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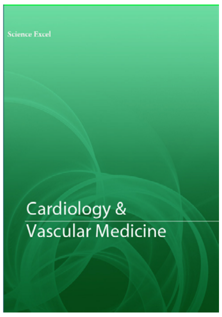
Original Article



The Impact of Diabetes Reversal on Myocardial Function and Quality of Life in Diabetic Cardiomyopathy -A Prospective Research Study

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Diabetes, diabetic cardiomyopathy, diabetes reversal, HbA1C, Left ventricle Global longitudinal strain (LV- GLS), Peak VO2, quality of life (QOL), Short Form- 12(SF-12)

Abstract

Introduction: Diabetes mellitus and its related consequences impose a significant worldwide cost on human health and economic resources. Cardiovascular illnesses are the primary cause of mortality among those with diabetes, who face a 2- to 5-fold increased likelihood of developing heart failure compared to non-diabetic individuals of the same age, regardless of any coexisting medical conditions. Diabetic cardiomyopathy refers to the manifestation of atypical heart structure and impaired cardiac function in the absence of other risk factors commonly associated with cardiac conditions, such as coronary artery disease, hypertension, and notable valve abnormalities. The density of patients with diabetic cardiomyopathy is rising progressively. Even now, the focus is more on diabetes blood sugar management, diabetic nephropathy, diabetic neuropathy, and poor quality of life; diabetic cardiomyopathy needs to be more pronounced in the treatment- guidelines; very few studies have been conducted on diabetic cardiomyopathy.

Methods: This prospective study was initiated in January 2021, was conducted for 18 months, and was completed in June 2022. This study is a prospective study of diabetic patients with manifested diabetic cardiomyopathy, the effect of an integrated approach of dietary modification and guided exercise protocol enhancing cardiac performance and the quality of life. The patients satisfying the inclusion criteria without exclusion criteria were randomized to intervention and control groups.

Results: The age group of the mean (years) ± SD (58.41±10.43) in the Intervention Group and (56.87±11.23.) in the Control Group. Both the groups comprised female participants, 39% in the Intervention Group and 27% in the Control Group. The initial evaluation was done at the beginning of this prospective study. The follow-ups were done in 1, 3, 6, 9, 12, and 18 months. Clinical examination, peak VO2 evaluation in a cardiopulmonary exercise test, and echocardiography with Left Ventricular Global Longitudinal Strain (LV-GLS) measurements. During the study period, it was noted that there were substantial improvements in HbA1C, low-density lipoprotein (LDL), peak VO2, and Quality of Life (QoL).

Conclusion: In Conclusion, based on the findings of this prospective study, the integrated approach of nutritional modification and guided exercise protocol in diabetic cardiomyopathy with or without heart failure patients has tremendous benefits in cardiac performance and remarkable improvement in QoL. As the life span improves, that leads to more heart failure patients presently and in the future. Along with pharmacotherapy against diabetes, diabetes reversal should be emphasized from the beginning of diabetes diagnosis to achieve a better quality of life. Considering the importance of a guided diabetes reversal program through this study, it would not be wrong to suggest it as an initial treatment strategy in case of diabetes with or without diabetic cardiomyopathy manifestations.

Introduction

In recent decades, there has been an exponential increase in the global burden and prevalence of diabetes mellitus (DM). According to the International Diabetes Federation (IDF), in 2021, there were approximately 537 million diabetes-affected individuals (20-79 years) worldwide. As per the diabetes growth trend globally, the total number of people living with diabetes is projected to rise to 643 million by 2030 and 783 million by 2045, an increase of 46 % [1].

Based on the data, it has been ascertained that diabetes, a persistent medical ailment, is accountable for the mortality of individuals at a frequency of one person per eight seconds. According to projections, over four million persons worldwide succumbed to diabetes in 2017 [1]. The aforementioned projection of global epidemics of DM is multifactorial, such as the notable increase in life expectancy, the shifting demography towards an elderly population, and the rapid rate of urbanization. Therefore, the long-lasting consequences linked to diabetes will continuously affect the health of individuals and groups living in these areas [2].

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Diabetic cardiomyopathy is a distinct type of cardiovascular disorder comprising functional deterioration and subsequent structural decremental effects on the heart in the absence of other cardiac risk factors such as coronary artery disease (CAD), hypertension, and valvular heart disease (VHD). Diabetic cardiomyopathy is the synergistic effect of insulin resistance, compensatory hyperinsulinemia, and progressive hyperglycemia. The initial introduction of the concept of diabetic cardiomyopathy was attributed to Rubler et al. [3]. The aforementioned observation was validated through a subsequent examination of the Framingham Heart Study in 1974. This analysis revealed that individuals with diabetes exhibited a 2.4-fold higher risk of heart failure (HF) in men and a fivefold higher risk in women in comparison to those without diabetes. Notably, this increased risk persisted even after accounting for other contributing factors such as age, hypertension, obesity, dyslipidemia, and CAD [4]. The clinical evolution of diabetic cardiomyopathy begins with subclinical cardiac abnormalities, including left ventricular fibrosis and diastolic dysfunction. Over time, this leads to severe diastolic HF with normal ejection fraction. Ultimately, individuals may experience systolic dysfunction accompanied by HF with reduced ejection fraction.

Prevalence of diabetic cardiomyopathy with type 1 and type 2 diabetes

The study aimed to assess the correlation between HbA1c levels and HF risk in a group of 20,985 individuals diagnosed with type 1 diabetes, averaging 38.6 years of age. Results demonstrated a noteworthy 30% rise in HF risk for every 1% increase in HbA1c levels compared to prior levels. This correlation was statistically significant, even accounting for established risk factors like hypertension, smoking, and obesity [5]. A cross-sectional study of middle-aged individuals with type 1 diabetes showed systolic dysfunction in both left and right ventricles, identified through Doppler imaging's assessment of isovolumetric contraction diabetic cardiomyopathy [6].

Individuals with type 2 diabetes are at an elevated risk for the onset of cardiac stiffness and diastolic dysfunction [7]. The Framingham Heart Study revealed that individuals diagnosed with type 2 diabetes had a heightened risk, ranging from two to eight times, for the onset of heart failure. Furthermore, it was seen that around 19% of them experienced heart failure manifestation [4]. The findings of a retrospective cohort study involving a sample size of 8231 individuals diagnosed with type 2 diabetes revealed that the occurrence of heart failure was observed in 30.9 individuals per 1000. In contrast, the incidence rate was 12.4 per 1000 in individuals without diabetes. This indicates a 2.5-fold higher risk of developing heart failure in individuals with type 2 diabetes [8].

Pathophysiology of diabetic cardiomyopathy

Insulin resistance and hyperinsulinaemia increase systemic metabolic disorders, activate the sympathetic nervous system (SNS), and activate the renin-angiotensin-aldosterone system (RAAS). The synergistic effect prompts oxidative stress, mitochondrial dysfunction, and endoplasmic reticulum stress. It impairs calcium homeostasis resulting in cardiac fibrosis, hypertrophy, cardiomyocyte death, and dysfunction of the coronary microcirculation. Eventually, it leads to diastolic dysfunction and, subsequently, HF. (Figure 1).

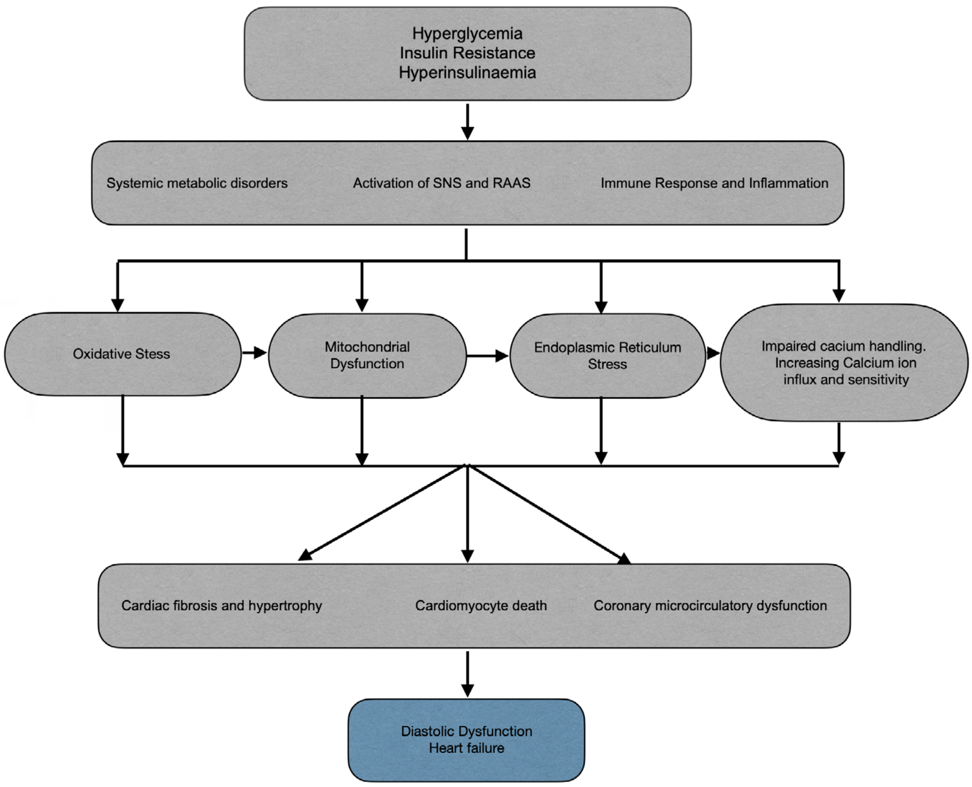

Figure 1. *Pathophysiology of Diabetic Cardiomyopathy*

Table1. *The stages of diabetic cardiomyopathy.*

Diabetic Cardiomyopathy	Stage 1	Stage 2	Stage 3	Stage 4
Symptom	Asymptomatic	Symptomatic	Symptomatic	Symptomatic
Phenotypes	Diastolic Dysfunction LV Hypertrophy	Systolic and Diastolic Dysfunction, LV -Dilatation	Systolic and diastolic dysfunction, LV -Dilatation associated with hypertension	Multiple confounders including Coronary artery disease
Correspondence NYHA Classification	NYHA |	NYHA II	NYHA III	NYHA IV
Correspondence ACC/ AHA Staging	Stage A	Stage B	Stage C	Stage D
Metabolic Error Associ-ated	Meabolic Syndrome Imparied Glucose Tolerence	Chronic Hyperglycemia Hyperinsuliniaemia	Insulin Resistance Microangiopathic complications	Micro- and macroangiopathic complications
Echocardiography	Normal LVEF, T LVMI, diastolic dysfunction, Tissue Velocity	LVEF <50% ,T LVMI,Systolic and diastolic dysfunction, LV mild dilation	Diastolic Dysfunction, Mild to moderate LV systolic	Severe LV systolic dysfunction LV Dilated ,
Monitoring	FBS, PPBS, HbA1C, Lipid Profile, NT Pro BNP, and MMP-3(if available)			

LV-left ventricle, LVEF- left ventricle ejection fraction, LVMI-left ventricle mass index, RWMA-regional wall motion abnormality, NYHA-New York Heart Association, ACC/AHA- Americal College of Cardiology/ American Heart Association.FBS-fasting blood sugar, PPBS,- postprandial blood sugar, NT Pro BNP-N-Terminal Pro-B Type Natriuretic peptide, MMP-3, Matrix Metalloproteinase-3

Stages of diabetic cardiomyopathy

Diabetic cardiomyopathy encompasses four distinct stages, which exhibit certain similarities with the HF categories established by the ACC/AHA and the New York Heart Association classification [9]. The diabetic cardiomyopathy staging is described in Table 1 [9].

Clinical determinants of diabetic cardiomyopathy

The development of HF in diabetes is multifactorial, such as elderly age, elevated glycosylated haemoglobin (HbA1c), higher body mass index (BMI), hypertension, CAD, longer duration of diabetes, and microvascular complications [10].

Cardiac structural alteration in diabetic cardiomyopathy

The study by Rubler et al. (1972) highlighted structural changes in the myocardium among individuals with diabetes [3]. Subsequent research has consistently supported their findings, demonstrating a strong association between diabetes and left ventricular (LV) morphology alterations. These changes include LV hypertrophy and widespread myocardial fibrosis, as evidenced by multiple studies.

Numerous echocardiographic and cardiovascular magnetic resonance imaging (CMR) studies have shown a strong link between elevated LV mass and diabetes, although this connection is not universally consistent [11,12]. One study indicated a significant correlation between a 1% rise in HbA1c levels and a 3.0 g increase in LV mass (13). Despite the modest increase in LV mass, it's crucial to recognize its established role as a significant predictor of cardiovascular morbidity and mortality [14] and its pivotal involvement in diabetic cardiomyopathy's progression into HF.

Functional impairments in diabetic cardiomyopathy

The functional impairments in the case of diabetic cardiomyopathy range from asymptomatic to overt symptomatic HF [9]. Echocardiographically, it starts with diastolic dysfunction and gradually progresses into impaired systolic function.

Diastolic Dysfunction

Diastolic dysfunction is often identified as the initial functional change in diabetic cardiomyopathy. Observational studies reveal a higher occurrence of diastolic dysfunction in type 2 diabetes mellitus (T2DM) using echocardiography and CMR. A study of 1810 individuals with T2DM found a positive link between HbA1c levels and diastolic dysfunction [15]. Despite managing metabolic risks associated with T2DM, like high HbA1c, hypertension, BMI, dyslipidemia, and albuminuria, diastolic dysfunction persists [16]. However, the prevalence of diastolic dysfunction in asymptomatic T2DM varies widely (15% to 78%), attributed to differing diagnostic methods [17].

Systolic Dysfunction

Despite the link between T2DM and HF, few studies demonstrated that T2DM leads to decreased Left Ventricular Ejection Fraction (LVEF). Taking advantage of myocardial strain and strain-rate assessment has led to the frequent documentation of subclinical abnormalities in systolic function in diabetic individuals. Tissue Doppler imaging [18], Speckle Tracking Echocardiography [19], and CMR [20] data have collectively demonstrated that individuals with T2DM have a decreased left ventricle global longitudinal strain (LV-GLS) during systole compared to individuals without diabetes.

The deterioration of global longitudinal strain is shown to deteriorate over time and exhibits variability throughout the range of the glycemic spectrum [19,21].

For over two decades, there have been extensive multicenter, randomized controlled trials regarding pharmacological interventions to reverse cardiovascular dysfunction in diabetes patients, such as UKPDS [22], ADVANCE [23], ACCORD [24], and VADT [25] failed to demonstrate an improvement in macrovascular outcomes with strict blood glucose control. A meta-analysis of these four extensive studies, which had a total of 27,000 patients who were randomly assigned to either more- intensive or less-intensive blood-glucose management, revealed a modest decrease in major adverse cardiovascular events (hazard ratio [HR] 0.91; 95% confidence interval [CI] 0.84–0.99) [26].

Recently, new therapeutic approaches for managing glucose levels in T2DM have emerged, such as glucagon-like peptide-1) (GLP-1) agonists [27] and sodium-glucose cotransporter-2 (SGLT2) inhibitors [28]. These interventions show positive results in improving blood sugar control and reducing cardiovascular mortality in individuals with T2DM [29]. However, there are significantly fewer studies regarding the beneficial effect of diabetes reversal on cardiovascular functions. Although the concept of diabetic cardiomyopathy has emerged for more than four decades, it is still not yet debated on a large scale. This prospective study focused on the impact of diabetes reversal on improving cardiac functions and structural alteration and improving quality of life in the case of diabetic cardiomyopathy.

Research Methodology

Research objective

The objective of this prospective research study was to assess the effects of diabetes reversal on cardiac function and quality of life in individuals diagnosed with both diabetes and cardiac dysfunction with a preserved LVEF. Through the examination of the combined impacts of organized exercise training and dietary interventions, this study aimed to provide insight into the possibility of a more holistic approach to enhancing cardiac function management, considering the numerous aspects of the disease.

The study provided valuable insights into the potential advantages of an integrated strategy by analyzing improvements in QoL, exercise capacity, heart function measures, and physical and psychological well-being. By enhancing insight regarding the synergistic outcomes resulting from the amalgamation of physical and dietary modification, the research can contribute to developing forthcoming therapeutic practices and improve the quality of life for diabetic persons afflicted with heart failure with preserved ejection fraction.

Research design

This prospective study was multicenter randomized research with 59 participants who participated between January 2021 and June 2022. The study's objectives and techniques were effectively conveyed to all participants, encompassing cardiologists, endocrinologists, physical therapists, nutrition specialists, and diabetic nurses. The study cohort consisted of individuals diagnosed with T2DM and LVEF >50%.

Before participating in the clinical trial, the chosen individuals were furnished with comprehensive details regarding the research study and were obligated to affix their signatures to the permission document. Participants had the autonomy to withdraw from the research at their discretion. The participants were randomized randomly to either a control or intervention group. In order to safeguard personally identifiable information, the collected data was subjected to encryption before transmission to researchers, therefore mitigating the risk of unauthorized access to such information from the database at any point in the process.

Research subject

This study included diabetic patients under treatment and undergoing treatment in the outpatient department. To interpret the effect of this integrated approach of rehabilitation and psychological support on HF effectively, a patient group aged 30-70 years was selected.

Inclusion Criteria-

1. Age 30-70 years
2. T2DM
3. Free of comorbidities
4. LVEF >50%
5. Able to consent

Exclusion Criteria-

1. Age <30 years and >70 years
2. Type I DM
3. Uncontrolled T2DM
4. Pregnancy
5. Patients with comorbidities
6. Patients with musculoskeletal problems
7. LVEF <50%
8. Noncompliance to therapy
9. Cancer patients
10. Severe breathlessness NYHA III-IV 11.Patients participating in other research studies 12.Failure to consent

Study Flow-Chart

According to the flowchart illustrated in Figure 2, 265 individuals with diabetes were identified after applying the specified inclusion and exclusion criteria during the screening process. A total of 59 participants were recruited for this prospective study. The participants registered in the study were randomly assigned to two groups, including 32 individuals in the Intervention Group and 27 individuals in the Control Group.

Control Group

The Control Group neither participated in physical exercise training nor received any dietary modification. The individuals within the Control Group received guideline-directed diabetic care from endocrinologists. The subjects adhere to the diabetic diet as suggested by the endocrinologist. Nevertheless, the diet did not undergo consistent inspection by any registered dietitian.

Intervention Group

The Intervention Group of patients received an integrated program that included physical training and strict dietary modification. The physiotherapist guided the participants through an exercise routine in a face-to- face setting. The physiotherapist observed individuals performing the exercises, offering immediate feedback and adjustments as necessary and facilitating peer support among participants utilizing this approach. Computerized slide presentations were utilized to deliver educational subjects. The participants were sent an invitation to see the designated presentation at their

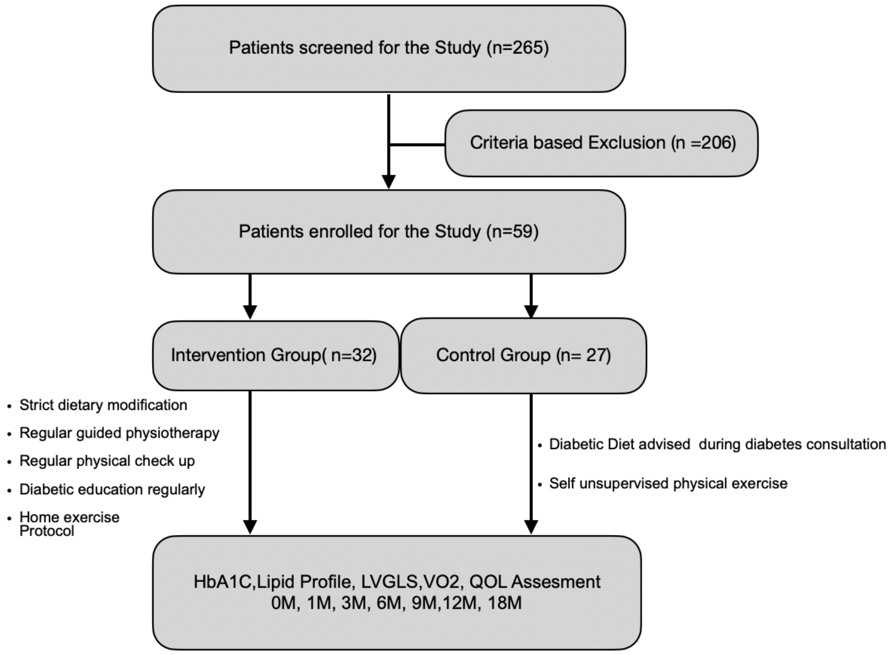

***Figure 2**. Flowchart of the prospective study*

convenience, either individually or accompanied by a support individual, in anticipation of forthcoming online collective deliberations. Every session consists of an introductory interaction period that takes place prior to the workout routine.

At the commencement of each session, participants underwent an examination of vital parameters, such as blood pressure, heart rate, and oxygen saturation levels, done by diabetic nurses. Body weight, blood sugar level, and psychological and physical well-being were also measured.

Outcome measures

Primary outcome: All the enrolled patients in both groups underwent laboratory investigations, including fasting blood sugar (FBS), HbA1C, and lipid profile at the beginning of this prospective study and subsequently in 0, 1, 3, 6, 9, 12, and 18 months to evaluate the impact of interventions and compare the two groups.

Secondary outcomes: Secondary outcome measures such as LV GLS, peak VO2 (Spiroergomerty test), and QoL were assessed at this prospective study's beginning and subsequent phases.

Validated surveys were used to measure health-related QoL and patient satisfaction.

The Short-Form-12 (SF-12) is a general health questionnaire comprised of 12 questions that assess the patient's state of health across eight distinct dimensions: General health perception – 1 question, Physical health – 2 questions, Limited physical role function – 2 questions, Physical pain – 1 question, Vitality – 1 question, Mental health – 2 questions, Limited emotional role function – 2 questions, Social functioning – 1 question.

Results

A total of 59 individuals were included in the trial, with 39% of the Intervention Group and 27% of the Control Group being female. In this prospective trial, a total of 32 patients

***Table 2**. Demographic Variables of the Participants*

Variables	Intervention Group	Control Group	P-Value
Weight (kg)	70.48±13.42	69.84±14.28	<0.001
Height (inch)	69.27±10.26	67.51±10.12	<0.001
BMI (kg/m^2)	26.64±12.14	24.68±8.62	0.21
Systolic BP (mm Hg)	154.28± 24.66	149± 21.29	<0.001
Diastolic BP (mm Hg)	75.40±10.62	78.24± 12.65	<0.001
Hypertension duration (years)	5.21± 2.12	4.18±2.69	0.03
Heart rate (per minute)	82.17±11.89	80,67± 10.63	<0.001
Respiratory rate (per minute)	18.93± 5.04	18,46± 6.43	<0.001
Smoking (yeras)	3.28± 1.32	2.12± 1.14	<0.001
Fasting blood sugar	176.44 ± 85.39	168.65 ± 79.46	<0.001
Diabestes duration (Years)	4.86± 1.46	5.48± 1,05	0.63
LDL	133.65±21.87	141± 22.63	0.03
Diabetic Neuropathy n(%)	8(25%)	6(22%)	0.6

(n=32) successfully completed the diabetes reversal program, representing 54% of the participants. A total of 27 individuals, comprising 46% of the sample, adhered to the recommended self-regulated food and exercise regimen in a self-paced manner. Table 2 comprehensively describes both groups' cardiovascular risk factors, cardiac intervention, and baseline characteristics. Initially, no statistically significant disparities were seen between the groups receiving the intervention and those in the control group. During the duration of this prospective trial, no untoward incidents were seen, and all participants successfully completed the prescribed exercise plan.

Demographic Variables of Participants(Figure-3)

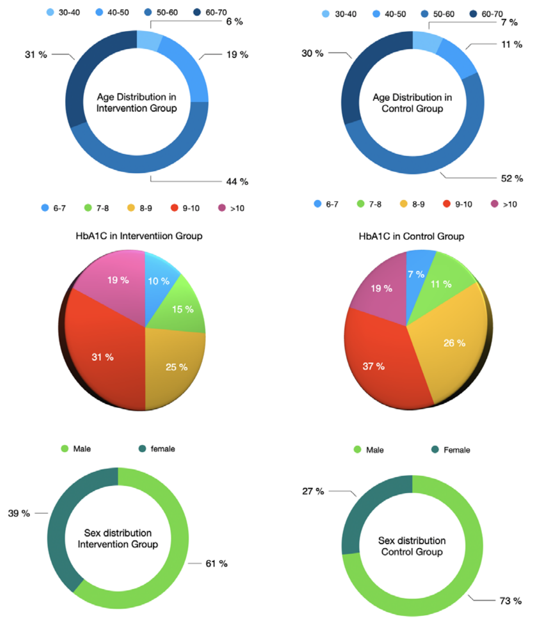

Figure 3*. Demographic Variables of Participants*

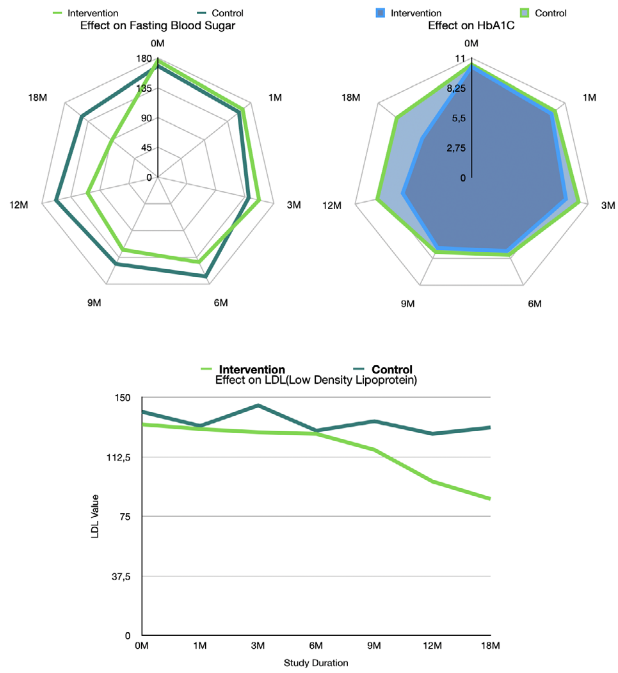

Figure 4*. Impact of diabetes reversal on fasting blood sugar, HbA1C, and low-density lipoprotein*

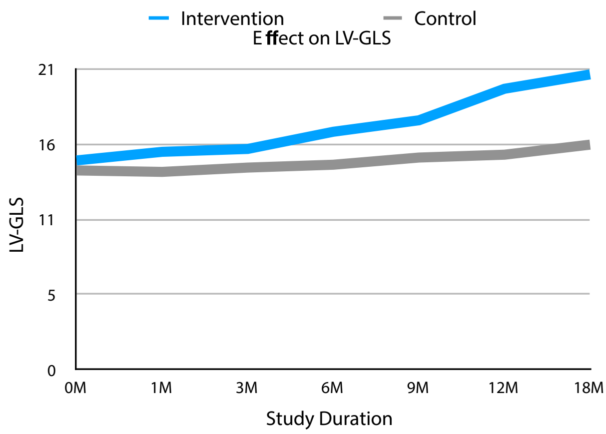

Figure 5*. Effect of diabetes reversal on Left Ventricle Global Longitudinal Strain*

Effect of diabetes reversal on Fasting Blood Sugar, HbA1C, and Low-density Lipoprotein (Figure 4)

As evident from the graphical representation, there is a positive impact of diabetes reversal on FBS, HbA1C, and LDL. There is a remarkable difference between the two groups after 12 and 18 months in FBS and HbA1C measurements. Better control of LDL has been documented in the Intervention Group after 6 months in comparison with the Control Group.

Left ventricle - global longitudinal strain (LV-GLS)

Based on the findings of the meta-analysis, it has been shown that a LV-GLS value of -16% signifies significant myocardial dysfunction, irrespective of the LVEF being within the typical range [30]. In this prospective investigation, a cutoff value of -16% was selected for LV-GLS. This value was determined based on a multicenter study involving various echocardiography equipment and echocardiographers. The present study aimed to assess the impact of supervised telerehabilitation on GLS, a recognized indicator of heart function. According to the visual depiction, physiotherapy-guided exercise and strict dietary modification have shown a positive enhancement in LV-GLS.

Peak VO2

Peak oxygen consumption (peak VO2) remains the gold standard for predicting prognosis in HF [31]. All participating patients of both groups have successfully performed cardiopulmonary exercise tests at the baseline and subsequent study intervals. The graph shows that the patients who underwent supervised training and a strict diabetes reversal program showed substantial improvement in peak VO2, with a visible difference in progress after six weeks.

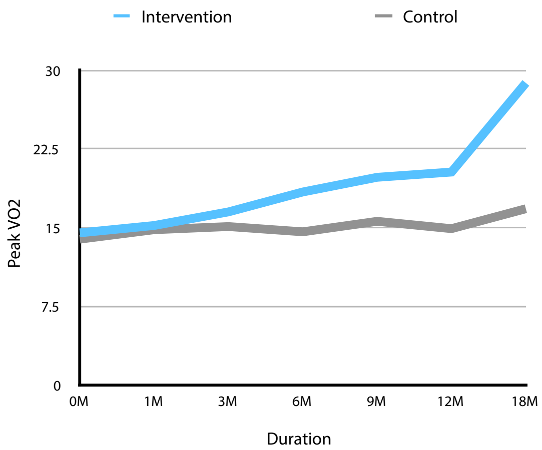

Figure 6. *Effect of diabetes reversal in diabetic cardiomyopathy on Peak VO2*

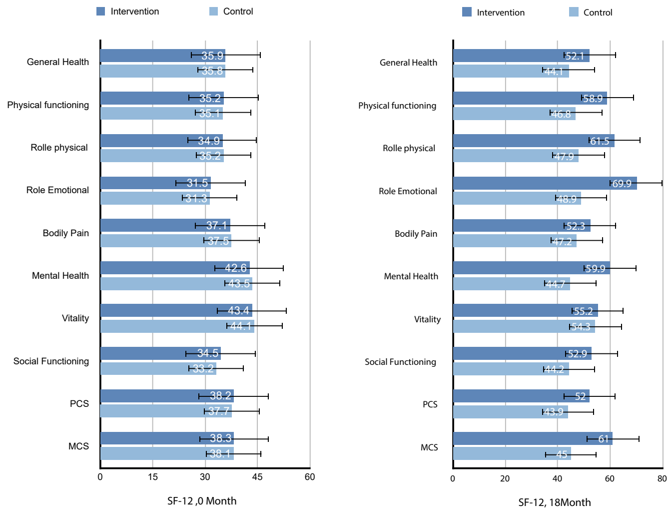

Figure 7. *E\ffect of diabetes reversal on Quality of Life (QOL)*

Table 3. *SF-12 (Quality of Life)Questionnaire and Scale*

Domain	Question No.	Description	Response Scale
General Health	2	General Health	1-5
Physical Functioning	3a	Health affected moderate activities	1-3
	3b	Health affected step climbing	1-3
Role Physical	4a	Physical health affected ability to accomplish	1-5
	4b	Physical health affected kind of work or other activities	1-5
Role Emotional	5a	Emotional health affected ability to accomplish	1-5
	5b	Emotional health affected kind of work or other activities	1-5
Bodily Pain	6	Pain interfered with normal work	1-5
Mental Health	7a	Felt calm and peaceful	1-5
	7c	Felt downhearted and depressed	1-5
Vitality	7b	Had a lot of enery	1-5
Social Functioning	8	Amount of time physical or emotional problems interfered with social activities	1-5

Quality of Life (QOL) Assessment

The SF-12 is a questionnaire designed to evaluate health-related QoL. It consists of twelve items that aim to examine both physical and mental health. These items measure eight distinct health domains. The physical health domains encompass General Health (GH), Physical Functioning (PF), Role Physical (RP), and Body Pain (BP). Vitality (VT), Social Functioning (SF), Role Emotional (RE), and Mental Health (MH) represent distinct dimensions within the realm of mental health. The validity of the instrument has been shown for a range of chronic diseases and disorders [32,33]. The SF-12 was employed for the assessment of QOL in both groups. Two summary scores, namely physical and mental health, were calculated for each participant based on the eight categories of the SF-12.

According to the graphical depiction of the QoL Assessment scores utilizing the SF-12 instrument (Figure 7), it is evident that patients who underwent an integrated approach consisting of strict dietary modification and specified physiotherapy-guided exercise protocol experienced a significant enhancement in both their Physical Component Score (PCS) and Mental Component Score (MCS).

Discussion

This prospective study examined the cardiopulmonary benefits after 1, 3, 6, 9, 12, and 18 months of strict dietary modification and physiotherapy-guided exercise program compared to conventional diabetes care at home and an exercise program as advised by the treating diabetologist. The main findings of this research were a remarkable improvement of LV-GLS, Peak VO2 peak, and in the case of an integrated approach.

Enhanced cardiopulmonary functional capacity is the main objective in case of HF patients to obtain a better QoL [34]. In this study, patients who followed a diabetes reversal program showed an increase in peak VO2 peak by 34% in 12 months.

Though there was an improvement in the Control Group, the peak VO2 improvement was only 13.51% after 12 months. The duration of the interventional diabetes reversal strategy was 18 months, like other investigations in the previous studies.

Regular exercise has increased vascular endothelial cell activity, potentially improving lower cardiac output and peripheral vasoconstriction in individuals with HF. Furthermore, exercise reduces cytokine secretion and neurohormonal system activation, improves oxygen utilization in mitochondria of peripheral muscle cells, increases muscle mass, increases respiratory efficiency without negatively impacting left ventricular remodeling, and ultimately improves the clinical outcome of HF patients [35].

The LV-GLS follow-up measurements reflected a gain of 41% in 18 months in the intervention group.

As shown in figure-7, there is substantial improvement in the mental health component in the intervention group, which underwent an integrated approach of supervised dietary modification and individualized physiotherapy.

Conclusion

This prospective research study aimed to examine the effects of diabetes reversal on cardiac function and quality of life in persons diagnosed with diabetic cardiomyopathy. The results of our research offer significant contributions to understanding the possible advantages associated with diabetes reversal, as well as its impact on cardiovascular function and the general state of health. The reversal of diabetes resulted in an augmentation in cardiac performance, characterized by enhancements in LV-GLS and total cardiac function. Furthermore, our research revealed a notable enhancement in the QoL for individuals who successfully reversed their diabetes.

The aforementioned results highlight the potential advantages of timely identification, proactive management of diabetes, and the significance of a collaborative strategy encompassing specialists in cardiology, endocrinology, nutrition, and physical therapy. Additional research is necessary to comprehend the enduring consequences comprehensively; nonetheless, our work indicates that the reversal of diabetes can benefit cardiac function and the overall well-being of persons afflicted with diabetic cardiomyopathy. The findings of this study provide a promising outlook for enhanced outcomes and more effective care for this complex illness.

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