoprotein profile, with the majority of the improvements being related to duration as opposed to intensity of exercise [62]. As stated in the STRIDDE study, whether the effects of exercise are only acute, lasting 1-3 days, as is a consistent finding with regards to insulin sensitivity, or whether the effects of regular exercise on lipids are more sustained [32]. As stated in the STRIDDE study investigators were, however, more interested in whether the early versus sustained nature of improved lipid profiles were related primarily to exercise training and/or exercise intensity.

The important findings of the study proved that the benefits and the improvements in HDL size and large HDL are sustained up to 2 weeks after exercise withdrawal. HDL cholesterol is thought to have significant clinical influence such as anti-inflammatory antioxidative, antiaggregatory, anticoagulant and profibrinolytic activities [63], in addition to its role in reverse cholesterol transport. Tables 4 to 7 reflect the lipid profiles in the exercise and control groups over the 20-week trial period. A promising but non-significant trend of increased HDL and decreased LDL, TC and TG was observed within the groups, but no difference was seen between groups. The LDL levels also proved to be insignificant over the 20 week period. It is also noted that with the TC a small reduction was seen in both control and exercise group but this was not significant to cause a significant reduction over 20 weeks of intervention. Triglycerides also proved to be non-significant when comparing the results over the 20 week period with and between groups. Due to the insignificant changes of lipid profiles i.e. LDL, TC, HDL and TG these are indicators of sustained cardiovascular risks. In general there is an inverse correlation between HDL and TG levels. Studies suggest that decreasing TG plays

a major role in increasing HDL levels [64]. The STRIDDE study [32] showed that there is a marked discordance in the effects of the exercise training responses in VLDL-TGs and HDL metabolism, which suggests it, is likely that these responses have a different mechanism.

Acute changes in lipid metabolism is due to the changes in insulin signaling mediated by recent bouts of exercise [65]. The rapid reversal of insulin action in muscle following cessation of exercise may be secondary to the rapid change in VLDL metabolism in muscle with enforced inactivity. A reduction in VLDL metabolism in muscle with inactivity leads to diversion of fatty acid metabolism away from mitochondrial oxidation and toward increases in triglyceride stores, which has a suppressing effect on insulin action. Changes in HDL-C, however, are harder to achieve, are likely related to changes in body habitus and possibly increases in oxidative capacity in muscle, are likely longer lasting, and are harder to reverse, even with enforced inactivity [32].

Although the current study using moderate PRT failed to show an improvement in lipid profile, other studies using moderate-intensity exercise resulted in twice the magnitude of triglyceride lowering as compared to higher intensity training, and proved beneficial to men with low HDL cholesterol, elevated TG, and abdominal obesity [66]. Using moderate-intensity exercise relative to high-intensity exercise relies more on lipid as a fuel source. This may imply that moderate-intensity exercise has a longer-lasting effect on lipoprotein lipase in muscle and hepatic lipase in liver. This theoretically leads to increased lipid uptake and oxidation in skeletal muscle, with resultant improvements in insulin action and lower steady-state glucose, insulin, and triglyceride levels. High-intensity exercise may lead to a higher rate of triglyceride mobilization from fat stores as a response to the higher catecholamine levels with high-intensity exercise, thereby counteracting any stimuli to reduce VLDL-TG levels through increased utilization and oxidation in muscle. Combined, these effects might explain the relative magnitude of the training-induced lowering of serum VLDL and triglycerides with moderate-intensity exercise relative to vigorous-intensity exercise. Alternatively, vigorous exercise tends to increase mitochondrial capacity relative to lower intensity exercise and the imbalance

between supply and demand, created by training cessation and lipid storage, may have a detrimental effect on mitochondrial fatty acid oxidation, storage, and insulin action in the tissues (muscle, fat, and liver) of vigorous-intensity exercisers, thereby resulting in a "rebound" in serum VLDL and triglycerides in these groups [66]. Physical inactivity has numerous, significant, detrimental metabolic consequences. Exercise thus has the potential to impact positively on the lipid profile of an individual, thus also reducing the blood pressure. Numerous positive effects such as cardiovascular fitness and serum lipid profiles can be induced by performing a minimum of a 10 minutes of exercise on a daily basis [67].

Circuit-type resistance training seems to be a feasible and effective therapeutic modality in moderately obese sedentary patients with type 2 DM [42]. However frequency, duration and intensity are important aspects of an exercise regime. In this study the supervised exercise sessions were presented twice a week. The intensity was determined from a pilot study and adjusted throughout the study over the duration of five months. This was expected to be sufficient when compared with other exercise studies. There were, however, some limitations in the present study. The design adopted was a randomised control study investigating PRT on numerous variables, over a relatively long term (5 months), with multiple group sessions. While the researcher relied on block randomization to control for confounding variables e.g. age, gender and activity levels, randomization of a relatively small sample (n=80) failed to address the equality in groups regarding the different confounding variables. Subjects with good and poor HbA1c were pooled prior to group assignment, and it is possible that the effect was diluted by those subjects with good control from the start. Given that the experimental intervention programme in this study showed the correct trends, the disappointing outcomes may be due to the fact that the exercise programme was not challenging enough in intensity and frequency. The logical deduction is the need to increase the frequency to at least 3 to 5 days a week at a greater intensity to result in a favourable outcome. However, the logistical challenge of implementing and managing such a programme within a resource-poor community setting must also be taken into consideration.

Although the study did not yield any significant differences between groups with regard to the HbA_{1c} and lipid profile, it did however create an awareness of the potential benefits of exercise to a diabetic patient in a resource-poor setting. There are a number of studies in the literature that have focused on the benefits of exercise in patients with type 2 DM. Although his study failed to demonstrate a statistically significant difference of at least 1% in the HbA_{1c} it is important to note that the 0.5% difference achieved could be clinically significant. This Mamelodi community study is unique in that no study has evaluated the efficacy of a PRT programme in such a setting in South Africa. Further studies should investigate the efficacy of progressive resistance training on HbA_{1c} and lipid profile, taking into account only poorly controlled type 2 DM patients.

3.11 References

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