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Efficacy of structured exercise protocol on functional capacity, HbA1c, and waist-hip ratio in post-myocardial infarction subjects with diabetes mellitus

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ABSTRACT

Diabetes mellitus is a well-established independent risk factor for myocardial infarction (MI) and other cardiovascular diseases (CVDs). According to the American Heart Association (AHA) 2023 Report, individuals with diabetes are 2 to 4 times more likely to develop coronary artery disease (CAD) and MI compared to non-diabetic subjects. The study was conducted to find the efficacy of structured exercise protocol training in post-angioplasty subjects type II diabetes patients Total 168 subjects were selected, met the inclusion and exclusion criteria, and were randomly divided into two groups. Group A (n= 84) received conventional physiotherapy with lifestyle Modifications and Group B (n= 84) received structured exercise training for 6 months. Subjects were evaluated based on pre and post-assessment by HBAIC, shuttle walk test, and waist-hip ratio. Both the groups showed significant improvement but Group B showed much more significant improvement as compared to Group A. Group B (HbA1c-3%, waist-hip ratio 9%, **functional capacity (VO_2 max** ($p < 0.001$), **SWT distance** ($p < 0.001$), **SpO_2 levels** ($p < 0.001$)), indicating the rejection of null hypothesis and acceptance of structured exercise protocol Given the robust evidence supporting the benefits of cardiac rehabilitation, it should be incorporated into standard post-MI care protocols to improve long-term cardiovascular outcomes.

Keywords: *Post-myocardial infarction, Type II diabetes, functional capacity, HbA1c, Waist-Hip ratio*

1. INTRODUCTION

A major global health concern faced worldwide is diabetes which has significantly increased its prevalence in the past few years. The global prevalence of diabetes according to the International Diabetes Federation (IDF) Diabetes Atlas (2023) among adults of around 20 to 79 years of age is 537 million, which is 10.5% in 2021, and is predicted to reach 783 million, which is 12.2% by 2025. Diabetic patients almost 3 in 4 are observed to be living in low to middle-income countries. By 2021, over 6.7 million of them who died were attributed to diabetes. The highest prevalence of diabetes in an area, making it the leading region of diabetes in the Western Pacific (206 million cases), Southeast Asia (90 million cases), and North America (51 million cases) [1].

India is counted among one of the highest burdens facing the country in diabetes throughout the globe. India is the second-highest country after China with around 101 million Indian adults suffering from diabetes according to the **Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) Study (2023). While also adding 136 million people who are pre-diabetic making them to stand at the edge of progression to diabetes. Every state shows different variations in the prevalence of diabetes, where urban areas show a high prevalence of 16.4% while on the other hand, rural areas show 8.9%. the state-wise differentiation in prevalence shows southern and eastern states, especially mentioning (Tamil Nadu, Kerala, and West Bengal) to be high in prevalence when compared with northern and central states [2].**

An independent as well as well-established risk factor of myocardial infarction along with the other associated cardiovascular diseases is known to be Diabetes mellitus (DM). As per the reports published by the American Heart Association (AHA) in 2023, coronary artery diseases and MI can have 2 to 4 times more probability of development among individuals with diabetes than those without diabetes [3]. According to the UK Prospective Diabetes Study (UKPDS), there is seen to be 14% increase in risk for MI with every 1% increase in HbA1c [4]. Around 30-50% of the occurrence of MI was reported among individuals with diabetes in a recent meta-analysis performed by Rawshani et al. in 2021, which significantly highlights the burden of same in the society [5].

A significant elevation in the risk of MI was seen among individuals with diabetes with the help of Pathophysiological mechanisms taking place in an individual which primarily included endothelial dysfunction, accelerated atherosclerosis, chronic inflammation, hypercoagulability as well as autonomic dysfunction. Coronary artery disease was the ultimate outcome of all the mechanisms mentioned above which eventually leads to plaque rupture, thrombosis, and also MI [5].

Vascular homeostasis is central to endothelial which is markedly impaired in diabetic patients. The glycation of endothelial proteins was induced by chronic hyperglycemia which eventually elevated the production of reactive oxygen species (ROS). This resulted in oxidative stress leading to endothelial cell injury [6]. Reduction in the synthesis of nitric oxide leads to impairment in vasodilation which results in increased vasoconstriction, thus, increasing vascular resistance [7]. Vasoconstriction, thus, taking place, is further exacerbated by the elevated levels of endothelial, which ultimately diminishes the myocardial perfusion (Tabit et al., 2020), collectively impairing the coronary blood flow along with increasing myocardial oxygen demand, ultimately increasing the susceptibility to ischemia as well as infraction[8].

The rapid progression seen in atherosclerosis is fostered by diabetes, which eventually contributes to coronary artery stenosis and ischemic heart disease. The low-density lipoprotein undergoing oxidation induced by hyperglycemia enhances the formation of foam cells, which ultimately promotes atheroma development [9]. Triglycerides as well as small dense LDL are elevated along with insulin resistance and dyslipidemia which ultimately evaluate the atherogenic potential [10]. Macrophagic infiltration along with plaque growth is stimulated by pro-inflammatory cytokines which include tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP) [11]. Larger and more lip-rich plaques are developed in individuals having diabetes, which hold a high consequence of getting ruptured which eventually precipitates acute thrombosis and MI.

The risk of occluding the coronary artery eventually increases as the hypercoagulable state is precipitated among diabetes individuals, eventually which can be followed by plaque rupture. The excessive aggregation as well as thrombus formation is promoted by the activation of platelets which is augmented by Hyperglycemia-mediated glycation of platelet receptors [12]. Clot formation is especially contributed by elevated fibrinogen levels which tend to hinder fibrinolysis, leading to the prolongation of occlusion of coronary artery [13]. Fibrinolytic activity is further inhibited by the overactivation of plasminogen activator inhibitor-1 (PAI-1), further contributing to the thrombotic risk [14]. Often an increased thrombus burden is exhibited by diabetes patients, which leads to reduced quality of revascularization and increasing the mortality rates.

Diabetes has a hallmark of low-grade chronic inflammation, which increases vascular damage and renders the atherosclerotic plaques to be more vulnerable for rupturing. Nuclear factor kappa B (NF-κB) is activated by hyperglycemia signaling pathways, which increase the release of inflammatory mediators including IL-1β, IL-6, and TNF-α [15]. Oxidized LDL accumulation is fostered by the persistent oxidative stress [16]. Fibrous caps of the plaques are weakened by the inflammatory responses which makes them vulnerable to rupture and lead to thrombotic events [17]. The elevation if incidences in MI is seen by the resultant increase observed in the instability of plaque among diabetic individuals.

An increased amount of significant decline in the functional capacity can be seen among diabetic patients who underwent an episode of MI. multiple factors are responsible in the precipitation of this reduction which primarily include impaired cardiac function, autonomic neuropathy, endothelial dysfunction, skeletal muscle abnormalities as well as chronic inflammation [5]. Assessment tools such as VO_2 max, **Incremental Shuttle Walk Test (ISWT), 6-Minute Walk Test (6MWT) as well as and Duke Activity Status Index (DASI)** are commonly used to asses the functional capacity of these individuals.

Post-MI cardiac rehabilitation is exacerbated due to diabetes which causes reduction in the ejection fraction of the heart along with left ventricular dysfunction [18]. A condition leading to fibrosis and myocardial stiffness resulting in diastolic dysfunction is known as diabetic cardiomyopathy. This condition eventually impairs the cardiac output along with the exercise tolerance of an individual [19]. 25-35% of reduced peak VO_2 max was reported in post-M diabetic patients

The endothelial nitric oxide production is impaled due to diabetes which leads to vasoconstriction resulting in reduced myocardial perfusion [8]. In diabetes, usually microvascular dysfunction leads to lower oxygen availability to the muscles which limits the exercise performance of an individual [20]. A 20% greater reduction is seen in exercise tolerance among diabetic mi patients due to impaired vasodilation [21].

Diabetes patients often face sarcopenia and muscle atrophy which ultimately contribute to weakened lower extremity strength and endurance affecting the working ability of an individual [22]. **Muscle contraction efficiency is also reduced due to increased intramuscular fat infiltration which causes reduction in oxygen utilization during exercise [**9]. **Mitochondrial function is also impaired due to insulin resistance which leads to decreased ATP production as well as muscle fatigue [**10].

Blunted heart rate can be seen as a response to exercise in diabetic autonomic neuropathy patients which limits the cardiac output adaptation taking place while performing any physical activity [23]. **A lower heart rate variability is seen among post MI diabetic patients eventually delivering poor functional outcomes [**24].

Increased fatigue levels as well as reduced exercise endurance is seen due to higher levels of inflammatory markers (IL-6, TNF-α, CRP) among diabetes patients [15]. **Lower grade inflammation is often associated with diabetes which impairs the myocardial recovery and also affects vascular function ultimately limiting the functional improvement among post MI patients [**16].

When diabetic post MI patients were made to walk along with no- diabetic MI patients, it was seen that diabetic patients walked 80 to 100 meters less than that of non-diabetic patients[18]. **Over 20 to 30% of less improvement in 6-minute walk test distance was seen after three months of cardiac rehabilitation programs delivered to the diabetic MI patients in a study performed by Huang et al in 2021. Around 15 to 25% low VO2 max was seen among diabetic MI patients when compared with non-diabetic ones after a structure rehabilitation program [**25]. **The lower VO2 max significantly correlated the higher baselines of HbA1c, which ultimately highlighted the direct connection between glycemic control and the aerobic fitness of an individual [**13].

Test to assess the functional capacity among post myocardial infarction patients was incremental shuttle work test which is a progressive field walking test. It gives an overview of exercise intolerance, rehabilitation progress and cardiovascular fitness of an individual. Here, individuals are made to walk back and forth around a 10 meter track which followed an audio cue, supposed to increase the speed of an individual at the set intervals. An individual was made to walk until he or she reaches the volatile exhaustion [26].

A reliable valid as well as widely accepted tool to measure the blood glucose level of an individual is by assessing the HbA1c values which of fer the long term assessment of glycemic control of an individual. It is one of the core stone of diagnosing diabetes and assessing the effectiveness of management as it shows a strong correlation with the blood glucose level, delivering the actual clinical stability of the patient and helping in the prediction of complications. An average blood glucose levels can be reflected by this test. Thus, provides important insights of metabolic status of an individual and also delivers the risks of diabetes related complications in an individual [27].

A widely recognized anthropometric measure used globally is waist-hip ratio which is used to assess the central obesity as well as cardiovascular risk of an individual. It also assesses in predicting the myocardial infarction prognosis among individuals while surpassing body mass index values, which were considered to be traditional measures [28].

The amount of central fat distribution is reflected with the help of WHR. Such central fat distribution is strongly associated with systemic inflammation, insulin resistance along with endothelial dysfunction which are considered to be the key contributors of atherosclerosis and MI [29].

A critical role in the rehabilitation programs arranged for post-myocardial infarction patients who suffer from diabetes is played by exercise, which has proven itself to be beneficial in the improvement of glycemic control body composition as well as the functional capacity of an individual. A significant enhancement in cardiovascular endurance, reduction in central obesity as well as improvement in metabolic function was seen among those who practiced regular aerobic and resistance training which ultimately helped them to get better long-term outcomes as well as reduction in cardiovascular mortality [30].

Myocardial oxygen uptake is significantly enhanced with the help of exercise which ultimately helps to increase the stroke volume and cardiac output of the heart [31]. **Reduction in insulin resistance is also seen in muscle fibers among those who perform regular training which results in improvement of oxygen utilization and increase endurance of an individual [**32]. **Nitric oxide production is also increased with the help of exercise which ultimately leads to vasodilation and better coronary blood flow [**33].

AMPK and GLUT-4 receptors are activated with the help of exercise which promote non-insulin dependent glucose uptake among the individuals [34]. Insulin sensitivity is enhanced due to regular training which help in the increase in mitochondrial function in skeletal muscles [35]. Pro-inflammatory cytokines **(TNF-α, IL-6, CRP)** are also lowered with the help of exercise which are the ultimate cause of insulin resistance as well as endothelial dysfunction [22].

A 0.5% to 0.1% reduction was seen in the values of HbA1c in a meta-analysis performed with 12 to 16 weeks of structured exercise protocol [34]. **HbA1c levels were significantly reduced with the help of high-intensity interval training programs than those with moderate-intensity exercise programs [**35]. **Sustained HbA1c reduction was seen among those who underwent a supervised cardiac rehabilitation program in order to increase long-term glycemic control and decrease the cardiovascular risk among the individuals [**36]. **HbA1c levels were more effectively improved with the combination of aerobic and resistance training. Insulin sensitivity was also enhanced with the help of such intensity programs. Not only exercise but also lifestyle modification played a significant role in improving glycemic control among these patients.**

Lipolysis is increased with the help of aerobic exercise which helps in the reduction of central adiposity [37]. The fat-to-lean mass ratio is effectively shifted with the help of resistance eventually lowering the WHR [38]. Adipose tissue inflammation can be significantly reduced with the help of exercise, thus, reducing the accumulation of fat in abdominal regions [33].

Aim: To study the efficacy of Structured exercise protocol on functional capacity and HbA1C Post-Myocardial Infarction subjects **with Diabetes Mellitus**

OBJECTIVES: Objectives: To determine the efficacy of Structured exercise protocol on Functional capacity post-myocardial Infarction subjects **with Diabetes Mellitus**

- To determine the efficacy of Structured Exercise Protocol HbA1C in post-myocardial Infarction subjects **with Diabetes Mellitus**
- To determine the efficacy of Structured Exercise Protocol waist-hip ratio in post Myocardial Infarction subjects **with Diabetes Mellitus**

2. HYPOTHESIS

Null hypothesis: There will be no significant difference between Structured exercise protocol and Conventional physiotherapy on Functional capacity and HbA1c in post-Myocardial Infarction subjects with **Diabetes Mellitus**

Alternate hypothesis: There will be no significant difference between Structured exercise protocol and Conventional physiotherapy on Functional capacity and hba1c in Post Myocardial Infarction subjects with **Diabetes Mellitus**

3. METHODOLOGY

Ethical Considerations

The present study was a Randomized Controlled Trial that was carried out in Krishna Hospital and Medical Research Center, Karad from August 2018 and May 2023 after obtaining permission from the ethical committee of Krishna Vishwa Vidyapeeth, Krishna Institute of Medical Sciences deemed to be university, Karad.

Research approach: Experimental study. Sampling: Convenient sampling. Sampling technique: Random Group Allocation. Study setting: Cardiorespiratory Physiotherapy department, KH&MRC, Karad. Sample size: 168.Study duration: 2 years Intervention duration for each patient: 6 months

Sample size: 168

The minimum members required for the study is calculated as follows:

FORMULA: N = (SD12 + SD22) (Z-1α + Z-1ß)

$(\bar{X}1-\bar{X}2)^2$

The minimum number of subjects required with the 95% confidence 95% power is n=76, since the follow-up study n= 76+8 (since 10% attrition rate) = 84. Hence minimum of 84 subjects in either group should be studied.

Inclusion Criteria: 1. Adults aged 40–75 years. 2. Clinically diagnosed with myocardial infarction within the past 3 months. 3. Diagnosed with Type 2 Diabetes Mellitus (HbA1c levels >6.5%) at baseline.4. Medically stable to participate in an exercise program (as per cardiologist clearance).

Exclusion Criteria: 1. Unstable angina or recent cardiac events within one month 2. Severe heart failure (NYHA Class III-IV).3. Presence of uncontrolled hypertension (BP > 180/110 mmHg). 4. Orthopedic or neurological conditions limiting exercise participation.5. Unwillingness to provide informed consent.

Randomization and Group Allocation

Participants will be randomly assigned to either:

Intervention Group (IG): Structured exercise protocol group and lifestyle advice

Control Group (CG): conventional physiotherapy and lifestyle advice.

A computer-generated randomization sequence will be used to ensure allocation concealment.

Exercise prescription for the intervention group

1. Intensity: Based on VO2 Max calculated 2. Frequency: 1 session/day, 5 sessions/week. 3. Duration Of Treatment: 60 minutes/session 4. Duration Of Study: 6 months 5. Study Setting: Cardiorespiratory Physiotherapy Dept

Exercise prescription for conventional group

1. Type: Brisk walking 2. Frequency: 5 sessions/week 3. Duration: 30-45 minutes per session.

6. Outcome Measures

Assessments will be conducted at baseline (Week 0), Week 12, and Week 24.

6.1 Primary Outcome Measures

1. Functional Capacity: Assessed by the Shuttle Walk Test (SWT) 2. HbA1c Levels: Blood sample analysis for glycemic control.3. Waist hip ration: measured by inch tape

Adherence and Compliance: Recorded via daily logs and session attendance.

7. Data C0llection and Analysis

Data will be collected by blinded assessors at baseline, mid-intervention (week 12), and post-intervention (week 24).

Statistical Analysis:

Table no 01. Baseline characteristics of overall participants of the study (n = 168)

Variables	**Frequency**	**Percentage %**
Sex		
Male	84	50.0
Female	84	50.0
Smoking		
Yes	105	62.5
No	63	37.5
ALCOHOLIC		
Yes	104	61.9
No	64	38.1
FAMILY		
Yes	103	61.3
No	65	38.7

Diseased vessel		
1	51	30.4
2	77	45.8
3	40	23.8
OBESITY		
YES	103	61.3
NO	65	38.7

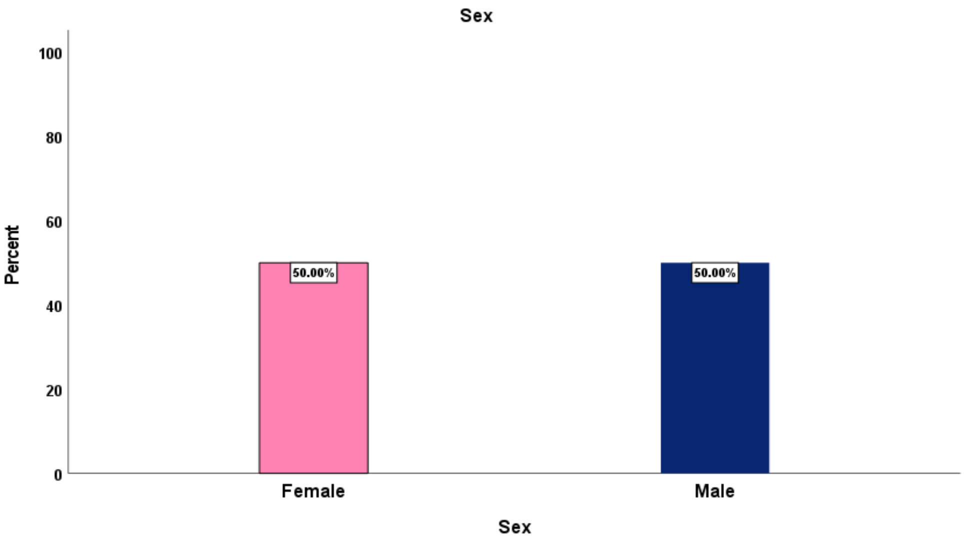


Figure:01. Frequency distribution of sex in the overall participants

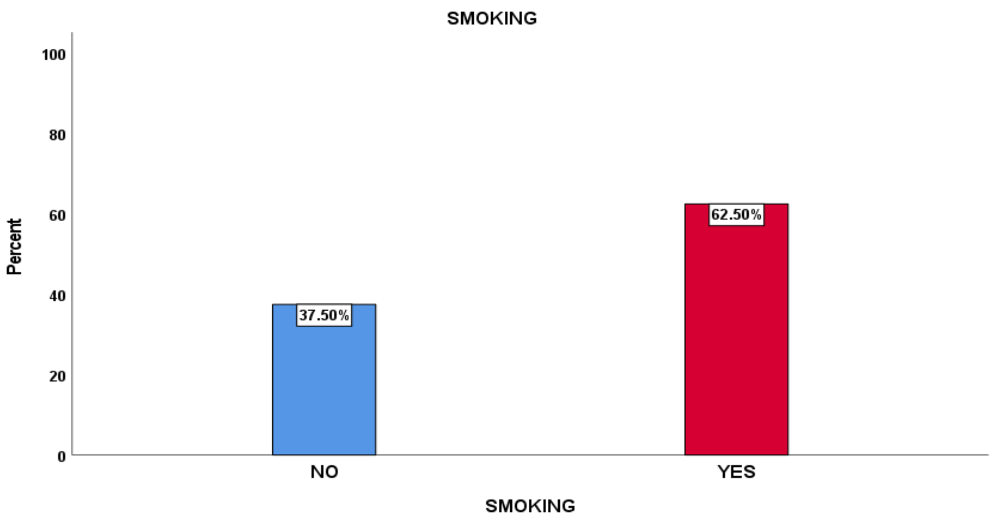


Figure:02. Frequency distribution of smokers in the overall participants

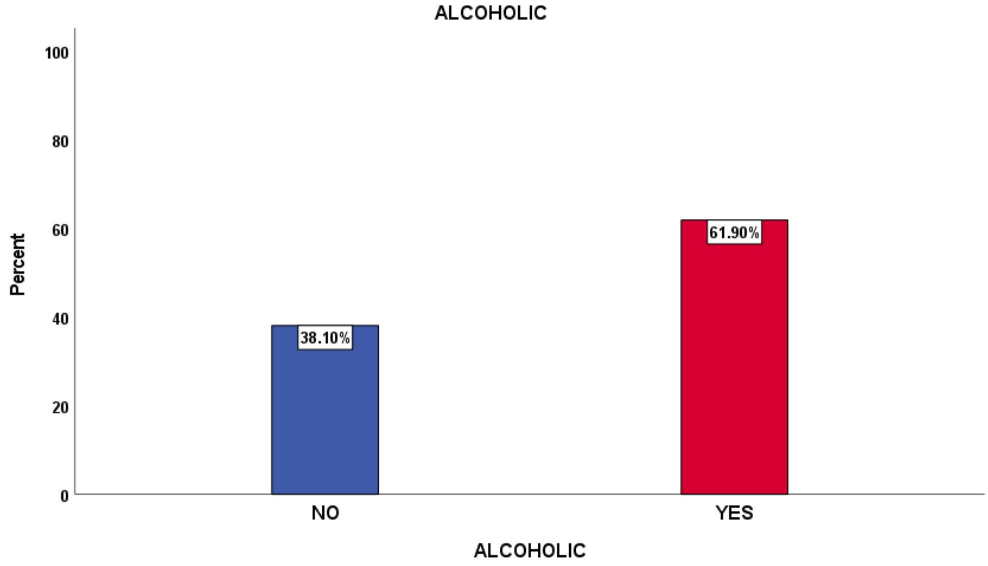


Figure:03. Frequency distribution of alcoholics in the overall participants

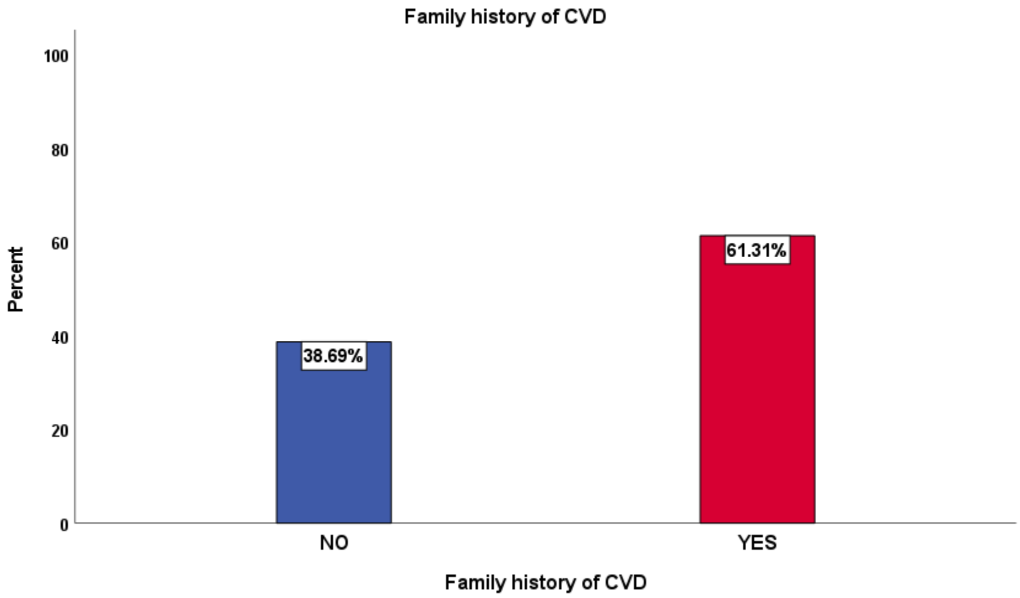


Figure:04. Frequency distribution of Family history of CVD in the overall participants

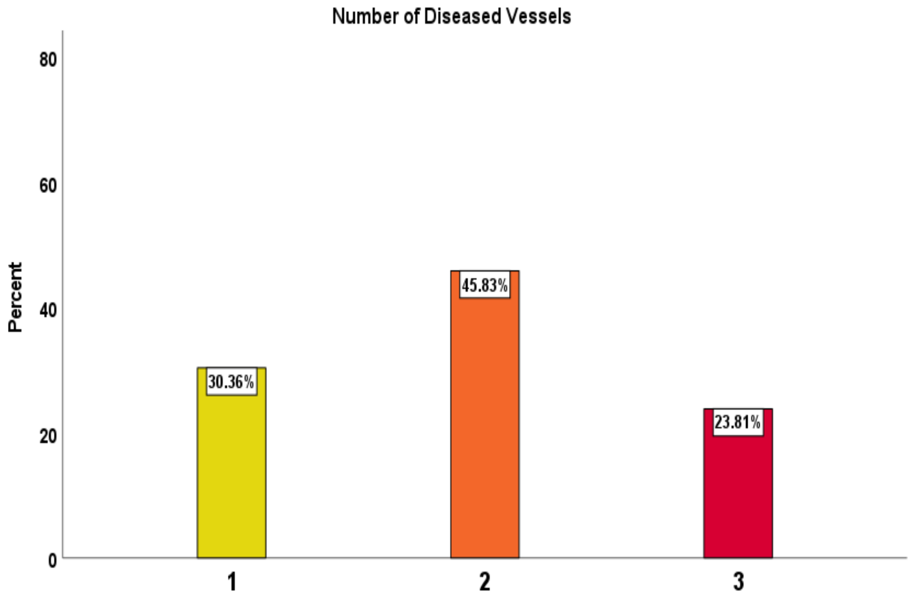


Figure:05. Frequency distribution of the Number of diseased vessels in the overall participants

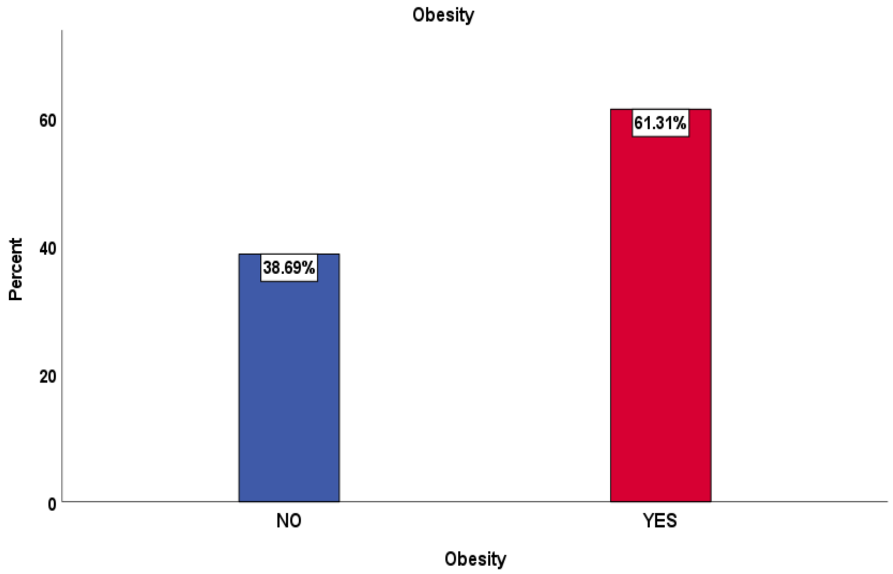


Figure:06. Frequency distribution of Obesity in the overall participants

4. OVERALL STATISTICS OF CONTINUOUS VARIABLES

Table no -02. Descriptive statistics of continuous variables (Age) expressed as mean and SD for the overall participants in this study

Variable	Mean (95% CI)	SD	Min - Max	IQR
Age	54.10(53.19-55.01)	5.962	45-65	10

Table no - 03. Descriptive statistics of Functional capacity outcomes expressed as mean and SD for the overall participants in this study

Variables	Mean (95% CI)	SD	Min - Max	IQR
Pre_VO2_SWT	25.3809 (24.4532-26.3086)	6.09029	14.06-5.37	5.37
Pre_RPE_SWT	14.99 (14.75-15.24)	1.603	13 - 17	4
Pre_MMRC_SWT	2.10 (1.94-2.25)	1.040	0 - 4	0
Pre_SPO2_SWT	96.09 (95.82-96.36)	1.788	90 - 99	3
Pre_Distance_SWT	320.15 (293.63-346.67)	174.128	750	170

Figure:07. Post-intervention VO2 MAX Shuttle Walk Test by Group

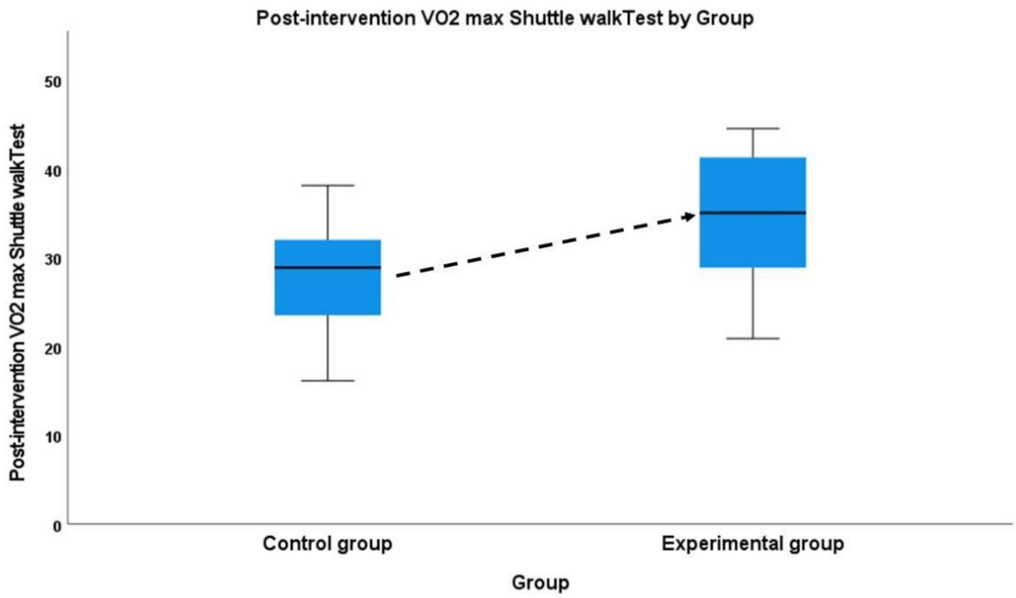


Figure:08. Post-intervention RPE Shuttle Walk Test by Group

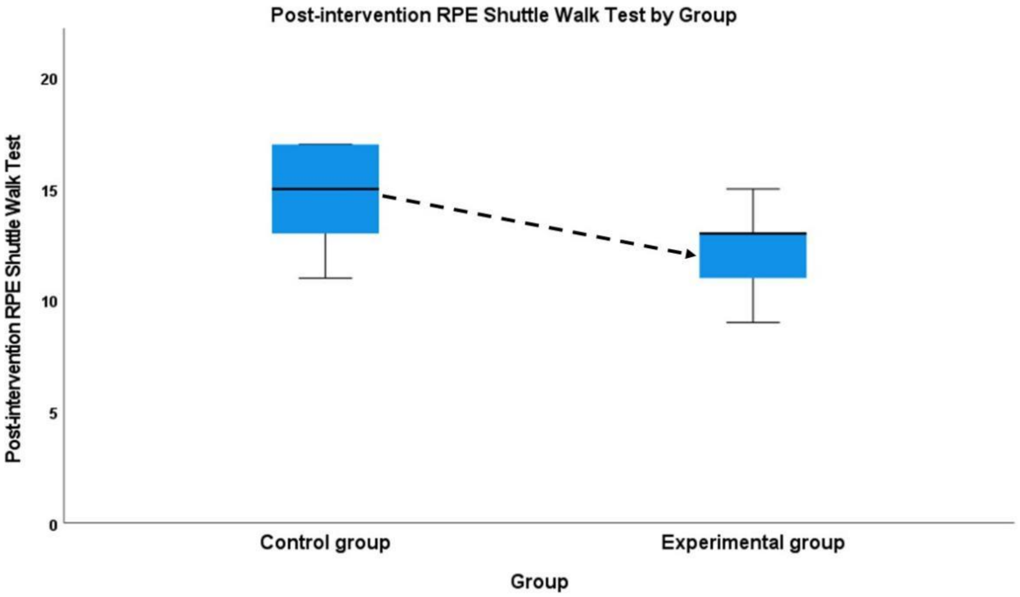


Figure:09. Post-intervention MMRC Shuttle Walk Test by Group

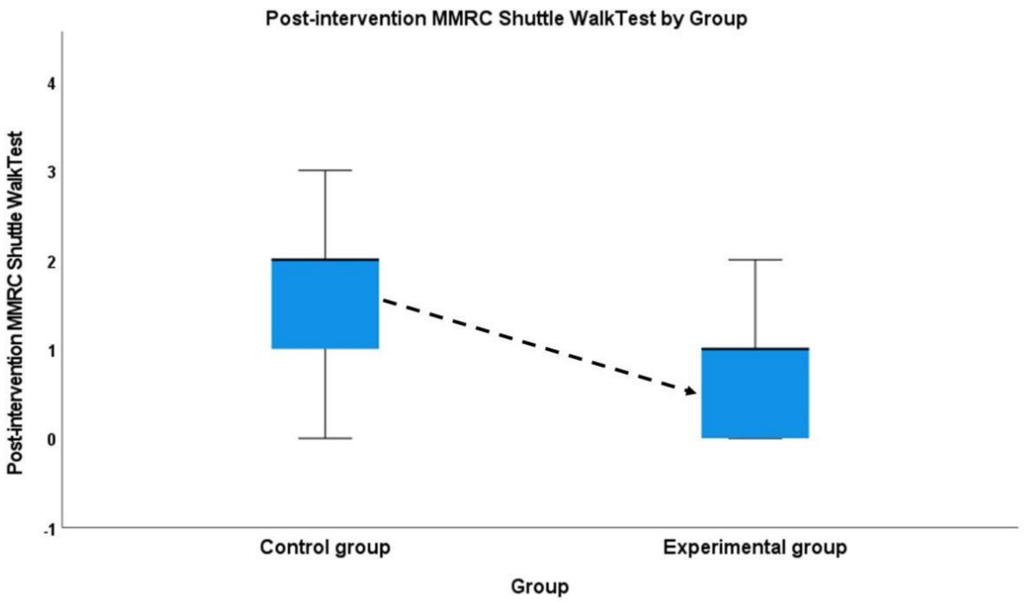


Figure:10. Post-intervention SPO2 Shuttle Walk Test by Group

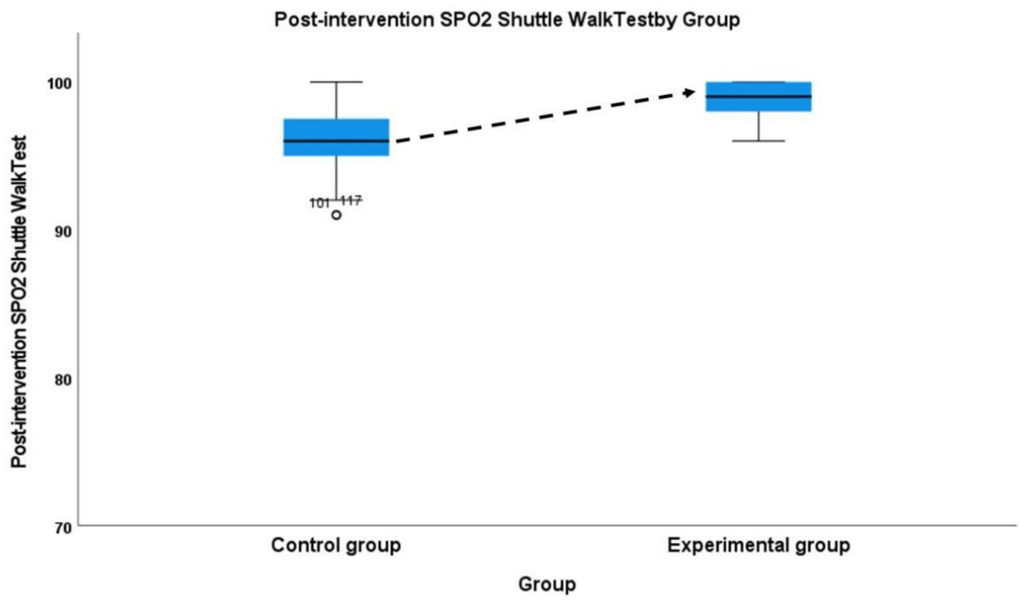
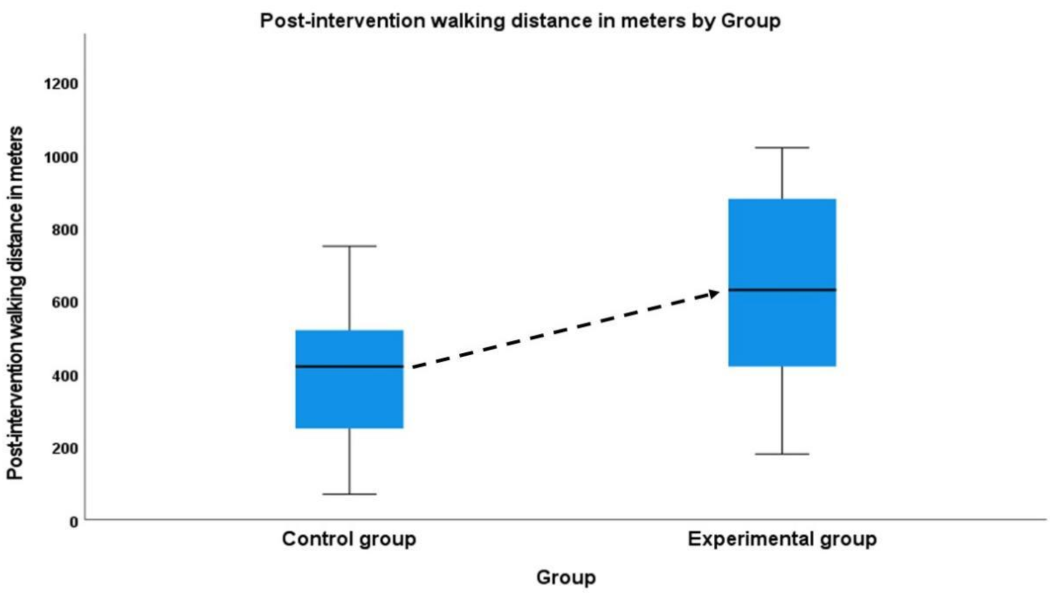


Figure:11. Post-intervention Walking Distance In Meters by Group



5. BIOMARKERS

Table no - 04. Descriptive statistics of investigated biomarkers expressed as mean and SD for the overall participants in this study

Variables	Mean (95% CI)	SD	Min - Max	IQR
HbA1c	10.630 (8.266-12.993)	15.5175	7.9 - 210.0	1.6
WHR	0.9801(0.9559-1.0043)	0.15885	0.81 - 1.50	0.11

Figure:12. Post-intervention Blood Glucose Levels (HbA1c) by Group

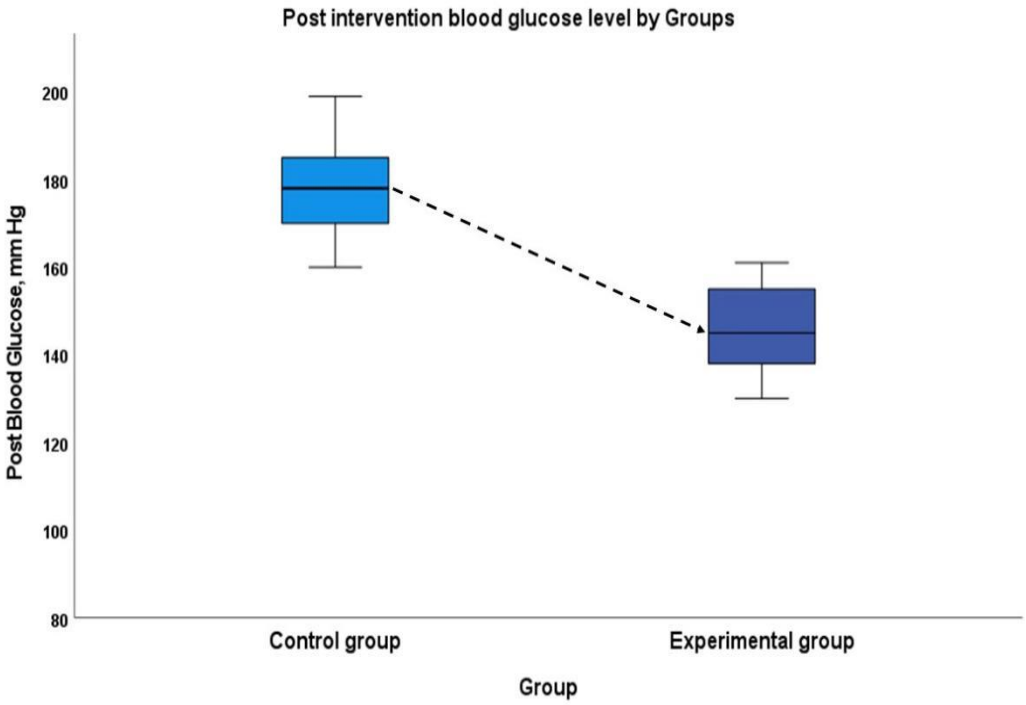
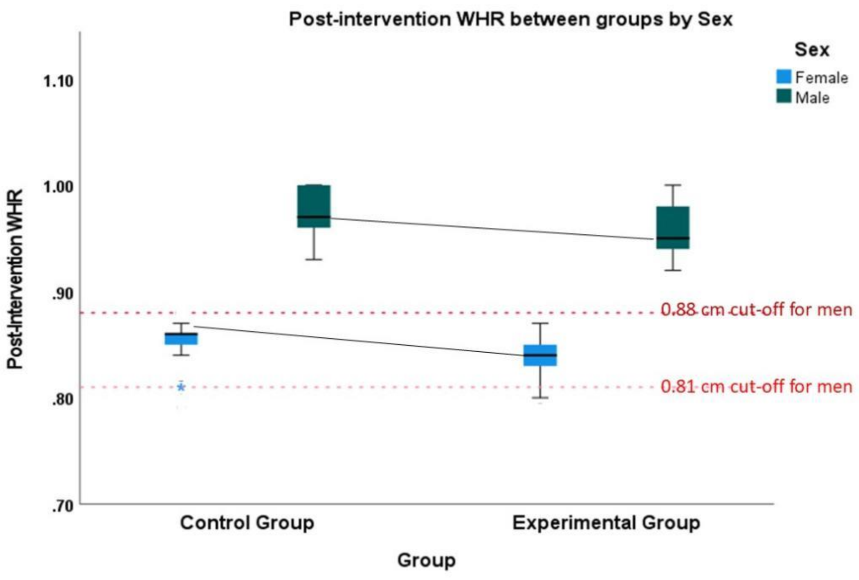


Figure:13. Post-intervention WHR between groups by Sex



6. DISCUSSION

A comprehensive comparison of certain baseline characteristics which include functional capacity outcomes as well as biomarker levels analyzed among 168 participants was presented in a study that divided the participants into a control group and an interventional group. The evaluation of the impact of interventional measures delivered to the participants which basically focused on exercise as well as lifestyle modification along with functional capacity and levels of biomarkers in blood samples of post-myocardial infraction patients was the primary objective of the study.

The equal distribution of sex was discovered in the baseline characteristics of the study which revealed 50% males and 50% females. A high prevalence of modifiable cardiovascular risk factors was seen in the participants who were also chronic smokers with a proportion of 62.5% in total participants. Also, 61.3% of participants were obese which further underscored the metabolic burden in the population.

Thus, as the readings provided by the previous research which significantly highlighted the major risk factor observed among participants who smoked, consumed alcohol or were obese were significantly correlating the findings of this study (Benjamin et al., 2023; Yusuf et al., 2023)[39,40]. The high disease burden was underscored by the presence of multi-vessel disease which included 3.4% with single vessel disease, 45.8% with two-vessel disease, and also 23.8% of them had a three-vessel disease which ultimately highlighted the critical need to engage the population in certain interventions which primarily focused on lifestyle modification along with structured exercise-based rehabilitation program.

By viewing with the help of a theoretical perspective, a framework that offers a better understanding of adherence towards lifestyle modifications in order to evaluate the severity, susceptibility as well as benefits of certain behavioral changes experienced by an individual who underwent an episode of MI was provided by Health Belief Model (HBM) (Rosenstock, 1974)[41].

Functional Capacity Outcomes

The key physiological indicators used to assess the functional capacity of the individuals included VO_2 mas (oxygen consumption), Borg Rating of Perceived Exertion (RPE), **the Modified Medical Research Council Dyspnea Scale (MMRC), SpO_2 levels, and the Shuttle Walk Test (SWT) distance.**

The reduced functional capacity was seen among pre-interventional population with the mean VO_2 max of 25.38 ml/kg/min among individuals when compared with age-matched healthy individuals. The existing evidence of post MI patients experiencing the reduced exercise tolerance was reinforced by the mean SWT distance of 320.15 meters. (Rees et al., 2022)[42].

In Post-Intervention, **A significant improvement was observed in all functional capacity measures in the intervention group. Notably:**

A significant increase in VO_2 max was seen with 25.56 to 34.04ml/kg/min ($p < 0.001$), also improvement in SWT distance was seen from 323.63 to 613.63 meters ($p < 0.001$), whereas, a significant reduction was seen in dyspnea scores obtained with the help of MMRC scale.

These results align with recent studies demonstrating the efficacy of structured exercise programs in enhancing functional capacity among post-MI patients (Taylor et al., 2023; Rauch et al., 2022)[43]. Cardiac rehabilitation programs have been shown to **reduce mortality by 20-30% and improve VO_2 max by 15-20%** within 12 weeks of structured training.

Thus, the efficacy of structured exercise programs was highlighted with the alignment of results with the results obtained by the recent studies performed for the same, which primarily included the enhancement of the functional capacity among the post-Mi patients (Taylor et al., 2023; Rauch et al., 2022)[44]. A significant reduction in mortality rates by 20-30% was seen along with an improvement of VO_2 max by 15-20% after the structured training program of 12 weeks was seen in individuals undergoing cardiac rehabilitation program.

The Fick principle was used to explain the improvements observed, which described the enhancement of cardiac output along with the utilization of oxygen in order to increase exercise capacity after the sessions of structured training programs. The enhanced functional performance among post-MI patients was seen due to certain physiological adaptations taking place after the targeted ad and resistance training was highlighted by the **Specific Adaptations to Imposed Demands (SAID) Principle**.

Biomarker Analysis

HbA1c (glycemic control) and Waist-to-Hip Ratio (WHR) were used as metabolic indicators to assess the study.

In the pre-interventional assessment, the elevation in HbA1c was seen in both the groups in which the control group showed 11.83% and the interventional group showed 9.42% of ranges which ultimately suggested poor glycemic control among post-MI patients.

The values of HbA1c showed a significant reduction in a post-intervention assessment done among the interventional group with a value of 6.72% when compared with the control group which was 7.81%. also, a reduction of 0.976 to 0.895 was seen in the WHR values of individuals which highlighted the shift taking place in the body composition of participants with the help of interventions.

Thus, it was observed that exercise can significantly improve the insulin sensitivity, glucose metabolism as well as HbA1c levels among post-MI patients who had diabetes, showing a recognizable alignment with the results of prior studies performed on the same.

Insulin sensitivity hypothesis was used to interpret the metabolic improvements seen among the individuals, which highlighted the enhancement of glucose uptake as well as metabolism with the help of physical activity in order to reduce HbA1c levels **(DeFronzo et al., 1985)[45]**. The link between improvement seen in the cardiovascular outcomes and the metabolic outcome with the reductions in the WHR was highlighted by the **Central Obesity Hypothesis**.

Between-Group Comparisons

Functional Capacity

The interventional group showed significantly superior post-interventional functional capacity when compared with the control group, the noticeable difference was seen in the levels of VO_2 max ($p < 0.001$), **SWT distance** ($p < 0.001$) and **SpO_2** ($p < 0.001$) which highlighted the effect of exercise-based intervention of an individual.

Biomarkers

The interventional group observed an increased 3% reduction in HbA1c values and 9% in WHR values which significantly delivered the **superiority of structured rehabilitation when compared with any other standard care.**

The meta-analysis done on the sane supported the findings of this study promoting the effectiveness of cardiac rehabilitation on exercise tolerance, metabolic control, as well as the quality of life of individuals who underwent the episode of MI. (Anderson et al., 2022; Cornelissen et al., 2021)[46,47].

Implications for Clinical Practice

The importance of the role of structured exercise program as an integral component, to be used in the management of post-MI patients was emphasized by the results obtained from the study. According to the evidence obtained which strongly supported the benefits provided by the cardiac rehabilitation programs, it is highly recommended to incorporate them in the standard post-MI care protocols in order to improve the long-term outcomes of the cardiovascular system.

Exercise-based cardiac rehabilitation was advocated to be the Class I intervention by the American Heart Association (AHA, 2023)[48] and the **European Society of Cardiology (ESC, 2023)[49]** which strongly suggested its inclusion in the routine management provided to the post-MI patients.

Limitations and Future Directions

Even though the findings of the research provided promising outcomes, there were also certain limitations present in the study. In order to evaluate the sustainability of the improvements observed, longer follow-up durations of about 6 to 12 months are highly recommended.

A crucial role is played by the nutritional intake of an individual in order to maintain metabolic health and is recommended to be the primary concern in future research.

Population with diverse genetic predispositions, as well as lifestyle factors, may not deliver generalizable findings.

Personalized exercise prescriptions should be explored in future research in order to tailor the individual patient profile which primarily incorporates the genetic as well as metabolic markers with a view to optimize the outcomes obtained from the rehabilitation programs.

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