ADDIS ABABA UNIVERSITY

COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICINE

DEPARTMENT OF PHYSIOLOGY

A Study on the Chronic Effects of Supervised Aerobic Exercise on Glycemic Control and Body Composition in Type-2 Diabetes Mellitus Patients Attending Outpatient Care Unit in *Goba* Referral Hospital, Southeast Ethiopia

A Thesis Submitted to school of graduate studies of Addis Ababa University, in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Medical Physiology

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The Chronic Effects of Supervised Aerobic Exercise on Glycemic Control and Body Composition in Type-2 Diabetes Mellitus Patients Attending Outpatient Care Unit in *Goba* Referral Hospital, Southeast Ethiopia

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CERTIFICATE

This is to certify that the thesis entitled "The Chronic Effects of Supervised Aerobic Exercise on Glycemic Control and Body Composition in Type-2 Diabetes Mellitus Patients Attending Outpatient Care Unit in *Goba* Referral Hospital, Southeast Ethiopia" was carried out by myself and has not been submitted in part or in full for any other degree or any other university.

The thesis comprises only my original work for a MSc degree in Medical Physiology. It is free of plagiarism. Due acknowledgment has been made in the text to all other materials used.

This thesis is submitted for the qualification of "MSc Degree in Medical Physiology" complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ACRONYMS AND ABBREVIATIONS

ACSM	American College of Sports Medicine
ADA	American Diabetes Association
AMPK	Adenine mono phosphate-activated protein kinase
BMI	Body Mass Index
BP	Blood Pressure
DBP	Diastolic Blood Pressure
DM	Diabetes Mellitus
ETB	Ethiopian Birr
FBG	Fasting blood glucose
FFA	Free Fatty Acids
FITT	Frequency, Intensity, Type and Time
GLUT-4	Glucose transporter-4
HbA1c	Hemoglobin A1C (Glycosylated Hemoglobin)
HHNS	Hyperosmolar hyperglycemic nonketotic syndrome
HR	Heart Rate
IDDM	Insulin-dependent diabetes mellitus
IDF	International Diabetes Federation
NIDDM	Noninsulin dependent diabetes mellitus
RPE	Rating of perceived exertion
SBP	Systolic Blood Pressure
SPEP	Structured Physical Exercise Program

SPSS	Statistical Package for Social Scientists
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
VO_2max	maximal oxygen uptake capacity
VO_2R	Oxygen Uptake Reserve
WHR	Waist to Hip Ratio
WHO	World Health Organization

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ABSTRACT

Background: Diabetes mellitus and its complications continue to be one of the highest causes of morbidity and premature mortality in recent times. Aerobic exercise is part of lifestyle modification that leads to positive health in general and advised to be used consistently in the management of diabetes mellitus in particular. In this connection, exercise is underutilized in the management of type 2 diabetes mellitus in Ethiopia. Management of diabetes needs continuous monitoring of hemoglobin A1c which indicates how effective glycemic control over a period of 2-3 months is.

Objective: This study was intended to assess the effects of supervised aerobic exercise on glycemic control and body composition in type -2 diabetes patients attending outpatient care unit in *Goba* Referral Hospital, Ethiopia, 2020.

Methods: Thirty physically active adult men, 35-65 years of age with type 2 diabetes mellitus living in *Goba* town were assigned to 12 weeks of supervised aerobic exercise. The subjects were selected using convenient sampling technique. Fasting blood glucose, Hemoglobin A1c, Body mass index, Blood Pressure and Waist to hip ratio were used as the main outcome variables. Epi-data (3.1 version) and SPSS (21 version) were used for data entry and statistical analysis, respectively. The paired sample T-test was used to test if there was a significant change in parameters.

Results: The mean age was 52.89 years, with response rate of 90%. Mean hemoglobin A1c level at twelfth week decreased significantly from baseline (8.7% vs 7.6 % with 12.64% decrease, p =0.013). The interventional exercise reduced body weight (1.54%), body mass index (1.55%) and waist to hip ratio (1.98%) significantly ($p<0.05$). Reduction in fasting blood glucose (12.33%), resting systolic blood pressure (0.31%) and resting diastolic blood pressure (1.43%) were not significant ($p > 0.05$).

Conclusion: A 12 weeks of moderate intensity aerobic exercise improved hemoglobinA1c, body weight, body mass index, Waist circumference and waist to hip ratio significantly, but the reduction in the blood pressure and fasting blood glucose were not statistically significant. So, health professionals should recognize and prescribe individualized exercise.

***Keywords**:* Type 2 diabetes mellitus, Hemoglobin A1c, fasting blood glucose, aerobic exercise and body mass index

1. INTRODUCTION

1.1 Background

Glucose is a simple sugar that gets absorbed from the intestine and distributed by the bloodstream to keep a constant energy supply to all cells in the body (Genet *et al.,* 2019). Glucose homeostasis is maintained by a complex neurohormonal system, which modulates peripheral glucose uptake, hepatic glucose production, and exogenous glucose utilization following food ingestion. This allows the maintenance of plasma glucose concentrations within normal range, with average value of around 90 mg/dl throughout a 24-hour period (Marcovecchio, 2017).

Hormones implicated in glucose regulation include insulin, glucagon, amylin, glucagon-like petide-1 (GLP-1), glucose-dependent insulinotropic peptide, epinephrine, cortisol, and growth hormone. These hormones act on several target tissues, including muscle, liver, adipocyte, and brain to regulate glucose levels (Marcovecchio, 2017).

Insulin, produced by pancreatic β-cells is a key glucoregulatory hormone. Insulin levels are low during the fasting state and high during postprandial phase. Another important hormone regulating glucose metabolism is glucagon. Glucagon is produced by pancreatic α-cells during fasting conditions (Marcovecchio, 2017). A lack of insulin, or the inability of cells to respond to it, leads to hyperglycemia, which is the biochemical indicator of diabetes (IDF, 2019).

The term diabetes mellitus (DM) describes a group of metabolic disorders characterized and identified by the presence of hyperglycemia in the absence of treatment (WHO, 2019). The heterogeneous etiopathology includes impairment of insulin secretion, defective insulin action or both, and disturbances of carbohydrate, fat and protein metabolism (Abebe SM, 2012; Punthakee *et al.,* 2018) The higher prevalence, premature morbidity, mortality, reduced life expectancy and financial and other costs of diabetes make it an important public health problem (Forouhi & Wareham, 2014).

A dysregulation in the mechanisms of glucose homeostasis can cause life-threatening acute or chronic hyperglycemia. Serious acute complications of hyperglycemia include diabetic ketoacidosis (DKA) and hyperosmolar hyperglycemic state (HHS). Both conditions can occur in the context of both type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) (Marcovecchio, 2017). The chronic hyperglycemia of diabetes is associated with microvascular complications that include retinopathy, nephropathy, peripheral and autonomic neuropathy. Besides, patients with diabetes have an increased risk of atherosclerotic cardiovascular, peripheral arterial and cerebrovascular disease (Punthakee *et al.*, 2018).

During chronic hyperglycemia, proteins react spontaneously in blood with glucose to form glycated derivatives. Of these, glycated hemoglobin A fraction or hemoglobin A1c (HbA1c) is the most important serving as a retrospective indicator of the average glucose concentration (Baynest, 2015) . The HbA1c value reflects the mean plasma glucose concentration over the previous 2 to 3 months, high HbA1c (> 6.5%) representing poor glucose control and deterioration in glycemic control (Sigal *et al.*, 2007). However, HbA1c measurement does not give any information about individual daily glucose fluctuations or acute hyperglycemia (Marcovecchio, 2017).

Type 1 diabetes formerly known as Insulin-dependent diabetes (IDDM) encompasses diabetes that is primarily a result of pancreatic β-cells destruction due to an autoimmune process with consequent insulin deficiency (Punthakee *et al.*, 2018). The incidence of T1DM is highest between birth and 14 years old (Forouhi & Wareham, 2014). T1DM represents more than 90% of all cases of diabetes diagnosed during childhood and adolescence (Marcovecchio, 2017) .The distinguishing characteristics of T1DM individuals included a lower body mass index, use of insulin within 12 months of diagnosis, and increased risk of diabetic ketoacidosis (WHO, 2019).

Type-2 diabetes, previously referred to as "non-insulin-dependent diabetes (NIDDM)" or "adult-onset diabetes,"(Genet *et al.*, 2019) may range from predominant insulin resistance with relative insulin deficiency to a secretory defect with insulin resistance (Punthakee *et al.*, 2018). T2DM accounts for 90-95% of all diabetes cases, with highest proportions in low- and middle income countries (WHO, 2019). The body does not use insulin properly leading to higher level of fasting blood glucose, increased plasma insulin level, impaired glycemic control (higher HbA1c) and insulin resistance. Most individuals with T2DM exhibit intra-abdominal (visceral) obesity, which is closely related to the presence of insulin resistance

(Shakil-ur-Rehman *et al.*, 2017). In most cases, the onset of T2DM occurs after 30 years, often between the ages of 40 and 60 years (Genet *et al.*, 2019).

Etiological factors for T1DM mellitus include genetic susceptibility, environmental factors, early social mixing, viral infections, toxins and dietary factors such as exclusive breastfeeding and delayed introduction of cows' milk (Forouhi & Wareham, 2014). The main etiological risk factors for T2DM are age (greater than 30 years), obesity, family history, physical inactivity, dietary risk factors such as red and processed meat and sugar-sweetened beverages (Forouhi & Wareham, 2014).

The two main pathological defects in type 2 diabetes are chronically impaired insulin secretion through a dysfunction of the pancreatic β-cell, and impaired insulin action through insulin resistance (Baynest, 2015). In people with type 2 diabetes, insulin levels are normal or high, but tissues such as liver, skeletal muscle and adipose tissue become resistant to insulin. The pancreas compensates by producing large amounts of insulin, and this overproduction of insulin can eventually fail. This increase in circulating insulin can result in impaired glucose transport into the liver, skeletal muscle, and adipose tissue (Stanford & Goodyear, 2014).

Four diagnostic tests for diabetes are currently recommended, including measurement of fasting blood glucose (FBG) values of ≥ 7.0 mmol/L (126 mg/dl), 2-hour post-load plasma glucose ≥ 11.1 mmol/L (200 mg/dl) , HbA1c ≥ 6.5% (48 mmol/mol); or a random blood glucose ≥ 11.1 mmol/L (200 mg/ dl) in the presence of signs and symptoms are considered to have diabetes (WHO, 2019). The American Diabetes Association (ADA) guidelines recommend that the HbgA1c goal for patients with DM should be less than 7% (Hickson *et al.*, 2014).

The goal of treatment in T2DM is to achieve and maintain optimal blood glucose, lipid, and blood pressure (BP) levels to relieve the symptoms of the disease and prevent or delay chronic complications of diabetes (ADA, 2019). According to the World Health Organization (WHO) recommendation, the first-line treatments of T2DM includes diet, physical activity, and weight loss prior to or in parallel with the initiation of pharmacological therapy (Johansen *et al.*, 2017; Wang *et al.*, 2018).

The role of aerobic exercise in improving glycemic control among T2DM patients in Ethiopia particularly in the study area is low (Debalkie, *et al.*, 2018). Therefore, the current study was intended to assess the effects of aerobic training on glycemic control and body composition in patients with T2DM attending outpatient care unit in *Goba* Referral Hospital.

1.2 Statement of the problem

Diabetes is found in every population in the world and all regions, including rural parts of low- and middle-income countries. The number of people with diabetes is steadily rising, with WHO estimating about 422 million adults with diabetes worldwide in 2014. The age-adjusted prevalence in adults rose from 4.7% in 1980 to 8.5% in 2014, with the greatest rise in low- and middle-income countries compared to high-income countries (WHO, 2019).

In addition, the International Diabetes Federation (IDF) estimated 463.0 million adults aged 20–79 years worldwide (9.3% of all adults in this age group) had diabetes in 2019. It is estimated that 79.4% live in low- and middle-income countries. Based on the 2019 estimation, by 2030 a projected 578.4 million, and by 2045, 700.2 million adults aged 20–79 years, will be living with diabetes (IDF, 2019).

In 2019, the IDF also estimated that, in the Africa region, 19 million adults aged 20–79 years had diabetes, representing a prevalence of 3.9%. This region has also the highest proportion of previously undiagnosed diabetes; over half (59.7%) of diabetes are unaware of their disease condition (Nardos Abebe, 2016).

Currently, Ethiopia has been challenged by the growing magnitude of non-communicable diseases such as diabetes. Ethiopia is among the top four countries with the highest adult diabetic populations in sub-Saharan Africa (Nardos Abebe, 2016). No population-based prevalence study exists in Ethiopia, but from hospital-based studies, it is reported that the prevalence of diabetes admission has increased from 1.9% in 1970 to 9.5% in 1999 of all medical admissions. WHO estimated the number of diabetes in Ethiopia about 800,000 cases by the year 2000, and the number is expected to increase to 1.8 million by 2030 (Fikre Enquselassie, 2006). On other hand, IDF reported 1.7 million cases and 2.3% prevalence of diabetes by 2019 (IDF, 2019).

The effects of diabetes extend beyond the individual to affect their families and whole society. It has broad socio-economic consequences and threatens national productivity and economy, especially in low- and middle-income countries where diabetes is often accompanied by other diseases (WHO, 2019).

Globally, approximately 4.2 million adults aged 20–79 years are estimated to die as a result of diabetes and its complications in 2019. This is equivalent to one death every eight seconds. Diabetes is estimated to be associated with 11.3% of deaths from all causes among people in this age group. Almost half (46.2%) of the deaths associated with diabetes among the 20–79 years age group are in people under the age of 60 years – the working-age group (IDF, 2019).

The rise in expenditure has been considerable, growing from USD 232 billion spent worldwide in 2007, to USD 727 billion in 2017 for adults aged 20–79 years. In 2019, IDF estimates that total diabetes-related health expenditure reached USD 760 billion. This represents a 4.5% increase in the 2017 estimate. The economic impact of diabetes is expected to continue to grow. It is projected that expenditure will reach USD 825 billion by 2030 and 845 billion USD in 2045. This represents an increase of 8.6% and 11.2%, respectively (IDF, 2019).

Though the primary goal of treatment of diabetes is decreasing the level of glycated hemoglobin, failure to achieve this goal is a major healthcare concern. Healthcare providers fail to adequately educate patients on how to implement behavioral modifications needed for successful management of the disease progress (Hickson *et al.*, 2014).

T2DM, with an increasing rate of prevalence in recent decades, has caused many health and socioeconomic problems throughout the world. Due to its various consequences and disabilities, T2DM has been known as a disabling disease, as well. Therefore, strategies for reducing the healthcare costs associated with the disease should be emphasized (Najafipour *et al.,* 2017).

Exercise, as one of the strategies, is found to have significant effects on the metabolism of nutrients. (Najafipour *et al.,* 2017). Exercise is widely prescribed in developed countries as a lifestyle intervention to control glucose and BP in type 2 diabetic patients. This is mainly because of their relatively sedentary lifestyle and availability of the facility and informed awareness (Hickson *et al.*, 2014). On the other hand, physical activity is assumed to be inherent in developing countries like Ethiopia and seldom prescribed to patients with T2DM (Yan *et al.*, 2014) .Therefore, little is known if a structured exercise program added to an already active lifestyle would affect glucose control, BP and associated parameters in this particular population with type 2 diabetes.

1.3 Significance of the Study

Varieties of medications are found to be effective in controlling blood glucose level in patients with T2DM. However, this approach is also associated with potential adverse drug interactions, scarcity, discomforts, increased economic costs and decreased quality of life. Therefore, change of lifestyle is an alternative strategy in glycemic control in diabetic patients. It also reduces drug doses.

The findings of this study may help health professionals to consider aerobic exercise in their management plan of treating T2DM. In addition, it may also help to provide basic and possible recommendations to concerned parties that work on DM such Ethiopian diabetes association to consider alternative lifestyle interventions and incorporate them in their guideline as part of treatment of T2DM.

This study has the benefit of creating possible awareness for patients with T2DM on the impact of supervised aerobic exercise on blood glucose level especially concerning HbA1c.

It may also serve as an input for further research in the wider range at a country level.

2. LITERATURE REVIEW

2.1 Exercise prescriptions in the Management of T2DM

Exercise is a useful option to treat and prevent T2DM. Exercise stimulates metabolism, promotes glucose uptake and increases insulin sensitivity. Exercise also improves body composition, contributes to a blood glucose reduction, long-term prevention of cardiovascular diseases and improved psychological well-being (Chiang *et al.*, 2019; Hickson *et al.,* 2014; Wang *et al.*, 2018)). ADA and other related associations have all strongly recommended a therapeutic and preventative ability of exercise. ADA recommends at least 150 min/week of moderate-intensity or at least 90 min/week of vigorous aerobic exercise (Yavari & Ahmed Hajiyev, 2012).

Depending on the overall effect on the human body Physical exercises can be generally grouped into two types: aerobic and anaerobic exercises (Elmagd, 2016). Aerobic (endurance) exercise is a form of physical exercise that involves repetitive, rhythmic contraction of large muscle groups. It depends predominantly on oxidative energy sources to improve cardiovascular endurance and produce adenosine triphosphate (ATP) through qualitative changes in skeletal muscle (Yavari & Ahmed Hajiyev, 2012). Resistance exercise on the other hand causes muscles to contract against an external resistance to increase muscle strength and muscle mass (through quantitative changes) (Wang *et al.*, 2018).

Aerobic training increases mitochondrial density, insulin sensitivity, oxidative enzymes, compliance and reactivity of blood vessels, lung function, immune function, and cardiac output (Garber *et al.*, 2011). Acutely, aerobic exercise increases muscle glucose uptake up to fivefold through insulin-independent mechanisms. After exercise, glucose uptake remains elevated by insulin-independent (2 hour) and insulin-dependent (up to 48 hours) mechanisms in prolonged exercise (Colberg *et al.,* 2016). Regular exercise increases muscle capillary density, oxidative capacity, lipid metabolism, and insulin signaling proteins, which are all reversible with detraining (Roberts *et al.,* 2014).

The Frequency, Intensity, Type and Time (FITT) principle of exercise treatment developed by the American College of Sports Medicine (ACSM) for healthy adults generally applies to individuals with DM (Table 1). Participating in a comprehensive exercise program confers benefits that are extremely important to individuals with T1DM and T2DM (ACSM, 2018).

Methods for quantifying the intensity of physical activity include specifying a percentage of oxygen uptake reserve (VO_2R) and rated perceived exertion (RPE). The RPE is a scale that could be used to guide/monitor exercise intensity if maximum heart rate (HR) is unknown or there is variability in HR. Moderate (40%–59% heart rate reserve (HRR) or VO_2R) to vigorous (60%–89% HRR or VO_2R) intensity aerobic exercise is recommended for adults (ACSM, 2018).

Table 1: FITT Recommendations of Aerobic Exercise for Individuals with T2DM

Frequency	3-7 days/week
Intensity	Moderate (40%-59% VO_2 R or 11-12 RPE rating) to Vigorous (60%-89%% VO_2 R or 14-17 RPE rating)
Time	150min /week at a moderately vigorous intensity
Type	Prolonged, rhythmic activities using large muscles groups (walking, cycling, swimming)

Exercise is widely prescribed in developed countries as a lifestyle intervention. Because of lack of awareness and inherent daily physical activity in developing countries, exercise is a rarely prescribed and used interventional method in the management of type 2 diabetes mellitus (Yan *et al.*, 2014).

Different studies conducted to assess level of physical activity in Ethiopia revealed that exercise is also underutilized in the management of type 2 diabetes. A study conducted in Wolaita reported that level of regular physical exercise practice among adult diabetic patients was found to be insufficient (Doda, 2017). This study found that only 18.4% of diabetic patients practiced physical exercise regularly. Similarly, study conducted in Jimma also stated that only 31.7 % of the DM patients had general knowledge about physical activity. They found that Only 11.9% practiced the recommended level of physical activity (Tamirat *et al.,* 2014). Specifically, in T2DM patients the practice of physical activity was reported to be only 34.3% (Debalkie *et al.*, 2018) .

2.2 Effects of Aerobic Exercise versus Resistant Exercise on glycemic control

Both aerobic and resistance trainings are recommended for the beneficial effects on glucose control. In addition, aerobic exercise retards the progression of other comorbidities common in patients with diabetes and cardiovascular diseases (Hickson *et al.*, 2014). Comparatively, aerobic training leads to a much faster effect in lowering HbA1c levels and the combination of the 2 forms of exercise was superior to either type of exercise alone. Exercise induced improvements in glycemic control were greater among people with higher baseline hemoglobin HbA1c values (Sigal *et al.*, 2007; Yavari & Ahmed Hajiyev, 2012).

Aerobic exercise is more efficient than resistance training in improving body composition as weight loss and energy expenditure are interrelated (Matinhomaee *et al.*, 2012). A systematic review and meta-analysis of 12 clinical trials comparing resistance exercise and aerobic exercise in T2DM patients reported that aerobic exercise is associated with greater body mass index BMI and HbA1c reduction and better physical fitness than resistance exercise (Yang *et al.*, 2014).

On the contrary, ACSM states the lack of evidence showing resistance exercise differs from aerobic exercise in their impact on cardiovascular risk markers or safety in individuals with T2DM (Yang *et al.*, 2014). Therefore, selecting one modality or the other may be less important than engaging in any form of physical activity. ACSM recommends a combination of aerobic and resistance protocols to improve blood glucose control (ACSM, 2018).

2.3 Effects of Aerobic Exercise on Glycated Hemoglobin

Decreasing HbA1c is a primary diabetes treatment goal (Hickson *et al.*, 2014). Studies reported a 40% reduction in the HbA1c concentration in the combined aerobic and resistance exercise group compared with the non-exercise group (Wang *et al.*, 2018). Besides, patients would have more adherence to continue these activities by themselves after the period of study even as walking, because such activities are not dependent on equipment and knowledge of exercise techniques (Yavari & Ahmed Hajiyev, 2012).

HbA1c is considered as gold standard for monitoring glycemic control and may serve as an indicator of diabetes related diseases. Epidemiological analyses have indicated that a 1% reduction in the HbA1c value is associated with a 14% reduction in myocardial infarction

(MI) and a 21% reduction in diabetes related death and 37% reduction in microvascular complications (Sigal *et al.*, 2007). For every 1% reduction in the results of the HbA1c blood test, the risk of developing eye, kidney, and nerve disease is reduced by 40 percent while the risk of heart attack is reduced by 14 % (Hickson *et al.*, 2014). Furthermore, establishing glucose control at or below 7% can reduce the long term complications of the disease up to 76% (Najafipour *et al.*, 2017).

A randomized controlled trial conducted among 65 Iranian indicated that an aerobic exercise program leads to a significant reduction of HbA1c value. The primary outcome of their study indicated that a 16-weeks aerobic exercise induced an apparent reduction in HbA1c value and an improvement in the glycemic control of T2DM patients (Yavari & Ahmed Hajiyev, 2012). Another 8 years trial done among 65 Iranian revealed that the level of HbA1c among T2DM subjects was decreased by 0.73% and 1.84% after 16 weeks post-intervention and 8 years after initiation of intervention follow-up, respectively. Their study revealed the direct relationship between long-term regular physical activity and the level of HbA1c (Najafipour *et al.*, 2017).

The supervised aerobic exercise conducted among 41 T2DM male east African males reported that following a 12-week aerobic program, HbA1c level was significantly reduced by 1.1% . The study, however , reported no significant change in BMI after the program (Yan *et al.*, 2014).

A 26-weeks, single-center, randomized, controlled trial with a parallel-group design done in USA on 251 subjects using both aerobic and anaerobic protocols. The study revealed that aerobic training and resistance training alone each led to improvements in glycemic control, and combined aerobic and resistance training had effects that were greater than those of either method alone. These effects were more powerful among individuals with poor glycemic control at baseline (Sigal *et al.*, 2007).

A systematic review and meta-analysis of 47 randomized controlled clinical trials assessing associations of structured exercise training regimens and physical activity advice on change in HbA1c in T2DM patients, indicated that structured exercise training was associated with a decline in HbA1c level (-0.67%) compared with control participants (Shakil-ur-Rehman *et al.*, 2017).

2.4 Effects of Exercise on Glucose Control and Blood Pressure

A study conducted in 41, T2DM East African male patients showed that a 12 weeks of supervised aerobic exercise reduced mean Systolic blood pressure (SBP) by 2 mmHg (Yan *et al.,* 2014). It has been estimated that a 2 -mmHg reduction of SBP results in a 6% reduction in stroke mortality and a 4% reduction in mortality attributable to coronary heart disease. Mean diastolic blood pressure (DBP) was decreased in the experimental group by 3mmHg. Small decrements in DBP, 3mmHg, reduced the risk of stroke by 25% and the risk of coronary artery disease by 9% (Yan *et al.,* 2014).

Randomized controlled trial conducted among 51 T2DM patients in Pakistan showed that patients in the experimental group who were exercising three times a week for 25 weeks produced significant improvements in FBG. Their supervised structured aerobic exercise program with routine medication and dietary plan, improved insulin resistance as compared with patients in control group treated for the same duration of time with routine medication and dietary plan (Sigal *et al.,* 2007). Another randomized controlled trial conducted among twenty-one obese males with T2DM in USA showed that 10 weeks of aerobic training with moderate intensity significantly reduced FBG in obese men with T2DM (Matinhomaee *et al.,* 2012). Another 16 weeks pretest posttest interventional study conducted in China among 49 subjects with type 2 diabetes also revealed that the program has significantly decreased FBG (Jiang *et al.,* 2020).

2.5 Effects of Exercise on Body Composition

According to a trial done in Iran on 65 patients with T2DM aged 33–69 years old with a pretest-posttest design, after 8 years of regular exercise training, the experimental group revealed significant improvement in BMI. There was a linear decrease in BMI during the first 6 years and an increase in the remaining 2 years of follow-up. In contrast, among the patients in the control group, a slightly constant increasing pattern was observed in the level of BMI during the 8 years of follow-up (Najafipour *et al.,* 2017).

A systematic review of 12 randomized controlled trials in China reported that aerobic exercise may be associated with greater BMI reduction and better physical fitness than resistance exercise. Resistance exercise is claimed to mainly increase the size and strength of muscles, while aerobic exercises force the body to burn the stored fat for energy (Yang *et al.,* 2014). Aerobic exercise may also enhance the strength of respiratory muscles and thus facilitate the body's utilization of oxygen (Plowman SA, 2007). Additionally, the heart muscles may be strengthened and enlarged during aerobic exercise to improve the pumping efficiency and reduce the resting heart rate (Yang *et al.,* 2014).

Supervised exercise training follows up study conducted in Australia on 25 subjects reported that though body weight and BMI did not change following exercise training, a significant decrease in waist-hip ratio and body fat was found in the exercise group. The control subjects experienced little increase in both measurements after the study period. The study suggested that their exercise program was an effective treatment to reduce abdominal obesity in elderly patients with a long history of T2DM (Tan *et al.,* 2012).

2.6 Factors That Can Influence Blood Glucose Levels in Patients with T2DM

In patients with T2DM, a variety of factors can influence blood glucose levels. These include exercise (frequency, intensity, time, mode and duration), dietary patterns, and individuals' clinical characteristics, for example, age, gender, maximal oxygen uptake capacity (VO_2max), baseline metabolic control, obesity and duration of diagnosed T2DM (Hickson, *et al.,* 2014).

2.6.1 Exercise

Exercise metabolism relies on several factors, but the most important are the intensity and duration of physical activity (Khan, 2013). Way and colleagues found that regardless of exercise intensity, the effect of exercise on insulin sensitivity persisted for 2 to 3 days. The duration of exercise may also be a crucial factor contributing to the improvement in insulin sensitivity. In another study, regular, moderately-high intensity exercise training for at least 12 weeks resulted in greater metabolic improvement compared to lower-intensity exercise (Hickson *et al.,* 2014).

Both carbohydrate and fat are the principal substrates for energy production during exercise (Spriet, 2014). The relative utilization of fat and carbohydrate during exercise can vary enormously and depends on exercise intensity (Luc J. C. van Loon *et al.,* 2001). The metabolic pathways that oxidize both fat and carbohydrate must be activated simultaneously to meet the energy demand during exercise. However, at a given exercise intensity and metabolic demand, there can be reciprocal shifts in the proportions of carbohydrate and fat that are oxidized. There is downregulation of fat metabolism when carbohydrate availability is increased and when moving from moderate to intense aerobic exercise (Spriet, 2014).

Plasma free fatty acids (FFAs) provide the majority of the substrate oxidized by skeletal muscle during low intensity (25% VO_2max) exercise (Luc J. C. van Loon et al., 2001). When exercise increases to a moderate level of intensity (60–70% VO_2max), plasma FFA and intramuscular triglyceride provides half of the energy demand. The rest half of the total energy is derived from oxidation of carbohydrates, both muscle glycogen and blood glucose (Mul *et al.*, 2016). During high-intensity exercise (85 % VO_2max) (Luc J. C. van Loon *et al.*, 2001), the contribution of plasma FFA oxidation declines and carbohydrate (glycogen) oxidation provides roughly two-thirds of the total energy need (Mul *et al.*, 2016). Carbohydrate metabolism is the preferred source of fuel during high intensity exercise because its' rate of ATP production is two times higher than fatty acids (Mul *et al.*, 2016).

Regarding duration , during the first 5-10 minutes of exercise, muscle glycogen is the main source of energy. With advancing exercises, muscle glycogen is depleted and glucose comes from hepatic glycogen initially and hepatic gluconeogenesis subsequently. Further continuation of exercise for more hours will cause depletion of glucose and non-esterified fatty acid becomes the major fuel (Khan, 2013).

2.6.2 Glycemic Control at High Altitude

A review by Mol *et al.* (2014) indicated that glucose regulation is affected by altitude exposure in subjects with and without diabetes (Mol *et al.*, 2014). Koufakis *et al.* (2018) reported that exposure to high altitude activates several complex and adaptive mechanisms aiming to protect human homeostasis from extreme environmental conditions, such as hypoxia and low temperatures (Koufakis *et al.*, 2018).

The effects of high altitude on FBG concentrations is dependent on the duration of exposure (Koufakis *et al.*, 2018). In a case of acute hypoxia, a state of relative hyperglycemia is induced (Mol *et al.*, 2014). Short-term exposure (2-3 days) increase in FBG is mainly triggered by the activation of the sympathetic nervous system and the increased secretion of stress hormones, mainly catecholamines and cortisol (Koufakis *et al.*, 2018).

The long-term exposure results in lower blood glucose, mediated by improved insulin sensitivity and augmented peripheral glucose disposal. Decreased hepatic and peripheral insulin resistance is a central physiological adaptation following long-term high-altitude exposure (Koufakis *et al.*, 2018). But, after prolonged altitude exposure (acclimatization), FBG seem to decrease due to subsequent increase in glucose disposal during a prolonged (weeks) stay at altitude (Mol *et al.,* 2014). The greatest reduction in blood glucose levels was observed when hypoxia was combined with exercise (Koufakis *et al.*, 2018).

A study by Chen *et al.* (2013) revealed that insulin resistance and glucose tolerance were significantly improved in people with metabolic syndrome at high altitude. This could possibly be due to the fact that hypoxia increases glucose uptake in skeletal muscle that may also influence the whole-body glucose tolerance and insulin sensitivity (Chen *et al.,* 2013). Insulin sensitivity was found to be increased due to increased concentration of adiponectin at high altitude compared with sea level (Koufakis *et al.,* 2018). Along with blood glucose improvements, a significant reduction in waist-to-hip ratio, with a small increase in lean body mass was observed (Chen *et al.,* 2013).

2.7 Conceptual Framework of Glycemic Control

The conceptual framework explores the relationships between the variables that influence the glycemic control among T2DM patients. These variables can be grouped into three categories: socio-demographic characteristics, lifestyle characteristics and socio-economic factors.

The model provides five key interrelated components and includes socio-demographic characteristics, lifestyle characteristics, socio-economic characteristics, blood glucose level control and health outcomes. This model postulates that socio-demographic characteristics, lifestyle characteristics and socio-economic characteristics impact glycemic control. These factors together then predict the health outcomes of T2DM patients (Figure 1).

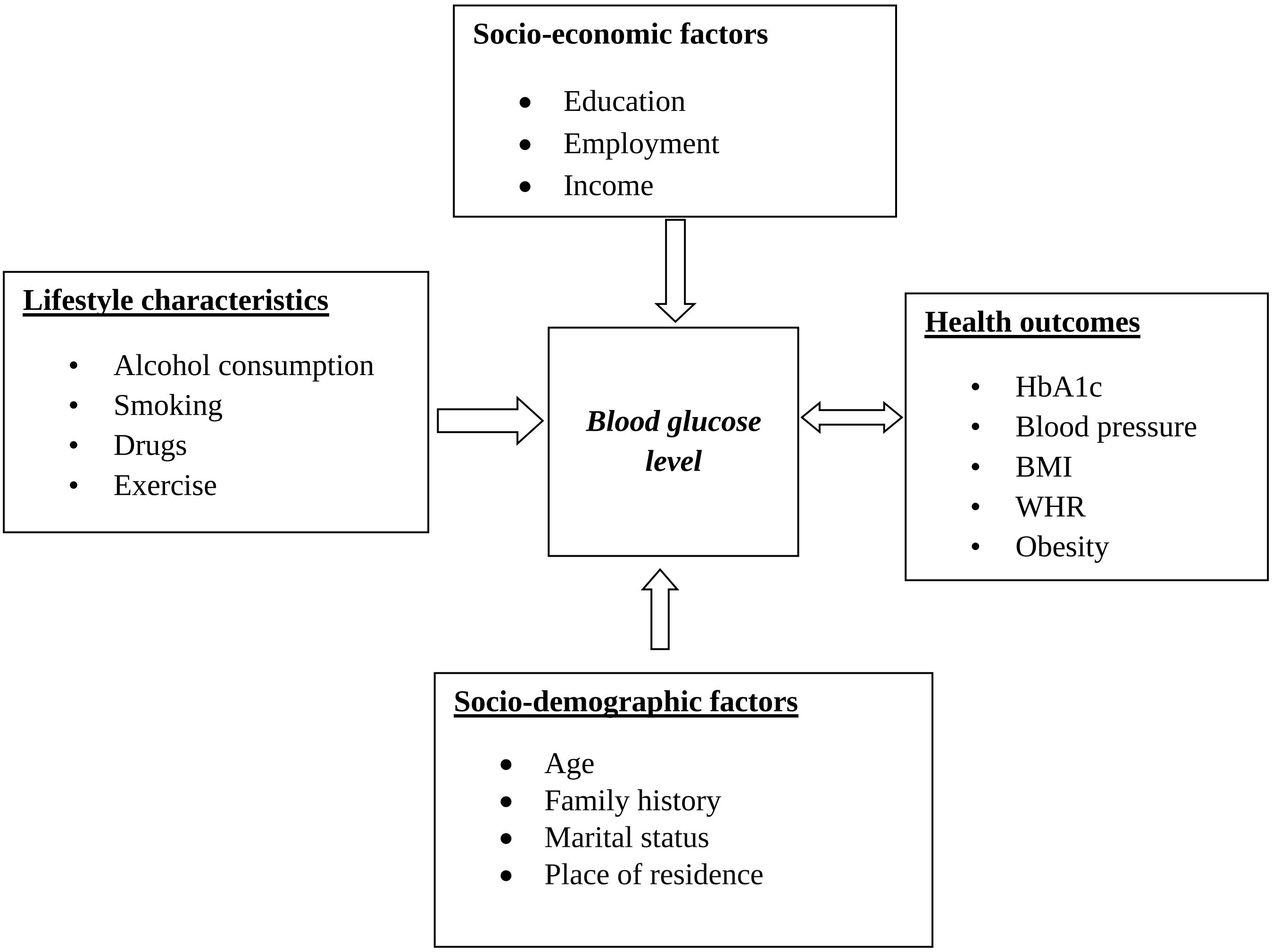

Figure 1: Conceptual Framework of the Study

2.8 Hypotheses

A 12 weeks supervised aerobic exercise:

- Would improve glycated hemoglobin
- Would affect body composition

3. OBJECTIVES

3.1 General Objective

To investigate the effects of aerobic training on glycemic control and body composition in patients with type-2 diabetes mellitus attending outpatient care unit in *Goba* Referral Hospital.

3.2 Specific Objectives

- To evaluate the efficiency of current management of glycemic control plan
- To assess the effect of aerobic exercise on HbA1c and FBG level.
- To determine the effects of aerobic exercise on BMI and WHR.

4. MATERIALS AND METHODS

4.1 Study Area and period

The study was conducted in *Goba* town, Bale zone, Oromia regional state. *Goba* town is a separate woreda/district located in the southeast part of Ethiopia located 445 km away from Addis Ababa and 12 km from Robe Town, capital of Bale Zone. It is one of the eighteen districts of Bale zone. The town has latitude and longitude of 7.0116° N, 39.9761° E, respectively and an elevation of 2,743 meters above sea level. Currently, the district has two *kebeles* with total population of approximately 51,652 of whom 25,309 are males and 26,343 are females.

Goba Referral Hospital is one of the 4 functional hospitals in Bale zone serving approximately 100,000 people. Currently, there are around 600 DM patients on follow up care at *Goba* Referral Hospital. The Hospital has a separate chronic follow up unit for diabetes and other chronic diseases. The study was conducted from November, 2019 to August, 2020.

4.2 Study Design

One group pre-test post-test prospective follow-up interventional study was used to assess the glycemic control. The quantitative research method was conducted to assess the effects of supervised aerobic exercise on glycemic control and body composition in T2DM patients attending outpatient care at *Goba* Referral Hospital.

4.3 Source Population

All diabetic patients coming to the diabetic center of *Goba* Referral Hospital for regular follow up.

4.4 Study Population

All T2DM male patients attending follow up care at the diabetic center of *Goba* Referral Hospital who were willing to participate in the study and gave informed consent during the study period.

4.5 Eligibility Criteria

4.5.1 Inclusion Criteria

All T2DM male patients aged 35 to 65 years and attending follow up care at the diabetic center of *Goba* Referral Hospital from February 3-15, 2020.

4.5.2 Exclusion Criteria

- Patients who were not willing to participate in the study and unable to give informed consent
- Patients with any diabetic complications
- Mentally and chronically ill patients.
- Individuals who were on fasting
- Patients with respiratory and cardiovascular diseases

4.6 Sample Size Determination

The sample size was determined using the G power software Statistical Power Analyses for Windows and Mac, (3.1.2.9 version).The following assumptions were considered; Significance level = 95%, Power = 80%, Type of test = one-sided paired T-test, Z $\alpha/2$=the critical value at 95% (α= 0.05) and effect size =0.5(medium), the software gave the sample size of 27 subjects. Considering 10% non-respondent rate, the total sample size was determined to be 30 subjects.

4.7 Sampling Technique

Thirty subjects were selected from T2DM patients attending follow up care at *Goba* Referral Hospital using convenience sampling method. Patients who fulfilled the eligibility criteria were invited to take part in the study. Following explanation on the purpose and procedures of the study, those who were volunteered had given consent both in written and oral forms. Then, the subjects were assigned to 12 weeks intervention follow up study of aerobic exercise.

4.8 Variables of the Study

4.8.1 Dependent Variables

- HbA1c
- FBG
- BMI
- Waist to hip ratio
- Blood pressure

4.8.2 Independent Variables

Intervention variables: supervised aerobic exercise.

Other independent variables: age, marital status, level of education, occupational status, family history of DM, history of hypertension, place of residence, income, exercise history, smoking and alcohol consumption.

4.9 Data collection tools and test procedure

4.9.1 Data collection tools and materials

4.9.1.1 Tools

- Structured Questionnaire that contains information on the socio-demographic factors, behavioural measurements (WHO STEPS instrument) and Global Physical Activity Questionnaire (GPAQ).
- Physical Measurements
- Biochemical Measurements

4.9.1.2 Instruments

- Glucometer Blood glucose monitor (DIAVUE prudential), Test strips, Alcohol swab, Single-use safety lancets or lancing device, Gloves, Cotton wool/gauze, Sharps box, Control solution for calibration
- HbA1c analyzer (FINECARE) with its full sets of equipment and reagents
- Portable weighing scale
- Portable height/length measuring board
- Sphygmomanometer (Riester) and stethoscope

4.9.2 Data collection procedures

4.9.2.1 Exercise Intervention Protocol

Structured physical exercise program (SPEP) was employed. Subjects were given orientation about the program, including its benefits, risks and recommendations to be followed. The aerobic training program involved three sessions per week, 40-60 min per session for 12 weeks. It's held at *Goba* stadium organized by trained professional trainer. Each session of SPEP included three phases:

Phase 1: Ten min warm-up which involved majority of skeletal muscle with stretches and joint movement. This allows the body to adjust to changes during main exercise.

Phase 2: The main Exercise protocol lasting 25-45 min involving walking or running with intensity of 60-70% of maximum HR. The exercise duration was increased gradually: 20-25 min in week 1; 30-35 min in weeks 2-5, and 45 min in weeks 6-12.

Phase 3: Finally, 5 min cool down period comprised of slow walking. This allows for a gradual recovery of heart rate and blood pressure and removal of metabolic end products.

At the beginning of the program, intensity of the physical exercise was kept at 60% of the maximum HR (max HR) predicted for the age (220 b/min – age in years) and was increased gradually until reaching the 70% of maximum HR target.

Besides the SPEP, subjects were advised to engage in daily life and home environment related activities such as walking, cycling, farming, gardening, washing clothes, cleaning, cooking etc. Throughout the study, all subjects were advised to adhere to their routine diet and medication as prescribed by their physicians.

4.9.2.2 Anthropometric measurements

Body Mass Index

Body weight was measured to the nearest 0.1 kg using a calibrated scale, with subjects wearing light clothing and no shoes. Height was measured to the nearest 0.5 cm using a stadiometer, with subjects barefooted. BMI (kg/m^2) was calculated dividing the individual's weight in Kg by the square of height in meters and compared with the standard.

Waist to Hip Ratio

Waist circumference was measured with a measuring tape placed around the smallest perimeter of the abdominal area with the patient standing and after normal expiration. Hip circumference was measured by positioning the measuring tape around the maximum circumference of the buttocks and reading the measurement to the nearest 0.1 cm. The waist to hip ratio (WHR) was calculated and compared with the standard.

4.9.2.3 Measurements of Biochemical parameters

Fasting Blood Glucose and Hemoglobin A1c Measurements

HbA1c measurements were made in duplicate at baseline and at the end of the 12 weeks moderate intensity aerobic exercise) using 'FINECARE' HbA1c analyzer.

The FINECARE Reader uses the fluorescence immunodetection method. The test is determined on a parameter-specific cartridge. The high-performance portable immunoassay system consists of the laser fluorescence reader FINECARE™, as well as the test cassette adapted to the respective parameter with the corresponding reagent. This allows the quantification of single or multiple analytes at the same time by measuring laser induced epifluorescence.

Figure 2 : Portable Laser-Fluorescence Reader "FINECARE"

When mixing detector buffer with the patient sample, the fluorescent anti-analyte antibodies in the buffer bind to the HbA1c present in the sample. Due to the capillary action, the mixture passes through the nitrocellulose reaction strip matrix and circulating antibody complexes are captured by the HbA1c antibody immobilized on the test strip. The greater the concentration of the HbA1c in the sample, the more complex they become and accumulate in the reaction strip.

FBG was measured using simple glucometer (DIAVUE prudential). The same glucometer was used throughout the study to keep consistency of the records. The FBG was checked every two weeks between baseline (week 0) and the end of the 12^{th} week. FBG was measured after a period of 8-12 hours of fasting. The measured values of FBG and HbA1c were compared with baseline.

Blood Pressure Measurements

Blood pressure was measured two times on the left arm, after keeping participants in a sitting position for 10 minutes with his/her legs uncrossed. The measurements were done by placing the left arm of the participant on the table with the palm facing upward and removing or rolling up clothing on the arm. The cuff was positioned above the elbow at the level of the heart so that the lower band was positioned 1-2 cm above the elbow joint and the readings were recorded. The two blood pressure measurements were taken with three minutes gap between each of the readings. The participants were told not to have coffee before or during the measurements. The measured values at baseline were compared with values at the end of the intervention.

4.9.3 Physical activity Level

The level of physical activity was assessed using the Global Physical Activity questionnaire developed by WHO.

4.10 Data Quality Assurance

The questionnaire was prepared in the English version and translated into Afan Oromo and/or Amharic versions and back to the English version. The questionnaire was pretested at Robe General Hospital on 10% of the total sample size to minimize the ambiguity of words and check applicability of the language to the local context. The subjects participated in the pretest were not included in the actual data collection due to the distance from the facility for the exercise protocol. Additional adjustments were made on the questionnaire based on the results obtained from the pre-test and the final version was administered in the main study.

Eight data collectors and two supervisors were recruited for data collection and supervision. One day training was given for data collectors and supervisors on the methods of extracting the pertinent data through the questionnaire and laboratory measurements. The procedure of filling the information on a checklist and the ethical aspect of keeping the confidentiality of subjects' information were another focus area of the training. Close supervision was provided during data collection and the questionnaire was checked daily for consistency and completeness by data collectors and supervisors. Finally, the completeness of the questionnaire was checked before entering data into the computer software program and before analysis and interpretation.

4.11 Data Analysis

G power software Statistical Power Analyses for Windows and Mac, (3.1.2.9 version) was used to calculate the sample size of the study. Epi-data (3.1 version) was used for data entry and the data were exported to SPSS. SPSS (version 21) was used for conducting the statistical analyses. First, descriptive analysis was performed to describe the sociodemographic, anthropometric and glycemic control parameters of the participants. The paired sample T-test was used to test if there was a significant difference between pretest and posttest blood glucose level, HbA1c and other values.

A p-value of <0.05 at 95% confidence level was used as a difference of statistical significance. Finally, results were compiled and presented using tables, figures and texts.

4.12 Ethical Consideration

The research was started after ethical clearance was obtained from the research and ethics committee of the department of Physiology, Addis Ababa University. Both verbal and written consents were obtained from the study subjects after explaining the objectives and procedures of the study. Subjects' right to refuse to participate in the study at any time was assured. For this very purpose, a one-page consent letter was attached to the cover page of each questionnaire stating the objectives of the study. Privacy and confidentiality were maintained.

Forty percent (40 %) glucose or sugar was kept around the exercise ground to be used in case of hypoglycemia/fainting. Medical personnel, including myself were always standby during the exercise session. For subjects who were unable to fit into the exercise program and need support, feedback was given to their follow up unit. Sample collection was performed by trained health professionals following ethical steps and procedures.

4.13 Dissemination of the Result

The findings of this study will be presented to Department of Medical Physiology, School of Medicine, College of Health Sciences, Addis Ababa University. The findings will be disseminated to *Madda Walabu* University, *Goba* Referral Hospital, Regional Health Bureau, Federal Ministry of Health, local institutions and other concerned bodies. The findings of this study will also be published in a peer-reviewed scientific journal.

4.14 Operational Definitions

- **Physical activity -**‘‘physical activity’’ (defined as ‘‘bodily movement produced by the contraction of skeletal muscle that substantially increases energy expenditure’’) is used interchangeably with ‘‘exercise,’’ which is defined as ‘‘a subset of PA done with the intention of developing physical fitness (i.e., cardiovascular, strength, and flexibility training).’’
- **Aerobic exercise –** walking or running with intensity of 60-70% of maximum heart rate.
- **Diabetes mellitus -** a metabolic disease characterized by high blood sugar level (Fasting blood glucose ≥126mg/dl or 2-houres postprandial ≥200mg/dl) over a prolonged period.
- **Family history of DM –** clients regarded as positive if either of parents, sister, or brother (s) have diabetes mellitus.
- **Fasting blood glucose -** blood glucose measured after no caloric intake for at least 8 hours.
- **Hyperglycemia-** high blood sugar, blood glucose level greater than 7.0 mmol/l (>115 mg/dl) when fasting and blood glucose level greater than11.0 mmol/l (>200 mg/dl) 2 hours after meals.
- **Hypoglycemia-** refers to low blood glucose levels that drop below <4mmol/l (<70 mg/dl)
- **Body Composition –** anthropometric measurements such as body mass index and waist to hip ratio.

5. RESULTS

5.1 Socio-Demographic Characteristics of the study subjects

Of the total 30 T2DM patients recruited for the interventional study, 27 had completed both the questionnaire and full sessions of the exercise protocol making the response rate of 90.0%.

Among study subjects completed the exercise protocol, majority of the study subjects (81.5%) were urban dwellers and less than quarter (18.5 %) were rural dwellers . All subjects were married (n=27), and most of them (96.3%) had attended some level of formal education. Regarding occupational status, 37% of the study subjects were pensioners. Nearly half (51.9%) of the subjects earn $\leq$ 2000 ETB per month. Only 14.8% and almost half (51.9%) of the study subjects have family history of DM and hypertension respectively (Table 2).

Table 2 : Socio-demographic Characteristics of Study Subjects (n=27).

Variables		**Frequency**	**Percentage**
Education status	No formal education	1	3.7
	Primary	11	40.7
	Secondary and diploma	10	37.0
	First degree and above	5	18.5
Residence	Rural	5	18.5
	Urban	22	81.5
Marital status	Married	27	100.0
Occupation	Government employee	7	25.9
	Self-employee	5	18.5
	Pensioner	10	37.0
	Farmer	5	18.5
Monthly income	$\leq$ 2000	14	51.9
	2000-3000	4	14.8
	3000-4000	4	14.8
	>4000	5	18.5
Family history of DM	Yes	4	14.8
	No	23	85.2
Family history of Hypertension	Yes	14	51.9
	No	13	48.1

Most of the patients (40.7%) lived with the disease for about 1 – 5 years since diagnosis and about 11.1% lived with DM for less than 1 year (Figure 3).

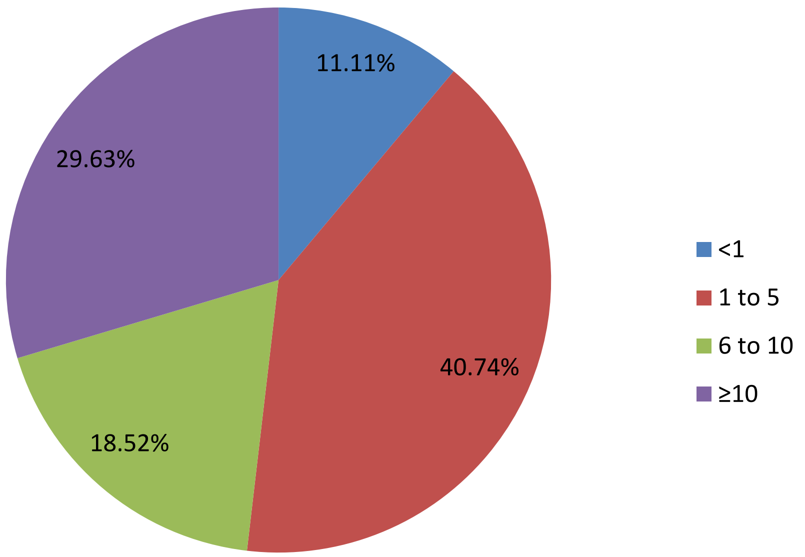

Figure 3: Duration of DM (years)

The mean age of the study subjects in year was 52.89 ± 10.44 and most of the subjects were in year greater or equal to 55 (Figure 4).

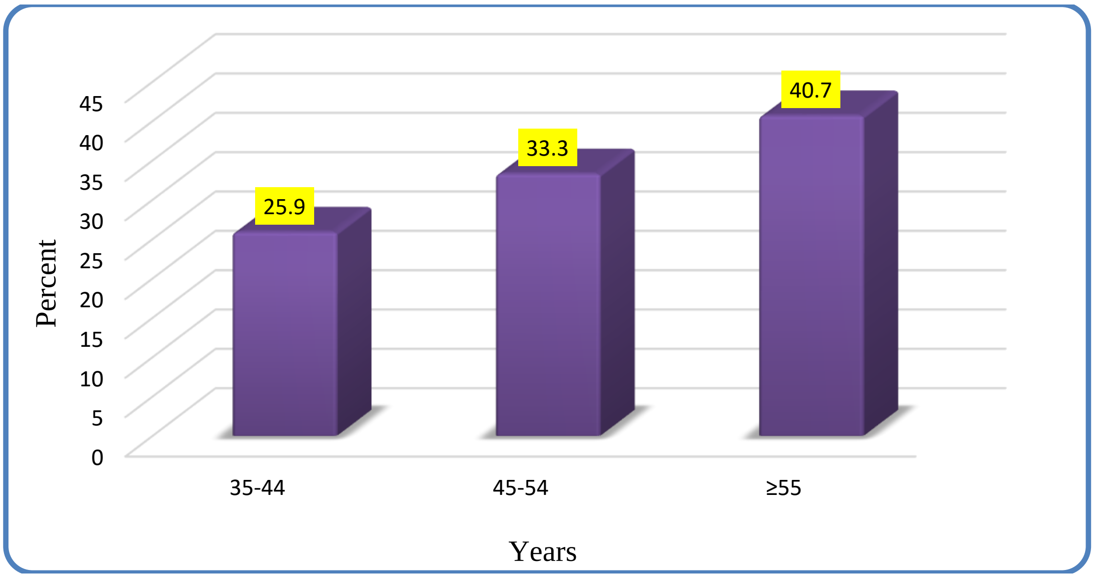

Figure 4: Age Distribution of Study Subjects

5.2 Behavioral and physical measurements of the study subjects

5.2.1 Life style history

From the total subjects, 23(85.2%) had never smoked cigarettes in their lifetime. Eight (29.6%) of the participants had drunk alcohol at least once in their lifetime and 6(22.2%) had drunk alcohol in the past 30 days. Only 8(29.6) % of the study subjects engaged in vigorous or moderate-intensity sports or recreational activities. Majority (44.4%) of the subjects spent 15-28 hours on sitting or reclining per week. (Table 3).

Table 3: Behavioural Characteristics of Study Subjects (n=27).

Variables		Frequency	Percentage
Ever smoke cigarettes	Yes	4	14.8
	No	23	85.2
Ever drink alcohol	Yes	8	29.6
	No	19	70.4
Drink alcohol in the last 30 days	Yes	6	22.2
	No	21	77.8
Physical Activity as part of work	Vigorous intensity	6	22.2
	Moderate intensity	17	63.0
	Physically inactive	4	14.8
Sports or recreational activities	Yes	8	29.6
	No	19	70.4
Number of hours spent on sitting or reclining per week	<14	10	37.0
	15-28	12	44.4
	29-42	3	11.1
	43-56	2	7.4

5.2.2 Body mass index of the study subjects

More than half of the study subjects in the pre (51.9%) and post (55.6%) test were under normal BMI. The number of subjects in the obesity range decreased from pretest value of 4 (11.1%) to posttest value of 3 (7.4%) (Figure 5). The mean BMI of the subjects was decreased from pretest value of 24.57 to posttest value of 24.19 (1.55% decrease, $p < 0.01$*).

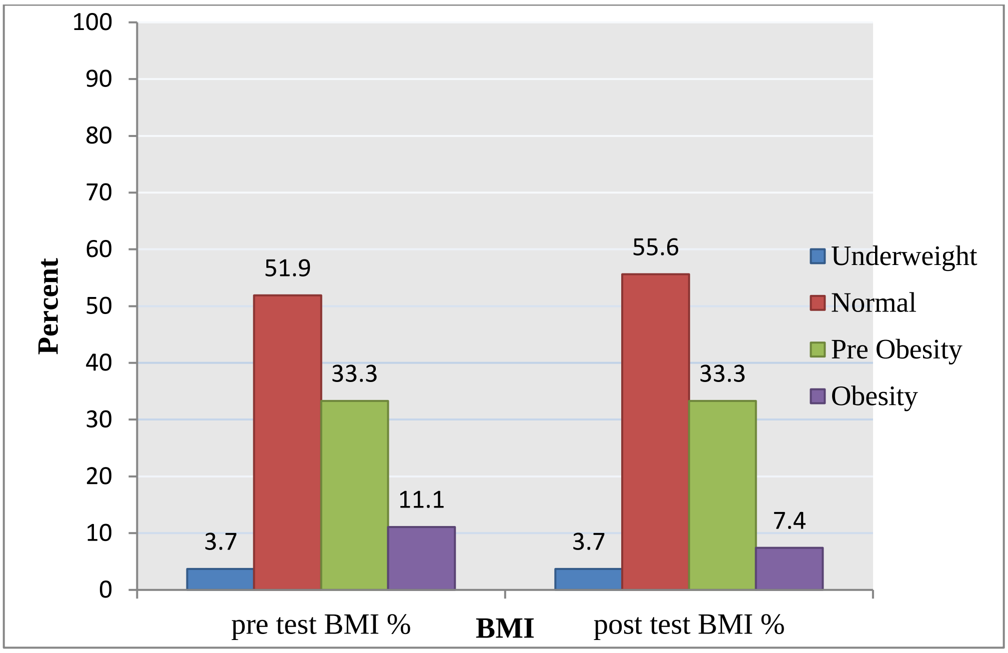

Figure 5: Percent Distribution of Pretest and Posttest BMI of Study Subjects

5.2.3 Waist to Hip Ratio of the study subjects

The mean WHR pretest and posttest value of the study subjects was 1.89 ± 0.3 and 1.85± 0.3 respectively (Figure 6).

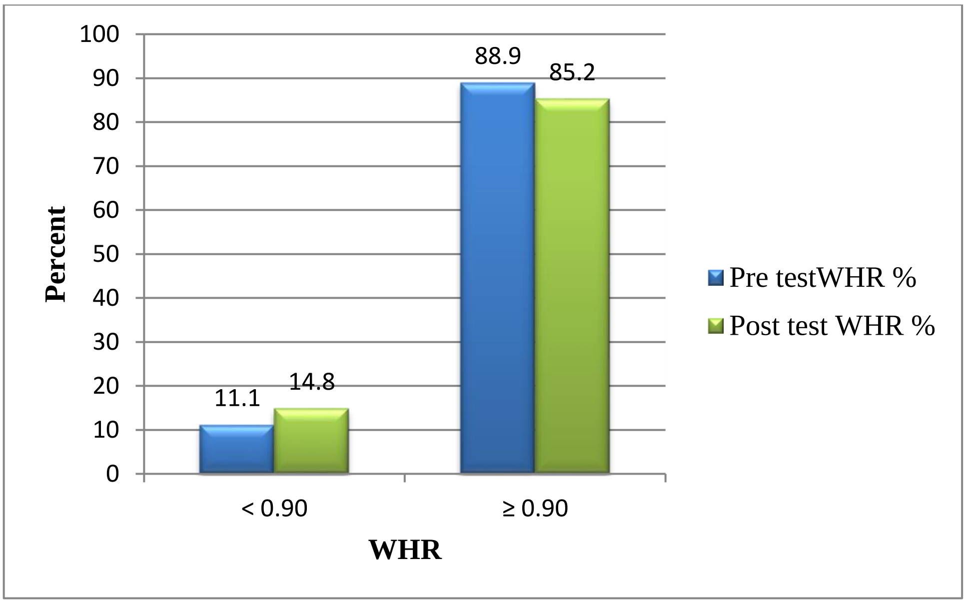

Figure 6: Percent Distribution of Pre and Posttest WHR of Study Subjects

5.2.4 Blood Pressure

Almost all (96.3%) of the study subjects had their BP in the recommended range during the pre-test measurements. The percentage of subjects in the recommended range increased to 100% during the posttest measurement, but the change was not statistically significant (p=0.832 for SBP and p=0.477 for DBP respectively) (Table 4).

Table 4: The Pretest and Posttest SBP and DBP Distribution of Study Subjects (n=27)

Blood pressure			Frequency	Percentage
SBP	Pre test	< 140	26	96.3
		≥ 140	1	3.7
	Posttest	< 140	27	100.0
		≥ 140	0	0
DBP	Pretest	< 90	26	96.3
		≥ 90	1	3.7
	Posttest	< 90	27	100.0
		≥ 90	0	0

5.3 Glycemic control Parameters of the study subjects

5.3.1 HbA1c values of the study subjects

The percentage of study subjects in the well-controlled category increased from pretest 25.9% to posttest 44.4% after the intervention (Figure 7).

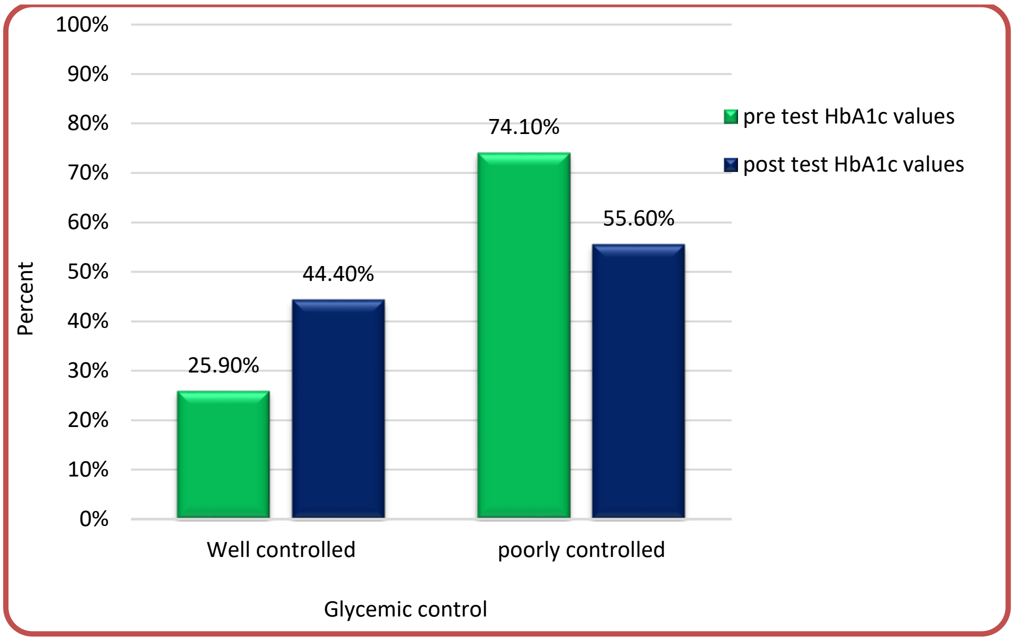

Figure 7: Percent Distribution of Pre and Posttest HbA1c of Study Subjects

The mean pretest HbA1c value was 8.7 ± 2.33 and mean posttest HbA1c value was 7.6 ± 1.77 (P=0.013) (Figure 8).

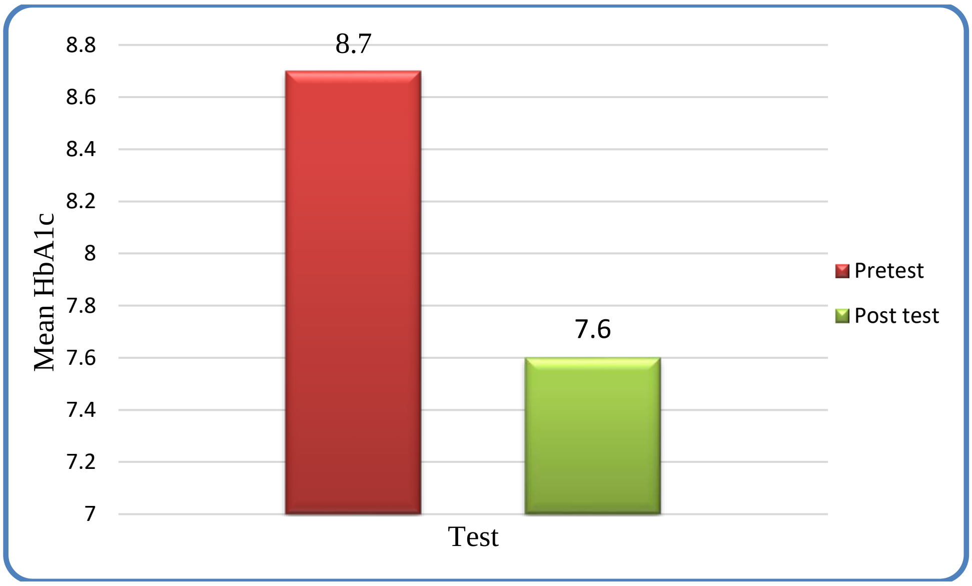

Figure 8: Mean Pre and Posttest HbA1c of Study Subjects

5.3.2 Fasting Blood Glucose

The percentage of subjects with FBG level greater than or equal to 130mg/dl reduced from 81.5% during pretest to 59.3% during posttest (Figure 9).

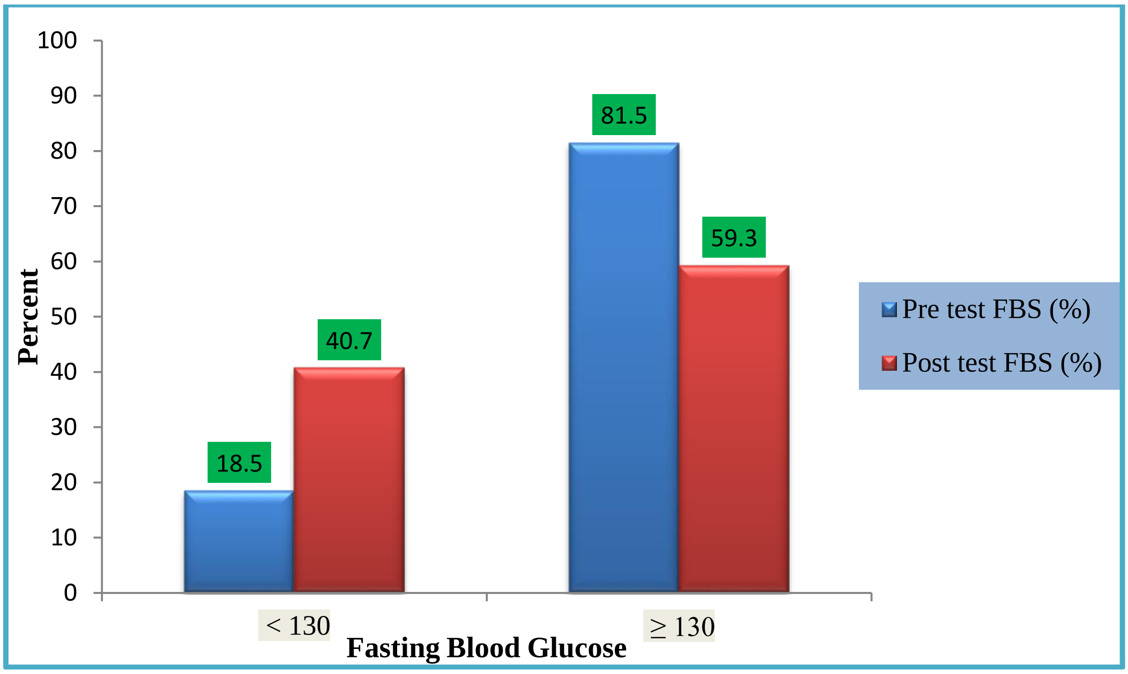

Figure 9: Percent Distribution of Pre and Posttest Fasting Blood Glucose of Study Subjects

The mean pretest FBG of the study subjects was 189.26 ±82.45 mg/dl whereas the posttest was 165.93 ± 56.78. The reduction in FBG level was not statistically significant ($p = 0.127$) (Table 5)

Table 5: The Pre and Posttest Fasting Blood Sugar of Study Subjects (n=27)

Fasting blood Glucose Statistics

	Pretest Fasting blood Glucose	Posttest Fasting blood Glucose
Mean	189.26	165.93
Median	171.00	150.00
Mode	158	98[a]
Std. Deviation	82.45	56.78
Range	304	180

The paired sample T-test showed the presence of statistically significant decrement in HbA1c, Body weight, body mass index, Waist circumference and waist to hip ratio (Table 6). Although, there was decrement in mean FBG, SBP and DBP of the study subjects, the change was not statistically significant (Table 6).

Table 6: Statistical Correlation of Paired Sample Test Between Pre and Posttest Measurements

Paired variables (Pretest-Posttest)	Paired Differences					T	df	P-Value
	Mean Difference	Std. Deviation	Std. Error Mean	95% CI of the Difference				
				Lower	Upper			
HbA1c	1.13	2.21	0.43	0.26	2.0080	2.66	26	**0.013***
FBG	23.33	76.90	14.80	-7.09	53.75	1.58	26	0.127
Body weight	1.11	1.1875	0.23	0.64	1.58	4.86	26	**< 0.001***
BMI	0.38	0.40	0.08	0.22	0.54	4.91	26	**< 0.001***
Waist circumference	2.04	3.13	0.60	0.80	3.28	3.38	26	**0.002***
Hip circumference	0.11	3.81	0.73	-1.40	1.62	0.15	26	0.881
WHR	0.021	0.04	0.01	0.01	0.04	2.94	26	**0.007***
SBP	0.37	8.98	1.73	-3.18	3.92	0.21	26	0.832
DBP	1.11	8.01	1.54	-2.06	4.28	0.72	26	0.477

*P <0.05 is statistically significant

Table 7: Comparison of Percentage Mean Change Between Pre and Posttest Measurements

No.	Variable	Baseline mean	After treatment mean	Change Mean
1	HbA1c	8.73	7.60	12.64%
2	FBS	189.26	165.93	12.33%
3	SBP	120.74	120.37	0.31%
4	DBP	77.41	76.30	1.43%
5	Body weight	72.30	71.19	1.54%
6	BMI	24.57	24.19	1.55%
7	Waist circumference	93.15	91.11	2.19%
8	Hip Circumference	91.93	91.81	0.12%
9	Waist hip ratio	1.01	0.99	1.98%

6. DISCUSSION

From the baseline pre-test data, we found that the current management of glycemic control in the study area was insufficient. Though the study subjects were on anti-diabetic medication, only 29.6% of the of them practiced physical exercise as part of the diabetes management. The baseline glycemic assessment of fasting blood glucose and HbA1c results indicated higher glycemic level with mean HbA1c of 8.7 ± 2.33 and mean fasting blood glucose of 189.26 ± 82.45. These values are much higher than the expected.

HbA1c reflects average glycemia over approximately 3 months. ADA on the current clinical practice recommended a reasonable HbA1c goal for adults to be less than 7%. Less stringent HbA1c goals (such as 8%) may be appropriate for patients with a history of severe hypoglycemia, limited life expectancy, advanced microvascular complications, extensive comorbid conditions or long-standing diabetes (ADA, 2019).

The twelve weeks of supervised aerobic exercise decreased fasting blood glucose and controlled HbA1c significantly. Moderate intensity aerobic exercise resulted in a significant improvement in patients' health status through controlling the blood glucose level. This study indicated that the addition of aerobic exercise to regular diabetic medication provided significantly favourable effects on glycemic control with significant reduction in HbA1c (12.94%) and FBG (12.33%).

The current study findings are in line with a study conducted in USA with Bi-Monthly Telephone Calls in Patients with T2DM regarding glycemic control (Hickson *et al.,* 2014). They reported that there was significant reduction in HbA1C levels during the three-months exercise follow up programme with mean HbA1c reduction of 21.23%. Another study conducted in obese T2DM in Iranian also showed that 10 weeks of moderate intensity aerobic training improved glycemic control with mean HbA1c and FBG reductions of 6.89% and 14.22% respectively (Matinhomaee *et al.,* 2012).

In parallel to the current study findings, an eight-years pretest- posttest trial conducted in Iran on 65 patients (35 experimental group and 30 control group) also revealed significant reduction in HbA1c (22.01%) (Najafipour *et al.*, 2017), much higher decrement in HbA1c than our study. The difference in the degree of reduction between the studies might arise from the methods utilized and the duration of the studies.

Another study conducted in china on aerobic exercise training at maximal fat oxidation intensity revealed improvement in glycemic control and physical capacity in older people with type 2 diabetes over 16 weeks (Yan Jiang *et al.*, 2020). The reduction in glucose level was 10% for HbA1c which was statistically significant but insignificant (0.24%) for FBG. These findings were consistent with the present study regarding both in HbA1c and FBG. A study on the effects of supervised structured aerobic exercise on FBG level in T2DM showed a significant improvement in fasting blood glucose (pre-mean = 276.41±25.31mg/dl, post-mean=250.07±28.23mg/dl, mean difference = 26.34mg/dl) (Shakil-ur-Rehman et al., 2017). This is comparable with our study (Pre-mean 189.26 ±82.45mg/dl to post-mean of 165.93 ± 56.78mg/dl, mean difference = 23.33mg/dl).

In contrast with the current study, supervised progressive resistance training conducted in Gondar for 12 weeks resulted in a significant improvement in glycemic control of Type 2 diabetes patients with fasting blood glucose reduction of 28.1% (Abebe SM, 2012). This could be probably due to the difference in the types of exercises implemented, dietary intervention during the study period and differences in the mean age among study subjects. Furthermore, fasting blood glucose is less reliable due to its' daily fluctuation as compared to HbA1c. HbA1c indicates the average glycemic control over the previous three months prior to the measurement and is a more reliable method to assess and monitor the glycemic level (ADA, 2019).

Aerobic exercise improves glycemic control in T2DM patients by augmenting the utilization of energy substrates (mainly glucose and free fatty acids) (Stanford & Goodyear, 2014). Aerobic exercise increases muscle glucose uptake up to fivefold through insulin-independent mechanisms (Colberg *et al.*, 2016). Furthermore, increased blood flow to exercising muscles can facilitate delivery of glucose to the muscles (Matinhomaee *et al.*, 2012).

Exercise affects the activation of insulin receptors and improve insulin sensitivity to enhance glucose uptake (Stanford & Goodyear, 2014). According to Stanford and Goodyear in people with type 2 diabetes, insulin-stimulated glucose uptake in skeletal muscle is impaired. However, exercise-stimulated glucose uptake is normal or at near normal level (Stanford &

Goodyear, 2014). Exercise can lead to an increase in insulin sensitivity by several mechanisms including increased glucose transporter 4 (GLUT4) expression, increased glycogen synthesis activity and increased lipid oxidation (Matinhomaee et al., 2012). Both insulin and exercise increase skeletal muscle glucose uptake by translocation of GLUT4 (Stanford & Goodyear, 2014). CAMP, the byproduct of energy phosphorylation is claimed to be responsible for the insulin-independent activation of GLUT4 (Marmett & Nunes, 2017).

Muscular contractions during exercise can stimulate glucose transport into skeletal muscles by an insulin independent mechanism (Matinhomaee *et al.,* 2012). This involves the enzyme AMP-activated protein kinase (AMPK). AMPK-stimulated glucose transport is mediated by multiple factors including increase of intracellular concentrations of Ca^{2+} and bradykinin, activation of Ca2+/calmodulin-dependent protein kinase, activation of protein kinase C and hypoxia. All these factors moderates effective translocation of GLUT4 and consequent entry of glucose into the cells (Ferrari *et al.,* 2019) .

Furthermore, aerobic training increases mitochondrial density, oxidative enzymes, compliance and reactivity of blood vessels, lung function, immune function, and cardiac output. It also enhances muscle capillary density, lipid metabolism and insulin signaling proteins (Colberg *et al.,* 2016). In individuals with type 2 diabetes, regular training reduces HbA1C, triglycerides, blood pressure, and insulin resistance (Colberg *et al.*, 2016).

In the present study, the improvement in glycemic control was accompanied by the improvement in their body composition. After 12 weeks of moderate intensity aerobic exercise, body weight, BMI, Waist circumference and waist hip ratio decreased significantly with mean decrement of 1.54%, 1.55%, 2.19% and 1.98% respectively. In line to the current study findings, another study (Yan Jiang *et al.,* 2020) found significant reduction in body mass, BMI, waist circumference, and WHR following 16 weeks of aerobic exercise.

The reduction in body weight (1.54%) in the current study is lower than ADA's recommendation (5%) (ADA, 2019). This could be due to relatively shorter duration of the intervention in our study. In parallel with current study findings, a study conducted in Iran indicated that a ten weeks moderate intensity had a significant effect on body composition (Matinhomaee *et al.,* 2012). Their study showed a significant reduction in weight (2.2%

decrease, p = 0.007) and body mass index (2.3% decrease, p = 0.009). In contrast to our findings, a study by Lade and colleagues did not find a significant change in anthropometric parameters such as body weight, BMI, WHR and circumferences over the 20 weeks of training (Lade *et al.*, 2016).

Although slight improvement has been observed in blood pressure in the current study, it was not statistically significant. The study also indicated that there was 51.9% coincidence of diabetes with hypertension. This is lower than the result reported by Abebe and Balcha (80%) (2012). This discordance may be due to the smaller sample size employed in the current study. Another study (Yavari & Ahmed Hajiyev, 2012) reported existence of a greater controversy in literature regarding blood pressure changes after exercise intervention. They reported that some studies have demonstrated the lowering effect of regular exercise on blood pressure. The results about SBP were not always in line with the changes of DBP (Yavari & Ahmed Hajiyev, 2012).

Inconsistent with the current study findings on blood pressure, Abebe and Balcha, reported significant reductions in mean values of systolic and diastolic blood pressure in all study subjects by 11.4 % and 6.9 %, respectively at week12 (Abebe SM, 2012). This difference could be attributed to the fact that the type of exercise employed (progressive resistance training) and additional dietary intervention introduced in their study.

Interventional studies have employed different protocols to assess impacts of exercise on glycemic control, body composition and lipid profile. Although there existed variations in duration, sample size, design and types of the exercise implemented, almost all have reached a consensus that exercise improves glycemic control. The current study is in line with most of these interventional studies revealing moderate intensity aerobic exercise has great impact on glycemic control and body composition.

7. CONCLUSION

Baseline data revealed that the current management of type-2 diabetes was not efficient with application of the usual treatment protocol.

The present study showed that HbA1c, body weight, hip circumference, BMI,WHR, reduced significantly after intervention. FBG and BP reduced non- significantly.

These findings suggested that improvement in glycemic control with aerobic training is accompanied by a decrease in percentage of body fat in these subjects.

8. STRENGTHS AND LIMITATIONS OF THE STUDY

STRENGTHS OF THE STUDY

Interventional study, which was difficult starting from recruitment of the subjects to the completion of the exercise protocol, was employed in this study.

Measurement of HbA1c, which is the high cost and less available method, was done to monitor the blood glucose control.

LIMITATIONS OF THE STUDY

Limitations of the study includes a small sample size selected by convenience method, which restricts further analysis of data and caution should be taken in generalizing the results to the source population.

The design of the study was a pretest and posttest type which lacks randomization and has the potential to introduce bias. No control was made on diet and type of medication.

This study didn’t involve control group due to financial constraints. The presence of control group in the study was important to demonstrate which variable influenced the glycemic control and body composition variables.

9. RECOMMENDATIONS

Exercise needs to be incorporated as one part of diabetes management, as drug treatment alone is not adequate to achieve good glycemic control in type – 2 diabetes patients. So, health professionals should recognize and prescribe individualized exercise, based on each patient's conditions.

Further research with large sample size involving control group and dietary control measures is highly recommended.

Furthermore, it is important to include parameters such as lipid profile and cardiovascular changes.

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11. ANNEXES

Annex I: Information Sheet and consent form

I. Information Sheet

Good morning/afternoon! My name is **Yohannes Dinku**. I am a graduate student in Addis Ababa University, College of health sciences, department of physiology doing the following research.

Title of the research: The chronic Effects of Supervised Aerobic Exercise on Glycemic Control and Body composition in Type 2 Diabetes Mellitus Patients Attending Outpatient Care Unit in *Goba* Referral Hospital, Ethiopia

Purpose: This questionnaire is provided to determine The Effects of Supervised Aerobic Exercise on Glycemic Control and Body Composition in Type 2 Diabetes Mellitus Patients. Your name will not be written in this form and all the information you will give is kept confidential. If you do not want to answer all or some of the questions, you do have the right to do so. However, your willingness to answer all of the questions is highly appreciated. If you are volunteer to participate in this study, you will be asked to do the following things: Filling the questionnaire, engaging in 12 weeks aerobic exercise at least 3 days a week and giving blood sample for RBS and HbA1c test.

Risk and Benefit

Participating in this study, you may feel mild pain and some discomfort related to needle insertion while giving blood for the determination of blood glucose. You may feel that it wastes your time (20-30minutes) to respond to question and around 150min/week for 12 weeks during the exercise schedules. This may not be too much as you get lot of benefits from exercise which is one of the life style interventions recommended for T2DM patients. You will get the benefit of reducing and controlling blood glucose levels, relieve the symptoms of the disease, and prevent complications. Your participation will help us in assessing effect of the effects of supervised aerobic exercise on glycemic control and body composition. If you have any questions or comments contact the investigator with the following address.

Address: **Yohannes Dinku**, MSc student in Medical Physiology, AAU, 2020.

Tel: +**251912299386**

Email: **yohannesdinku34@gmail.com**

II. Consent Form

Code number ----------------------------------

I have read the information on the title and aim of the study given above. The title and aim of the study were clear to me. I understood that participation in this study is completely voluntary and that I can withdraw from the study at any time. My answers are confidential and my name will not be shown on any documents. I understand no one other than the investigator and his advisors will have access to the questionnaire at any time. I understand that there is no risk associated with participating in this study but, it has the benefit of reducing and controlling blood glucose levels, relieve the symptoms of the disease, and prevent complications. So, I agree to this, provided that my privacy is guaranteed. I hereby give informed consent to participate to this study.

Participant:

________________________ ___________________________ ________________

Name of Participant Signature Date

Data collector:

________________________ ___________________________ ________________

Name of the data collector Signature Date

Researcher:

________________________ ___________________________ ________________

Name of Researcher Signature Date

Annex II: የመረጃ ወረቀትና የፈቃደኝነት ማረጋገጫ ቅፅ

I. የመረጃ ወረቀት

እንደምን አደሩ/ዋሉ! ስሜ ዮሐንስ ድንቁ ነው ፡፡ በአዲስ አበባ ዩኒቨርስቲ ፣ በጤና ሳይንስ ኮሌጅ ፣ በድህረ ምረቃ ት/ቤት ፣ የፊዚዮሎጂ ትምህርት ክፍል ተመራቂ ተማሪ ነኝ ፡፡

የጥናቱ ርዕስ- ኤይሮቢክ እንቅስቃሴ በአይነት 2 የስኳር ህመምተኞች የደም ስኳር መጠን ቁጥጥር ላይ ያለው ተፅእኖዎች፡፡

ዓላማው - ይህ መጠይቅ ኤይሮቢክ እንቅስቃሴ በአይነት 2 የስኳር ህመምተኞች የደም ስኳር መጠን ቁጥጥር ላይ ያለው ተፅእኖዎች ለማወቅ የተዘጋጀ ነው ፡፡ ስምዎ በዚህ ቅጽ አይጻፍም በተጨማሪም የሚሰጡት መረጃ ሁሉ በሚስጢር ይጠበቃል ፡፡ ሁሉንም ወይም የተወሰኑ ጥያቄዎችን መመለስ የማይፈልጉ ከሆነ ፣ ያለመመለስ መብት አለዎት ፡፡ ሆኖም ሁሉንም ጥያቄዎች ለመመለስ ፈቃደኛ ቢሆኑ ከፍተኛ ይበረታታል። በዚህ ጥናት ውስጥ ለመሳተፍ ፈቃደኛ ከሆኑ የሚከተሉትን ነገሮች እንዲያደርጉ ይጠየቃሉ፤

1. መጠይቁን መሙላት

2. በሳምንት ቢያንስ ለ 3 ቀናት ኤይሮቢክ የአካል ብቃት እንቅስቃሴ ማድረግ

3. ለደም ስኳር መጠን ምርመራ የደም ናሙና መስጠት

ስጋት እና ጥቅም

በዚህ ጥናት ውስጥ ተሳታፊ ከመሆንዎ በፊት እና በኋላ በደም የስኳር መጠን ላይ ለምርመራ የሚሆን ደም በመስጠት ሂደት መለስተኛ ህመም እና ከመርፌ መወጋት ጋር ተያይዞ አንዳንድ ምቾት ማጣት ሊሰማዎት ይችላል፡፡ ለጥያቄዎቹ መልስ ለመስጠት (20-30 ደቂቃዎችን) በአካል ብቃት እንቅስቃሴ መርሃግብሮች ውስጥ ለ 12 ሳምንታት ያህል በሳምንት ለ 150 ደቂቃዎች ጊዜዎን ይወስድብዎታል ፡፡ ለ አይነት 2 የስኳር ሕመምተኞች ከሚመከሩት የህይወት ዘይቤዎች ውስጥ አንዱ የአካል ብቃት እንቅስቃሴ ስለሆነ ብዙ ጥቅሞች ሊያገኙ ይችላሉ ፡፡

በዚህ ጥናት ውስጥ በመሳተፍዎ ኤይሮቢክ እንቅስቃሴ በአይነት 2 የስኳር ህመምተኞች የደም ስኳር መጠን ቁጥጥር ላይ ያለውን ተፅእኖዎች ለመገምገም ይረዳናል ፡፡ እርሶን ደሞ የደም ውስጥ የስኳር መጠንን መቀነስ እና ለመቆጣጠር ፣የበሽታውን ምልክቶች ለማስታገስ እንዲሁም ውስብስብ ችግሮች ለመከላከል ይረዳዎታል ፡፡ ጥያቄ ወይም አስተያየት ካለዎት ተመራማሪውን በሚከተለው አድራሻ ጋር ያነጋግሩ ፡፡

አድራሻ ዮሐንስ ድንቁ፣ በአ.አ ዩኒቨርሲቲ፣ የሜዲካል ፊዚዮሎጂ የ2ኛ ዲግሪ ተማሪ

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II. የፈቃድ መሙያ ቅጽ

ኮድ -----------------------------------

ከዚህ በላይ በተጠቀሰው ጥናት ርዕስ እና ዓላማ ላይ ያለውን መረጃ አንብቤያለሁ ፡፡ የጥናቱ ርዕስ እና ዓላማ ግልፅ ነው ። በዚህ ጥናት ውስጥ መሳተፍ ሙሉ በሙሉ በፈቃደኝነት እንደሆነና ከጥናቱ በማንኛውም ጊዜ መውጣት እንደምችል ተረድቻለሁ ፡፡ መልሶቼ ምስጢራዊ እንደሆኑና እና ስሜ በማንኛውም ሰነዶች ላይ እንደማይታይ ተረድቻለሁ ፡፡ ከተመራማሪው ና አማካሪዎቹ በስተቀር ሌላ ማንም ሰው በማንኛውም ጊዜ መጠይቁን ማግኘት እንደማይችል ተረድቻለሁ ። በዚህ ጥናት ውስጥ መሳተፍ ምንም አደጋ እንደሌለው ተረድቻለሁ ፣ ነገር ግን የደም ግሉኮስ መጠንን ለመቀነስ እና ለመቆጣጠር ፣ የበሽታውን ምልክቶች ለማስታገስ እና ውስብስብ ችግሮች ለመከላከል የሚያስችል ጠቀሜታ አለው ፡፡ ስለዚህ ፣ ሚስጥራዊነቱ እስከተጠበቀ ድረስ በዚህ ጥናት ለመሳተፍ በስምምነት ፈቃዴን እሰጣለሁ ፡፡

ተሳታፊ

______________________ ___________________ ___________________

የተሳታፊ ስም ፊርማ ቀን

ተመራማሪ

_______________________ _______________ ___________________

የተመራማሪ ስም ፊርማ ቀን

Annex III: English Questionnaires

Part I: Socio Demographic Characteristics and information

Instruction: circle the response from the alternative and write the answer for open ended question on the space provided.

S.no.	Questions	Response	Code
101	How old are you?	____________years	S1
102	Residence	1. Rural 2. Urban	S2
103	BMI (kg/m^2)	______________	S3
104	What is your marital status?	1. Married 2. Single 3. Divorced 4. Widower	S4
105	What is the highest grade you completed?	1. Illiterate 2. Primary 3. Secondary and Diploma 4. First degree and above	S5
106	What is your occupation?	1. Government employee 2. Self-employee 3. Pensioner 4. Farmer	S6
107	Ethnicity	1. Oromo 2. Amhara 3. Guraghe 4. Other	S7
108	Did you have family history of diabetes?	1. No 2. Yes. If yes, who _____	S8
109	Duration of disease after diagnosis	________	S9

Part II: Behavioural Measurements (WHO STEPS instrument)

Tobacco Use			
Questions		**Response**	**Code**
201	Do you currently smoke any tobacco products, such as cigarettes, cigars or pipes?	Yes 1 No 2 *If No, go to T6*	T1
202	Do you currently smoke tobacco products daily?	Yes 1 No 2 *If No, go to T6*	T2
203	How old were you when you first started smoking daily?	Age (years)________ Do not know 77, *If Known, go to T5a*	T3
204	Do you remember how long ago it was? Do not know 77	In Years______	T4a
		In months_____	T4b
		In weeks_______	T4c
205	On average, how many of the following do you smoke each day? Do not know 77	Manufactured cigarettes______	T5a
		Hand-rolled cigarettes________	T5b
		Pipes full of tobacco________	T5c
		Other____ *If Other, go to T5other, else go to T9*	T5e
		Other (please specify): __________ *Go to T9*	T5other
206	In the past, did you ever smoke daily?	Yes 1 No 2	T6
207	During the past 7 days, on how many days did someone **in your home** smoke when you were present?	Number of days____________ Do not know 77	T13
Alcohol Consumption			
208	Have you ever consumed an alcoholic drink such as beer, wine, katikala or Tella?	Yes 1 No 2, *If No, go to D1*	A1a
209	Have you consumed an alcoholic drink within the past 12 months?	Yes 1 No 2, *If No, go to D1*	A1b
210	During the past 12 months, how frequently have you had at least one alcoholic drink?	Daily 1 5-6 days per week 2 1-4 days per week 3 1-3 days per month 4 Less than once a month 5	A2
211	Have you consumed an alcoholic drink within the past 30 days?	Yes 1 No 2, *If No, go to D1*	A3

212	During the past 30 days, on how many occasions did you have at least one alcoholic drink?	Number____________ Do not know 77	A4
213	During the past 30 days, when you drank alcohol, on average, how many standard alcoholic drinks did you have during one drinking occasion?	Number____________ Do not know 77	A5
214	During the past 30 days, what was the largest number of standard alcoholic drinks you had on a single occasion, counting all types of alcoholic drinks together?	Largest number____________ Do not know 77	A6
215	During the past 30 days, how many times did you have standard alcoholic drinks in a single drinking occasion?	Number of times Do not know 77	A7

Part III: Global Physical Activity Questionnaire (GPAQ)

Questions		**Response**	**Code**
Activity at work			
301	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate for at least 10 minutes continuously?	Yes 1 No 2 If No, go to P 4	P4
302	In a typical week, on how many days do you do vigorous intensity activities as part of your work?	Number of days______	P2
303	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours___: minutes_____.	P3 (a-b)
304	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking [or carrying light loads] for at least 10 minutes continuously?	Yes 1 No 2 If No, go to P 7	P4
305	In a typical week, on how many days do you do moderate intensity activities as part of your work?	Number of days ____	P5
306	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours____: minutes_____	P6 (a-b)
Travel to and from places			

307	Do you walk or use a bicycle for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
308	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days_____	P8
309	How much time do you spend walking or bicycling for travel on a typical day?	Hours____: minutes__	P9 (a-b)
Recreational activities			
310	Do you do any vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate like for at least 10 minutes continuously?	Yes 1 No 2 If No, go to P 13	P10
311	In a typical week, on how many days do you do vigorous intensity sports, fitness or recreational activities?	Number of days______	P11
312	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours____: minutes_____	P12 (a-b)
313	Do you do any moderate-intensity sports, fitness or recreational activities that causes a small increase in breathing or heart rate such as brisk walking, for at least 10 minutes continuously?	Yes 1 No 2 If No, go to P16	P13
314	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational activities?	Number of days______	P14
315	How much time do you spend doing moderate-intensity sports, fitness or recreational (leisure) activities on a typical day?	Hours_____: minutes______	P15 (a-b)
Sedentary behavior			
316	How much time do you usually spend sitting or reclining on a typical day?	Hours___: minutes ___	P16 (a-b)

Thank you in advance for your cooperation!

Annex IV: የአማርኛ መጠይቅ

ክፍል 1: የሶሺዮግራፊ እና የስነ-ሕዝብ ባህሪዎች መረጃዎች

መመሪያ- ከተሰጡት አማራጮች መካከል መልስዎን ያክብቡ ፤ ለተሰጡት ክፍት ጥያቄዎች በተሰጦት ቦታ ላይ ይፃፉ ፡፡

ተ. ቁ	ጥያቄዎች	መልስ	ኮድ
101	እድሜዎ ስንት ነው?	---------- ዓመት	S1
102	መኖሪያ ቦታ	1. ገጠር 2. ከተማ	S2
103	የጋብቻ ሁኔታዎ ምንድ ነው?	1. ያገባ 2. ነጠላ 3. የፈታ 4. ሚስቱ የሞተችበት	S3
104	ያጠናቀቁት ከፍተኛው ክፍል ምን ያህል ነው?	1. ማንበብና መጻፍ የማይችል 2. መጀመርያ ደረጃ 3. ሁለተኛ ደረጃ እና ዲፕሎማ 4. የመጀመሪያ ዲግሪ እና ከዚያ በላይ	S4
105	ሥራህ ምንድን ነው?	1. የመንግስት ሰራተኛ 2. የግል 3. ጡረተኛ 4. ገበሬ	S5
106	ብሔር	1. ኦሮሞ 2. አማራ 3. ጉራጌ 4. ሌላ	S6
107	ከቤተሰዎ ውስጥ የስኳር ታማሚ አለ?	1. የለም 2. አዎ ፡፡ አዎ ከሆነ ፣ ማን---------	S7
108	ህመምዎ ከታወቀ ምን ያህል ጊዜ ነው?	________	S8

ክፍል II: የስነምግባር መለኪያዎች (የ WHO STEP መሣሪያዎች)

የትምባሆ ማጨስን በተመለከተ			
ተ.ቁ	ጥያቄ	መልስ	ኮድ
201	በአሁኑ ጊዜ ሲጋራና እንደ ሲጋራ ያሉ የትምባሆ ምርቶችን ያጨሳሉ?	አዎ 1 የለም 2, የለም ከሆነ ፣ ወደ T6 ይሂዱ	T1
202	በአሁኑ ጊዜ የትምባሆ ምርቶችን በየቀኑ ያጨሳሉ?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ T6 ይሂዱ	T2
203	በየቀኑ ማጨስ ሲጀምሩ ዕድሜዎ ስንት ነበር?	ዕድሜ (ዓመት) ____ አላውቅም 77 ፣ የማያውቁ ከሆነ ወደ T5a ይሂዱ	T3
204	ከምን ያህል ጊዜ በፊት እንደነበር ታስታውሳለህ? አላውቅም 77	በዓመት ______	T4a
		በወራት _____	T4b
		በሳምንታት_______	T4c
205	በአማካይ በየቀኑ ከሚከተሉት ውስጥ ምን ያህሉን ያጨሳሉ? አላውቅም 77	የተመረቱ ሲጋራዎች______	T5a
		በእጅ የተሰሩ ሲጋራዎች ----	T5b
		በትምባሆ የተሞሉ ጥቅሎች ----------	T5c
		ሌላ____ ሌላ ከሆነ ፣ ወደ ፣ T5 other ይሂዱ ፤ ካልሆነ ወደ ወደ T9	T5e
		ሌላ (እባክዎን ይግለጹ) ___________ወደ T9 ይሂዱ	T5other
206	ከዚህ በፊት በየቀኑ ያጨሱ ነበር?	አዎ 1	T6

		የለም 2	
207	በአለፉት 7 ቀናት ውስጥ በሚኖሩበት ቤት ውስጥ ያለ ሰው እርስዎ ቤት ውስጥ እያሉ ስንት ቀን ሲጋራ አጨሰ?	የቀናት ብዛት _____ አላውቅም 77	T13
የአልኮል አጠቃቀም			
208	እንደ ቢራ ፣ ወይን ፣ አረቄ ወይም ጠላ ያሉ የአልኮል መጠጦችን ጠጥተው ያውቃሉ?	አዎ 1 የለም 2 ፣ የለም ከሆነ ፣ ወደ P1 ይሂዱ	A1a
209	ባለፉት 12 ወራት ውስጥ የአልኮል መጠጥ ጠጥተዋል?	አዎ 1 የለም 2 ፣ የለም ከሆነ ፣ ወደ P1 ይሂዱ	A1b
210	ያለፉት 12 ወሮች ቢያንስ አንድ ጊዜ የአልኮል መጠጥ የሚጠጡት ስንት ጊዜ ነበሩ?	በየቀኑ 1 በሳምንት ከ5-6 ቀናት 2 በሳምንት ከ1-4 ቀናት 3 በወር ከ1-3 ቀናት 4 በወር ከአንድ ጊዜ በታች 5	A2
211	ባለፉት 30 ቀናት የአልኮል መጠጥ ጠጥተዋል?	አዎ 1 የለም 2 ፣ የለም ከሆነ ፣ ወደ D1 ይሂዱ	A3
212	ያለፉት 30 ቀናት ውስጥ ቢያንስ አንድ የአልኮል መጠጥ ምን ያህል ጊዜ ጠጥተዋል?	ቁጥር ___________ አላውቅም 77	A4
213	ባለፉት 30 ቀናት ውስጥ አልኮልን ሲጠጡ በአማካይ ምን ያህል የአልኮል መጠጥ መጠጦች ጠጥተዋል?	ቁጥር ___________ አላውቅም 77	A5
214	ያለፉት 30 ቀናት ውስጥ በአንድ ወቅት በአንድ ጊዜ በአንድ ጊዜ በአንድ ጊዜ ውስጥ በሙሉ የአልኮል መጠጦች ሲቆጠሩ የነበራችሁ የአልኮል መጠጥ መጠኖች ስንት ነበሩ?	ትልቁ ቁጥር___________ አላውቅም 77	A6

215	ያለፉት 30 ቀናት ውስጥ በአንድ መደበኛ የመጠጥ ሁኔታ ውስጥ መደበኛ የአልኮል መጠጦች ስንት ጊዜ ነበሩዎት?	የጊዜዎች ብዛት አታውቅም 77	A7

ክፍል III -ዓለም አቀፍ የአካል ብቃት እንቅስቃሴ መጠይቅ (GPAQ)

	ጥያቄ	መልስ	ኮድ
በሥራ ላይ እንቅስቃሴ			
301	ሥራዎ ቢያንስ ለ 10 ደቂቃዎች ያለማቋረጥ የትንፋሽ ወይም የልብ ምት መጨመር የሚያስከትሉ እንደ [ከባድ ሸክሞችን መሸከም ፣ ማንሳት ወይም የግንባታ ስራ ያሉ] **ጠንካራ እንቅስቃሴዎችን** ያካትታል?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ P4 ይሂዱ	P1
302	በሳምንት ውስጥ እንደ ሥራዎ አንድ አካል ጠንካራ እንቅስቃሴዎችን ለስንት ቀናት ያደርጋሉ?	የቀኖቹ ብዛት______	P2
303	በአንድ ቀን ውስጥ በሥራ ላይ ያሉ ጠንካራ-እንቅስቃሴዎችን ለመስራት ምን ያህል ጊዜ ያጠፋሉ?	ሰዓታት___ ደቂቃዎች _	P3 (a-b)
304	ሥራዎ በትንሹ የአተነፋፈስ መጨመር ወይም የልብ ምት እንደ ቀላል እርምጃ [ወይም ቀላል ሸክም] ያሉ **መካከለኛ እንቅስቃሴን** ቢያንስ ለ 10 ደቂቃዎች ያለማቋረጥ ያካትታል?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ P 7 ይሂዱ	P4
305	በሳምንት ውስጥ እንደ ሥራዎ አንድ አካል መጠነኛ እንቅስቃሴ የሚያደርጉት ለስንት ቀናት ነው?	የቀኖች ቁጥር ____	P5

306	በአንድ ቀን ውስጥ በመጠነኛ-ጉልበት እንቅስቃሴዎችን ለመስራት ምን ያህል ጊዜ ያጠፋሉ?	ሰዓታት____: ደቂቃዎች_____	P6 (a-b)
ከአንድ ቦታ ወደ ሌላ ቦታዎች መጓዝ			
307	ወደ ተለያዩ ቦታዎች ለመሄድ ያለማቋረጥ ቢያንስ ለ 10 ደቂቃዎች በብስክሌት ይጠቀማሉ ወይም ይራመዳሉ?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ P 10 ይሂዱ	P7
308	በሳምንት ወደ ተለያዩ ስራዎች ለመሄድ ያለማቋረጥ ስንት ቀናት በእግር ወይም በብስክሌት ቢያንስ ለ 10 ደቂቃዎች ያህል ይራመዳሉ?	የቀኖች ብዛት_____	P8
309	በቀን በእግር ወይም በብስክሌት ለመጓዝ ምን ያህል ጊዜ ያጠፋሉ?	ሰዓታት____: ደቂቃዎች__	P9 (a-b)
የመዝናኛ እንቅስቃሴዎች			
310	ቢያንስ ለአስር ደቂቃዎች ያህል በአተነፋፈስ ወይም የልብ ምት (እንደ ሩጫ ወይም እግር ኳስ) ያሉ የልብ ምት መጨመርን የሚያስከትሉ ጠንካራ የስፖርት ፣ የአካል ብቃት ወይም የመዝናኛ እንቅስቃሴዎች ያደርጋሉ?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ P 13 ይሂዱ	P10
311	በሳምንት ውስጥ ጠንካራ የከብደት ስፖርቶችን ፣ የአካል ብቃት እንቅስቃሴዎችን ወይም የመዝናኛ እንቅስቃሴዎችን ለስንት ቀናት ያደርጋሉ?	የቀኖች ብዛት______	P11
312	በቀን ጠንካራ ስፖርት ፣ የአካል ብቃት እንቅስቃሴ ወይም የመዝናኛ እንቅስቃሴዎችን ምን ያህል ጊዜ ያሳልፋሉ?	ሰዓታት____: ደቂቃዎች_____	P12 (a-b)

313	በአተነፋፈስ ወይም በልብ ምት እንደ ብስክሌት፡ መራመድ ፣ (ብስክሌት ፣ መዋኘት ፣ ኳስ መጫወቻ ኳስ] ያሉ ቢያንስ ለ 10 ደቂቃዎች ያለማቋረጥ ኃይለኛ የስፖርት ፣ የአካል ብቃት ወይም የመዝና እንቅስቃሴዎች ያደርጋሉ?	አዎ 1 የለም 2 የለም ከሆነ ፣ ወደ P16 ይሂዱ	P13
314	በአንድ ሳምንት ውስጥ በመጠነኛ ጊዜ ስፖርቶችን ፣ የአካል ብቃት እንቅስቃሴዎችን ወይም የመዝናኛ እንቅስቃሴ የሚያደርጉት ለስንት ቀናት ነው?	የቀኖቹ ብዛት______	P14
315	በቀን መጠነኛ-ስፖርቶችን ፣ የአካል ብቃት እንቅስቃሴን ወይም የመዝናኛ እንቅስቃሴ በአንድ ቀን በማከናወን ምን ያህል ጊዜ ያሳልፋሉ?	ሰዓታት_____: ደቂቃዎች______	P15 (a-b)
የመቀመጥ ባህሪ			
316	በቀን በመቀመጥ ወይም በማረፍ ምን ያህል ጊዜ ያጠፋሉ?	ሰዓታት_____: ደቂቃዎች ____	P16 (a-b)

ለትብብርዎ እጅግ በጣም እናመሰግናለን!

Annex V: Standard Operating Procedures

The Exercise Protocol

Phases of the exercise session include the following:
The warm-up phase consists of a minimum of 5–10 min of light-to-moderate intensity cardiorespiratory and muscular endurance activities. The warm-up is a transitional phase that allows the body to adjust to the changing physiologic, biomechanical, and bioenergetic demands of the conditioning or sports phase of the exercise session. Warming up also improves range of motion and may reduce the risk of injury.

The conditioning phase includes at least 20–60 min of aerobic sports activities (exercise bouts of 10 min are acceptable if the individual accumulates at least 20–60 min · d^{-1} of daily aerobic exercise)

Cool-down period involves at least 5–10 min of light-to-moderate intensity cardiorespiratory and muscular endurance activities to allow for a gradual recovery of heart rate and blood pressure and removal of metabolic end products.

The stretching phase at least 10 min of stretching exercises performed after the warm-up or cool-down phase. This could be performed following the warm-up or cool-down, as warmer muscles improve ROM.

The ACSM FITT principle of exercise treatment for healthy adults generally applies to individuals with DM with the following protocol.

FITT

FITT RECOMMENDATIONS FOR INDIVIDUALS WITH DIABETES

	Aerobic	Resistance	Flexibility
Frequency	3–7 d · wk^{-1}	A minimum of 2 nonconsecutive d · wk^{-1}, but preferably 3	≥2–3 d · wk^{-1}
Intensity	Moderate (40%–59% $\dot{V}O_2R$ or 11–12 RPE rating) to vigorous (60%–89% $\dot{V}O_2R$ or 14–17 RPE rating)	Moderate (50%–69% of 1-RM) to vigorous (70%–85% of 1-RM)	Stretch to the point of tightness or slight discomfort.
Time	T1DM: 150 min · wk^{-1} at moderate intensity or 75 min · wk^{-1} at vigorous intensity or combination T2DM: 150 min · wk^{-1} at moderate-to-vigorous intensity	At least 8–10 exercises with 1–3 sets of 10–15 repetitions to near fatigue per set early in training. Gradually progress to heavier weights using 1–3 sets of 8–10 repetitions.	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Prolonged, rhythmic activities using large muscle groups (*e.g.*, walking, cycling, swimming)	Resistance machines and free weights	Static, dynamic, and/or PNF stretching

1-RM, one repetition maximum; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; $\dot{V}O_2R$, oxygen uptake reserve.

Steps to measure HbA1c (Automated)

Hemoglobin A1c Analysis was developed for screening and monitoring diabetes mellitus in human blood samples. The analysis time is 1.5 minutes. And also 0.5 minutes column washing done at analysis end.

Blood sample was collected at 8:00 am from the antecubital vein while the patients were in the recumbent position.

Before start, wash the column by 1mL/min flow of %100 mobile phase B for 10 minutes. Then activate HbA1c method and wait for 5 minutes. After conditioning step, injections can be started. At the end of analysis, definitely wash the column with Wash Buffer before putting it away.

1. Select the proper size needle and attach the syringe
2. Put on gloves.
3. Apply a tourniquet
4. Instruct the patient to make fist and hold it.
5. Select the vein puncture site by palpating with the gloved index finger
6. Clean the area with alcohol swab and allow to air dry
7. Grasp the patients arm firmly using your thumb and draw the skin taut and anchor the vein
8. Swiftly insert through the skin and into the vein
9. Loosen the tourniquet and collect adequate amount of blood
10. When collection is complete, remove the tourniquet and place gauze and apply adequate pressure until bleeding stops.
11. Mix sample with reagent
12. Add sample mixture to test cartridge
13. Give test cartridge into the reader
14. Analysis will automatically start after clicking **Start** button on software.
15. Injections, calculations and reporting done automatically by instrument.

Steps to measure Blood Glucose (FBS)

The level of glucose in the blood can be measured by applying a drop of blood to a chemically treated, disposable ‘test-strip’, which is then inserted into an electronic blood glucose meter. The reaction between the test strip and the blood is detected by the meter and displayed in units of mg/dL or mmol/L.

Apply these general principles when using the different types of electronic blood glucose meters available.

1. Ask the patient to sit down and explain what you are going to do.
2. Wash your hands and put on gloves.
3. Choose the site for the blood sample: usually the side of a finger, but the arm or thigh may be used (change the site used if frequent measurements are needed).
4. Use an alcohol swab to clean the site and let the alcohol dry.
5. Insert the test strip into the monitor, following the instructions.
6. Use a single-use lancet or a lancing device to draw blood and dispose of it in a sharp’s container.
7. Apply the blood to the testing strip in the correct way: some strips need the blood drop to be over the whole of the test pad and some suck up the blood directly from the site of the bleeding.
8. Place the alcohol swab (note: it will sting) or a piece of gauze over the site and hold it there, or let the patient hold it there until the bleeding stops. Monitor for excess bleeding.
9. Read and record the result, reporting and/or responding to abnormal readings.
10. Tell the patient what the result is, explain it and discuss options.
11. Dispose of all used equipment safely, in line with hospital or health care policies.

Steps to Measure Blood Pressure

1. Apply the cuff (Sphygmomanometer).
2. Put stethoscope earpieces in-ear and set to a bell.
3. Palpate pulse at either brachial or radial artery. Take a pulse count for one full minute.
4. Pump up pressure and inflate the cuff until unable to feel the pulse.
5. Continue to inflate cuff 30 mmHg beyond this point.
6. Apply the bell of the stethoscope to the right antecubital fossa.
7. Listen for pulse sounds while deflating the cuff slowly.
8. Record the systolic blood pressure (SBP) when a pulse is first audible.
9. Record the diastolic blood pressure (DBP) when the pulse sound disappears.
10. Deflate the cuff fully and let the armrest for three minutes (between each of the readings).
11. Repeat Steps 2-10 twice to obtain three readings.
12. Check that all readings are correctly recorded.
13. Inform the participant about the blood pressure readings only after the whole process is completed.

Steps to measure Height

Height measurement will be taken using portable tape meter without shoes and they will be recorded to the nearest 0.5 millimeters.

1. Ask the participant to remove their:
    a. footwear (shoes, slippers, sandals, etc.)
    b. Headgear (hat, cap, hair bows, comb, ribbons, etc.).
2. Ask the participant to stand on the board facing you.
3. Ask the participant to stand with:
    a. feet together
    b. heels against the backboard
    c. Knees straight.
4. Ask the participant to look straight ahead and not tilt their heads up.
5. Make sure the eyes are at the same level as the ears.
6. Move the measuring arm gently down onto the head of the participant and ask the participant to breathe in and stand tall.
7. Read the height in centimeters at the exact point to the nearest mm.
8. Ask the participant to step away from the measuring board.

9. Record the height measurement in centimeters.

Steps to measure Weight

Weight will be measured while patients are wearing light clothing without shoes by using the weighing scale. Reading will be taken to the nearest 0.5kilograms.

1. Ask the participant to remove their footwear (shoes, slippers, sandals, etc) and socks. They should also take off any heavy belts and empty their pockets of mobiles, wallets and coins.
2. Ask the participant
    a. standstill
    b. face forward
    c. place arms on the side and
3. Wait until asked to step off.
4. Record the weight in kilograms

Measuring Waist Circumference

1. Standing to the side of the participant, locate the last palpable riband the top of the hip bone. You may ask the participant to assist you in locating these points on their bodies.
2. Ask the participant to wrap the tension tape around themselves and then position the tape at the midpoint of the last palpable riband the top of the hip bone, making sure to wrap the tape over the same spot on the opposite side.
3. Ask the participant to:
    - stand with their feet together with weight evenly distributed across both feet;
    - hold the arms in a relaxed position at the sides;
    - Breathe normally for a few breaths, and then make a normal expiration.
4. Measure waist circumference and read the measurement at the level of the tape to the nearest 0.1 cm, making sure to keep the measuring tape snug but not tight enough to cause compression of the skin.
5. Record the measurement

Measuring Hip Circumference

1. Stand to the side of the participant, and ask them to help wrap the tape around them.
2. Position the measuring tape around the maximum circumference of the buttocks.
3. Ask the participant to:
   - stand with their feet together with weight evenly distributed over both feet;
   - Hold their arms relaxed at the sides.
4. Check that the tape position is horizontal all around the body and snug without constricting.
5. Measure the hip circumference and read the measurement at the level of the tape to the nearest 0.1 cm.
6. Record the measurement.