Combined effect of Yog-vyayama on different levels of HbA1c in patients with Type 2 Diabetes Mellitus

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By

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Dedicated to

my beloved Parents

Late Sukdeb Dhali

&

Smt. Pratima Dhali

and

my teachers

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Biswajit Dhali

Biswajit Dhali
(Research Scholar)

Certified that the Thesis entitled

"Combined effect of Yog-vyayama on different levels of HbA1c in patients with Type 2 Diabetes Mellitus" submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under the Supervision of Prof. Sudip Sundar Das, Department of Physical Education, Jadavpur University. And that neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere / elsewhere.

22.11.2024

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Preface

Type 2 Diabetes Mellitus (T2DM) is a global health pandemic, affecting millions worldwide. The management of T2DM requires a multifaceted approach, incorporating lifestyle modifications, pharmacological interventions, and complementary therapies. Yoga, an ancient Indian practice, has garnered attention for its potential benefits in improving glycemic control and overall well-being.

This study investigates the combined effect of Yog-Vyayama, a structured yoga program, on patients with T2DM, focusing on its impact on Haemoglobin A1c (HbA1c) levels. HbA1c, a critical marker of glycemic control, is essential for assessing the effectiveness of T2DM management strategies.

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Abbreviations

Sl. No.	Abbreviations	Full Form
1	A.F.R	Africa
2	ADA	American Diabetes Association
3	b/m	Beat Per Minute
4	BMI	Body Mass Index
5	CAM	Complementary And Alternative Medicine
6	cm	Centimetre
7	DBP	Diastolic Blood Pressure
8	Df	Degrees Of Freedom
9	E.U.R	Europe
10	FBG	Fasting Blood Glucose
11	FI	Fasting Insulin
12	FPG	Fasting Plasma Glucose
13	HbA1c	Glycosylated Haemoglobin
14	HC	Hip Circumference
15	HOMA	Homeostatic Model Assessment
16	HR	Heart Rate
17	I.D.F	International Diabetes Federation
18	IDF	International Diabetes Federation
19	IFT	Impaired Fasting Glucose
20	IGT	Impaired Glucose Tolerance
21	IR	Insulin Resistance
22	IS	Insulin Sensitivity
23	kg	Kilogram
24	LGS	Left Grip Strength
25	M.E.N.A	Middle East & North Africa
26	mg/dL	Milligrams Per Deciliter
27	mmHg	Millimeters of Mercury
28	N.A.C	North America & Caribbean
29	OGTT	Oral Glucose Tolerance Test
30	OHA	Oral Hypoglycemic Agent
31	PPBG	Postprandial Blood Glucose
32	PPPG	Postprandial Plasna Glucose
33	QUICKI	Quantitative Insulin Sensitivity Check Index
34	RGS	Right Grip Strength
35	RM ANOVA	Repeated Measures Analysis Of Variance
36	S.A.C.A.	South And Central America
37	S.E.A	South-East Asia
38	SBP	Systolic Blood Pressure
39	SpO_2	Pulse Oximeter
40	SPSS	Statistical Package for Social Sciences
41	T1DM	Type 1 Diabetes Mellitus
42	T2DM	Type 2 Diabetes Mellitus
43	W.P	Western Pacific
44	WC	Waist Circumference
45	WHO	World Health Organization

CHAPTER – I

Introduction

CHAPTER - I

INTRODUCTION

1. Introduction

This chapter is the initial part of a research study, with the goal of producing the best possible work that includes an extensive overview and background, as well as a clear rationale for the entire research process.

1.1 Background of Diabetes:

Clinical structures related to diabetes were identified 3000 years prior to the ancient World. In Ayurveda Diabetes Mellitus is significantly similar to Madhumeha, one of twenty forms of Prameha as described in all Ayurvedic texts.[43] Acharaya Sushruta has described two types of Prameha Roga in Chikitsa Sthana: Sahaja Prameha (Hereditary Diabetes), and Apathya Nimittaja Prameha (Acquired Diabetes).[187] As Acharya has enlightened Madhumeha is a 'Mahagada' or 'Maharoga' i.e., a disease which has serious clinical manifestation.[42, 33] The word "Diabetes" was first discovered by Araetus of Cappodocia (81-133 AD). Later, the term Mellitus (sweet honey) was merged by British physician Thomas Willis in 1675 after reliving the sweet taste of diabetic urine named 'Madhumeha' (honey urine) in Ayurveda.[6] Sir Frederick G Banting, Charles H Best and JJR Macleod first discovered the insulin by at the University of Toronto in 1921. Harold Percival Himsworth first differentiated between type 1 and type 2 diabetes in 1936.[150, 92] Type 2 diabetes mellitus (T2DM) is categorized by autoimmunity of carbohydrate, lipid and protein metabolism, and outcomes from diminished insulin secretion, insulin resistance or a blend of together. [61]

Type 2 diabetes mellitus (T2DM) is a most common metabolic disorder categorized by prolonged hyperglycemia,[90] is caused by combining two primary factors: imperfect insulin secretion through β-cells of pancreas and the failure of insulin-sensitive tissues to respond properly to insulin.[73] A key property of type 2 diabetes mellitus is insulin resistance (IR).[1] Diabetes mellitus is a multifactorial chronic disease established by hyperglycemia or a high level of blood glucose due to the lacks of insulin secretion, function, or both.[129] Insulin resistance as well as defective beta cell indicate to remaining hyperglycemia which describes type 2 diabetes.[39]

1.2 Clinical structure of Blood Glucose:

Glucose is a sugar with the molecular formula $C_6H_{12}O_6$, the most vital fuel of carbohydrate in the body. In the fed condition, the maximum amount of circulating glucose derives from the diet;

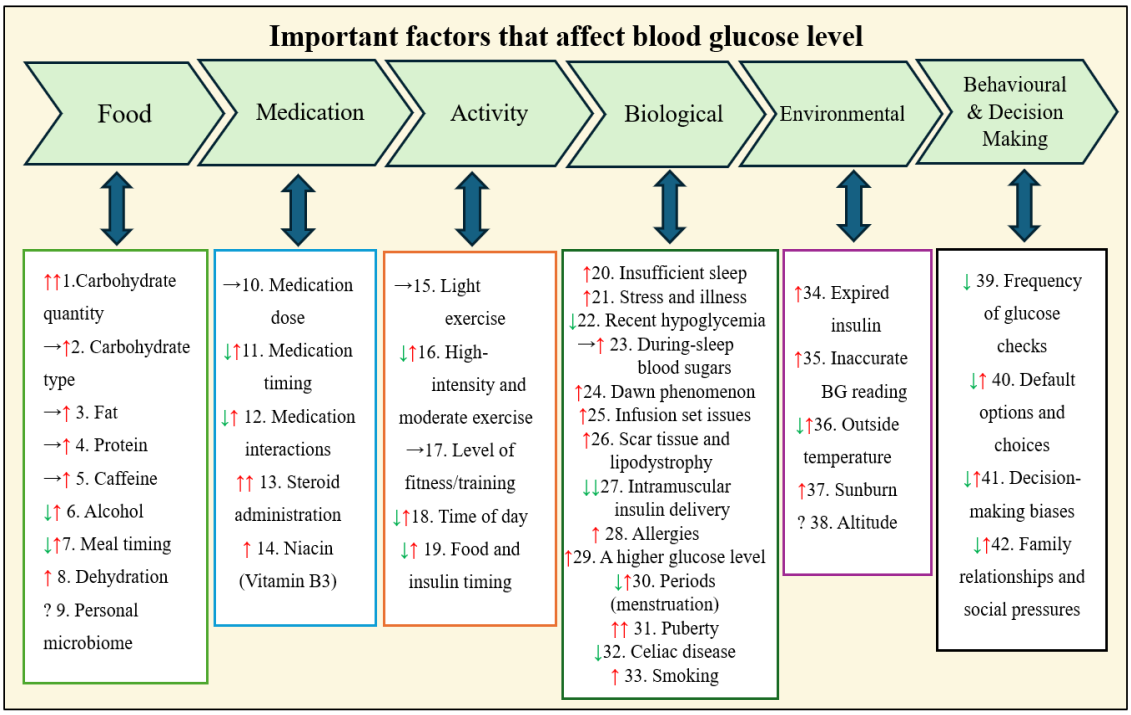


Figure 1: Factors of blood glucose level

In the fasting condition, gluconeogenesis and glycogenolysis keep glucose absorption constant. Glucose is found in more complex carbohydrates that are broken down to

monosaccharides through the digestive process. There are various types of factors that affect blood glucose levels (Figure-1). [35]

1.3 Types of Diabetes:

1.3.1 Type 1 Diabetes:

Another name of Type 1 Diabetes Mellitus (T1DM) is Insulin Dependent Diabetes Mellitus (IDDM) or Juvenile Onset Diabetes Mellitus. T1DM is a group of pancreatic ß cell disorders causing insulin insufficiency due to autoimmune destruction, often resulting from hereditary issues in glucose sensation.[215] T1DM is an autoimmune disease requiring lifelong insulin replacement, including daily injections, insulin pump therapy, or automated insulin delivery systems, to prevent life-threatening diabetic ketoacidosis. T1DM occurs when the immune system destroys pancreatic insulin-making cells, causing blood glucose levels to rise above normal, necessitating daily insulin intake for survival. T1DM is a common condition in children and young adults, and can be heightened by having a parent or sibling with the disease. Indications of type-1 diabetes consist of increased thirstiness, fatigue, urination, hunger, blurred vision, and unsolved weight loss, typically happening rapidly over a few days to weeks.[133]

1.3.2 Type 2 Diabetes:

Non-Insulin Dependent Diabetes Mellitus (NIDDM) is another name of Type 2 diabetes mellitus (T2DM). T2DM is also called Adult-Onset Diabetes Mellitus. T2DM, the most common type of diabetes, is separated by insulin resistance, which is produced by abnormalities in insulin action to liver, muscle, and fat tissues, which is exacerbated through varied and typically increasing failure the ability of beta cells' insulin secretion. In the United States and Europe, most T2DM patients are obese; but, in China and India, the majority of T2DM patients have a lean body mass, although with increased hepatic

and visceral fat.[215] The regulation of insulin synthesis and response in tissues is crucial to meet metabolic demands, leading to a metabolic imbalance and the pathogenesis of T2DM.[73]

1.3.3 Monogenic Diabetes

Monogenic diabetes is a rare condition characterised by reduced insulin making from pancreatic β cells due to the mutation of a single gene in a germ cell (egg or sperm). There are different types of diabetes include Maturity Onset Diabetes of the Young (MODY), mitochondrial diabetes and Neonatal Diabetes Mellitus (NDM).[215] Alternatively, a monogenic diabetes arises because of a de novo mutation in either the paternal or maternal germ line. Sometimes the Gene variants can develop spontaneously, meaning they are not carried by either parent that disrupt the body's ability to produce insulin, a crucial protein for energy use. Most cases of monogenic diabetes are incorrectly diagnosed, often mistaken for type 2 diabetes. Genetic testing and family testing may be necessary to identify the type and risk. Some methods can be considered with oral medicines, while others require insulin injections. Correct diagnosis leads to better glucose control and long-term health.[96]

1.3.4 Gestational Diabetes

Gestational diabetes mellitus (GDM) is another kind of diabetes arises when pregnant that can cause health risks to both the mother and the child. Gestational diabetes, often without symptoms, is linked to hormonal changes during pregnancy, genes, and extra weight, affecting insulin utilization. Doctors test for gestational diabetes between 24 and 28 weeks of pregnancy using glucose challenge and Oral Glucose Tolerance Tests (OGTT). Gestational diabetes management involves a healthy diet and physical activity, and if these are insufficient, insulin may be required. Reducing these risks may be achieved

through healthy weight management, healthy food choices, and physical activity.[133] GDM may happen at any stage during the pregnancy and is unlikely to continue after birth.[93] It has been expected that maximum (75%–90%) cases of hyperglycaemia in pregnancy remain GDM. [10, 94]

1.4 Diagnostic norms for diabetes

Maximum guidelines follow International Diabetes Federation (IDF), World Health Organization (WHO) and American Diabetes Association (ADA) diagnostic criteria that explains in table 1. According to the ADA, "prediabetes" should be identified when the fasting plasma glucose level is between 100–125 mg/dL and the HbA1c value is between 5.7–6.4%. The WHO recommends HbA1c above 6.5% for diabetes, yet not for intermediate hyperglycemia due to measurement issues worldwide.[111, 112] For the purpose of identifying IGT and IFG, the WHO and IDF currently advise using the 75-gram OGTT, which measures plasma glucose levels during both the fasting and 2-hour cycles. A growing body of research supports the use of the 75-gram OGTT, which can detect intermediate hyperglycemia and may be a more sensitive approach.[24] In case of unexpected weight loss are present, the diagnosis of T2DM may be made on the basis of a random plasma glucose test of at least 11.1 mmol/l, and if there are no indications, then a fasting plasma glucose concentration of at least 7.0 mmol/l (HbA1c $\geq$ 6.5%). If asymptomatic individuals show elevated results, it is recommended to repeat testing, ideally with the same test, the following day to confirm the diagnosis.[94]

Table 1: Recent Criteria of diagnosing Prediabetes & Diabetes as stated by International Diabetes Federation (IDF), World Health Organization (WHO) and American Diabetes Association (ADA)[94]

Test	**Impaired Glucose Tolerance** (IGT)	**Impaired Fasting Glucose** (IFT)	**Pre-diabetes**	**Diabetes**
Fasting Plasma Glucose (No caloric intake for at least eight hours)	≥126mg/dL (7.0mmol/L)	110 – 125mg/dL (6.1 – 6.9 mmol/L)	100-125mg/dL (5.6 and 6.9 mmol/L) *[ADA]*	≥126mg/dL (7.0 mmol/L)
Oral Glucose Tolerance Test (OGTT) (2 Hours Plasma Glucose After 75g Oral Glucose Load dissolved in water)	≥140 – 200 mg/dL (≥7.8 and -11.1 mmol/L)	<140 mg/dL (7.8 mmol/L)	(140-199 mg/dL)	≥200 mg/dL (11.1 mmol/L)
HbA1c	-	-	5.7–6.4% (39 and 47 mmol/mol) ***	≥6.5% (48 mmol/mol)
Random plasma glucose Presence of signs of hyperglycemia	-	-	-	≥200 mg/dL (11.1 mmol/L)

After performing the preceding tests in the absence of hyperglycemic symptoms, diabetes mellitus is identified using two abnormal tests.

1.5 Pathophysiology of Type 2 Diabetes

Hyperglycaemia is triggered by an absolute or partial lack of endogenous insulin. Insulin resistance in muscle, fat, and liver, as well as poor pancreatic beta cell responsiveness, are major reasons for relative insulin deficiency. Increased the levels of plasma free fatty acid, which have been linked to IR.[29] So, muscle glucose transportation slows, hepatic gluconeogenesis rises, and fat breakdown speeds up. Sedentary lifestyles combined with susceptible genotypes are most likely to cause T2DM problems. The BMI at which the risk of diabetes increases varies according to race. persons of Asian heritage, for example, are more prone to acquire diabetes while being less obese than persons of European descent.[110]

It is particularly evident when insulin secretion is impaired in response to glucose stimulation, the liver produces more glucose than usual, and there are no signs of

pancreatic autoimmunity.[62] Even with intensive medical care, the β cell function gradually declines more quickly in youths (20–30%) than in adults (7–11% annually). [215]

1.6 Etiology of Diabetes Mellitus

The Etiology of diabetes involves a complex interplay of genetic predisposition, lifestyle factors, and environmental influences, contributing to impaired insulin function and glucose regulation.

1.6.1 Genetic Factors

Type 2 diabetes is believed to have a significant hereditary component, with twin studies providing the most robust evidence. In research, 53 twin pairs were investigated, and one twin was found to have type 2 diabetes. When the second twin was examined, 91% (48/53) of the co-twins had developed type 2 diabetes. Although the five discordant twins were not obviously diabetic, they did exhibit mild glucose intolerance and aberrant insulin retorts during OGTT, signifying that they may develop over diabetes.[21] Studies across the entire genome have revealed single-nucleotide polymorphisms (SNPs) at various genetic positions that control the release of insulin. Over 30 SNPs linked to diabetes, known as diabeto SNPs, have been shown. [215]

1.6.2 Acquired Factors

Lifestyle: Diet, stress, Exercise, and Obesity

Urbanization leads to changes of lifestyle for example diet, inactivity, stress, causing increased insulin resistance through sedentary lifestyles. Both active and passive smoking,[111] combined with alcohol consumption and lifestyle risk behaviours, contribute to (Type 2 diabetes Mellitus) T2DM.[97] Over the past few decades, energy intake has gradually increased in developing countries such as India. Asian diets traditionally emphasise cereals, fibre rich food, low in cholesterol. As the socioeconomic status has gradually changed both in the food structures and patterns that led to T2DM manifestation,

which in turn caused T2DM to become highly prevalent in recent years.[185] These changes in Indian lifestyle, particularly in dietary patterns, may contribute to an increased susceptibility to glucose intolerance.[124] These alterations in lifestyle clearly put one at risk for obesity, and a wealth of research indicates that obesity plays a significant role in the onset of diabetes. The Diabetes Prevention Programme has provided recent evidence that lifestyle variables have a role in the development of diabetes.[110] Evidence from both epidemiologic and experimental studies suggests that Individuals with lower levels of physical activity have a greater chance of becoming diabetes, and that is not influenced by obesity.[87] Low birth weight is a risk factor for future insulin resistance and diabetes mellitus in various groups over the past two decades.[38, 82]

Aging: Aging leads to decreased glucose tolerance, insulin sensitivity, and secretion, which can contribute to type 2 diabetes, influenced by factors like reduced physical activity and increased fat accumulation.[47, 89]

Obesity and Insulin resistance (IR): Insulin resistance syndrome (IRS) is also known as syndrome X or metabolic syndrome, is a medical condition characterized by a genetic predisposition to hyperinsulinemia. [62; Reaven GM. 1993] Insulin resistance (IRS) is caused by genetic abnormalities in early life, with some families exhibiting symptoms due to dominant transmission mechanisms, such as mutations altering insulin receptors or PPAR-gamma expression. [99, 215]

1.7 Comorbidity of diabetes

Comorbidities of diabetes refer to other health conditions that often occur along with diabetes. These conditions can increase the risk of complications, deteriorate outcomes, and require comprehensive management. Here are some common comorbidities associated with diabetes- [8]

1.7.1 Cardiovascular Comorbidities: Hypertension (High Blood Pressure), coronary artery disease (CAD), Heart Failure (HF), Stroke, Peripheral Artery Disease (PAD) etc.

1.7.2 Metabolic Comorbidities: Obesity, Dyslipidemia (High Cholesterol), Insulin Resistance, Polycystic Ovary Syndrome (PCOS), Thyroid Disorders etc.

1.7.3 Renal Comorbidities: Diabetic Nephropathy (Kidney Damage), chronic kidney disease (CKD), End-Stage Renal Disease (ESRD) etc.

1.7.4 Neurological Comorbidities: Diabetic Neuropathy (Nerve Damage), Alzheimer's Disease, Parkinson's Disease, Stroke-Induced Cognitive Impairment etc.

1.7.5 Ophthalmological Comorbidities: Diabetic Retinopathy, Macular Edema, Cataracts, Glaucoma etc.

1.7.6: Musculoskeletal Comorbidities: Osteoporosis, Osteoarthritis, Rheumatoid Arthritis, Musculoskeletal Disorders (e.g., carpal tunnel syndrome) etc.

1.7.7 Mental Health Comorbidities: Depression, Anxiety Disorders, Eating Disorders, Cognitive Impairment etc.

1.7.8 Infectious Comorbidities: Tuberculosis (TB), Pneumonia, Urinary Tract Infections (UTIs), Skin and Soft Tissue Infections etc.

1.7.9 Other Comorbidities: Sleep Apnea, Chronic Liver Disease, Pancreatic Cancer, Cognitive Impairment etc.

Multimorbidity, or having two or more chronic conditions, is common in T2DM patients. The prevalence of multimorbidity in T2DM patients increases over time.[52] Managing comorbidities requires different ways of comprehensive treatment plans, regular monitoring and follow-up, Patient education and empowerment and different Lifestyle modifications like diet, exercise, stress management etc. [58]

1.8 Prevalence of Type 2 Diabetes Mellitus:

The global prevalence of T2DM and Prediabetes has significantly increased in recent decades, with the rate expected to rise due to rising obesity and reduced physical activity levels.

Table 2: World Prevalence of Diabetes in 2021, 2030 and 2045[94]

Briefly	2021	2030	2045
Entire population of world	7.9 billion	8.6 billion	9.5 billion
In adult (20 – 79 years)	5.1 billion	5.7 billion	6.4 billion
Diabetes (20 – 79 years)			
Global Prevalence *	10.5%	11.3%	12.2%
The number of adults with diabetes	536.6 million	642.7 million	783.2 million
The number of deaths because of diabetes	6.7 million	-	-
Impaired glucose tolerance (IGT) (20–79 years)			
Global Prevalence *	10.6%	11.0%	11.4%
Number of people with IGT	541.0million	622.7million	730.3 million
Impaired fasting glucose (IFG) (20–79 years)			
Global Prevalence *	6.2%	6.5%	6.9%
Number of people with IFG	319.0million	369.7million	440.8million

* Prevalence is standardised to each country's population for the specific year.

Type 2 Diabetes Mellitus (T2DM) is a serious and deteriorating health problem in humanity. As stated by the International Diabetes Federation's (Diabetes Atlas - 2021b) of, the global diabetes population is estimated to reach 536.6 million in 2021, rising to 642.7million in 2030 and 783.2million in 2045. Table 3, taken from the IDF Diabetes Atlas 2021, depicts the world's key regions and their present and projected diabetes rates.

Table 3: Diabetes prevalence of adults (20 to 79 years) in the Regions of IDF in 2021, 2030 and 2045[94]

		2021		2030		2045	
Rank	Region of IDF	Number of persons with diabetes (millions)	Prevalence of diabetes (%)	Number of persons with diabetes (millions)	Prevalence of diabetes (%)	Number of people with diabetes (millions)	Prevalence of diabetes (%)
	Worldwide	536.6	10.5	642.7	11.3	783.2	12.2
1	**M.E.N.A.**	72.7	16.2	95	17.6	135.7	19.3
2	**N.A.C.**	50.5	14.0	57	14.6	62.8	15.2
3	**S.E.A.**	90.2	8.7	113.3	9.6	151.5	11.3
4	**W.P.**	S205.6	11.9	238.3	13.2	260.2	14.4
5	**S.A.C.A.**	32.5	9.5	40	10.6	48.9	11.9
6	**E.U.R.**	61.4	9.2	67	9.8	69.2	10.4
7	**A.F.R.**	23.6	4.5	33	4.8	54.9	5.2

I.D.F.- International Diabetes Federation; N.A.C.- North America & Caribbean; M.E.N.A.- Middle East & North Africa; S.E.A.- South-East Asia; W.P.- Western Pacific; S.A.C.A.- South and Central America; E.U.R.- Europe; A.F.R.- Africa.

Table 4: Highest Ten countries representing the number of adults (20–79 years) with diabetes in 2021 with 2045[94]

2021			**2045**		
Rank	**Areas**	**Number of Diabetes patients (millions)**	**Rank**	**Areas**	**Number of Diabetes patients (millions)**
1.	China	140.90	1.	China	174.40
2.	India	74.20	2.	India	124.90
3.	Pakistan	33.00	3.	Pakistan	62.20
4.	USA	32.20	4.	USA	36.30
5.	Indonesia	19.50	5.	Indonesia	28.60
6.	Brazil	15.70	6.	Brazil	23.20
7.	Mexico	14.10	7.	Bangladesh	22.30
8.	Bangladesh	13.10	8.	Mexico	21.20
9.	Japan	11.00	9.	Egypt	20.00
10.	Egypt	10.90	10.	Turkey	13.40

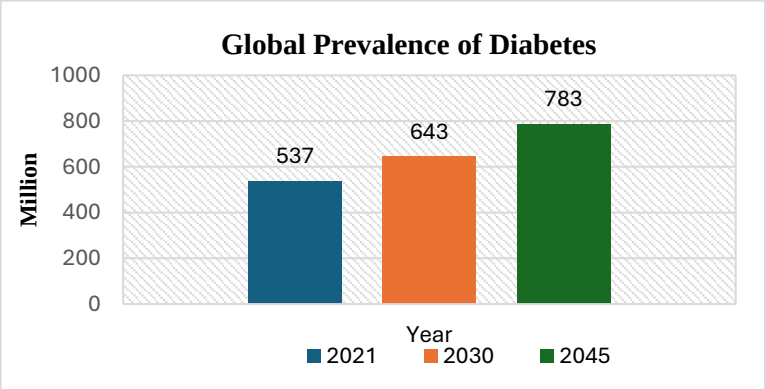


Figure 2: Global Prevalence of Diabetes [94]

1.9 Position Statements: Role of Complementary and Alternative Medicine for the management of Type 2 Diabetes Mellitus

For individuals with Type 2 Diabetes, Complementary and Alternative Medicine (CAM) offers promising adjunctive therapies to conventional treatments. CAM approaches such as botanicals (e.g., berberine, cinnamon), supplements (e.g., chromium, alpha-lipoic acid), and mind-body practices (e.g., yoga, meditation) have shown potential in improving insulin sensitivity, glucose metabolism, and blood sugar control. Acupuncture, tai chi, and qigong have also been found to enhance insulin function and reduce inflammation. Additionally, dietary approaches like the Mediterranean diet and traditional Chinese medicine's emphasis on balancing Life force have demonstrated benefits in managing blood glucose levels and complications. While CAM should not replace conventional care, integrating evidence-based CAM therapies into a comprehensive treatment plan, under the guidance of a healthcare professional, may help improve quality of life, reduce medication dependence, and enhance overall well-being for individuals with Type 2 Diabetes.[151, 171, 179]

Table 5: Complementary and Alternative Medicine for the management of Type 2 Diabetes Mellitus

Sl. No.	'Complementary and Alternative Medicine'	
1	Naturopathy	Natural therapies, Supplements & Botanicals, Mud bath, Acupuncture, hydrotherapy
2	Exercise therapy	Tai chi, Massage, strength training, and high-intensity interval training
3	Ayurvedic medicine	Turmeric, Ginger, Cumin, Coriander
4	Mind-body therapy	Yoga, Qigong, visualization and mindfulness meditation
5	Herbal supplement	Cinnamon, Chromium, Gymnema etc.
6	Natural product	Alpha-lipoic acid, Probiotics, Omega-3 fatty acids
7	Traditional Chinese medicine	Acupuncture, Chinese herbal medicine, Tuina massage, Qigong
8	Aerobic exercise training	Brisk walking, cycling, swimming, Dance-based exercise

1.10 Position Statements: Role of Yoga for the management of Type 2 Diabetes Mellitus

Yoga plays a vital role in managing Type 2 Diabetes Mellitus (T2DM) by improving insulin sensitivity, glucose metabolism, and cardiovascular health. Regular yoga practice, including asanas, pranayama, and meditation, reduces stress, anxiety, and inflammation, while enhancing pancreatic beta-cell function and autonomic nervous system balance. Studies show yoga significantly improves glycemic control, reduces HbA1c levels, and promotes weight management. As an adjunct therapy, yoga complements conventional T2DM treatment, improving overall well-being and quality of life. [48, 77, 198]

Table 6: Role of Yoga with combined approaches for the management of Type 2 Diabetes Mellitus		
Sl. No.	Alternative and Complementary Medicine as an intervention	
1	Yoga only	Surya Namaskar, Asanas, Pranayama, Kriyas, Meditation etc.
2	Yoga with Allopathy	Yoga with Hypoglycemic allopathy drug
3	Yoga with Naturopathy	Combined and individual intervention of Naturopathy and yoga
4	Yoga and Ayurveda	Yoga with Ayurveda
5	Yoga and Diet	Yoga with different diabetic diet
6	Yoga and Homeopathy	Yogic exercise with Homeopathy medicine

1.11 Background of Yoga

The practice of yoga is believed to have originated in the early stages of civilization. According to Indian mythology, Lord Shiva is considered the founder of yoga, with Adiyogi as the first guru. Several thousand years ago, on the banks of Lake

Kantisarovar in the Himalayas, Adiyogi imparted his extensive wisdom to the renowned seven sages (saptarshi), who then spread this profound yogic knowledge across the world. Current historians, archaeologists, and indologists have discovered evidence of yoga in various ancient texts and traditions, including the Indus Valley Civilization (circa 2700 BC), the Vedas, the Upanishads, and Buddhist and Jain traditions, as well as in the Bhagavad Gita, Ramayana, and Mahabharata. Yoga was practiced during the classical period (around 300 BC) when Patanjali codified the Patanjala Yoga Sutra. Evidence of yoga also appears during the Medieval Ages (700-1200 AD). In modern times, Swami Vivekananda introduced yoga to the Western world in Chicago on 1893. Subsequently, many Indian philosophers, such as Rishi Aurobindo and Yogananda, further disseminated the knowledge of yoga internationally. In addition, Hatha yogis like Krishnamacharya, Swami Sivananda, and B.K.S. Iyengar played significant roles in popularizing yoga around the globe. [120, 188] The evolution of Yoga from the Vedic period to contemporary times is presented in Figure 3.

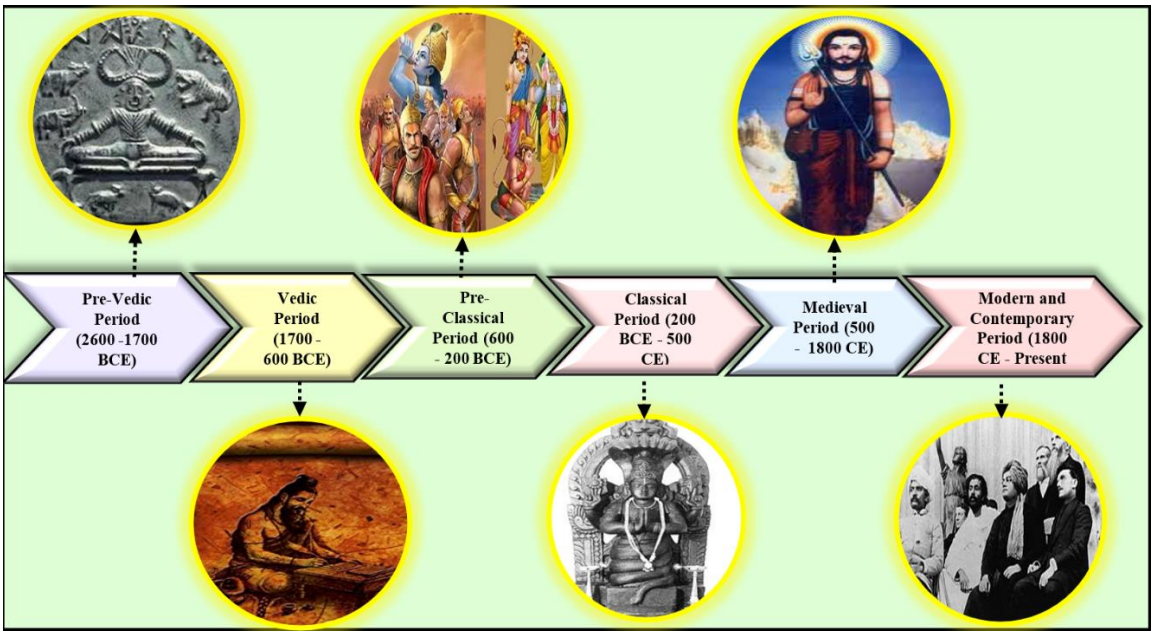


Figure 3: The evolution of Yoga from the Vedic period to contemporary times

1.12 Theoretical Context of Yoga

The word yoga (योग) has been derived from the Sanskrit root yuj (युज्), which means to join or to bind or to merge together. So, yoga is the practice that joins. In Sanskrit it is translated as "**युज्यते अनेन इति योग**" *(Yujyate anena iti yogaḥ)*. Yoga traditionally refers to the unification of the individual self (jivatma) with the universal self (paramatma). Practically, it serves as a way to balance and harmonize the body, mind, and spirit. According to Maharshi Patanjali, "yoga is the complete cessation of mental modification." In Patanjala Yoga Sutra, this is defined in Sanskrit as "**योगश्चित्तवृत्तिनिरोधः**" ॥१:२॥ (*Yogaschitta vṛtti nirodhaḥ ॥1:2॥*). [169] In Yoga-Vāsiṣṭha, Sage Vasistha said that

"**मनः प्रशमन उपायः योग इत्यभिधीयते**" **॥३:९:३२॥**

(manaḥpraśamanopāyo yoga ityabhidhīyate ॥3:9:32॥)

which is translated as "yoga is called a skillful trick to calm down the mind" (3:9:32).[205] The Bhagavad Gita, Lord Sri Krishna explains the definitions of yoga to Prince Arjuna. In Chapter 2 verse 48, and 50 which have been quoted and translated below:

योगस्थः कुरु कर्माणि सङ्गं त्यक्त्वा धनञ्जय ।

सिद्ध्यसिद्ध्योः समो भूत्वा समत्वं योग उच्यते ॥ २:४८ ॥

"Yoga--sthaḥ-kuru-karmāṇi-saṅgaṁ-tyaktvā-dhanañ--jaya

Siddhy--asiddhyoḥ-samo-bhūtvā-samatvaṁ-yoga-ucyate" ॥2:48॥

Carry out your duty, Arjuna, with a balanced mind, letting go of any attachment to success or failure. This state of balance is known as yoga.

बुद्धियुक्तो जहातीह उभे सुकृतदुष्कृते |

तस्माद्योगाय युज्यस्व योगः कर्मसु कौशलम् ॥ २: ५०॥

"buddhi--yukto-jahātīha-ubhe-sukṛita--duṣhkṛite

tasmād-yogāya-yujyasva-yogaḥ-karmasu-kauśhalam" ॥2:50॥

One who properly pursues the science of effort without attachment may overcome both positive and negative emotions in this life. Therefore, aim for Yoga, which is the art of functioning skillfully and with right attention. [74]

According to Kaṭhopaniṣad yoga is a spiritual practice that promotes a steady sense of mind and distancing from worldly concerns.

(ताम्-योगमिति-मन्यन्ते-स्थिरामिन्द्रियधारनाम्॥२:३:११॥

(tāṁ sthirām indriyadhāraṇāṁ yogam iti manyate||2:3:11||).[202]

In the Yoga Yājñavalkya, "yoga is defined as the union of the individual self (jivatma) with the universal self (paramatma)" which is quoted as

"संयोगो योग इत्युक्तो जीवात्मपरमात्मनोः" ॥१:४ ४॥

(saṁyogo yoga ityukto jīvātma-paramātmanoḥ ||1:44||). [67]

1.13 Components of Yoga

Traditional yogic practices encompass social disciplines (yama), personal disciplines (niyama), postures (asanas), breathing techniques (pranayamas), cleansing processes (kriyas), physical gestures and locks (mudras and bandhas), chanting, meditation (dhyana), and more.

1.13.1 Prayer

Prayer is an ancient spiritual process usually prayed in yoga sessions to promote peace. [15, 68, 112] Taittīriyopaniṣad has given an ancient Vedic mantra which are quoted and elaborated below: [174]

ॐ सह नाववतु । सह नौ भुनक्तु । सह वीर्यं करवावहै ।

तेजस्वि नावधीतमस्तु मा विद्विषावहै । ॐ शान्तिः शान्तिः शान्तिः ॥

"oṃ-saha-nāvavatu- /-saha-nau-bhunaktu- /-saha-vīryaṃ-karavāvahai /

Tejasvi-nāvadhītamastu-mā-vidviṣāvahai- /-oṃ-śāntiḥ-śāntiḥ-śāntiḥ" //

Om, may Brahman keep us both safe! May Brahman grant us the fruits of knowledge! May we both gain the strength to seek wisdom! May our studies reveal the truth! May we appreciate each other without any ill feelings. Om shanti, shanti, shanti.

1.13.2 Background of Yogic Sūkṣma Vyāyāma

Yogic Sūkṣma Vyāyāma (Yogic Subtle Exercises) was designed and developed by Maharishi Kartikeya Ji Maharaj, a Himalayan yogi. Later, in the 20th century, it was propagated by Dhirendra Brahmachari to the modern world. It is a set of forty-eight subtle exercises that focus on enhancing flexibility, circulation, and energy flow (prana) throughout the body and preparing an individual for more advanced yogic practices. Yogic Sūkṣma Vyāyāma typically involves: 1. subtle physical movements (mudras, bandhas); 2. breath work (pranayama); 3. visualization; and 4. meditation. Regular practice of Yogic Sūkṣma Vyāyāma enhances the physical and mental well-being. [34]

1.13.3 Backgrounds of Sūryanamaskāra

The term "Sūryanamaskāra" comes from the Sanskrit word Sūrya (सूर्य), meaning "Sun," and Namaskāra (नमस्कार), meaning "Salute" or "Greeting." Surya, the Hindu lord or the Sun, symbolizes the Sun as the spirit and source of all life. [148] The Sun is revered as a god in numerous cultures, known as Mithras by the Persians, Osiris by the Egyptians, Apollo by the Greeks, and Surya in the Vedic period in India.[167] The Tṛcākalpa mantras of the Rig Veda highlight the importance of the sun. These have been cited and translated as follows[80]

उ॒द्यन्न॒द्य मि॑त्रमह आ॒रोह॒न्नुत्त॑रां॒ दिव॑ं ।

हृ॒द्रो॒गं मम॑ सूर्य हरि॒माणं॑ च नाशय ॥१: ५०:११॥

"Udyann-adya-mitramaha-ārohann-uttarāṃ-divam |

Hṛdrogam-mama-sūrya-harimāṇaṃ-ca-nāśaya" ||1.50.11||

As I rise today, O generous friend, ascending to the higher heavens, Surya, heal my heart's afflictions and remove this yellow hue from me.

शुके॑षु मे हरि॒माणं॑ रोप॒णाका॑सु दध्मसि ।

अथो॑ हारिद्र॒वेषु॑ मे हरि॒माणं॒ नि द॑ध्मसि ॥१: ५०:१२॥

"śukeṣu-me-harimāṇaṃ-ropaṇākāsu-dadhmasi |

Atho-hāridraveṣu-me-harimāṇaṃ-ni-dadhmasi" ||1.50.12||

Let us give yellowness to parrots and starlings, or transfer this yellowness to Haritala trees.

उद॑गादु॒यमा॑दि॒त्यो विश्वे॑न॒ सह॑सा स॒ह ।

द्वि॒ष॒न्तं॒ मह्यं॑ र॒न्धय॒न्मो अ॒हं द्वि॑ष॒ते र॑धम् ॥१: ५०:१३॥

"Ud-agād-ayam-ādityo-viśvena-sahasā-saha |

dviṣantam-mahyaṃ-randhayan-mo-ahaṃ-dviṣate-radham ||1.50.13||

With all his conquering vigour, this Aditya has ascended high, delivering my enemy into my hands: let me not become my foreman's prey.

In the Ramayana, Sage Agasthya advises Lord Sri Rama to worship the Sun by performing the Aditya Hridayam in order to triumph in his battle against the demon king Ravana. In the Yuddha Kanda of the Ramayana, these verses describe the various forms and titles of the sun god, highlighting his magnificent beauty and his twelve forms, which symbolize the months of the year. [204] The Sun is honored as the Pratyaksha Swarupa (the ultimate force perceivable by the eye), representing truth and serving as a manifestation of knowledge, as well as the source of intelligence and wealth.

The origins of Sūryanamaskāra are somewhat unclear. Indian mythology associates the 17th-century saint Samarth Ramdas with Sūryanamaskāra exercises, although the specific movements were not clearly defined at that time. Bhawanrao Shriniwasrao Pant Pratinidhi, the king of Aundh, was the one who originally taught Sūryanamaskāra and promoted the practice in his 1928 book, "The Ten-Point Way to Health: Surya Namaskars".[149] While it has been claimed that Pant Pratinidhi developed this practice, he himself noted that it was already a popular ritual in Maharashtra. Sūryanamaskāra was further promoted by figures such as Sri K.V. Iyer, Sri Krishnamacharya, Swami Sivananda, and Swami Satyananda from the Bihar School of Yoga. The modern form of Sūryanamaskāra includes 12 physical postures, or asanas, which are related to Danda (दंड) exercises. The Suryanamaskar movement consists of 12 postures and 24 steps for each round. Dandaal is a traditional physical training method used by wrestlers and martial artists in India. It is believed that the Western push-up, often associated with bodybuilding, may have originated from Dandaal. The Danda exercises described in the "Vyayama Dipika" in 1896 were found to be the foundation of Surya Namaskar.[25] Many of the Danda exercises resemble the asanas found in Sun Salutation, such as Parvatasana, Ashtanga Namaskara, and Bhujangasana.

Sūryanamaskāra has been practiced by different Schools of Yoga such as Krishnamacharya Vinyasa Yoga Tradition, [155] Sivananda Yoga Vedanta Centre tradition,[180] Swami Vivekananda Kendra Tradition, [208] and Bihar School of Yoga (BSY) Tradition. [168] Bihar School of Yoga (BSY) Tradition includes twelve postures (Fig. 4). These are 1. Pranamasana; 2. Hasta utthanasana; 3. Pada hastasana; 4. Ashwasanchalanasana; 5. Parvatasana; 6. Ashtanga namaskara; 7. Bhujangasana; 8. Parvatasana; 9. Ashwasanchalanasana; 10. Pada hastasana; 11. Hasta utthanasana; 12. Pranamasana.

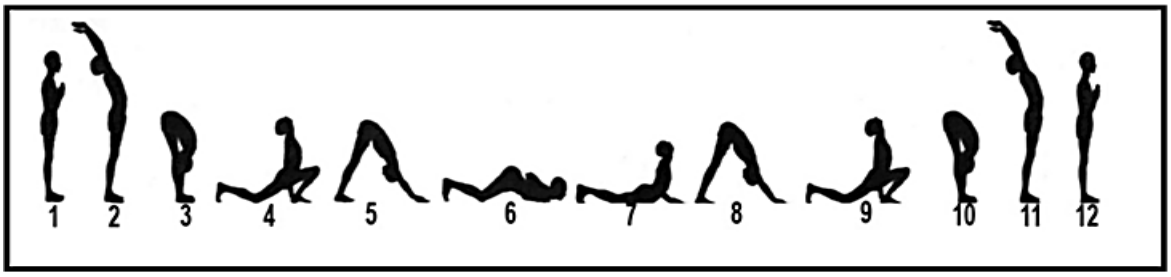


Figure 4: Twelves posture of Sūryanamaskāra (BSY) [148]

1.13.4 Background of Asana

Asana is a Sanskrit term which is often interpreted as "posture" or "pose". The term "Asana" comes from the Sanskrit word "Aas," which means "to sit," or "Asi," which means "to be." So, asana can be translated as "a steady, comfortable seat," mostly for the purpose of meditation. Great Sage Maharishi Patanjali defines asana as: **स्थिरसुखमासनम् ॥२:४६॥** *sthira-sukham-āsanam ||2:46||*. The posture should be 'steady' and 'comfortable'. Maharishi Patanjali also explains how to perform an asana: **"प्रयत्नशैथिल्यानन्तसमापत्तिभ्याम् ॥२:४७॥** *prayatna-śaithilya-ananta-samāpattibhyām ||2:47||*. By loosening of effort and by meditation on the serpent ananta, asana is mastered.[169] Swami Swatmarama in Hatha Yoga Pradipika states that both relaxation of continued effort and unity in the infinite, asana is mastered. Having done asana, one gets steadiness (firmness) of body and mind; diseaselessness and lightness (flexibility) of the limbs ("kuryāttadāsanaṃ sthairyamāroghyaṃ chānggha-lāghavam" ||1.17||. [128] The Gheranda Samhita describes asana to Chapter 2 verse 1, and 2 which have been quoted and translated below:

आसनानि समस्तानि यावन्तो जीवजन्तव: ।

चतुरशीतिलक्षाणि शिवेन कथितानि च ।।२:१।।

āsanāni samastāni yavanto jivajantavaḥ ।

caturasiti lakṣāṇi šivena kathitani ca ।।2:1।।

तेषां मध्ये विशिष्टानि षोडशोनं शतं कृतम् ।

तेषां मध्ये मर्त्यलोके द्वात्रिंशदासनं शुभम् ।।२:२।।

teṣām madhye viśistani sodaśonam satam kṛtam ।

teṣām madhye martyaloke dvātrimśadāsanam śubham ।।2:2।।

The number of asana is the same as the number of animal species in the world. Lord Shiva described eighty-four lakhs (8,400,000) asanas first of all, out of which eighty-four (84) are best. Out of these eighty-four asanas, thirty-two (32) asanas should be considered as especially auspicious in this normal world. [136]

Modern Authentic Techniques of Asana

Vakrāsana

Vakrāsana is an easy version of Ardha-Matsyendrāsana. Those who cannot do Ardha-Matsyendrāsana should practice this asana. Swami Kuvalāyanandaji introduced this concept. Sit with your legs together and extend them out in front of you. Place the hands at the sides of the body, palms down and fingers pointing forward. Slowly fold your right leg at the knee, then lay the sole of your foot on the ground near your left knee. The right knee should form a 90º angle, pointing skyward. Taking your right hand back, rest your palm on the ground 9 inches straight from your spine. Fingers should be together. Then, lay your left arm across your right knee and your palm on the ground. If you stretch your leg to the east, the fingers of that hand will point north. Now twist your trunk, shoulders, and head to the right. Try to keep your sight on your behind. In a similar fashion, practice the stance with the opposing leg. [193]

Uttanapādāsana

This asana is the first stage of Viparitakarani-Sarväṅgāsana-Halasana. Take a supine position, knees together and hands by your sides. Palms should be lying on the

ground, pointing downward. Slowly, without bending your knees, elevate both legs to a 30° angle. Hold this posture for a few seconds, then elevate the legs to a 45° angle. Again, elevate the legs to a 60° angle. Hold this position for some time. Slowly return and pause at a 45° or 30° angle. Keep your legs here for a few seconds. Finally, bring both legs to the ground.[193]

Pavana muktāsana

Pavana means “wind,” and mukta means “to release” or “to make free.” As the name suggests, this āsana is effective in relieving wind or flatulence from the stomach and intestines. To perform Pavanamuktāsana, lie flat on your back. Bend both knees and, while exhaling, bring them towards your chest. Inhale, interlock your fingers, and clasp your shins below the knees. Exhale again, raising your head until your chin touches your knees, and then relax. Bring your head back to the ground. While exhaling, lower your legs back to the floor. Finally, rest in Śavāsana.[23]

Ardhahalāsana

Ardha Halasana, or Half Plough Pose, is practiced starting from a supine position. Lie flat on your back with your arms resting beside your body and your palms on the ground. Inhale deeply and, without bending your knees, slowly raise your legs together until they form a 90-degree angle with the ground. Keep your body straight from your hips to your shoulders. Hold this position comfortably for 10 to 30 seconds while maintaining normal breathing. When you're ready to exit the pose, exhale as you lower your legs back to the ground without lifting your head. Finally, relax in Śavāsana.[23]

Setubandhasana (Kandharasana)

Bend the knees and place the soles of the feet flat on the floor, heels touching the buttocks. The feet and knees may be hip-width apart. Hold the ankles with your hands.

Raise the buttocks, chest and navel raise as high as possible without strain, bringing the chest up towards the chin and head while maintaining the posture of the feet and shoulders. Keep your feet flat on the floor. The head, neck, shoulders, arms, and feet provide support for the body in its ultimate posture. Hold the stance for as long as you feel comfortable, then return to the base position. Relax your ankles with the legs outstretched. Practise it for 5 to 10 rounds. [168]

Traditional Techniques of Asana

Makarāsana

In Gheranda Samhita, Sage Gheranda describes the technique of makarāsana in Chapter 2 verse 40 which is quoted and translated below:

अध्यास्य शेते हृदयं निधाय, भूमौ च पादौ प्रसार्यमाणौ ।

शिरश्च धृत्वा करदण्डयुग्मे, देहाग्निकारं मकरासनं तत् ।।२:४०।।

Adhyaasya shete hridayam nidhaaya, bhoomau cha paada prasaaryamaanau;

Shirashcha dhritvaa karadandayugme, dehaagnikaaram make aasanam tat. ।।2:40।।

Lie on your chest with your arms supporting your head, legs spread out. This asana, which ignites the body's inner fire, is called Makarasana. [136]

Shalabhāsana

In the Gheranda Samhita, chapter 2 verse 39 as stated below, explain the technique of shalabhasana, which has been narrated by Sage Gheranda himself.

अध्यास्य शेते करयुग्मवक्ष आलम्ब्य भूमिं करयोस्तलाभ्याम् ।

पादौ च शून्ये च वितस्ति चोर्ध्यं वदन्ति पीठं शलभं मुनीन्द्राः ॥२:३९॥

Adhyaasya shete karayugmavaksha aalambya bhoomim karay ostalaabhyaam;

Paadau cha shoonye cha vitasti chordhyam vadanti peethan shalabham munindraa. ॥2:39॥

Lie flat with your face towards the ground. Place both arms by the sides of your chest, with palms firmly on the ground. Raise your legs in this position. This pose is known as Shalabhasana, according to sages. [136]

Bhujangāsana

The technique of bhujangāsana is discussed in Gheranda Samhita as given below:

अङ्गुष्ठनाभिपर्यन्तमधोभूमौ च विन्यसेत् ।

धरां करतलाभ्यां धृत्वोध्वशीर्ष फणीव हि ॥२:४२॥

Angushthanaabhiparyantamadhobhoomau cha vinyaset;

Dharaam karatalaabhyaam dhritvordhvasheersham phaneeva hi. ***॥2:42॥***

Keep the body from the toes to the navel on the floor, and with palms firmly placed on the floor, raise the head like a snake. This position is called Bhujangasana. [136]

Shavasana

In the Hatha Yoga Pradipika, chapter 1 verse 32 as stated below, explain the technique of shavasana, which has been recounted by Svatmaram himself.

उत्तानं शबवद्भूमौ शयनं तच्छवासनम |

शवासनं शरान्ति-हरं छित्त-विश्रान्ति-कारकम || १:३२ ||

uttānaṃ śabavadbhūmau śayanaṃ tachchavāsanam |

śavāsanaṃ śrānti-haraṃ chitta-viśrānti-kārakam || 1.32 ||

Lying flat on the ground facing upwards represents shavasana. It alleviates tiredness and relaxes the mind and body. [128]

1.13.5 Background of Shatkarma

Shatkarma are a set of six cleansing procedures described in the Hatha Yoga Pradipika. These are dhauti, basti, neti, trataka, nauli, and kapalbhati. [128]

धौतिर्बस्तिस्तथा नेतिस्त्राटकं नौलिकं तथा |

कपाल-भातिश्छैतानि षहट-कर्माणि परछक्षते ॥२:२२॥

dhautirbastistathā netistrāṭakaṃ naulikaṃ tathā |

kapāla-bhātiśchaitāni ṣhaṭ-karmāṇi prachakṣhate || 2:22 ||

Kapalbhati

In the Hatha Yoga Pradipika, Svatmarama explains the technique of kapalbhati which has been quoted and translated below:

भस्त्रावल्लोह-कारस्य रेछ-पूरौ ससम्भ्रमौ |

कपालभातिर्विख्याता कफ-दोष्ह-विशोष्हणी || २:३५ ||

bhastrāvalloha-kārasya recha-pūrau sasambhramau |

kapālabhātirvikhyātā kapha-doṣha-viśoṣhaṇī || 2.35 ||

Perform exhalation and inhalation rapidly like the bellows (of a blacksmith). This is called kapalbhati and it destroys all mucous disorders. [128]

1.13.6 Background of Pranayama

The term Pranayama is derived from two root words ‘Prana’ and “Ayama”. Prana means vital energy or life force and ‘Ayama’ means extension or expansion. So, the word Pranayama means extension of the vital force. The main purpose of Pranayama is to gain control over the autonomic nervous system through breath control and by it influence the mental function. According to Hatha Yoga Pradipika:

छले वाते छलं छित्तं निश्छले निश्छलं भवेत||

योगी सथाणुत्वमाप्नोति ततो वायुं निरोधयेत || २:२||

chale vāte chalaṃ chittaṃ niśchale niśchalaṃ bhavet||

yoghī sthāṇutvamāpnoti tato vāyuṃ nirodhayet || 2:2 ||

When Prana moves, chitta (the mental force) moves. When prana is still, Chitta is still. By this (steadiness of prana) the yogi attains steadiness and should thus restrain the vayu (air). [128]

In Patanjala Yoga Sutra, Maharishi Patanjali defines Pranayama as:

तस्मिं सति श्वासप्रश्वासयोर्गतिविच्छेदः प्राणायामः ॥२.४९॥

Tasmin sati svasa-prasvasayorgati vicchhedah pranayamah ||2.49||

Asana having completed cessation of inhalation and exhalation (Kevala Kumbhaka) is called as Pranayama**.** [169]

Nadi shodhana pranayama

The Hataha Yoga Pradipika defines the technique of nadi shodhana pranayama step by step which has been quoted and translated below-[128]

बद्धपद्मसना योगी प्राणं चंद्रेण पूरयेत् ।

धारयित्वा यथाशक्ति भूयः सूर्येण रेचयेत् ॥२:७॥

baddha-padmāsano yoghī prāṇaṃ chandreṇa pūrayet |

dhārayitvā yathā-śakti bhūyaḥ sūryeṇa rechayet || 2.7 ||

Sitting in baddha padmasana, the yogi should inhale through the left nostril and hold the breath to capacity, and then exhale through the right nostril.

प्राणं सूर्येण चाकृष्य पूरयेदुदरं शनैः ।

विधिवत्कुंभकं कृत्वा पुनश्चंद्रेण रेचयेत् ॥२:८॥

prāṇaṃ sūryeṇa chākṛṣhya pūrayedudaraṃ śanaiḥ |

vidhivatkumbhakaṃ kṛtvā punaśchandreṇa rechayet ||2.8||

Then inhaling through the right nostril, gradually fill the abdomen, perform kumbhaka as before, then exhale completely through the left nostril.

येन त्यजेत्तेन पीत्वा धारयेदतिरोधतः ।

रेचयेच्च ततोऽन्येन शनैरेव न वेगतः ॥२:९॥

Inhale with the same nostril through which exhalation was done, hold the breath to utmost capacity and exhale through the other nostril slowly and not forcibly.

प्राणं पिबेदिडया पिबेन्नियमितं भूयोऽन्यया रेचयेत्

पीत्वा पिंगलया समीरणमथो बद्ध्वा त्यजेद्वामया ।

सूर्याचन्द्रमसोरनेन विधिनाभ्यासं सदा तन्वतां

शुद्धा नाडिगणा भवंति यमिनां मासत्रयाद्ऊर्ध्वतः ॥२:१०॥

When the prana is inhaled through the left nostril, then it must be Exhaled through the other. When it is inhaled through the right, hold Et inside and then exhale through the other nostril. The yamini who practises in this way, through the right and left nostrils, alternately purifies all his nadis within three months.

Bhastrikā pranayama

Bhastrikā is known as vitalizing pranayama. In the Hatha Yoga Pradipika, chapter 2 verse 60 to 63 explains the technique of bhastrika pranayama which have been quoted and translated below: [128]

सम्यक् पद्मासनं बद्ध्वा समग्रीवोदरं सुधीः।

मुखं संयम्य यत्नेन प्राणं घ्राणेन रेचयेत् ॥२:६०॥

samyak padmāsanam baddhvā samagrivodaram sudhiḥ ।

mukham samyamya yatnena präṇam ghrāṇena recayet ॥2:60॥

यथा लगति हृत्कण्ठे कपालावधि सस्वनम्।

वेगेन पूरयेच्चापि हृत्पद्मावधि मारुतम् ॥२:६१॥

yathā lagati hṛtkanthe kapālāvadhi sasvanam ।

vegena pūrayeccāpi hṛtpadmavadhi marutam ॥2:61॥

Getting settled in Padmasana, the wise should, with the neck and body held erect, close the mouth and effortfully exhale through the nostrils, making a sound, so that exhalation is felt in the chest, throat and (upper part of the) skull; then he should breathe in quickly till the (inhaled) air reaches the cardiac region (i.e. the lungs)

पुनर्विरेचयेत्तद्वत् पूरयेच्च पुनः पुनः

यथैव लोहकारेण भस्त्रा वेगेन चाल्यते। ॥२:६२॥

punarvirecayettadvat pūrayecca punaḥ punaḥ ।

yathaiva lohakāreṇa bhastrā vegena cālyate ॥2:62॥

The Yogi should exhale and inhale in this manner again and again. (Care should be taken that) air is moved in and out of one's body rapidly in the manner in which the blacksmith moves the bellows.

तथैव स्वशरीरस्थं चालयेत् पवनं धिया

यदा श्रमो भवेद्देहे तदा सूर्येण पूरयेत् ॥२:६३॥

tathaiva svaśarīrastham cālayet pavanam dhiyā ।

yadā śramo bhaveddehe tadā sūryeṇa pürayet ॥2:63॥

In the same way, the air of the body should be moved intelligently, filling it through Sûrya when fatigue is experienced.

Bhramari pranayama

Bhramari is one type of soothing pranayama. The chapter 2 verses 68 of Hatha Yoga Pradipika defines bhramari pranayama which has been explained below:

वेगाद्घोष्हं पूरकं भृङ्ग-नादं भृङ्गी-नादं रेछकं मन्द-मन्दम।

योगीन्द्राणमेवमभ्यास-योगाछ छित्ते जाता काछिदानन्द-लीला ॥२:६८॥

veghādghoṣhaṃ pūrakaṃ bhṝnggha-nādaṃ bhṝngghī-nādaṃ rechakaṃ manda-mandam|

yoghīndrāṇamevamabhyāsa-yoghāch chitte jātā kāchidānanda-līlā || 2:68 ||

Breathe in quickly, making a reverberating sound like the male black bee, and exhale slowly while softly making the sound of the female black bee. By this yogic practice one becomes lord of the yogis and the mind is absorbed in bliss. [128]

1.13.7 BACKGROUND OF DHYĀNA

Dhyāna translates to “contemplation or reflection”. Origin of the word is Dhi, which in the Vedas' oldest text mentions "imaginative vision" and is associated with the goddess Saraswati's abilities of knowledge and wisdom. This word evolved into the variants dhya- and dhyana, which means “meditation”. This is the seventh step of Ashtanga yoga. Dhyana (meditation) is an introspective path of self-discovery or, more specifically, re-discovery. Maharshi Patanjali states that dhyana is a steady and continuous flow of concentration on a point or object.

तत्र प्रत्यय ऐकतनता ध्यानम् ॥३:२॥

tatra pratyayaikatanata dhyanam //3:2 // [169]

AUM meditation

In Bhagwad Gita, Chapter 8, Verse 13 Shri Krishna speaks about the significance of Om which has been quoted and translated below:

ओमित्येकाक्षरं ब्रह्म व्याहरन्मामनुस्मरन् ।

य: प्रयाति त्यजन्देहं स याति परमां गतिम् ॥ ८:१३॥

oṁ ityekākṣaraṁ brahma vyāharan mām anusmaran

yaḥ prayāti tyajan dehaṁ sa yāti paramāṁ gatim //8:13 //

One who leaves from the body while remembering me, the Supreme Personality, and chanting Om, will attain the supreme goal. [74]

Mandukya Upanishad

ओमित्येतदक्षरमिदं सर्वं तस्योपव्याख्यानं भूतं भवद् भविष्यदिति सर्वमोङ्कार एव।

यच्चान्यत् त्रिकालातीतं तदप्योङ्कार एव ||१||

omityetadakṣaramidaṁ sarvaṁ tasyopavyākhyānaṁ bhūtaṁ bhavad bhaviṣyaditi

sarvamoṅkāra eva| yaccānyat trikālātītaṁ tadapyoṅkāra eva //1//

What is becoming, what is becoming, what will become – verily, all of this is OM. And what is beyond these three states of the world of time – that too, verily, is OM. [134]

Shvetashvatara Upanishad

The text asserts that OM is a tool of meditation empowering one to know the God within, to realize one's Atman. (1.14-1.16). [189]

1.14 Background of Vyayama:

Vyayama, or physical activity, is an integral component of the Ayurvedic method of preventive and health treatment, often known as the science of positive health. Vyayama is a term used specifically in Ayurveda to describe physical exercises, the meaning of which is quite close to "physical exercise in the present time". Between the 7th and 15th centuries AD, significant literature on Vyayama-Vida was produced. The most essential study resources were two books: King Someswara's Manasollasa and Mallapurana. Ayurveda is regarded as one of the most significant UpaVeda, as it mentions Vyayama, or physical activity, for preventative, therapeutic, and rehabilitative purposes. The three most major Ayurvedic scriptures, Charaka Samhita, Susruta Samhita, and Astanga hrdyayam, all provide a detailed description of Vyayama.[160, 194]

Ancient Indian literature on the science of exercise, as well as current research on exercise's ability to prevent and cure several diseases. Ayurveda is distinguished as a comprehensive system of restorative therapy that evolved gradually among the Brahmin sages of ancient India about 3000-5000 years ago, and vyayama is extensively detailed in Ayurvedic literature. Vyayama is not only the consequence of physical activity, bodily force for exertion, collectedness, and long-term need; it also cleanses all toxins from the body and boosts digestive fire, physical and mental strength. As a result, the preventative and curative benefits of Vyayama have been demonstrated before. It is the oldest alive

medical science and is still widely practiced across the world. The concept of vyayama is extremely thoroughly articulated in Ayurveda. Vyayama has done a lot of work to prevent and treat a variety of diseases, including diabetes, hypertension, obesity, and stress disorders. [194]

Ancient Indian history was divided into various periods, including the Harappan civilization, Vedic period, Epic Age, Jaina and Buddha period, and Hindu period. Despite the lack of research on Vyayama (exercise) in the Vedas and Upanishads, the Ayurvedic texts strongly reflect ancient Indian culture. Ayurveda, the science of long and healthy life, suggests Vyayama (exercise) and Krida (sports) for the body and Yoga techniques for the mind and soul. Vyayama is derived from vy (specific) + aa (particular) + yam (control) + ghamg, and in complete sense it means specific and particular body control.[66] The researcher gathered Vyayama literature from review articles on Caraka Samhita and Susruta Samhita, presenting them as evidence of ancient Indian culture on Vyayama.[160]

1.14.1 Vyayama in Caraka Samhita

Caraka Samhita is an ancient Ayurvedic literature that defines Vyayama (exercise) and its application for positive health and therapy. It emphasizes the importance of maintaining positive health through proper diet, sleep, rest, active habits, and regular exercise. The text also warns against excessive Vyayama, which can lead to exhaustion, consumption, thirst, bleeding, dyspnea, cough, fever, and vomiting. Vyayama is prescribed for various diseases, including kaphaja (phlegm) diseases, diabetes mellitus, and obesity. The text also explains that Vyayama should be stopped during hot summers and heavy rainy seasons, and should be resumed in autumn.[126]

1.14.2 Vyayama in Susruta Samhita

Susruta Samhita, a key figure in the history of exercise physiology, defined Vyayama (exercise) as a daily sense of weariness from bodily labor and recommended its

practice.[192] He advocated for moderate exercise to improve limb growth, endurance, muscle stoutness, strength, digestion power, resistance against fatigue, mental alertness, and intelligence. He also identified two serious diseases in ancient times, obesity and diabetes, which were more prevalent among sedentary individuals. Samhita believed that Vyayama could help prevent these diseases by reducing the elevation in kapha humor caused by inactivity and excessive food and fluid consumption.

1.14.3 Vyayama in different Ayurvedic Literature

According to more than 3,000 years of documented history, vyayama is crucial for an individual to stay in normal health and facilitates day-to-day activities. Vyayama should be performed according to the four seasons—sarat (autumn), sisira (winter), hemanta (early winter), and vasanta (spring), according to Ayurveda. Activities that cause fatigue, stability, and strength in the body are referred to as Vyayama in Ayurveda.[66] Ayurvedic literature states that Vyayama promotes a healthy skin tone, increases agni, and makes the body feel lighter. However, it should only be performed to half of the body's strength.[194] Vyayama has several positive effects, but only under the situations indicated in Ayurveda. Also, Vyayama should not be practiced by persons who have rakta pitta, kara, are really feeble, or are very old. Vyayama has a connection to the intellect and heart. Ayurveda deals with all aspects of life. It primarily aims to safeguard and promote health, as well as to cure disorders. According to Ayurveda, Vyayama is a necessary component for preventative health, rejuvenation, and longevity.[18]

1.14.4 Application of Yoga and Vyayama as a mind-body medicine

Yoga and Vyayama of Ayurveda is the term of Indian origin, while the concept of “Mind-Body Medicine” is essentially the western one. Yoga and Ayurveda are sister sciences that influence each other throughout history, rooted in the Vedic tradition of India. Ayurveda is the science of healing for both body and mind. Yoga is the science of self-

realization that signifies the harmonious relationship between mind and body. Both disciplines developed together and have always been used together. [160]

Mind-body medicine focuses on the relationships between the brain, mind, body, and behaviour of an individual in order to promote positive health. Yoga's psycho-physiological and mento-spiritual approach is extremely important in relating to the notion of mind-body medicine in terms of comprehensive health and wellness. The ancient Indian sages never saw man as a simple biological creature, but rather focused on the working of the mind and its inner mechanisms. Psychology has recently embraced this fundamental feature of recognizing the relationship between the body and mind as a whole. People's lifestyles have changed dramatically in recent decades, which has had a negative impact on their health in several ways. Yoga is shown to be beneficial in dealing with the tensions and illnesses brought on by unwanted lifestyle changes. Yoga has grown in popularity as the scientific medical community recognizes the mind-body connection. When the mind is distracted, the body becomes more susceptible to emotional disturbance, resulting in non-coordination between various organs and reducing the body's effectiveness. According to Yoga, the mind plays an important part in all types of ailments, even acute ones.[127, 141] The Ayurvedic approach to shareera is based on vata, pitta, and kapha, which are three bio-regulating factors inherent inside the body and known as tridoshas. If properly performed, Vyayama regulates doshas and dhatus, which govern numerous physiological functions.[194]

1.15 Relevance of the study based on research gap:

Despite existing research on the individual benefits of Yoga and Vyayama for patients with type 2 diabetes mellitus, a significant research gap remains in understanding the combined effect of Yog-vyayama on different levels of HbA1c, particularly in relation to specifically structured training regimen having six-month duration of practice. This gap

highlights the need for a comprehensive insightful study to investigate the synergistic impact of Yog-vyayama on glycemic control in patients with type 2 diabetes mellitus. Hence this study has been designed to achieve its unsolved queries.

1.16 Statement of the Problem

The combined effect of Yog-vyayama on HbA1c levels in patients with type 2 diabetes mellitus is unknown, making it essential to investigate their integrated impact on glycemic control and potential reduction of complications.

1.17 Formation of research questions:

i. Does the combination of yoga and Vyayama significantly reduce HbA1c levels in patients with type 2 diabetes compared to conventional treatment alone?

ii. What will be the optimal duration and frequency of Yog-vyayama practice required to achieve significant reductions in HbA1c levels in patients with type 2 diabetes?

iii. How do the patients with different HbA1c levels (e.g., <6.4%, 6.5-8%, >8%) respond to the combined Yog-vyayama intervention?

iv. How does the combined Yog-vyayama intervention is effective in improving glycemic control, insulin resistances and insulin sensitivity in patients with type 2 diabetes?

1.18 Aim of the Study:

To investigate the combined effect of Yog-vyayama on glycemic control in patients with type 2 diabetes mellitus, and to determine its efficacy in improving glycemic control across different HbA1c categories.

1.19 Objectives of the study

The present study was taken into consideration based on the following objectives:

i. To determine the effects of Yog-vyayama on selected anthropometric characteristics, muscular fitness and vitals in patients with T2DM at three different time points.

ii. To assess the impact of Yog-vyayama on glycemic control, insulin resistance and insulin sensitivity in patients with T2DM at three different time points.

iii. To compare the effects of Yog-vyayama in three different groups of HbA1c levels; i.e., 5.7% - 6.4%, 6.5% - 8%, and >8%.

1.20 Hypothesis:

It was hypothesized that –

i. To determine the effects of Yog-vyayama on selected anthropometric characteristics, muscular fitness and vitals in patients with T2DM at three different time points.

ii. To assess the impact of Yog-vyayama on glycemic control, insulin resistance and insulin sensitivity in patients with T2DM at three different time points.

iii. To compare the effects of Yog-vyayama in three different groups of HbA1c levels; i.e., 5.7% - 6.4%, 6.5% - 8%, and >8%.

1.21 Delimitations of the study:

This study is delimited in the following ways:

i. **Population:** The study focuses solely on patients with type 2 diabetes mellitus, excluding those with type 1 diabetes or other types of diabetes.

ii. **Sample size:** The study is limited to a specific sample size of 54, which may not be representative of the entire population with type 2 diabetes.

iii. **Age range:** The study only includes patients within a specific age ranging from 40 to 70 years, excluding older or younger adults.

iv. **HbA1c level:** The study is limited to a specific HbA1c level from 5.7% to > 8.5% for three different groups.

v. **Geographical location:** The study was conducted at Jadavpur University; Subjects were from the near to Jadavpur University to avail the developed laboratory services. which may not be generalizable to other regions or cultures.

vi. **Duration of intervention:** The study's Yog-vyayama intervention was delimited to a duration of 24 weeks, which may not reflect long-term effects.

vii. **Variables:** Disease related physical, physiological and biochemical variables were considered in this research study, may not capture other relevant aspects of diabetes management.

viii. **Control group:** Control group was not included in this study.

ix. **Study design:** The study applies a purposive sampling method, which may have limitations compared to other designs (e.g., non-randomized controlled trial).

1.22 Limitations of the study

Despite the contributions of this study, several limitations need to be acknowledged:

i. Sample Size and Selection: The study's sample size was limited to 52 participants, which may not be representative of the entire population with type 2 diabetes. Additionally, participants were selected based on specific criteria, which may introduce selection bias.

ii. Subjects: Genetical characteristics of the subjects were beyond the control of the researcher.

iii. Study Duration: The study's duration was limited to 24 weeks, which may not capture long-term effects of yoga and vyayama on T2DM.

iv. Lack of Control Group: The study did not include a control group, making it difficult to compare outcomes and establish causality.

v. Environment: Environmental conditions on different test days were away from the control of the researcher.

vi. Confounding Variables: The study did not control for potential confounding variables, such as medication adherence or dietary habits, which may impact on the outcomes.

vii. Follow-up Period: The study's follow-up period was not done, which may not obtain sustainability of outcomes.

viii. Blinding: Participants and researchers were not blinded to the intervention, which may introduce performance bias.

ix. Generalizability: The study's findings may not be generalizable to other populations, such as those with type 1 diabetes or other health conditions.

1.23 Significance of the Study:

This study is significant for the following reasons:

i. **Scientific information:** This research offers Scientific information into T2DM and Yog-vyayama practices, useful for exercise, yoga, and medical professionals in various fields.

ii. **Implications for diabetes management:** The study's findings can inform the development of alternative or complementary therapies for glycemic control, enhancing treatment options for patients with type 2 diabetes.

iii. **Potential for improved health outcomes:** By identifying effective interventions, this research can contribute to reduced diabetes-related complications and improved quality of life for patients.

iv. **Relevance to public health:** With the global prevalence of type 2 diabetes increasing, this study's findings can have significant implications for public health policies and interventions.

v. **Holistic approach to healthcare:** By examining the combined effect of Yog-vyayama, this research promotes a holistic approach to diabetes management, considering physical, mental, and emotional well-being.

vi. **Empowering patients and healthcare providers:** The study's results can empower patients and healthcare providers with evidence-based information, enabling informed decisions about diabetes management.

vii. **Inspiring policy makers**: It may provide valuable evidence to the policy makers of those who are employed for the diabetes population.

viii. **Scientific Yog-vyayama training:** This study may be the first to utilize a progressive training load in combination with a proper scientific Yog-vyayama training program. With a few modifications, this training program could be beneficial for different groups of people.

CHAPTER – II

Review of Related Literature

2.1 Effect of Yoga on type 2 diabetes.

2.2 Effect of Vyayama on type 2 diabetes.

2.3 Comparison of Yoga and Vyayama on type 2 diabetes.

2.4 Combined effect of Yog-vyayama on type 2 diabetes.

2.5 Summary of the Literature Review

CHAPTER - II

REVIEW OF RELATED LITERATURE

After a thorough literature review with a detailed comprehensive reading of all relevant recorded data, an extensive analysis and in-depth study of the relevant research works were conducted. The researcher conducted a systematic literature review, which is further elaborated upon in this chapter under the numerous subsections that follow.

2.1 Effect of Yoga on type 2 diabetes.

2.2 Effect of Vyayama on type 2 diabetes.

2.3 Comparison of Yoga and Vyayama for Type 2 Diabetes.

2.4 Combined effect of Yog-vyayama on type 2 diabetes.

2.5 Summary of the Literature Review.

The review of related literature is involved in selecting the topic, formulating the hypothesis, and deductive thought leading to the problem. It helps to get a clear idea and supports the findings with regard to the problem under study. The present investigator has completed through available books, journals, articles, research papers, and literature by searching the online databases Scopus, PubMed, Web of Science, and the International Clinical Trials Registry Platform (ICTRP). The related research works acquired from the above databases were brought together and duplicates were removed; some inappropriate studies were further screened and excluded by reading the title, abstract, and full manuscripts. After the final calculation, eligible articles that are related to this current study exist in this chapter. The reviews of the literature have been classified under the following headings and meaningful sections arranged in chronological order for better understanding and to justify the study.

2.1 Effect of yoga on type 2 diabetes.

In 2009, Amita et al,[11] assessed the effect of Yoga-Nidra on Diabetic patients. 41 middle aged T2DM patients were separated into two groups of 20 patients on oral hypoglycemic drugs with Yoga-nidra, and 21 were on oral hypoglycemic drugs alone. Yoga-Nidra trained for 30 minutes daily and up to 90 days; parameters were recorded every 30th day. There was a significant reduction in fasting blood glucose and postprandial blood glucose level. They suggested that on Yoga-nidra subjects with drugs had better control in their unstable blood glucose, compared to those taking oral hypoglycemic medicines alone.

In 2011, Hegde et al.[85] conducted a study to determine the effect of 3-Month Yoga on Oxidative Stress in Type 2 Diabetes with or without complications. A total of 123 type 2 diabetic patients aged between 40 and 75 years were included with 3 months yogic practice. They suggest that Yoga can be used as a therapy in falling oxidative stress in T2DM. Yoga with standard care improves BMI and glycemic control in T2DM.

Vaishali (2012)[199] conducted a study to determine the effects of yoga glycemic control of T2DM subjects. Sixty aged with more than 15 years of T2DM were allocated into control and Yoga groups. Control group takes instruction on overall healthy lifestyle. The yoga group offered yoga asanas and Pranayama for 6 days per week for 12 weeks. After following 12 weeks of intervention, results showed a significant improvement in HbA1c level and Fasting glucose level in the yoga group compared to the control group.

Shantakumari et al. (2013)[172] evaluated the effect of yoga for the management of hypertensive Type 2 diabetes mellitus patients. 100 hypertensive Type 2 diabetes patients were randomly divided into control and yoga groups. The yoga group performed 60 minutes yoga Programme every day with oral hypoglycemic agents for 12 weeks. The control group given oral hypoglycemic agents only. After 3 months yoga group presented

a significant decrease in SBP, DBP and FBG. They believe that diabetic patients might benefit from yoga's potential to enhance their disease condition.

Hegde (2013)[86] conducted a study to determine the effect of yogic exercise on glycemic control and oxidative stress in prediabetes. Twenty-nine prediabetes subjects aged 30—75 years were randomized to either 3-month yoga or wait-list control groups. Yoga may improve BMI, waist circumference, blood pressure, glycemic control and oxidative stress in prediabetes subjects.

Dash and Thakur (2014)[57] carried out a study on "Effect of Yoga in Patient's with Type-II Diabetes Mellitus". Sixty patients (Yoga group-30 and control group-30) with Type 2 Diabetes Mellitus (NIDDM), in the age group of 40 – 60 years, were selected. They found that yoga helps in decreasing blood sugar level and keeping the diabetes in control.

Chimkode et al.[48] (2015) conducted a study to determine the effect of yoga on blood glucose levels in patients with Type 2 Diabetes Mellitus". Thirty T2DM patients enrolled in the yoga group and thirty non-diabetic persons were allocated in control group and their age ranged from 36 to 55 years. They suggest that yoga with oral hypoglycemic agents reduces the blood glucose levels of T2DM patients.

Kumpatla et al. (2015)[115] investigated the efficacy of yogasanas on glycemic control in newly identified type 2 diabetics with oral hypoglycemic drugs (OHA). This prospective study included 303 patients (M:F 199:104), who were placed into two groups. Group 1 subjects (N=149) were given only OHA, whereas group 2 subjects (N=154) were given both OHA and individual training for 30 minutes of yoga practice each day. After three months of training, both groups' BMI did not differ substantially at follow-up. Fasting Blood Glucose levels and HbA1c decreased more in group 2 who practiced yoga. The first group improved their systolic blood pressure, whereas the second group improved both

their systolic and diastolic blood pressures. They suggest that regular yogic practice, along with conventional medications, may help to improve glycemic control.

Keerthi 2017[106] evaluated the impact of 12 weeks yoga therapy on prediabetes and patients with T2DM. Where 310 patients were separated and obsessed by controls, prediabetics and diabetics. Their age ranges from 18 to 45 years. Yogic exercise for 12 weeks with oral hypoglycemic medicine may improve fasting glucose and fasting insulin of Indian pre diabetics and diabetics compared to only oral hypoglycemic medicine.

In 2018, Agrawal[5] established HbA1c estimation methods, identifying pre-diabetics and diabetics, and predicting micro and macrovascular complications. HbA1c test remains the gold standard for monitoring glycaemic control.

In 2021, Viswanathan[207] found that yoga intervention significantly reduced biochemical and oxidative stress markers in type 2 diabetes patients, with yogasanas group showing a significant reduction in BMI, blood glucose, HbA1c, and lipid levels.

Dhali B et al. (2023)[64] reviewed the efficacy of yoga on insulin resistance in type 2 diabetes. From six articles 375 patients aged 15–75 years were assigned to a yoga and control group. They observed that yoga had a significant reduction in fasting blood glucose level, post-prandial blood glucose level, fasting insulin and insulin resistance in type 2 diabetes mellitus.

2.2 Effect of vyayama on type 2 diabetes.

Shenoy (2010)[175] conducted a study to examine the impact of eight weeks of aerobic walking with a pedometer for monitor and heart rate monitoring exercise intensity on glycemic results in T2DM patients. Forty T2DM patients were enrolled in an 8-week supervised walking program (group A n=20) and control group (group B n=20). Walking improved glycemic control and general well-being.

Karstoft's 2013[102] study compared interval-walking and continuous-walking for type 2 diabetic patients. Results showed interval-walkers experienced decreased BMI and glycemic control, while continuous walkers showed no significant changes.

Gainey (2016)[72] investigates the impact of Buddhist walking meditation vs conventional walking on glucose control in T2DM patients. Buddhist walking meditation on the treadmill had a wider range of positive effects improving glycemic control and the conventional walking programs on individuals with type 2 diabetes.

Rafii[151] **2018** investigates to determine the comparative effects of walking and Tai Chi exercise on fasting blood glucose (FBG) among 100 T2DM patients. The patients in the group of Tai-Chi and walking performed exercise of 30 minutes and three days per week for eight weeks. FBG were significantly reduced after eight weeks of Tai Chi and the walking exercise intervention in T2DM patients.

Youssef[216] **(2019)** investigated to find out the effect of walking and aerobic exercise on 40 type 2 diabetes mellitus (T2DM) patients. They were divided into walking (30min, 3 times/week) and aerobic exercise (30min, 3 times/week) groups for 3 months. Both walking and aerobic exercise improved glycemic control where aerobic exercise improves better results.

Seyam[171] **et al. (2020)** carried out a study to determine the effects of sand walking and normal walking on T2DM. 66 overweight T2DM patients were allocated to the group of sand walking (n = 33) or normal walking (n = 33). They determine that regular sand walking combined with careful dietary management resulted batter improvements in HbA1c, BMI and waist circumference compared to the regular walking group.

In 2021, Leischik[118] found that physical activity, specifically walking, significantly improved cognitive function of type 2 diabetes patients. The intervention, which included

walking, pedometer-controlled activity, and standard care, also improved body composition and waist circumference.

2.3 Comparison of Yoga and Vyayama on type 2 diabetes:

In 2008, Gordon[78] et. al. suggest that Hatha yoga exercise and traditional PT exercise reduced fasting blood glucose level and oxidative stress. Relatively, Hatha yoga exercise has more significant effects in comparison to conventional PT exercise for the control of type 2 diabetes.

McDermott[122] 2014 investigated to determine the effect of yoga and walking on T2DM. Forty-one participants were divided into yoga (n = 21) and walking group (n = 20). For eight weeks, patients took yoga and walking lessons 3-6 days a week. They observed that eight weeks of yoga intervention decreased in more weight loss and waist circumference than a walking control.

Saberipour[161] B 2020 compared the effect of walking and yoga on T2DM. 108 T2DM patients were randomly assigned to walking, yoga, and control groups. The yoga and walking groups exercised for 60 minutes three times each week for eight weeks, whereas the control group did not exercise at all. The results showed that yoga improves in BMI, fasting blood sugar and cholesterol but only in HDL in the walking group. However, yoga had a better effect on clinical and laboratory markers in T2DM patients than walking.

Yuniartika[219] W 2021 investigated to know the effect of yoga and walking on diabetes mellitus patients. Total 54 diabetes mellitus patients divided into three groups of yoga, walking and control. They included criteria for people with type 2 diabetes mellitus who did not have complications, were not on insulin therapy, or used diabetic medication. The intervention group had treatment for 12 weeks, three times per week. Both yoga therapy and walking therapy reduced fasting glucose levels.

Dhali[65] B et al. (2023) reviewed to find out the efficiency of yoga or walking on glycemic control in T2DM. 1820 T2DM patients (age ranging 17–75 years) were allocated to the yoga, walking, and control group. They found that yoga or walking with oral hypoglycemic agents had a significant reduction in fasting blood glucose, postprandial blood glucose, HbAlc, fasting insulin and insulin resistance related to the control group. Yoga has comparatively more significant effects on glycemic variables than walking for the management of T2DM.

2.4 Combined effect of Yog-vyayama on type 2 diabetes.

In **2019, Esha[69] K et al.** investigate to achieve better glycaemic control through yoga, walking or combined yoga and walking. 30 patients with type 2 diabetes were allotted to three groups: walking, yoga, or a combination of the two. Participants were given a four-week intervention with three to five sessions. Four weeks later, post-intervention values were collected. All three groups show substantial intra-group differences in fasting and postprandial blood sugar levels before and after intervention. The study found no significant difference in fasting and postprandial blood sugar levels between the three groups.

Biswas D & Debnath M[27] (2020) carried out a study to find out the effect of in the three groups of Raja-Yoga meditation (RM) only, diet and exercise only, and RM, diet and walking exercise on Glycemic control. All diabetes patients between the ages of 30 and 60, who have been on therapy for 5-10 years. In combined RM, diet and walking exercise groups, fasting blood sugar and HbA1c improved better than the other groups.

Gupta U[81] et al. 2020 conducted a study to determine the effect of a yogic exercise program for improving glycemic control in patients with type 2 diabetes mellitus. HbA1c reduced in yogic exercise group as compared to usual care of the control group.

2.5 Summary of the Literature review

The researcher was able to identify relevant topic and variables after reviewing the literature. The researcher also used the recent literature to back up his conclusions about the problem. Furthermore, the material obtained for the study aids the research of the investigator in understanding similar areas of study.

The reviews were presented under the four sections such as Effect of Yoga on type 2 diabetes (n=12) Effect of Vyayama on type 2 diabetes (n=7), Effect of Yoga and Vyayama on type 2 diabetes(n=5), Combined effect of Yog-Vyayama on type 2 diabetes (3) in chronological order.

The literature review reveals that yoga and vyayama (physical exercise) have a positive impact on Type 2 Diabetes Mellitus (T2DM) management, demonstrating significant reductions in blood glucose levels, HbA1c, and blood pressure, and improvements in insulin sensitivity, cardiovascular health, and stress reduction. Studies show that yoga-based interventions enhance pancreatic beta-cell function, improve glycemic control, and reduce inflammation, while vyayama increases muscle strength, flexibility, and glucose uptake. Combination therapy of yoga and vyayama yields better outcomes than either alone, highlighting the potential for these complementary therapies to augment conventional T2DM treatments. However, limitations include variability in study designs, small sample sizes, and inconsistent protocols, underscoring the need for standardized interventions and further investigation into molecular mechanisms and long-term adherence. Despite existing research on the individual benefits of Yoga and Vyayama for patients with type 2 diabetes, there is still a significant research gap in understanding the combined effect of Yog-vyayama on different levels of HbA1c, particularly in relation to a specifically structured training regimen with a six-month duration of practice.

CHAPTER – III

Methodology

CHAPTER – III

METHODOLOGY

3. Methodology

Research Methodology is described as the scientific and systematic approach to answering a research topic. This chapter goes into depth about the study's procedural choices and research strategy. The technique includes a full description of the people, the location, the processes for collecting and analysing data, and the ethical issues.

3.1 Study Location with Laboratory setup:

The present study was Carried out in the exercise and sports physiology laboratory, Yoga Centre and small area games arena of the Dept. of physical education, Jadavpur University, Kolkata, India.

A “Yog-vyayama Camp” was organized jointly by the researcher, Jadavpur University Yoga Centre and Health Centre of Jadavpur University. Practice areas of Yog-vyayama Camp were Yoga Centre, Small Area Games Arena and Open-Air Theatre (OAT) in the premises of Jadavpur University.

3.2 Participants:

3.2.1 Targeted Population:

In the present study, an interested elderly population with pre-diabetes and type 2 diabetes mellitus patients were considered as subjects of the study for this research work.

Figure 5: Study location and Laboratory Set up

3.2.2 Sample Size:

The sample size calculated using G*Power software was 54. Sample size was arrived at considering a power (1-β = 0.95), (α = 0.05) and effect size (d = 0.25), from a research study conducted at Jadavpur University.

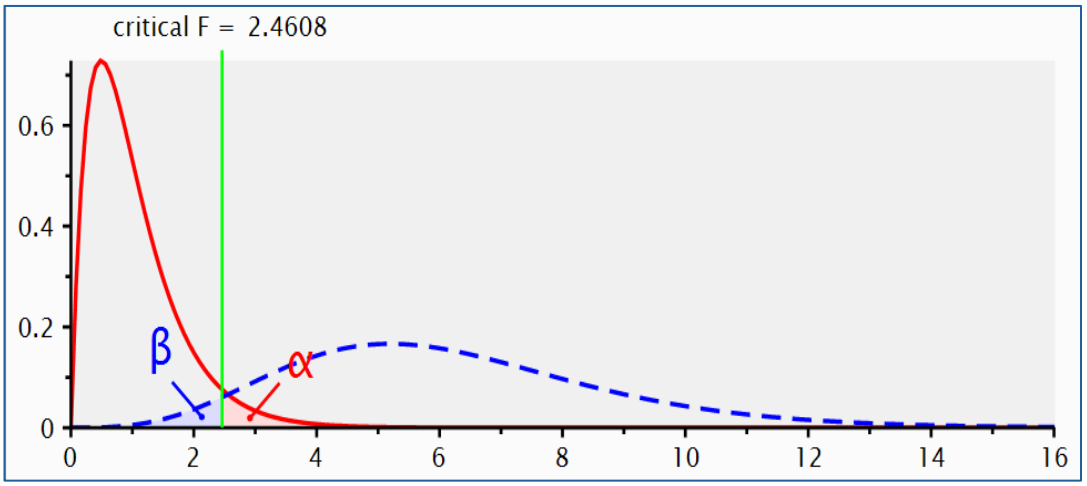


Figure 6: G Power analysis chart

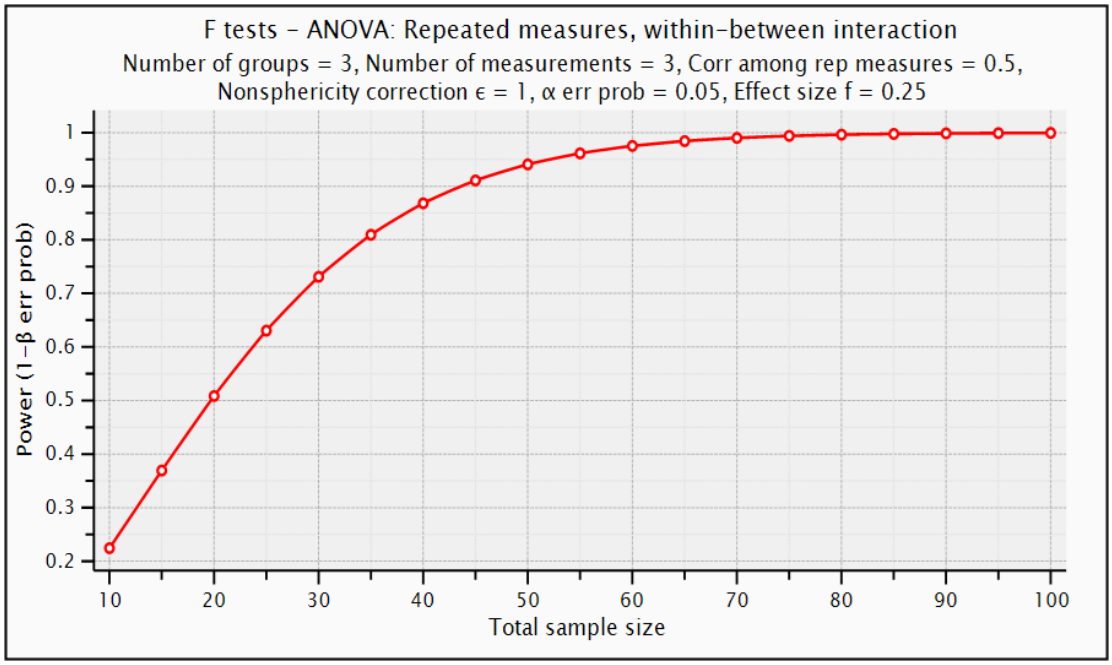


Figure 7: Plot for range of power with sample size for this study

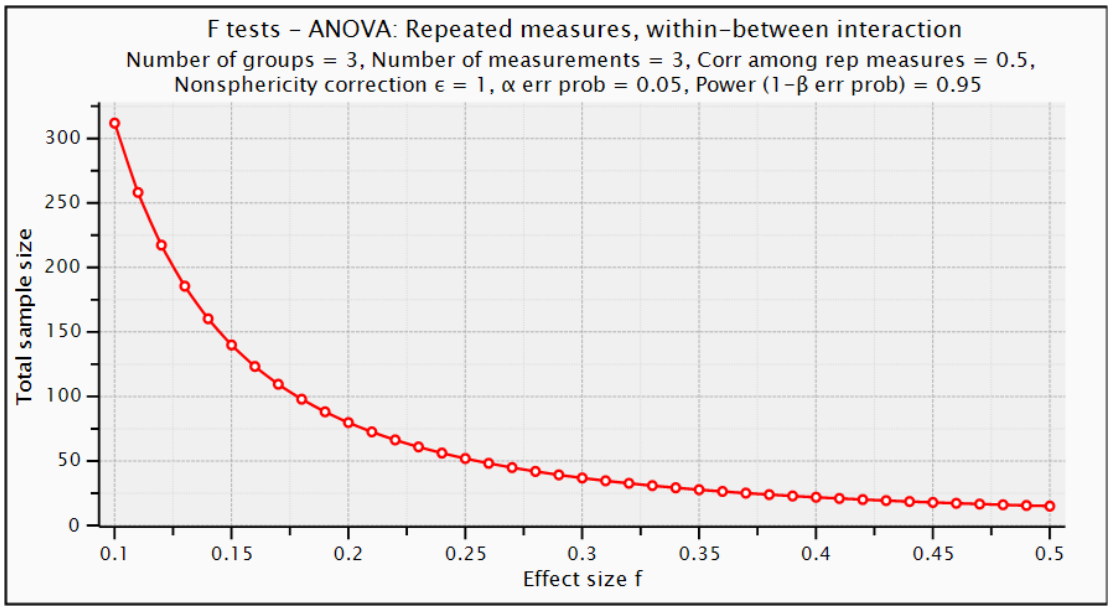


Figure 8: Plot for range of effect size chart with sample size for this study

3.2.3 Selection of subjects:

Initially total 230 participants with both gender, ages ranging from 40 to 70 years from both genders, having no prior regular practice of yogic exercise were selected for this study. After the screening process 162 subjects (Male:75, Female:87) were identified with pre-diabetes and Type 2 diabetes patients and they were further purposively divided into three groups, 51 for Group A (M-24, F-27), 54 for Group B

(M-24, F-30) and 57 for Group C (M-27, F-30) according to their HbA1c level at the time of baseline measurements. After three months and six months intervention total 22 and 31members dropped out respectively. Finally, 109 participants with the division of 32 for Group A (M-15, F-17), 35 for Group B (M-16, F-19) and 42 for Group C (M-20, F-22) were selected for statistical analysis that is illustrated in figure 9. All participants were near Jadavpur area and other areas around Kolkata, West Bengal, India.

3.2.4 Inclusion Criteria:

- Pre-diabetes and Type 2 diabetes mellitus through a history of diabetes for 0-15 years.
- The HbA1c level of subjects was above 5.7 %.
- Age ranging from 40 to 70 from both genders.
- The included activities were some selected combined Yog-vyayama.
- 55-75 Minutes Yog-vyayama took place for 24 weeks and four days per week.
- Participants must be willing to provide written consent to participate in the study.

3.2.5 Exclusion Criteria:

- Patients with type-1 Diabetes, gestational diabetes, patients > 30 BMI.
- Alcoholic Patients, or addiction to any forms of drug usage.
- Patients previously performing any other regular and controlled physical exercises.
- Mobility restrictions or inability to do Yog-vyayama practices.
- Diagnosed with cardiovascular diseases, hyper retinopathy, recent major trauma or surgery that would interfere with participation.
- Persons identified with any other serious problem that can confound the outcome.

3.2.6 Case history logbook of subjects:

Case histories Logbook was maintained throughout the study for all willing participants were to in the study are as follows:

- History of Comorbidity
- List of medicine or Drug History (Annexure – 6)
- Attendance records
- Problem faced by the participants during intervention

3.3 Study Design:

A Yog-vyayama camp for diabetes management was organized for a one-month advertisement process via posters, leaflets, flex, and social media. Due to the public demand, the advertisement was extended for an additional fifteen days. The registration process for participating in the camp was available both online and offline. 'Registration form' and 'Patient consent form' were filled out by each patient. All registered patients were given an orientation programme, followed by a general health check-up by a diabetologist. Then patients were screened based on the above exclusions criteria. After screening of patients, baseline data were collected by the researcher and the expert team members at the exercise and sports physiology laboratory of the department of physical education at Jadavpur University. Following the collection of baseline data, patients were purposively divided into three groups according to their different HbA1c levels. After the division of the three groups of patients, the six-month Yog-vyayama training camp was started by yoga experts. This camp was held at the small area games arena and sometimes due to the bad weather conditions it was performed in the yoga centre and open-air theatre (OAT) of Jadavpur University campus. During training, some patients dropped out from this camp. A midterm data collection was conducted following the three months of training camp. The progression of each patient's physical and blood reports was observed by the

diabetologist and experts from the Research Advisory Committee. If some reports of the patients were aberrant, then immediately rechecked the patients by the researcher. The final data for each patient was collected after six months of training camp. Participants were not blinded from the intervention because of its cooperating nature. However, for the lab assessments and data analysis, participant identity was hidden by coding.

3.4 Enrolment of subjects and follow up scheduled:

A total of 230 registered members were assessed and 47 members excluded from the study as they did not meet the inclusion criteria; 21 members were denied participation in the study. The remaining members recruited for the study are 162 members. These 162 members were purposively divided into three groups these are Group: A (Pre-diabetes - HbA1c Level 5.7% to 6.4%) n=51 (M-24, F-37) did not take any oral hypoglycemic agent or insulin, Group: B (T2DM Stage 1 - HbA1c Level 6.5% to 8%) n=54 (M-24, F-30) with taking oral hypoglycemic agent and Group: C (T2DM Stage 2 - HbA1c Level > 8%) n=57 (M-27, F-30) with taking oral hypoglycemic. Baseline measurements were done before the start the Yog-vyayama intervention, after 3 months intervention total 22 members dropped out; finally, after six months intervention total 31 members dropped out from the study. Therefore, data analysis was done for all the participants' n=109 that is illustrated in figure 9.

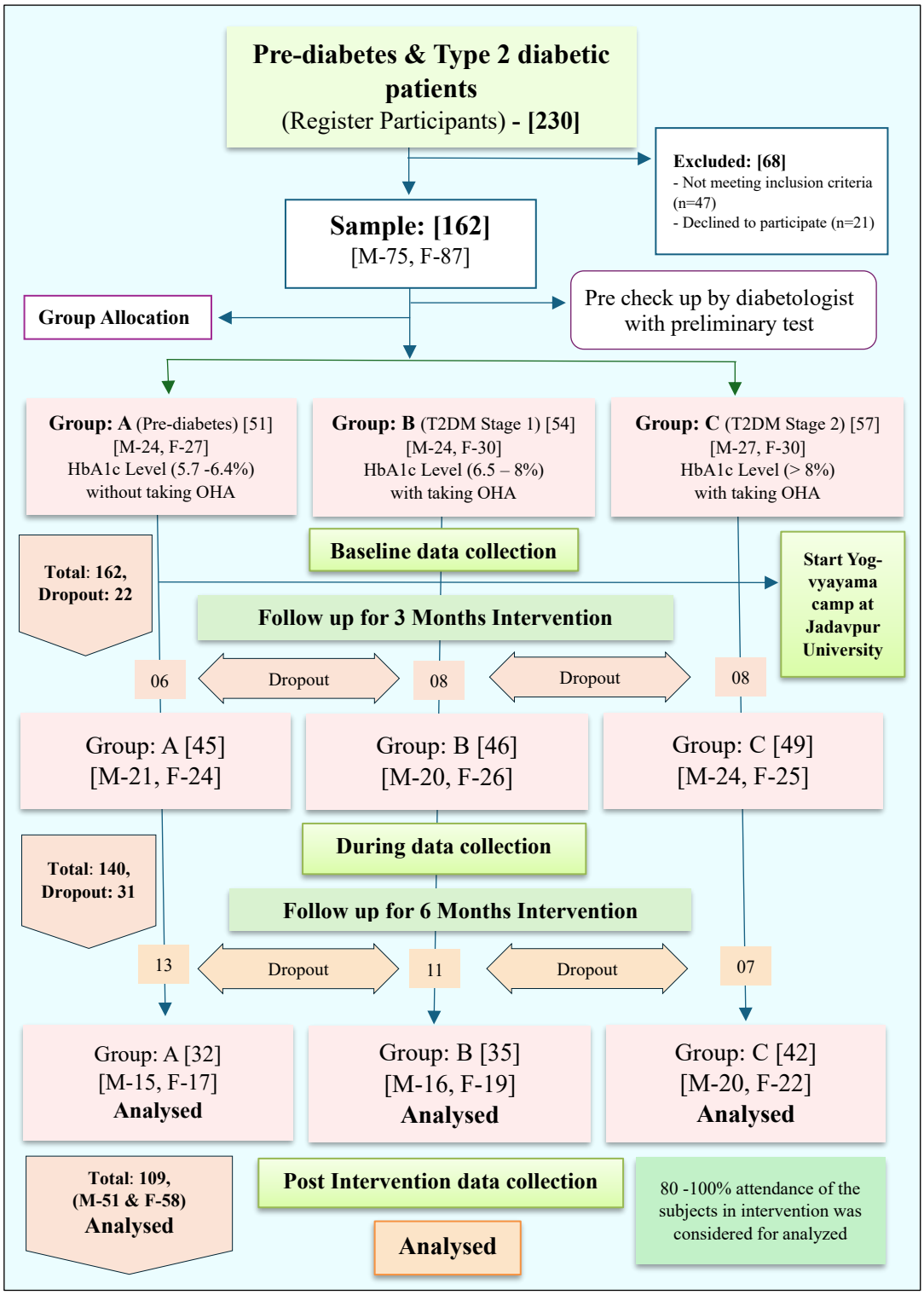


Figure 9: Enrolment of Subjects and Follow up scheduled

3.5 Ethical Consideration

- This present study followed the ICMR prescribe Ethical guidelines (Last accessed on 28th April 2020)[132]
- Individual consent was taken from each subject according to ICMR guideline of ICMR Common Forms for Ethics Review that was Last accessed on 28th April 2020. (Annexure 4)[91]
- This clinical trial was approved by the Institutional Ethics Committee (IEC) of Jadavpur University (Reference No: IEC/27/C/23 dated 06.07.2023). (Annexure 2)
- This clinical trial was further registered at the Clinical Trial Registry of India (Trial Registration No: CTRI/2024/08/072487). (Annexure 2)

3.6 Variables Studied:

As per the aim and objectives of the study, the researcher reviewed different areas and then came to the conclusion that some variables were studied in depth but some other variables were kept open for further research. In this study the following variables with a broad heading were examined for logical conclusion:

- **Anthropometric Variables:**
  - Body Weight (kg)
  - Standing Height (Meter)
  - Body mass index (kg/m2)
  - Waist circumference (cm)
  - Hip circumference (cm)
- **Physical Variables:**
  - Grip Strength (kg)
  - Trunk Flexibility (cm)
- **Physiological Variables:**
  - Heart Rate (b/m)
  - Blood Pressure (mmHg)
  - Pulse oximeter-(SpO_2) (%)
- **Biochemical Variables:**
  - Fasting Plasma Glucose (mg/dl)
  - HbA1c (%)
  - Fasting Insulin (µIU/mL)
  - Insulin Resistance
  - Insulin sensitivity

3.6.1 Criterion measure:

Table 7: Criterion measure of selected variables with unit

Sl. No.	Variables	Measured by	Unit
1	Age	Age proof ID card	Year
2	Weight	Digital Weighing Machine	kg
3	Height	Stadiometer	cm
4	BMI	Weight in kg/Height in m^2	kg/m^2
5	Waist circumference	Anthropometric tape	cm
6	Hip circumference	Anthropometric tape	cm
7	Grip strength	Digital Grip dynamometer	kg
8	Trunk Flexibility	Sit and reach test box	cm
9	Heart rate	Patient Monitoring Device (Nasan PARA 1005, 12.1" Multipara Monitor)	b/m
10	Systolic blood pressure		mm/Hg
11	Diastolic blood pressure		mm/Hg
12	Pulse oximeter (SpO_2)		%
13	Fasting plasma glucose (FPG)	Semi Auto Biochemistry Analyzer [2, 3] (AGD 2020 Clinical Chemistry Analyzer)	mg/dL
14	HbA1c		%
15	Fasting Insulin	Elisa machine (BeneSphera™ E-21, ELISA microplate reader)	µIU/mL
16	Insulin Resistance	HOMA IR formula[121] [Fasting insulin (µU/ml) × Fasting glucose (mmol/l) / 22.5]	µU/mL x mmol/L
17	Insulin Sensitivity	QUICKI Formula[104] 1 / [log (Fasting Insulin in µU/mL) + log (Fasting Glucose in mg/dL)]	-

3.7 Details of Intervention: (Yog-vyayama Training Protocol)

The Yog-vyayama intervention regimen was designed specifically for the individuals' health and physical circumstances. All included participants took part in a specific Yog-vyayama intervention. This intervention included prayer, Yogic Suksma Vyayama, Surya namaskara, brisk walking, dynamic stretching and deep breathing, asana, kriya, pranayama, and meditation. Certified yoga trainers took the classes of Yog-vyayama and they recorded regular attendance. Detailed yogic practices are set in accordance with the demands of science of yoga to fulfil the purposes of the study.

Table 8: Outlook of Structured Yog-vyayama Module	
1	**Initial Prayer:** oṃ saha nāvavatu । saha nau bhunaktu । saha vīryaṃ karavāvahai । tejasvi nāvadhītamastu mā vidviṣāvahai ।oṃ śāntiḥ śāntiḥ śāntiḥ ॥
2	**Yogic Suksma Vyayama:** Tatha Dhrti-Sakti-Vikasaka, Medha Sakti-Vikasaka-1, Griva-Sakthi-Vikasaka-1, Griva-Sakthi-Vikasaka-2, Griva-Sakthi-Vikasaka-3, Mani-Bandha-Sakthi-Vikasaka, Kara-Tala-Sakti-Vikasaka, Anguli-Sakti-Vikasaka, Vaksha-Sthala-Sakti-Vikasaka-1, Kati-Sakti-Vikasaka-1, Kati-Sakti-Vikasaka-3, Kati-Sakti-Vikasaka-4, Kati-Sakti-Vikasaka-5, Jangha-Sakti-Vikasaka-2, Janu-Sakthi-Vikasaka, Pada-Mula-Sakti, Gulpha-Pada-Prstha-Pada-Tala-Sakti-Vikasaka.
3	**Surya Namaskara:** 1.Pranamasana; 2.Hasta utthanasana; 3.Pada hastasana; 4.Ashwasanchalanasana; 5.Parvatasana; 6.Ashtanga namaskara; 7.Bhujangasana; 8.Parvatasana; 9.Ashwasanchalanasana; 10.Pada hastasana; 11.Hasta utthanasana; 12.Pranamasana.
4	**Brisk Walking:** 80-100 steps/min.
5	**Recovery** (Slow Walking with dynamic stretching and deep breathing).
6	**Asanas:** Vakrasana, Uttanapadasana, Ardha Halasana, Pavanmuktasana, Setubandhasana, Makarasana, Parivrtta Trikonasana, Bhujangasana, Salvasana and Savasana.
7	**Kriya:** Kapalbhati. **Pranayamas**: Nadisodhan, Bhastrika and Bhramari.
8	**A – U – M** Meditation **/** chanting or complete Aum
9.	**Closing Prayer:** Oṃ sarve bhavantu sukhinaḥ sarve santu nirāmayāḥ| sarve bhadrāṇi paśyantu mā kaścidduḥkhabhāg bhavet||

The principles of "Holistic approach of Yogic science", were considered in the present study. 50-75 minutes (200-280 minutes per week) per day and four (4) days per

week for six (6) months of structured Yog-vyayama intervention modules were considered in this current study. The method of progressive training load was applied in the arrangement of duration, intensity, repetitions, volume from 1st month to 6th months of schedule that is illustrated in table 8 to 14. [44, 45]

Details of Structured Yog-vyayama Module

Table 9: Detailed of Yog-vyayama Module for 1st month (1 – 4 week)

Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	-	-	-	5 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	5 min
Recovery phase: Dynamic stretching and deep breathing	-	-	-	5 min
Asanas	Holding time – 5 sec 10 Asana x 1.5 min = 15 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	15 min
Kriya: Kapalbhati	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Nadisodhan	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	8min
Closing Prayer: Oṃ sarve bhavantu sukhinaḥ.	1 min	1 time	No recovery during prayer	1 min
				Total Time: 50 Minutes

Table 10: Detailed of Yog-vyayama Module for 2nd month (5 – 8 week)				
Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	5 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	10 min
Recovery phase: Dynamic stretching and deep breathing	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	3 min
Asanas	Holding time – 5 sec 10 Asana x 1.5 min = 15 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	15 min
Kriya: Kapalbhati	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Nadisodhan	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	10min
Closing Prayer: oṃ sarve bhavantu sukhinaḥ…	1 min	1 time	No recovery during prayer	1 min
				Total Time: 55 Minutes

Table 11: Detailed of Yog-vyayama Module for 3rd month (9 – 12 week)				
Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	8 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	10 min
Recovery phase: Dynamic stretching and deep breathing	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	5 min
Asanas	Holding time – 5 sec 10 Asana x 1.5 min = 15 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	15 min
Kriya: Kapalbhati	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Nadisodhan	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	10min
Closing Prayer: oṃ sarve bhavantu sukhinaḥ…	1 min	1 time	No recovery during prayer	1 min
Total Time: 60 Minutes				

Table 12: Detailed of Yog-vyayama Module for 4th month (13 – 16 week)				
Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	5 min
Surya namaskar (12 counts)	1.5 × 5 = 7.5 min	5 times	30 sec × 5 = 2.5 min	10 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	10 min
Recovery phase: Dynamic stretching and deep breathing	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	3 min
Asanas	Holding time – 5 sec 10 Asana x 1.5 min = 15 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	15 min
Pranayama: Bhastrika	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Bhramari	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	10min
Closing Prayer: oṃ sarve bhavantu sukhinaḥ…	1 min	1 time	No recovery during prayer	1 min
				Total Time: 65 Minutes

Table 13: Detailed of Yog-vyayama Module for 5th month (17 – 20 week)				
Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	10 min
Surya namaskar (12 counts)	1.5 × 5 = 7.5 min	5 times	30 sec × 5 = 2.5 min	10 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	10 min
Recovery phase: Dynamic stretching and deep breathing	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	3 min
Asanas	Holding time – 5 sec 10 Asana x 1.5 min = 15 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	15 min
Pranayama: Bhastrika	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Bhramari	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	10min
Closing Prayer: oṃ sarve bhavantu sukhinaḥ…	1 min	1 time	No recovery during prayer	1 min
				Total Time: 70 Minutes

Table 14: Detailed of Yog-vyayama Module for 6th month (21 – 24 week)				
Name of the Yog-vyayama Practice	Intensity	Repetition	Recovery Time	Volume
Initial Prayer: oṃ saha nāvavatu…	1 min	1 time	No recovery during prayer	1 min
Yogic Suksma Vyayama	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	10 min
Surya namaskar (12 counts)	1.5 × 5 = 7.5 min	5 times	30 sec × 5 = 2.5 min	10 min
Brisk walking	80-100 steps/min = 4.5 min	2 times	1 min slow walk in between set = 1 min	10 min
Recovery phase: Dynamic stretching and deep breathing	Depend upon Individual capacity	Depend upon Individual capacity	Depend upon Individual capacity	3 min
Asanas	Holding time – 5 sec 10 Asana x 2 min = 20 min	1 time	30 sec rest in between each Asana 10 x 30 sec = 5 min	20 min
Pranayama: Bhastrika	30 strokes 1 stroke / sec = 2.5 min	5 times	30 sec rest in between each round = 2.5 min	5 min
Pranayama: Bhramari	5 min	1 time	1 min rest in between 2min of each Pranayama	5 min
Meditation: A-U-M	Practice span: 10 min	Depend upon Individual capacity	Complete relaxation during recitation	10min
Closing Prayer: oṃ sarve bhavantu sukhinaḥ…	1 min	1 time	No recovery during prayer	1 min
				Total Time: 75 Minutes

Figure 10: Yog-vyayama training Programme

3.8 Data Extraction procedure:

3.8.1. Age: Verified age using official documents like birth certificate, Passport, Voter ID, AADHAAR card, Driving licenses etc.

3.8.2. Weight:

Instruments: standard weighing machine.

Procedure: A standard and calibrated weighing machine was used to measure the weight of the subject in kilograms. Subjects were asked to come on the weighing machine bare footed. They were asked to stand keeping the body erect.

Scoring: The scores were recorded in kilograms.

Figure 11: Measuring body weight

3.8.3. Standing Height:

Instruments: Stadiometer

Procedure: Stretch stature method was applied to measure the standing height. In this method subject requires to stand with the feet and heels together; Upper back and buttocks make contact with the scale. When placing the head in the Frankfort plane, it should not come into contact with the scale. The Frankfort plane is reached when the Orbital is in the same horizontal plane as the Tragion. When aligned, the Vertex is the highest point of the skull.

Scoring: The measurement was recorded in meters.

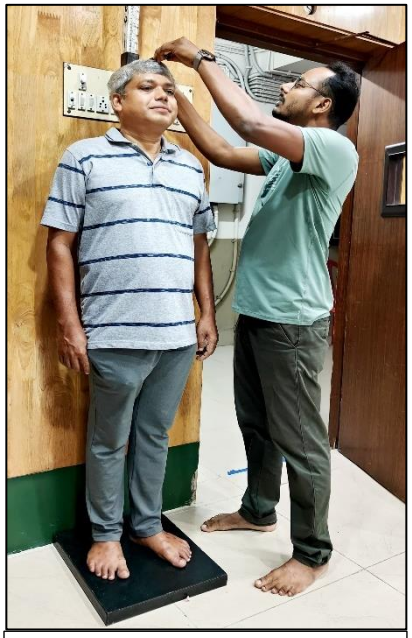


Figure 12: Measuring standing height

3.8.4. Body mass index (kg/m^2)

Procedure: Body Mass Index or Quetelet's body mass index is calculated by the following equation:

Body Mass Index = Body Weight (kg) / (Standing height in meters)^2

Scoring: Body Mass Index may be found by measuring body weight and height and then consulting the ready reckoner of Body Mass Index.

3.8.5. Heart Rate

Instruments: Patient Monitoring Device (Nasan PARA 1005, 12.1" Multipara Monitor)

Procedure: Here's a step-by-step procedure for measuring heart rate using patient monitoring device:

1. *Prepare the device:* Ensure the patient monitoring device is turned on and functioning properly. Select the heart rate monitoring mode (e.g., pulse oximetry).

2. *Prepare the patient:* Ensure the patient is comfortable and relaxed. Remove any jewelry or clothing that may interfere with the monitoring leads.

3. *Attach the monitoring leads*: For pulse oximetry, attach the sensor to the patient's finger.

4. *Set the monitoring parameters:* Set the heart rate monitoring range (e.g., 30-200 bpm).

5. *Start the monitoring:* Begin the heart rate monitoring. Ensure the device is displaying a clear and accurate heart rate reading.

6. *Maintain patient safety:* Ensure the patient's safety and comfort during monitoring, Adjust the device settings as needed.

Scoring: The device displays the score of calculated heart rate value as a beat/minute.

3.8.6. Blood Pressure (Systolic and Diastolic)

Instruments: Patient Monitoring Device (Nasan PARA 1005, 12.1" Multipara Monitor)

Method: Oscillometric Technique

Procedure: Place the cuff on the patient's upper arm, about 1 inch above the elbow, with the tubing facing downwards. Press the "NIBP" button to inflate the cuff to a pressure of around 180 mmHg. The device starts measuring blood pressure and displays "Measuring" on the screen.

Scoring: The device displays the score of calculated Systolic and Diastolic blood pressure value as a mm/Hg.

Figure 13: Measuring Vitals through Patient Monitoring Device

3.8.7. SpO_2 Monitoring

Instruments: Patient Monitoring Device (Nasan PARA 1005, 12.1" Multipara Monitor)

Procedure:

1. *Sensor placement:* Attach the SpO2 sensor to the patient's finger, earlobe, or toe, depending on the device's design. Ensure proper alignment and secure attachment.

2. *Signal detection:* The sensor emits light through the patient's tissue and detects the changes in light absorption caused by oxygenated and deoxygenated haemoglobin.

3. *Pulse detection*: The device detects the patient's pulse and synchronizes the SpO2 measurement with each heartbeat.

4. *Calculation:* The device calculates the ratio of oxygenated haemoglobin to total haemoglobin, using the detected changes in light absorption. The device calculates the ratio of the absorbed red light to infrared light, which is directly related to the oxygen saturation level.

Measuring Principle: According to Lambert-Beer law, the light absorption of a substance is exactly proportional to its density or concentration. When light of a specific wavelength is sent into human tissue, the measured intensity of light after absorption, reflection, and attenuation in tissue can reflect the structure of the tissue through which the light passes. The absorption characteristics of oxygenated haemoglobin (HbO2) and deoxygenated haemoglobin (Hb) in the spectrum range from red to infrared light (600nm~1000nm wavelength) can be used to measure SpO2. This monitor measures functional oxygen saturation (SpO2), which is the percentage of haemoglobin capable of transporting oxygen. In contrast, hemoximeters report fractional oxygen saturation—a percentage of all measured haemoglobin, including defective haemoglobin, such as carboxyhaemoglobin.

Scoring: The device displays the score of calculated SpO2 value as a percentage (%), indicating the patient's oxygen saturation level.

3.8.8. Waist circumference

Figure 14: Measuring Waist circumference

Subject position: The individual stands in a relaxed position with elbows folded across the thorax.

Method: The girth is measured at the narrowest point between the lower costal border (10th rib) and the iliac crest. The anthropometrist stands in front of the subject, who slightly abducts their arms to allow the tape to be wrapped around their abdomen. The anthropometrist then holds both the stub of the tape and the housing in his right hand while using his left hand to adjust the level of the tape at the back to the exact narrowest point. The anthropometrist takes control of the stub with his left hand and uses the cross-hand technique to position the tape in front of the goal level. The individual is encouraged to lower their arms into a relaxed stance. The tape is then readjusted as needed to avoid slipping and undue indentation of the skin. The individual should breathe regularly, and the measurement is obtained at the conclusion of a normal expiration (tidal). If there is no visible narrowing, measure at the midpoint of the lower costal (10th rib) border and the iliac crest.

3.8.9. Hip circumference

Subject position: The individual is standing relaxed, with arms folded across the thorax, feet together, and gluteal muscles relaxed.

Method: The girth is measured at the level of the most posterior protuberance of the buttocks, which often corresponds anteriorly to the symphysis pubis. The anthropometrist applies the tape to the hips from the side. The anthropometrist then holds the stub of the tape and the housing in his right hand while using his left hand to adjust the level of the tape at the back to the adjudicated level of the buttocks' greatest posterior protuberance.

The anthropometrist regains control of the stub with his left hand, using the cross-hand technique, arranges the tape in front and on the sides so that it is held in a horizontal plane at the desired level. The tape is readjusted to prevent sliding and over indenting the skin.

3.8.10. Grip Strength

Figure 15: Measuring grip strength

Purpose: To measure hand grip strength

Equipment: Digital hand grip dynamometer

Procedure: Grip strength was measured using a digital grip dynamometer with an adjustable handle; test protocols were presented to the participants, and they were advised to stand upright and hold the grip dynamometer somewhat away from their bodies. They gradually squeezed the handle to exert maximal force without any jerking while maintaining a 90-degree angle with their bent elbow. Each participant performed three trials with both hands. The best score was taken from three trials.

3.8.11. Flexibility

Figure 15a: Measuring Flexibility

Purpose: To measure the flexibility (extensibility) of the low back and posterior thighs.

Equipment: Lafayette Adjustable Sit and Reach Flexibility Test box. with a measuring scale where 23cm is at the level of the feet.

Procedure: To assume the starting position, subjects removed their shoes and sat down at the test apparatus with their knees fully extended and the feet shoulder-width apart. The feet should be flat against the end board. The arms were extended forward with the hands placed on top of each other to perform the test. The

subject reached directly forward, palms down, along the measuring scale four times and held the position of maximum reach on the fourth trial. The position of maximum reach must be held for one second.

Scoring: The score was the most distant point reached on the fourth trial measured to the nearest centimetre. The test administrator should remain close to the scale and the most distant line touched by the fingertips of both hands. If the hands reached unevenly, the test was re-administered. The tester should place one hand on the subject's knees to ensure that they remain extended.

3.9 Good clinical Practices:

3.9.1 Sample collection:

Venous blood samples (fasting, 5ml) were collected by a trained phlebotomist at baseline and the midterm after three months of exercise intervention and the end of six months of post exercise intervention. Blood was drawn into serum vacutainers (BD Vacutainer). Serum was separated from serum vacutainers by a centrifugation process (except HbA1c estimation). It was instantly analysed by a professional Medical Laboratory Technician (MLT).

Figure 16: Venous blood samples (fasting, 5ml) were collected by phlebotomist

Figure 17: Centrifugation (Serum Separation): 5-10 minutes at 1,000-1,500 x g3.

Figure 18: Pipetting blood samples with reagent

Figure 19: Semi Auto Biochemistry Analyzer (AGD 2020 Clinical Chemistry Analyzer)

Figure 20: Blood sample run for getting result

3.9.2 Estimation of Serum Glucose level:

Instruments: Semi Auto Biochemistry Analyzer (AGD 2020 Clinical Chemistry Analyzer).

Method: Glucose Oxidase - Peroxidase (GOD-POD) method [2, 195]

Procedure: Serum glucose level was assessed from serum from blood cells. After the centrifugation process to separate serum or plasma from blood cells, only serum was to assess glucose level. In this step, 1000 µl of the Glucose oxidase (GOD) reagent was given into a suitably test tube (Ria Vial). Then 10 µl of serum sample was added into the tube and incubated for 10 minutes at 37°C.

Principle: Glucose oxidase (GOD) converts the sample glucose to gluconate and hydrogen peroxide (H202). Hydrogen peroxide, in the form of Peroxidase (POD), oxidizes the chromogen 4-amino antipyrine / phenolic molecule to a red compound. The intensity of the red molecule is proportional to its glucose concentration and measured at 505 nm.

$$Glucose + O_2 + H_2O \xrightarrow{GOD} Gluconic\ Acid + H_2\ O_2$$

$$2H_2O_2 + 4 - amino\ antipyrine + Phenol \xrightarrow{POD} Red + 4H_2O\ \ Quinone$$

Normal Reference Range: Random – 79 to 160 mg/dL, Fasting- 70 to 110 mg/dL and PP - < 140 mg/dL

Calculation: $\boldsymbol{Glucose\ (mg/dL) = \frac{Absorbance\ of\ sample}{Absorbance\ of\ slandard}\ X\ concentration\ of\ standard}$ (Figure 21a)

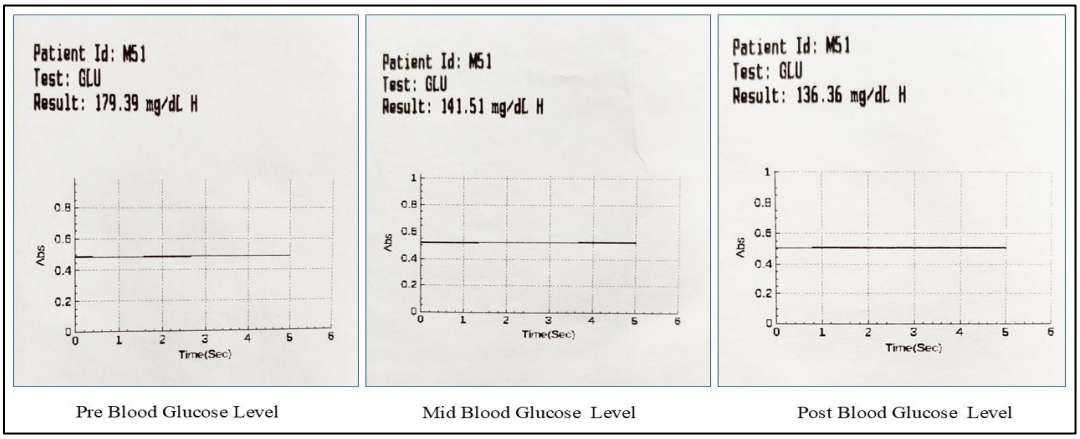


Figure 21a: Printed copy of Blood Glucose Sample through Semi Auto Biochemistry Analyzer

3.9.3 Estimation of Glycosylated Haemoglobin:

Instruments: Semi Auto Biochemistry Analyzer (AGD 2020 Clinical Chemistry Analyzer)

Method: Turbilatex method [3, 196]

Procedure: Glycosylated haemoglobin was assessed from whole blood. The first step was the preparation of hemolysate. In this step, 500 µl of the Hemolysing Reagent (R3) was given into a proper test tube (Ria Vial). Then 10 µl of the mixed blood sample was added into the tube and the tube was then incubated for 5 min at room temperature. The next step was the separation step of glycosylated haemoglobin. In this step, 375 µl of the latex solution (R1) was given into a separate Ria Vial. Then 10 µl of the well-mixed hemolysate sample was added into this Ria Vial and mixed properly then the tube was incubated for 5 minutes at 37°C. Then 125 µl of the antibody reagent (R2) was added into this Ria Vial and mixed properly and incubated for 5 mins at 37°C. The test tube was then mixed properly and run at Semi Auto Biochemistry Analyzer for estimated the result of Glycosylated haemoglobin.

Principle: The Latex-Enhanced Immunoturbidimetry method measures HbA1c levels in the blood by contacting antigen and antibody. The first reaction involves unspecified binding of total haemoglobin and HbA1c to latex particles. The second reaction,

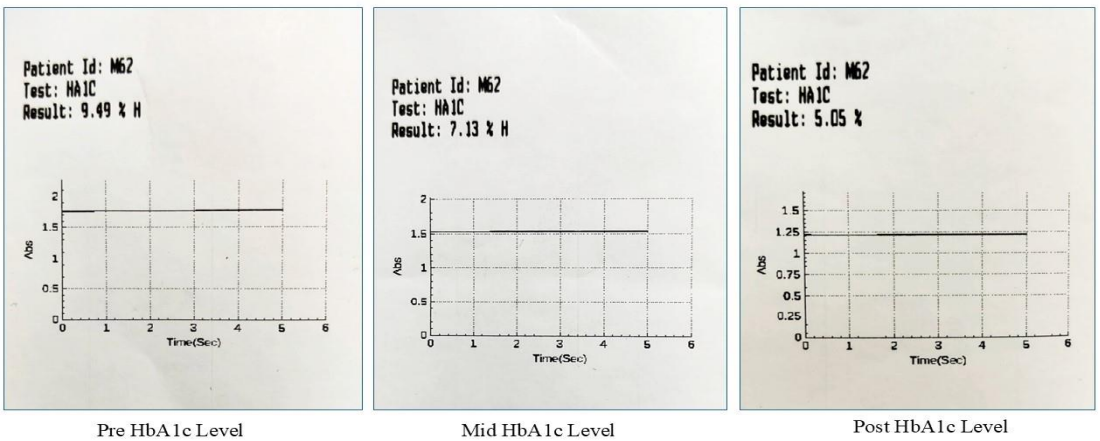


Figure 21b: Printed copy of HbA1c Sample through Semi Auto Biochemistry Analyzer

containing mouse anti-human monoclonal antibody, forms agglutination when goat anti mouse lgG polyclonal antibodies react with monoclonal antibodies. The absorbance is proportional to the amount of HbA1c bound to the latex.

Normal Reference Range: *Recommended value:* <6% for a non-diabetic; <7 % for glycemic control of a person with diabetes. Each lab should set its own estimated values. (Figure 21b)

3.9.4 Estimation of Fasting Insulin:

Instruments: Elisa machine (BeneSphera™ E-21, ELISA microplate reader)

Method: Solid phase sandwich ELISA method

Procedure: The fasting insulin level was measured from blood cells, ensuring reagents were allowed to stand at room temperature before the test. To conduct an ELISA test, place coated strips in a holder, pipette insulin standards, control, and patient sera into wells, mix 100 µl of Insulin Conjugate Reagent, and incubate at ambient temperature for 60 minutes. After removing fluids, wash wells three times, add 100µl of TMB substrate, incubate for 15 minutes, add 50 µl of stop solution, shake the plate, and read absorbance on an ELISA Reader.

Principle: Calbiotech Inc.'s Insulin ELISA uses solid phase sandwich ELISA technology, where samples and conjugate reagents are applied to Streptavidin-coated wells. Insulin binds to matched pairs Abs, creating a sandwich complex. The intensity of color is related to insulin concentration, creating a standard curve by matching it to the samples.

Normal Reference Range: In a study of healthy people, Insulin ELISA revealed levels of less than 25 µlU/ml. It is extremely advised that each laboratory establish its own normal and abnormal values.

Figure 22: Elisa machine: (BeneSphera™ E-21, ELISA microplate reader)

Figure 23: Pipetting blood samples with reagent and Sample run for getting result

3.9.5 Estimation of Insulin Resistance: [121]

Insulin resistance can be estimated using various methods, the present researcher selects one of the formulas to assess the insulin resistance that is Homeostatic Model Assessment (HOMA-IR).

Procedure: Homeostatic Model Assessment insulin resistance (HOMA-IR): A mathematical model that uses insulin levels and fasting glucose to estimate insulin resistance. HOMA-IR = Fasting glucose (mmol/L) x Fasting insulin(μU/mL) / 22.5.

The value in mmol/L was converted by the formula of: mg/dL × 0.0555 = mmol/L [159]

Normal Reference Range: For diabetes patients, the Homeostatic Model Assessment (HOMA) Insulin Resistance (IR) values are interpreted as follows: [31]

- HOMA-IR and insulin resistance in type 2 diabetes]

- Mild insulin resistance: HOMA-IR = 2.0-4.0
- Moderate insulin resistance: HOMA-IR = 4.1-6.0
- Severe insulin resistance: HOMA-IR = 6.1-8.0
- Very severe insulin resistance: HOMA-IR > 8.0

3.9.6 Estimation of Insulin sensitivity: [104]

Insulin sensitivity is the body's ability to effectively use insulin, allowing glucose to enter cells and regulating blood sugar levels.

*Formula: Quantitative Insulin Sensitivity Check Index (QUICKI) = 1 / [log (Fasting Insulin in μU/mL) + log (Fasting Glucose in mg/dL)]

QUICKI Ranges:

- High Insulin Sensitivity: 0.400-0.457
- Normal Insulin Sensitivity: 0.357-0.399
- Low Insulin Sensitivity: 0.321-0.356
- Severe Insulin Resistance: <0.321

3.10 Statistical Analysis

In the present study, G*Power statistical software was used to determine the sample size. To ensure the authenticity and accuracy of the result of parametric tests, a normality test was conducted to examine the normal distribution of the data. Here Shapiro–Wilk normality test was applied to know the normal form of the sample population. [9, 123] The subjects' basic characteristics were summarised using descriptive statistics such as mean and standard deviation. The statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) for Windows version 20.0 computer program. In the present study the Repeated measures analysis of variance (RM ANOVA) was used for significant differences between the assessments, that is, at baseline (pre-test), after three months (mid-test), and after six months (post-test), and this was a within subjects' factor represented by time, followed by Post hoc analysis with Bonferroni adjustment to determine which of the paired means difference was significant at 0.05 level. Percentage changes were calculated to establish the effect or outcomes of treatment on both male and female of every group of the study.

CHAPTER – IV

Results and Discussion

CHAPTER - IV

RESULTS AND DISCUSSION

4. Results and Discussion:

This chapter presents a comprehensive overview of the collected data, statistical analysis results, and subsequent interpretations. The findings are contextualized within the existing body of knowledge and expertise in the field, providing insightful conclusions. The results are systematically organized and discussed in alignment with the study's dimensional framework, ensuring a thorough and structured presentation.

4.1 Study Profile:

The present study was a type of non-randomized interventional study aimed to evaluate the effect of Yog-vyayama on anthropometric, physical, physiological and bio-chemical variables in different HbA1c levels of people with pre-diabetes and type 2 diabetes.

Based on inclusion and exclusion criteria a total of 162 people were recruited for the study. They were divided into three groups based on their baseline HbA1c levels. Based on the availability of the subjects' 51 subjects in the group A (pre-diabetes), 54 subjects in the Group B (T2DM Stage 1), and 57 subjects in the Group C (T2DM Stage 2) were recruited for the study. Further, each of these groups were subdivided into male (n=75) and female (n=87). For the participants all variables were measured at the time of enrolment (Baseline), after 3 months of intervention and after 6 months of intervention. 109 of the 162 people who enrolled stayed until the end of the study and received the specified intervention. The number of dropouts after 3 months and after 6 months intervention of male and female were 06 and 13 for the Group A, 08 and 11 for the Group B and 08 and 07 for the Group C respectively; as shown in the flow diagram (Figure 9).

The participants' baseline demographic and clinical characteristics details of all groups are specified in the table 15:

Table 15: Baseline Characteristics of Study Participants

Characteristics (Mean ± SD)	**Group A** (Pre-Diabetes) **n=32**		**Group B** (T2DM stage 1) **n=35**		**Group C** (T2DM stage 2) **n=42**	
Gander (%)	Male (46.88%)	Female (53.12%)	Male (45.71%)	Female (54.29%)	Male (47.62%)	Female (52.38%)
Age (y)	61.53±6.20	56.82±7.367	64.13±7.22	55.89±7.07	58.00±9.36	53.86±8.89
40 – 50	2	4	2	7	6	8
>50 – 60	4	7	3	6	4	9
>60 – 70	9	6	11	6	10	5
Total	15	17	16	19	20	22
Weight (kg)	69.13±7.32	59.76±8.057	64.13±7.22	65.74±8.20	70.00±11.18	64.57±9.59
Height (cm)	168.00±2.98	150.41±5.112	169.88±4.62	153.11±4.58	166.10±5.31	154.59±5.44
BMI (kg/m2)	24.48±2.47	26.44±3.64	25.46±2.53	28.07±3.53	25.28±3.21	27.03±3.85
Waist circumference (cm)	94.33±7.07	97.00±7.84	97.75±6.70	103.26±9.72	99.60±10.15	102.00±9.28
Hip circumference (cm)	96.67±3.48	101.41±9.33	97.50±3.58	104.84±7.65	97.05±6.04	101.23±8.64
Left Grip Strength (kg)	29.40±6.10	16.55±3.17	25.27±7.10	16.32±3.38	25.09±6.10	16.27±3.99
Right Grip Strength (kg)	31.77±7.59	17.04±4.23	25.91±7.17	18.46±2.85	27.64±7.51	18.58±4.64
Flexibility (cm)	15.60±5.29	25.50±6.65	19.83±6.15	22.00±4.89	19.65±10.97	19.32±4.24
Heart Rate (b/m)	69.33±5.73	85.18±8.37	77.88±6.66	84.74±9.72	82.05±13.16	84.18±10.96
Systolic Blood Pressure (mm/Hg)	136.60±14.36	144.53±21.66	144.13±13.86	143.58±16.54	141.35±18.33	136.45±13.84
Diastolic Blood Pressure (mm/Hg)	76.47±8.32	83.47±9.52	84.81±6.48	79.58±7.32	81.80±8.97	79.82±6.46
SpO_2 (%)	97.93±0.96	97.65±1.17	97.44±0.96	97.16±1.12	97.90±1.07	97.77±1.02
Fasting Plasma Glucose (mg/dL)	120.35±12.54	114.69±8.05	146.52±19.40	140.18±18.69	185.56±45.07	199.10±53.75
HbA1c (%)	6.28±0.30	6.15±0.24	7.40±0.45	7.35±0.41	11.03±2.33	10.55±1.78
Fasting Insulin (μIU/mL)	19.08±5.81	23.49±8.61	29.18±8.71	28.97±6.90	33.93±9.72	34.60±8.19
Insulin Resistance (μU/mL x mmol/L)	5.76±2.18	6.60±2.35	10.50±3.47	10.04±2.97	16.06±7.62	17.29±7.19
Insulin Sensitivity	0.30±0.01	0.29±0.01	0.28±0.01	0.28±0.01	0.27±0.01	0.26±0.01

4.2 Results of Normality Tests:

Normality tests were used before parametric tests to examine the normal distribution of the data by ensuring that the data meets the assumptions of the statistical test. There are various methods accessible to measure the normality of the continuous data. However, the two well-known tests, namely the Kolmogorov-Smirnov test and Shapiro-Wilk test. Shapiro-Wilk test is the most popular normality test, especially for smaller (<50) sample sizes. It revealed a significant deviation from normality ($p < 0.05$), indicating that the data is not normally distributed. Here the present researcher used the Shapiro-Wilk test to assess data of all variables of the entire group where baseline scores of male and female indicate that all variables had no significant difference ($p>0.05$) which assesses whether the data follows a normal distribution that is shown in table 16 - 18.

Table 16: Normality Tests (Shapiro-Wilk) of Baseline Data of Group A

Variables	Male (n=15)			Female (n=17)		
	Statistic	df	Sig.	Statistic	df	Sig.
BMI (kg/m^2)	.899	14	.091	.919	16	.142
Waist circumference (cm)	.912	14	.146	.942	16	.339
Hip circumference (cm)	.942	14	.412	.902	16	.074
Left Grip Strength (kg)	.932	14	.292	.908	16	.092
Right Grip Strength (kg)	.932	14	.294	.917	16	.130
Flexibility (cm)	.899	14	.093	.937	16	.290
Heart Rate (b/m)	.905	14	.112	.963	16	.692
Systolic Blood pressure (mm Hg)	.916	14	.170	.933	16	.247
Diastolic Blood pressure (mmHg)	.897	14	.086	.921	16	.153
SpO_2 (%)	.898	14	.088	.925	16	.181
Fasting Plasma Glucose (mg/dL)	.905	14	.114	.972	16	.857
HbA1c (%)	.956	14	.623	.936	16	.270
Fasting Insulin (μIU/mL)	.921	14	.198	.906	16	.085
Insulin Resistance (μU/mL*mmol/L)	.894	14	.076	.893	16	.052
Insulin Sensitivity	.926	14	.234	.949	16	.446

** Significant p-value < 0.05 indicates non-normality.*

Table 17: Normality Tests (Shapiro-Wilk) of Baseline Data of Group B						
Variables	Male (n=16)			Female (n=19)		
	Statistic	df	Sig.	Statistic	df	Sig.
BMI (kg/m^2)	.892	15	.060	.909	18	.070
Waist circumference (cm)	.947	15	.439	.903	18	.055
Hip circumference (cm)	.945	15	.418	.927	18	.151
Left Grip Strength (kg)	.908	15	.109	.924	18	.132
Right Grip Strength (kg)	.913	15	.129	.942	18	.337
Flexibility (cm)	.902	15	.088	.923	18	.126
Heart Rate (b/m)	.928	15	.227	.948	18	.368
Systolic Blood pressure (mm Hg)	.927	15	.217	.914	18	.089
Diastolic Blood pressure (mmHg)	.928	15	.230	.958	18	.527
SpO_2 (%)	.892	15	.061	.910	18	.074
Fasting Plasma Glucose (mg/dL)	.917	15	.153	.918	18	.103
HbA1c (%)	.914	15	.134	.952	18	.426
Fasting Insulin (µIU/mL)	.949	15	.475	.973	18	.835
Insulin Resistance (µU/mL*mmol/L)	.905	15	.096	.913	18	.083
Insulin Sensitivity	.946	15	.436	.945	18	.329
** Significant p-value < 0.05 indicates non-normality.*						

Table 18: Normality Tests (Shapiro-Wilk test) for Baseline Data of Group C						
Variables	Male (n=20)			Female (n=22)		
	Statistic	df	Sig.	Statistic	df	Sig.
BMI (kg/m^2)	.912	19	.070	.986	21	.980
Waist circumference (cm)	.938	19	.216	.959	21	.475
Hip circumference (cm)	.910	19	.063	.921	21	.079
Left Grip Strength (kg)	.971	19	.777	.942	21	.220
Right Grip Strength (kg)	.977	19	.884	.978	21	.886
Flexibility (cm)	.923	19	.113	.946	21	.261
Heart Rate (b/m)	.954	19	.433	.913	21	.055
Systolic Blood pressure (mmHg)	.931	19	.158	.952	21	.342
Diastolic Blood pressure (mmHg)	.950	19	.362	.955	21	.404
SpO_2 (%)	.926	19	.128	.920	21	.076
Fasting Plasma Glucose (mg/dL)	.964	19	.620	.922	21	.082
HbA1c (%)	.911	19	.065	.939	21	.192
Fasting Insulin (µIU/mL)	.975	19	.856	.944	21	.239
Insulin Resistance (µU/mL*mmol/L)	.924	19	.120	.933	21	.143
Insulin Sensitivity	.979	19	.917	.982	21	.946
** Significant p-value < 0.05 indicates non-normality.*						

4.3 Results of Anthropometric and Physical Variables:

In this study Repeated Measures ANOVA were performed for three time points (baseline, after three months and six months of Yog-vyayama intervention) and groups (Pre-diabetes, T2DM stage 1 and T2DM stage 2) of BMI, Waist circumference, Hip circumference; Grip Strength (left & right) and Flexibility.

Table 19: Repeated Measure ANOVA with mean and SD of Anthropometric and physical variables of each group

Variables	Groups	Male							Female						
		Pre (Mean± SD)	(Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig	η_p^2	Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig	η_p^2
BMI (kg/m2)	**Pre-Diabetes** [n=15(m), 17(f)]	24.48± 2.47	23.73± 2.35	23.11± 2.37	2, 28	56.680*	.000	.802	26.44± 3.64	25.71± 3.72	24.74± 3.53	2, 28	39.813*	.000	.713
	T2DM stage 1 [n=16(m), 19(f)]	25.46± 2.53	24.85± 2.69	24.33± 2.93	2, 30	47.675*	.000	.761	28.07± 3.53	27.48± 3.55	26.77± 3.51	2, 30	152.422*	.000	.894
	T2DM stage 2 [n=20(m), 22(f)]	25.28± 3.21	24.84± 2.98	24.72± 2.83	2, 38	2.862	.070	.131	27.03± 3.85	26.51± 3.82	25.59± 3.80	2, 38	42.500*	.000	.669
Waist circumference (cm)	**Pre-Diabetes** [n=15(m), 17(f)]	94.33± 7.07	91.47± 5.50	88.87± 5.85	2, 32	51.462*	.000	.786	97.00± 7.84	93.53± 7.09	89.12± 6.59	2, 32	27.986*	.000	.636
	T2DM stage 1 [n=16(m), 19(f)]	97.75± 6.70	95.00± 6.48	91.69± 5.97	2, 36	46.826*	.000	.757	103.26± 9.72	99.58± 9.17	96.32± 9.35	2, 36	117.638*	.000	.867
	T2DM stage 2 [n=20(m), 22(f)]	99.60± 10.15	96.15± 9.33	90.70± 11.12	2, 42	37.764*	.000	.665	102.00± 9.28	98.36± 9.38	95.27± 9.07	2, 42	69.038*	.000	.767
Hip circumference (cm)	**Pre-Diabetes** [n=15(m), 17(f)]	96.67± 3.48	92.93± 4.43	90.67± 4.56	2, 28	49.455*	.000	.779	101.41± 9.33	98.53± 9.11	95.29± 7.48	2, 28	48.592*	.000	.752
	T2DM stage 1 [n=16(m), 19(f)]	97.50± 3.58	95.25± 3.15	92.13± 2.80	2, 30	66.199*	.000	.815	104.84± 7.65	102.37± 7.31	98.47± 7.39	2, 30	72.201*	.000	.800
	T2DM stage 2 [n=20(m), 22(f)]	97.05± 6.04	96.10± 6.45	92.20± 5.67	2, 38	60.903*	.000	.762	101.23± 8.64	98.68± 7.95	96.23± 7.87	2, 38	67.973*	.000	.764
Left Grip Strength (kg)	**Pre-Diabetes** [n=15(m), 17(f)]	29.40± 6.10	30.86± 5.60	37.29± 5.71	2, 32	51.179*	.000	.785	16.55± 3.17	20.36± 2.44	24.66± 5.74	2, 32	17.671*	.000	.525
	T2DM stage 1 [n=16(m), 19(f)]	25.27± 7.10	29.32± 6.41	34.43± 7.15	2, 36	18.748*	.000	.556	16.32± 3.38	19.97± 3.31	23.15± 4.10	2, 36	35.970*	.000	.666
	T2DM stage 2 [n=20(m), 22(f)]	25.09± 6.10	29.06± 7.11	32.49± 5.49	2, 42	36.492*	.000	.658	16.27± 3.99	20.64± 4.75	24.04± 3.82	2, 42	111.302*	.000	.841
Right Grip Strength (kg)	**Pre-Diabetes** [n=15(m), 17(f)]	31.77± 7.59	34.52± 8.54	38.85± 6.87	2, 28	20.078*	.000	.589	17.04± 4.23	20.25± 2.97	23.41± 5.36	2, 28	16.586*	.000	.509
	T2DM stage 1 [n=16(m), 19(f)]	25.91± 7.17	30.56± 6.43	34.58± 8.37	2, 30	36.176*	.000	.707	18.46± 2.85	20.34± 3.00	22.51± 3.10	2, 30	31.960*	.000	.640
	T2DM stage 2 [n=20(m), 22(f)]	27.64± 7.51	30.76± 6.15	34.88± 5.94	2, 38	60.063*	.000	.760	18.58± 4.64	21.98± 5.03	23.76± 4.42	2, 38	89.086*	.000	.809
Flexibility (cm)	**Pre-Diabetes** [n=15(m), 17(f)]	15.60± 5.29	21.30± 7.65	26.17± 7.65	2, 32	60.239*	.000	.811	25.50± 6.65	32.62± 5.87	34.12± 5.03	2, 32	27.119*	.000	.629
	T2DM stage 1 [n=16(m), 19(f)]	19.83± 6.15	24.50± 6.82	29.09± 5.77	2, 36	86.181*	.000	.852	22.00± 4.89	31.92± 6.81	33.84± 6.86	2, 36	80.331*	.000	.817
	T2DM stage 2 [n=20(m), 22(f)]	19.65± 10.97	24.10± 10.60	24.48± 8.88	2, 42	15.502*	.000	.449	19.32± 4.24	28.05± 7.19	30.55± 6.99	2, 42	127.274*	.000	.858

* p-value ≤ 0.05 indicates the significant changes
Note: η_p^2 = partial eta square (effect size)

From Table 19 it was found that statistical differences of **BMI** in three time points of each group of male and female. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 56.680, p = .000, η_p^2 = .802 for pre-diabetes; F (with df 2, 30) = 47.675, p = .000, η_p^2 = .761 for T2DM stage 1 and F (with df 2, 38) = 2.862, p = .000, η_p^2 = .131 for T2DM stage 2. This result suggests that there were significant changes in BMI of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 39.813, p = .000, ηp^2 = .713 for pre-diabetes; F (with df 2, 36) = 152.422, p = .000, ηp^2 = .894 for T2DM stage 1 and F (with df 2, 42) = 42.500, p = .000, η_p^2 = .669 for T2DM stage 2. It may be interpreted that there were significant changes in BMI of all groups across the three measurement periods.

Statistical differences of **waist circumference (cm)** in three time points of each group of male and female are shown in Table 19. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 51.462, p = .000, η_p^2 = .786 for pre-diabetes; F (with df 2, 30) = 46.826, p = .000, η_p^2 = .757 for T2DM stage 1 and F (with df 2, 38) = 37.764, p = .000, η_p^2 = .665 for T2DM stage 2. This result suggests that there were significant changes in waist circumference of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 27.986, p = .000, ηp^2 = .636 for pre-diabetes; F (with df 2, 36) = 117.638, p = .000, ηp^2 = .867 for T2DM stage 1 and F (with df 2, 42) = 69.038, p = .000, η_p^2 = .767 for T2DM stage 2. It may be interpreted that there were significant changes in waist circumference of all groups across the three measurement periods.

Statistical differences of **hip circumference (cm)** in three time points of each group of male and female are shown in Table 19. The results of male subjects indicated a

significant effect on measurement time, F (with df 2, 28) = 49.455, p = .000, η_p^2 = .779 for pre-diabetes; F (with df 2, 30) = 66.199, p = .000, η_p^2 = .815 for T2DM stage 1 and F (with df 2, 38) = 60.903, p = .000, η_p^2 = .762 for T2DM stage 2. This result suggests that there were significant changes in hip circumference of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 48.592, p = .000, ηp^2 = .752 for pre-diabetes; F (with df 2, 36) = 72.201, p = .000, ηp^2 = .800 for T2DM stage 1 and F (with df 2, 42) = 67.973, p = .000, η_p^2 = .764 for T2DM stage 2. It may be interpreted that there were significant changes in hip circumference of all groups across the three measurement periods.

Statistical differences of **left grip strength (kg)** in three time points of each group of male and female are shown in Table 19. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 51.179, p = .000, η_p^2 = .785 for pre-diabetes; F (with df 2, 30) = 18.748, p = .000, η_p^2 = .556 for T2DM stage 1 and F (with df 2, 38) = 36.492, p = .000, η_p^2 = .658 for T2DM stage 2. This result suggests that there were significant changes in left grip strength of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 17.671, p = .000, ηp^2 = .525 for pre-diabetes; F (with df 2, 36) = 35.970, p = .000, ηp^2 = .666 for T2DM stage 1 and F (with df 2, 42) = 111.302, p = .000, η_p^2 = .841 for T2DM stage 2. It may be interpreted that there were significant changes in left grip strength of all groups across the three measurement periods.

Statistical differences of **right grip strength (kg)** in three time points of each group of male and female are shown in Table 19. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 20.078, p = .000, η_p^2 = .589 for pre-diabetes; F (with df 2, 30) = 36.176, p = .000, η_p^2 = .707 for T2DM stage 1 and F (with df 2, 38) = 60.063, p = .000, η_p^2 = .760 for T2DM stage 2. This result suggests that there

were significant changes in right grip strength of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 16.586, p = .000, ηp^2 = .509 for pre-diabetes; F (with df 2, 36) = 31.960, p = .000, ηp^2 = .640 for T2DM stage 1 and F (with df 2, 42) = 89.086, p = .000, η_p^2 = .809 for T2DM stage 2. It may be interpreted that there were significant changes in right grip strength of all groups across the three measurement periods.

Statistical differences of **flexibility (cm)** in three time points of each group of male and female are shown in Table 19. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 60.239, p = .000, η_p^2 = .811 for pre-diabetes; F (with df 2, 30) = 86.181, p = .000, η_p^2 = .852 for T2DM stage 1 and F (with df 2, 38) = 15.502, p = .000, η_p^2 = .449 for T2DM stage 2. This result suggests that there were significant changes in flexibility of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 27.119, p = .000, ηp^2 = .629 for pre-diabetes; F (with df 2, 36) = 80.331, p = .000, ηp^2 = .817 for T2DM stage 1 and F (with df 2, 42) = 127.916, p = .000, η_p^2 = .858 for T2DM stage 2. It may be interpreted that there were significant changes in flexibility of all groups across the three measurement periods.

4.3.1 Body Mass Index (BMI):

Table 20: Repeated Measure ANOVA of BMI of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects' factor (Time: pretest, midtest, and posttest)	26.476	2	21.775	42.438*	.000	.469
	Between subjects' factors (Groups: A, B, C)	41.744	2	20.872	.944	.396	.038
	Interaction Time ∗ group	3.208	4	1.319	2.571*	.043	.097
	Error (within subjects' factor)	29.946	96	.513			
	Error (between subjects' factor)	1061.342	48	22.111			
Female	Within subjects' factors (Time- pretest, midtest, and posttest)	63.490	2	41.141	149.028*	.000	.730
	Between subjects' factors (Groups: A, B, C)	90.032	2	45.016	1.124	.332	.039
	Interaction Time ∗ group	.890	4	.288	1.045	.378	.037
	Error (within subjects' factor)	23.432	110	.276			
	Error (between subjects' factor)	2203.455	55	40.063			

* p-value ≤ 0.05 indicates the significant changes

Statistical differences of BMI in time points, groups, interaction between time points and groups, and errors of male and female are shown in Table 20. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 42.438, p = .000, η_p^2 = .469. This obtained value suggests that there were significant changes in BMI across the three measurement periods. Additionally, the effect on groups indicated that the waist circumference did not differ between the three groups. The interaction between time and group was significant, F (with df 4, 96) = 2.571, p = .043, η_p^2 = .097. This interaction suggests that the changes in BMI across time differed between the three groups of male participants.

Consequently, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 149.028, p = .000, η_p^2 = .730. This obtained value

suggests that there were significant changes in BMI around the three measurement periods. There was a significant effect of groups, F (with df 2, 55) = 1.124, p = .332, η_p^2 = .039, indicating that the BMI significantly did not differ between the three groups. The interaction between time and group was not changed, F (with df 4, 110) = 1.045, p = .378, η_p^2 = .037. This interaction suggests that the changes in BMI across time did not differ between the three groups.

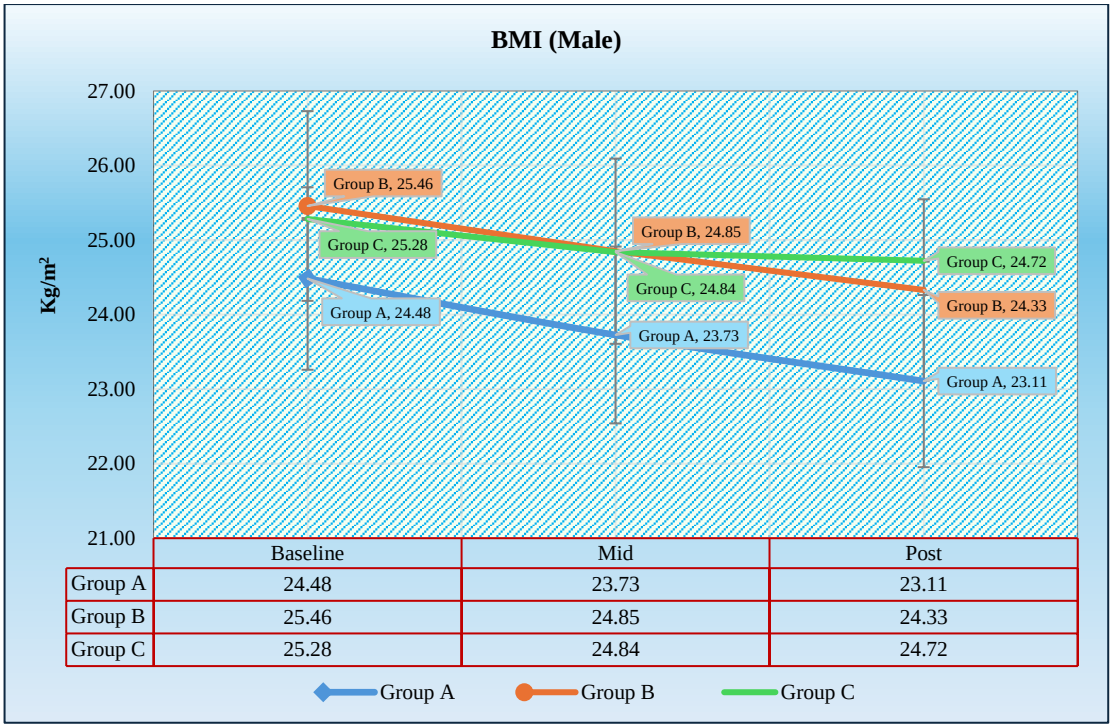
Table 21: Multiple comparisons (Bonferroni Post Hoc) of BMI in three time point of all groups

BMI	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	.603*	.083	.000	.397	.808
		Post	1.021*	.150	.000	.650	1.392
	Mid	Post	.418*	.090	.000	.196	.640
Female	Pre	Mid	.613*	.079	.000	.417	.809
		Post	1.481*	.107	.000	1.217	1.744
	Mid	Post	.868*	.068	.000	.699	1.036

*. The mean difference is statistically significant at the.05 level.

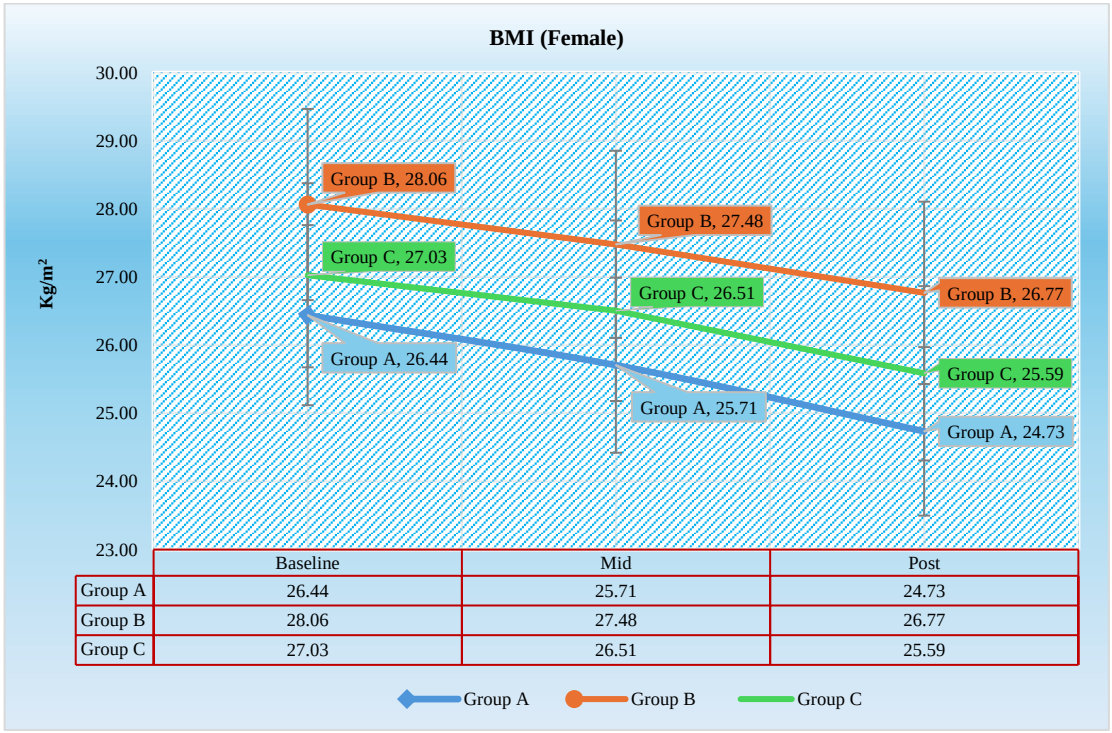
b. Bonferroni method was used for multiple comparisons

From table 21, the Bonferroni post hoc test indicates that there was a significant difference of BMI in three time points (pre, mid and post) (p=.000) in both male and female.



	Baseline	Mid	Post
Group A	24.48	23.73	23.11
Group B	25.46	24.85	24.33
Group C	25.28	24.84	24.72

Figure 24: The Results of changes of BMI in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	26.44	25.71	24.73
Group B	28.06	27.48	26.77
Group C	27.03	26.51	25.59

Figure 25: The Results of changes of BMI in three time points (Pre, Mid & Post) of all female participants groups

4.3.2 Waist circumference:

Table 22: Repeated Measure ANOVA of waist circumference of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, mid-test, and post-test)	1169.603	2	820.282	100.124*	.000	.676
	Between subjects factors (Groups: A, B, C)	430.475	2	215.238	1.169	.319	.046
	Interaction Time * group	68.502	4	24.021	2.932*	.042	.109
	Error (within subjects factor)	560.714	96	8.193			
	Error (between subjects factor)	8840.074	48	184.168			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	1480.802	2	908.886	155.021*	.000	.738
	Between subjects factors (Groups: A, B, C)	1285.960	2	642.980	2.916	.063	.096
	Interaction Time * group	11.027	4	3.384	.577	.645	.021
	Error (within subjects factor)	525.376	110	5.863			
	Error (between subjects factor)	12128.500	55	220.518			

* p-value ≤ 0.05 indicates the significant changes

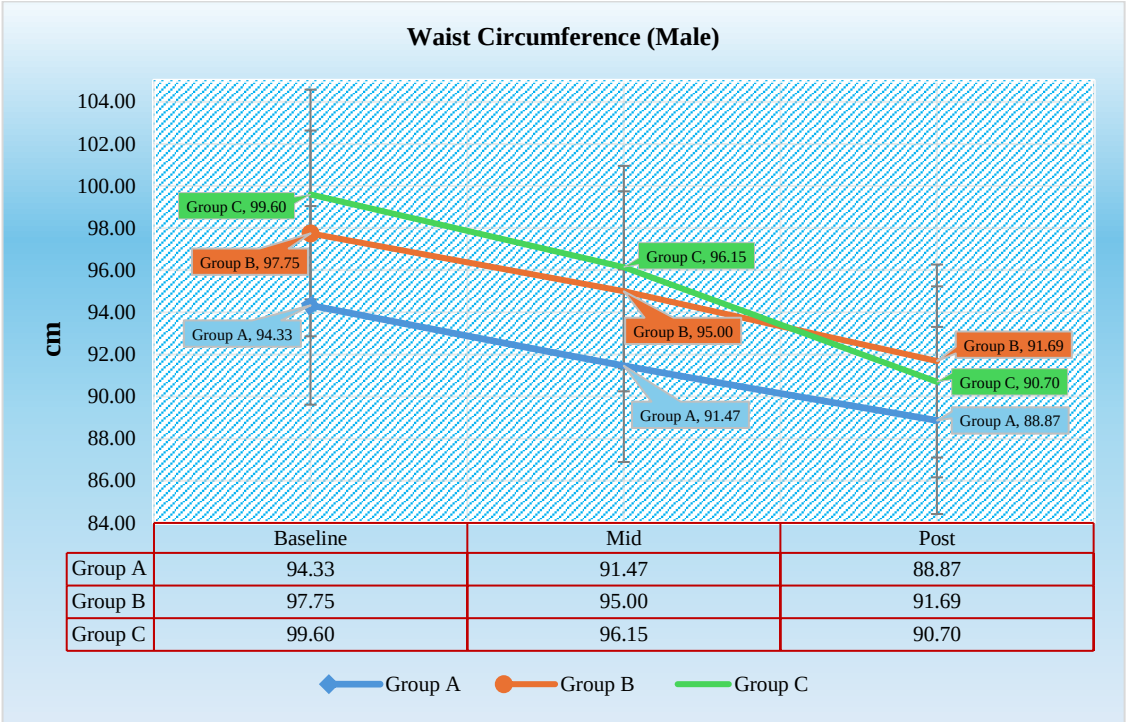
Statistical differences of waist circumference in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 22. After that Bonferroni post hoc test indicated that there was a significant difference of waist circumference in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 23.

Table 23: Multiple comparisons (Bonferroni Post Hoc) of Waist Circumference level in three time point of all groups

Waist Circumference	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference [b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	3.022*	.396	.000	2.040	4.004
		Post	6.810*	.617	.000	5.280	8.339
	Mid	Post	3.787*	.401	.000	2.792	4.783
Female	Pre	Mid	3.597*	.338	.000	2.761	4.433
		Post	7.186*	.508	.000	5.932	8.439
	Mid	Post	3.589*	.357	.000	2.708	4.470

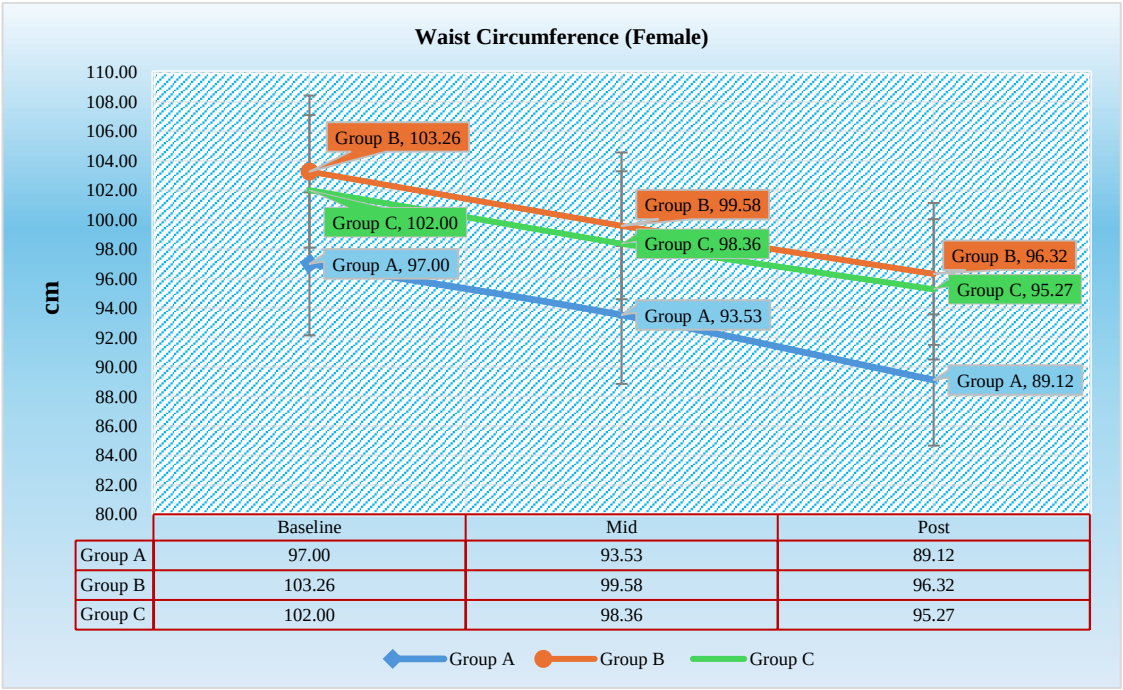
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	94.33	91.47	88.87
Group B	97.75	95.00	91.69
Group C	99.60	96.15	90.70

Figure 26: The Results of changes of waist circumference in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	97.00	93.53	89.12
Group B	103.26	99.58	96.32
Group C	102.00	98.36	95.27

Figure 27: The Results of changes of waist circumference in three time points (Pre, Mid & Post) of all female participants groups

4.3.3 Hip circumference:

Table 24: Repeated Measure ANOVA of Hip Circumference of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	739.827	2	437.054	166.548*	.000	.776
	Between subjects factors (Groups: A, B, C)	84.452	2	42.226	.659	.522	.027
	Interaction Time * group	33.601	4	9.925	3.782*	.011	.136
	Error (within subjects factor)	213.222	96	2.624			
	Error (between subjects factor)	3075.078	48	64.064			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	977.336	2	534.230	186.981*	.000	.773
	Between subjects factors (Groups: A, B, C)	423.415	2	211.708	1.106	.338	.039
	Interaction Time * group	14.967	4	4.091	1.432	.232	.049
	Error (within subjects factor)	287.482	110	2.857			
	Error (between subjects factor)	10526.585	55	191.392			

* p-value ≤ 0.05 indicates the significant changes

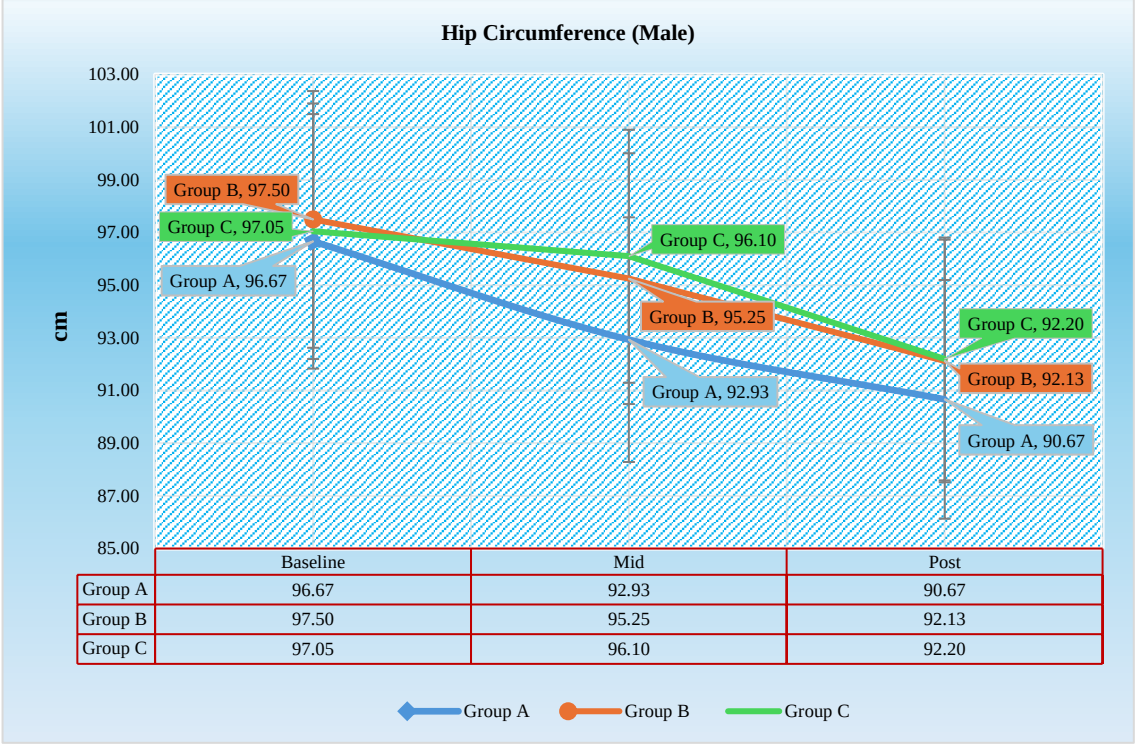
Statistical differences of hip circumference in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 24. After that Bonferroni post hoc test indicated that there was a significant difference of hip circumference in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 25.

Table 25: Multiple comparisons (Bonferroni Post Hoc) of Hip Circumference in three time point of all groups

HC	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	2.311*	.325	.000	1.505	3.118
		Post	5.408*	.330	.000	4.590	6.227
	Mid	Post	3.097*	.225	.000	2.538	3.656
Female	Pre	Mid	2.634*	.275	.000	1.956	3.312
		Post	5.829*	.358	.000	4.945	6.713
	Mid	Post	3.195*	.264	.000	2.542	3.847

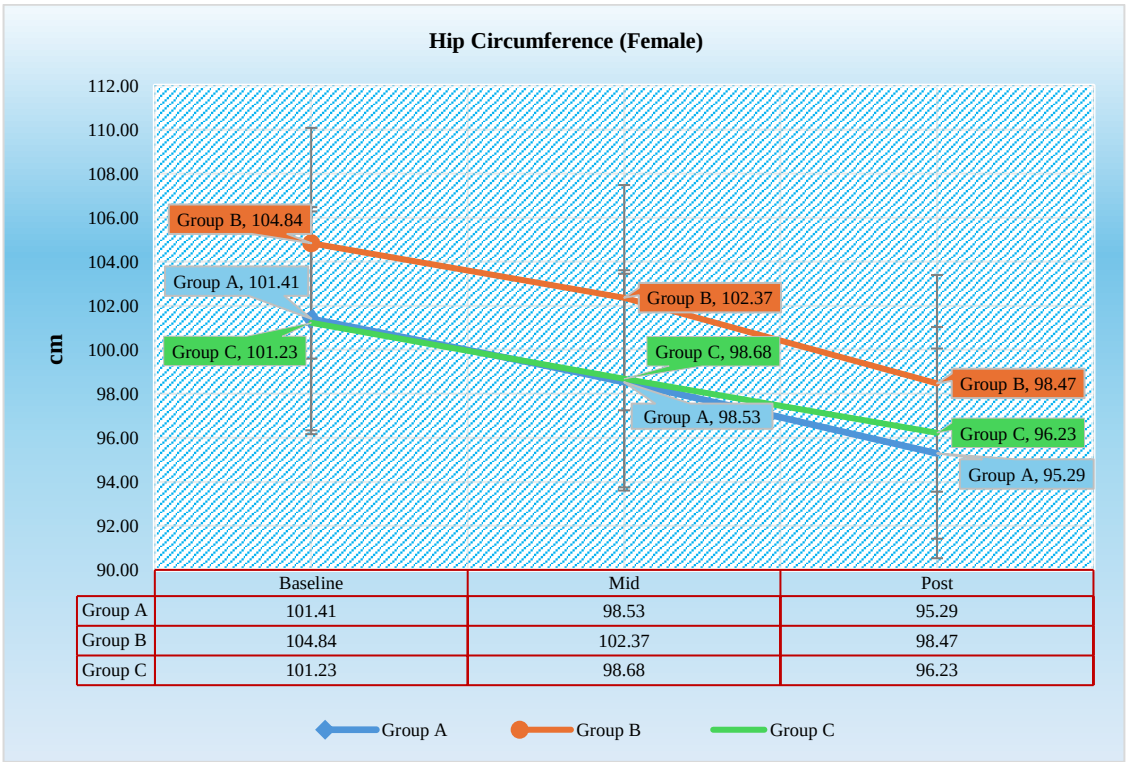
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	96.67	92.93	90.67
Group B	97.50	95.25	92.13
Group C	97.05	96.10	92.20

Figure 28: The results of changes of hip circumference in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	101.41	98.53	95.29
Group B	104.84	102.37	98.47
Group C	101.23	98.68	96.23

Figure 29: The Results of changes of hip circumference in three time points (Pre, Mid & Post) of all female participants groups

4.3.4 Left Grip Strength:

Table 26: Repeated Measure ANOVA of Left Grip Strength of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	1695.916	2	1016.652	83.967*	.000	.636
	Between subjects factors (Groups: A, B, C)	359.528	2	179.764	1.787	.178	.069
	Interaction Time ∗ group	58.554	4	17.551	1.450	.232	.057
	Error (within subjects factor)	969.480	96	12.108			
	Error (between subjects factor)	4827.393	48	100.571			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	1646.115	2	1179.517	105.763*	.000	.658
	Between subjects factors (Groups: A, B, C)	14.700	2	7.350	.231	.794	.008
	Interaction Time ∗ group	11.656	4	4.176	.374	.757	.013
	Error (within subjects factor)	856.031	110	11.152			
	Error (between subjects factor)	1748.306	55	31.787			

* p-value ≤ 0.05 indicates the significant changes

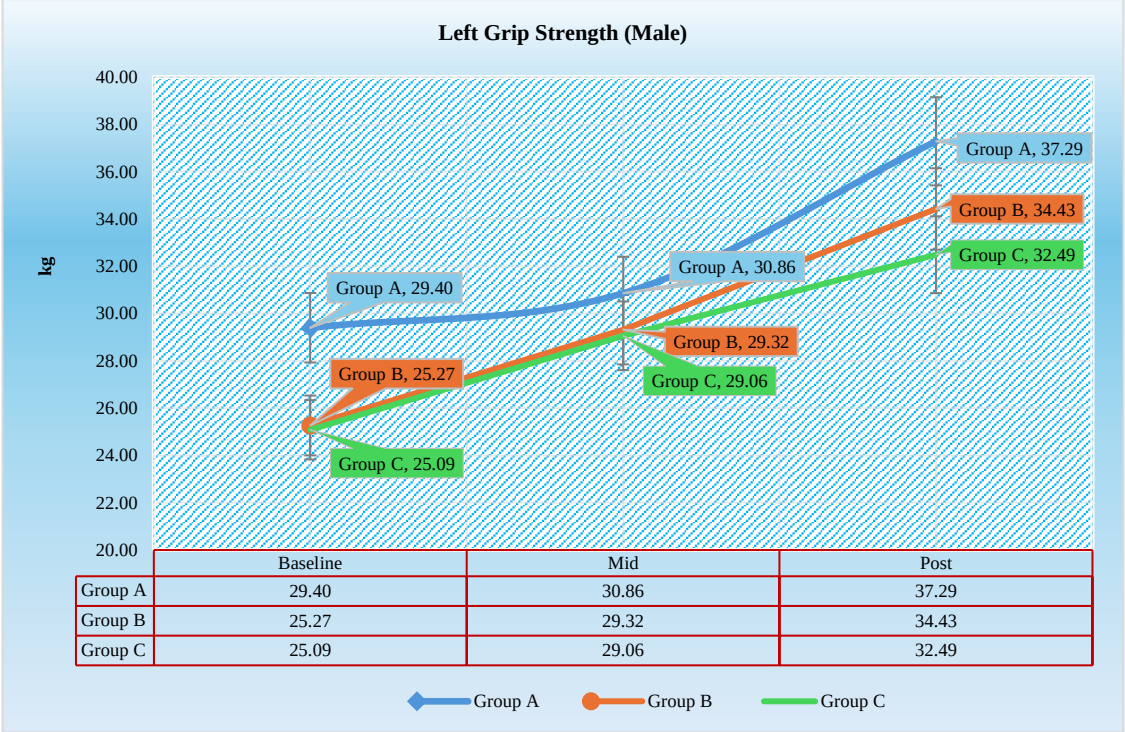
Statistical differences of Left Grip Strength in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 26. After that Bonferroni post hoc test indicated that there was a significant difference of Left Grip Strength in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 27.

Table 27: Multiple comparisons (Bonferroni Post Hoc) of Left Grip Strength in three time point of all groups

Left Grip Strength	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig. [b]	95% Confidence Interval for Difference [b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	-3.162*	.558	.000	-4.546	-1.777
		Post	-8.149*	.763	.000	-10.041	-6.258
	Mid	Post	-4.988*	.560	.000	-6.377	-3.599
Female	Pre	Mid	-3.944*	.381	.000	-4.885	-3.003
		Post	-7.574*	.666	.000	-9.219	-5.929
	Mid	Post	-3.630*	.474	.000	-4.801	-2.459

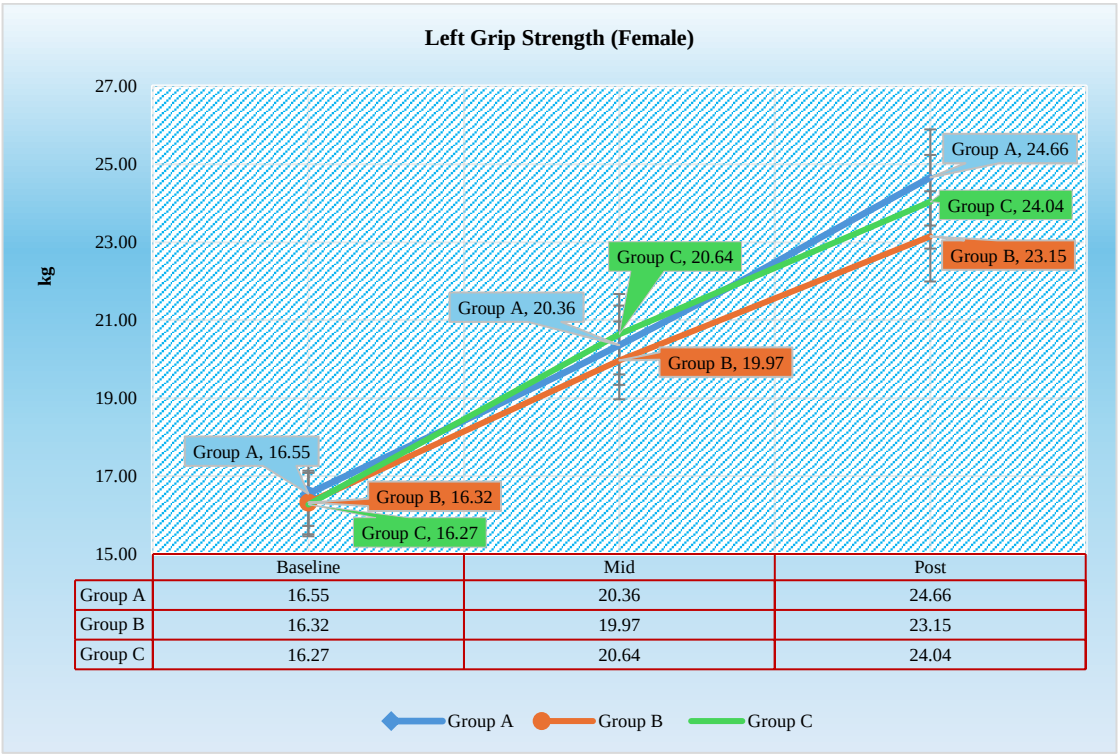
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	29.40	30.86	37.29
Group B	25.27	29.32	34.43
Group C	25.09	29.06	32.49

Figure 30: The Results of changes of left grip strength in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	16.55	20.36	24.66
Group B	16.32	19.97	23.15
Group C	16.27	20.64	24.04

Figure 31: The Results of changes of left grip strength in three time points (Pre, Mid & Post) of all female participants groups

4.3.5 Right Grip Strength:

Table 28: Repeated Measure ANOVA of Right Grip Strength of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	1477.568	2	738.784	103.877*	.000	.684
	Between subjects factors (Groups: A, B, C)	598.226	2	299.113	2.141	.129	.082
	Interaction Time * group	19.337	4	4.834	.680	.608	.028
	Error (within subjects factor)	682.761	96	7.112			
	Error (between subjects factor)	6705.303	48	139.694			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	777.541	2	458.602	86.834*	.000	.612
	Between subjects factors (Groups: A, B, C)	50.836	2	25.418	.616	.544	.022
	Interaction Time * group	31.353	4	9.246	1.751	.155	.060
	Error (within subjects factor)	492.491	110	5.281			
	Error (between subjects factor)	2268.787	55	41.251			

* p-value ≤ 0.05 indicates the significant changes

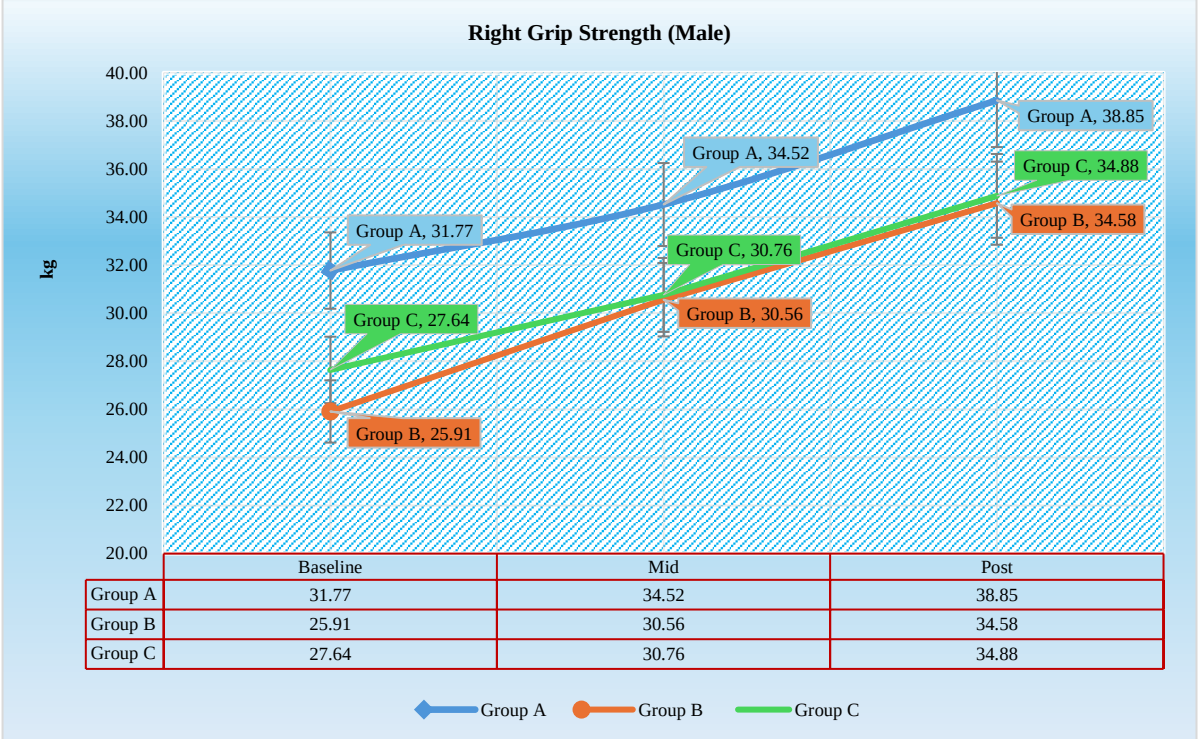
Statistical differences of right grip strength in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 28. After that Bonferroni post hoc test indicated that there was a significant difference of right grip strength in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 29.

Table 29: Multiple comparisons (Bonferroni Post Hoc) of Right Grip Strength in three time point of all groups

Right Grip Strength	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	-3.506*	.498	.000	-4.740	-2.271
		Post	-7.661*	.602	.000	-9.155	-6.167
	Mid	Post	-4.155*	.489	.000	-5.368	-2.942
Female	Pre	Mid	-2.834*	.303	.000	-3.581	-2.086
		Post	-5.200*	.448	.000	-6.307	-4.093
	Mid	Post	-2.366*	.419	.000	-3.402	-1.331

*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	31.77	34.52	38.85
Group B	25.91	30.56	34.58
Group C	27.64	30.76	34.88

Figure 32: The Results of changes of right grip strength in three time points (Pre, Mid & Post) of all male participants groups

	Baseline	Mid	Post
Group A	17.04	20.25	23.41
Group B	18.46	20.34	22.51
Group C	18.58	21.98	23.76

Figure 33: The Results of changes of right grip strength in three time points (Pre, Mid & Post) of all female participants groups

4.3.6 Flexibility:

Table 30: Repeated Measure ANOVA of Flexibility of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	1719.824	2	859.912	123.628*	.000	.720
	Between subjects factors (Groups: A, B, C)	276.864	2	138.432	.735	.485	.030
	Interaction Time * group	190.263	4	47.566	6.838*	.000	.222
	Error (within subjects factor)	667.741	96	6.956			
	Error (between subjects factor)	9043.504	48	188.406			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	3617.818	2	2472.304	194.821*	.000	.780
	Between subjects factors (Groups: A, B, C)	711.544	2	355.772	3.732*	.030	.119
	Interaction Time * group	61.712	4	21.086	1.662	.183	.057
	Error (within subjects factor)	1021.349	110	12.690			
	Error (between subjects factor)	5243.020	55	95.328			

* p-value ≤ 0.05 indicates the significant changes

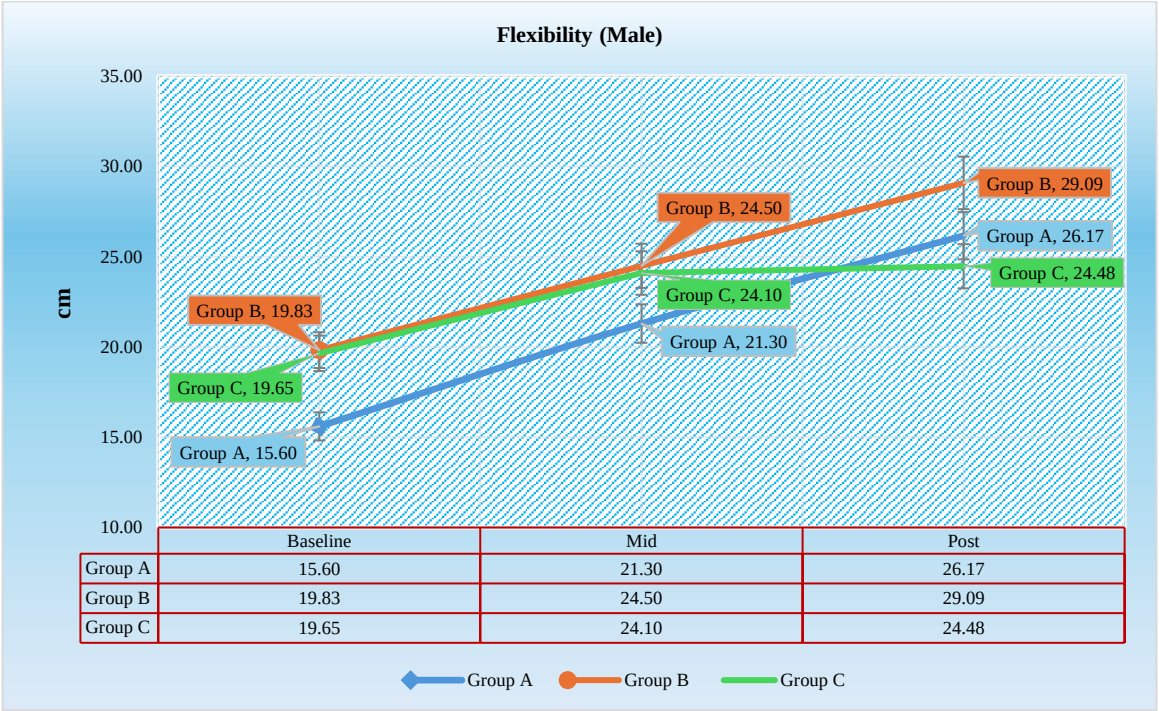
Statistical differences of flexibility in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 30. After that Bonferroni post hoc test indicated that there was a significant difference of flexibility in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 31.

Table 31: Multiple comparisons (Bonferroni Post Hoc) of Flexibility in three time point of all groups

Flexibility	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	-4.941*	.487	.000	-6.148	-3.734
		Post	-8.219*	.581	.000	-9.659	-6.779
	Mid	Post	-3.278*	.507	.000	-4.536	-2.021
Female	Pre	Mid	-8.589*	.583	.000	-10.029	-7.148
		Post	-10.562*	.696	.000	-12.282	-8.843
	Mid	Post	-1.974*	.383	.000	-2.918	-1.029

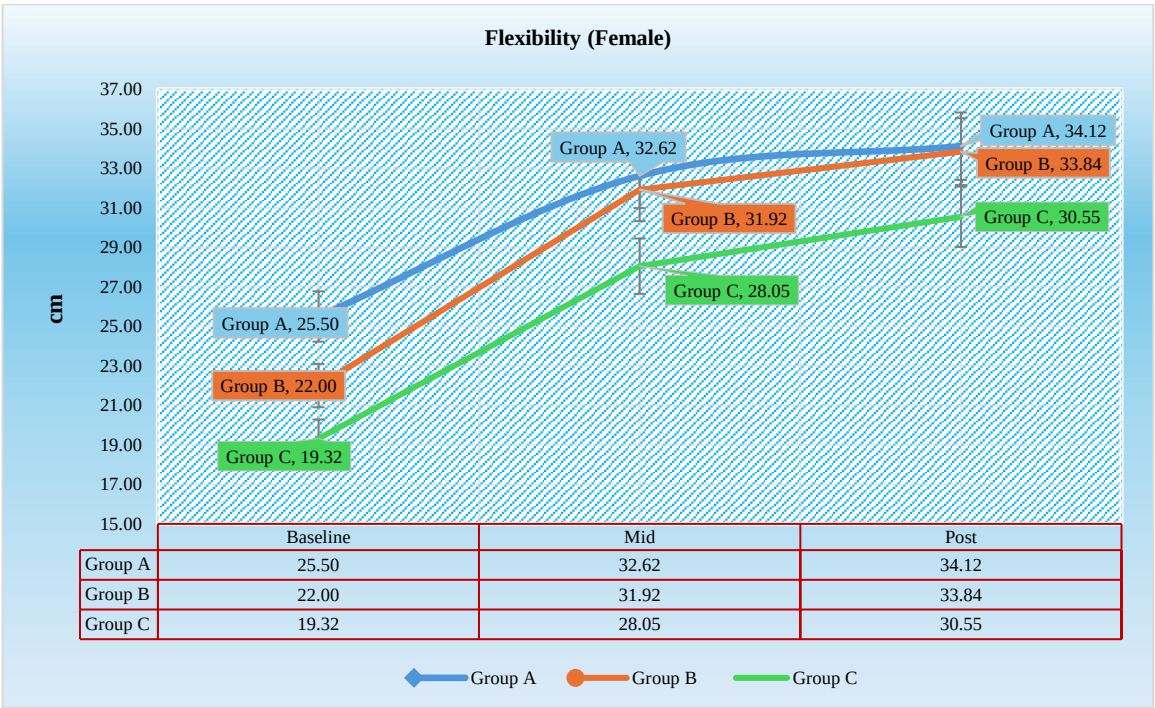
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	15.60	21.30	26.17
Group B	19.83	24.50	29.09
Group C	19.65	24.10	24.48

Figure 34: The Results of changes of Flexibility in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	25.50	32.62	34.12
Group B	22.00	31.92	33.84
Group C	19.32	28.05	30.55

Figure 35**:** The Results of changes of Flexibility in three time points (Pre, Mid & Post) of all female participants groups

Table 32: Percentage interchanges within time points (Pre, Mid & Post) of anthropometric and physical variables

Variables	Groups	Male			Female		
		Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)	Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)
BMI (kg/m2)	Pre-Diabetes [n=15(m), 17(f)]	3.07	2.64	5.62	2.82	3.72	6.45
	T2DM stage 1 [n=16(m), 19(f)]	2.46	2.21	4.60	2.12	2.61	4.67
	T2DM stage 2 [n=20(m), 22(f)]	1.64	0.35	1.91	1.95	3.51	5.38
Waist circumference (cm)	Pre-Diabetes [n=15(m), 17(f)]	2.93	2.86	5.73	3.50	4.61	7.92
	T2DM stage 1 [n=16(m), 19(f)]	2.79	3.45	6.14	3.54	3.30	6.73
	T2DM stage 2 [n=20(m), 22(f)]	3.37	5.83	8.94	3.56	3.13	6.58
Hip circumference (cm)	Pre-Diabetes [n=15(m), 17(f)]	3.87	2.45	6.21	2.83	3.16	5.90
	T2DM stage 1 [n=16(m), 19(f)]	2.28	3.26	5.47	2.34	3.79	6.06
	T2DM stage 2 [n=20(m), 22(f)]	0.98	4.01	4.97	2.46	2.49	4.89
Left Grip Strength (kg)	Pre-Diabetes [n=15(m), 17(f)]	6.31	21.77	29.36	26.59	21.60	56.41
	T2DM stage 1 [n=16(m), 19(f)]	21.89	18.46	46.39	25.03	16.73	47.57
	T2DM stage 2 [n=20(m), 22(f)]	16.45	15.27	33.61	28.48	18.78	51.83
Right Grip Strength (kg)	Pre-Diabetes [n=15(m), 17(f)]	9.28	14.89	25.31	23.60	16.47	42.69
	T2DM stage 1 [n=16(m), 19(f)]	22.84	12.67	37.77	10.55	11.39	23.24
	T2DM stage 2 [n=20(m), 22(f)]	14.78	14.26	31.55	19.93	9.33	31.01
Flexibility (cm)	Pre-Diabetes [n=15(m), 17(f)]	37.70	25.58	72.66	33.46	5.90	42.24
	T2DM stage 1 [n=16(m), 19(f)]	25.75	21.04	53.45	46.34	7.08	57.06
	T2DM stage 2 [n=20(m), 22(f)]	39.36	9.83	56.82	44.84	9.92	59.18

From table 32 it was observed that **BMI (kg/m2)** of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 3.07%, 2.64% & 5.62% for pre-diabetes group (A), 2.46%, 2.21% & 4.60% for T2DM stage 1 group (B) and 1.64%, 0.35% & 1.91% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed less reduction and pre-diabetes group showed more reduction of male participants (Figure 24). BMI of female participants were also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 2.82%, 3.72% & 6.45% for pre-diabetes group, 2.12%, 2.61% & 4.67% for T2DM stage 1 group and 1.95%, 3.51% & 5.38% for T2DM stage 2 group where T2DM stage 1 group showed less reduction and pre-diabetes group showed more reduction of female participants (Figure 25).

Waist circumference (cm) of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 2.93%, 2.86% & 5.73% for pre-diabetes group (A), 2.79%, 3.45% & 6.14% for T2DM stage 1 group (B) and 3.37%, 5.83% & 8.94% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of male participants (Figure 26). Waist circumference of female participants was also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 3.50%, 4.61% & 7.92% for pre-diabetes group, 3.54%, 3.30% & 6.73% for T2DM stage 1 group and 3.56%, 3.13% & 6.58% for T2DM stage 2 group where T2DM stage 2 group showed less reduction and pre-diabetes group showed more reduction of female participants (Figure 27).

Hip circumference (cm) of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 3.87%, 2.45% & 6.21% for pre-diabetes group (A), 2.28%, 3.26% & 5.47% for T2DM stage 1 group (B) and 0.98%, 4.01% & 4.97% for T2DM stage 2 group (C) respectively where T2DM stage 2 group

showed less reduction and pre-diabetes group showed more reduction of male participants. Hip circumference of female participants was also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 2.83%, 3.16% & 5.90% for pre-diabetes group, 2.34%, 3.79% & 6.06% for T2DM stage 1 group and 2.46%, 2.49% & 4.89% for T2DM stage 2 group where T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of female participants.

Left grip strength (kg) of male participants were improved (increases) at the end of first 3 months, last 3 months and 6 months intervention 6.31%, 21.77% & 29.36% for pre-diabetes group (A), 21.89%, 18.46% & 46.39% for T2DM stage 1 group (B) and 16.45%, 15.27% & 33.61% for T2DM stage 2 group (C) respectively where T2DM stage 1 group increased more and pre-diabetes group increased less in male participants. Left grip strength of female participants was also improved (increases) after first 3 months, last 3 months & 6 months intervention, 26.59%, 21.60% & 56.41% for pre-diabetes group, 25.03%, 16.73% & 47.57% for T2DM stage 1 group and 28.48%, 18.78% & 51.83% for T2DM stage 2 group where T2DM stage 1 group increased less and pre-diabetes group increased more in female participants.

Right grip strength (kg) of male participants were improved (increases) at the end of first 3 months, last 3 months and 6 months intervention 9.28%, 14.89% & 25.31% for pre-diabetes group (A), 22.84%, 12.67% & 37.77% for T2DM stage 1 group (B) and 14.78%, 14.26% & 31.55% for T2DM stage 2 group (C) respectively where T2DM stage 1 group showed with maximum increase and pre-diabetes group showed minimum increase in male participants. Right grip strength of female participants was also improved (increases) after first 3 months, last 3 months & 6 months intervention, 23.60%, 16.47% & 42.69% for pre-diabetes group, 10.55%, 11.39% & 23.24% for T2DM stage 1 group and 19.93%, 9.33% & 31.01% for T2DM stage 2 group where T2DM stage 2 group

increased less and pre-diabetes group increased more in case of female participants (Figure 28 & 29).

Flexibility (cm) of male participants were improved (increases) at the end of first 3 months, last 3 months and 6 months intervention 37.70%, 25.58% & 72.66% for pre-diabetes group (A), 25.75%, 21.04% & 53.45% for T2DM stage 1 group (B) and 39.36%, 9.83% & 56.82% for T2DM stage 2 group (C) respectively where T2DM stage 1 group increased fewer and pre-diabetes group increased more in male participants (Figure 30). Right grip strength of female participants was also improved (increases) after first 3 months, last 3 months & 6 months intervention, 33.46%, 5.90% & 42.24% for pre-diabetes group, 46.34%, 7.08% & 57.06% for T2DM stage 1 group and 4484%, 9.92% & 59.18% for T2DM stage 2 group where T2DM stage 2 group increased more and pre-diabetes group increased less in case of female participants (Figure 31).

4.4 Results of Physiological Variables:

Repeated Measures ANOVA were performed for three time points (baseline, after three months and six months of Yog-vyayama intervention) and groups (Pre-diabetes, T2DM stage 1 and T2DM stage 2) of Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure and SpO_2.

Table 33: Repeated Measure ANOVA of Physiological variables of individual group

Variables	Groups	Male							Female						
		Pre (Mean± SD)	(Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig (P value)	η_p^2	Pre (Mean± SD)	(Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig (P value)	η_p^2
Heart Rate (b/m)	Pre-Diabetes [n=15(m), 17(f)]	69.33± 5.73	64.87± 7.59	63.27± 6.30	2, 28	9.639*	.006	.408	85.18± 8.37	79.88± 12.82	75.41± 10.74	2, 28	14.535*	.000	.476
	T2DM stage 1 [n=16(m), 19(f)]	77.88± 6.66	75.13± 4.38	70.94± 8.52	2, 30	13.473*	.000	.473	84.74± 9.72	78.05± 9.17	72.47± 7.70	2, 30	36.864*	.000	.672
	T2DM stage 2 [n=20(m), 22(f)]	82.05± 13.16	81.00± 12.99	75.70± 14.21	2, 38	3.636*	.036	.161	84.18± 10.96	79.41± 10.95	73.77± 7.35	2, 38	18.221*	.000	.465
Systolic Blood Pressure (mm/Hg)	Pre-Diabetes [n=15(m), 17(f)]	136.60± 14.36	124.67± 5.72	125.47± 9.55	2, 32	9.579*	.003	.406	144.53 21.66	132.94± 14.74	128.29± 16.09	2, 32	12.333*	.002	.435
	T2DM stage 1 [n=16(m), 19(f)]	144.13± 13.86	136.38± 11.95	130.13± 11.77	2, 36	7.714*	.002	.340	143.58± 16.54	135.11± 15.91	129.26± 12.24	2, 36	19.015*	.000	.514
	T2DM stage 2 [n=20(m), 22(f)]	141.35± 18.33	128.80± 13.80	130.7± 11.06	2, 42	12.111*	.001	.389	136.45± 13.84	131.91± 16.70	130.6± 12.97	2, 42	2.358	.122	.101
Diastolic Blood Pressure (mm/Hg)	Pre-Diabetes [n=15(m), 17(f)]	76.47± 8.32	71.80± 6.60	74.93± 6.42	2, 28	2.842	.075	.169	83.47± 9.52	78.24± 6.39	77.18± 6.01	2, 28	3.694*	.036	.188
	T2DM stage 1 [n=16(m), 19(f)]	84.81± 6.48	78.88± 6.94	75.88± 5.83	2, 30	12.383*	.000	.452	79.58± 7.32	76.16± 5.20	75.11± 6.69	2, 30	3.879*	.039	.177
	T2DM stage 2 [n=20(m), 22(f)]	81.80± 8.97	77.30± 8.96	74.85± 9.43	2, 38	7.442*	.005	.281	79.82± 6.46	74.50± 7.96	74.05± 7.05	2, 38	9.971*	.000	.322
SpO_2 (%)	Pre-Diabetes [n=15(m), 17(f)]	97.93± 0.96	98.13± 0.74	98.47± 0.64	2, 32	4.261*	.024	.233	97.65± 1.17	97.71± 0.77	98.41± 0.62	2, 32	13.727*	.000	.462
	T2DM stage 1 [n=16(m), 19(f)]	97.44± 0.96	97.56± 0.81	98.13± 0.62	2, 36	8.351*	.001	.358	97.16± 1.12	97.63± 0.68	98.42± 0.61	2, 36	22.235*	.000	.553
	T2DM stage 2 [n=20(m), 22(f)]	97.90± 1.07	97.95± 0.76	98.30± 0.66	2, 42	4.857	.020	.204	97.77± 1.02	97.86± 0.89	98.23± 0.61	2, 42	3.615	.036	.147

Note: η_p^2 = partial eta square (effect size)
* p-value ≤ 0.05 indicates the significant changes

Statistical differences of **heart rate (b/m)** in three time points of each group of male and female are shown in Table 33. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 9.639, p = .006, η_p^2 = .408 for pre-diabetes; F (with df 2, 30) = 13.473, p = .000, η_p^2 = .473 for T2DM stage 1 and F (with df 2, 38) = 3.636, p = .036, η_p^2 = .161 for T2DM stage 2. This result suggests that there were significant changes in heart rate of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 14.353, p = .000, η_p^2 = .476 for pre-diabetes; F (with df 2, 36) = 36.864, p = .000, ηp^2 = .672 for T2DM stage 1 and F (with df 2, 42) = 18.221, p = .000, η_p^2 = .465 for T2DM stage 2. It may be interpreted that there were significant changes in heart rate of all groups across the three measurement periods.

Statistical differences of **systolic blood pressure (mm/Hg)** in three time points of each group of male and female are shown in Table 33. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 9.579, p = .003, η_p^2 = .406 for pre-diabetes; F (with df 2, 30) = 7.714, p = .002, η_p^2 = .340 for T2DM stage 1 and F (with df 2, 38) = 12.111, p = .001, η_p^2 = .389 for T2DM stage 2. This result suggests that there were significant changes in systolic blood pressure of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 12.333, p = .002, ηp^2 = .435 for pre-diabetes; F (with df 2, 36) = 19.015, p = .000, η_p^2 = .514 for T2DM stage 1 and F (with df 2, 42) = 2.358, p = .122, η_p^2 = .101 for T2DM stage 2. It may be interpreted that there were significant changes in systolic blood pressure of all groups across the three measurement periods.

Statistical differences of diastolic **blood pressure (mm/Hg)** in three time points of each group of male and female are shown in Table 33. The results of male subjects

indicated a significant effect on measurement time, F (with df 2, 28) = 2.842, p = .075, η_p^2 = .169 for pre-diabetes; F (with df 2, 30) = 12.383, p = .000, η_p^2 = .452 for T2DM stage 1 and F (with df 2, 38) = 7.442, p = .005, η_p^2 = .281 for T2DM stage 2. This result suggests that there were significant changes in diastolic blood pressure of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 3.694, p = .036, ηp^2 = .188 for pre-diabetes; F (with df 2, 36) = 3.879, p = .039, η_p^2 = .177 for T2DM stage 1 and F (with df 2, 42) = 9.971, p = .000, η_p^2 = .332 for T2DM stage 2. It may be interpreted that there were significant changes in diastolic blood pressure of all groups across the three measurement periods.

Statistical differences of **SpO_2 (%)** in three time points of each group of male and female are shown in Table 33. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 4.261, p = .024, η_p^2 = .233 for pre-diabetes; F (with df 2, 30) = 8.351, p = .001, η_p^2 = .358 for T2DM stage 1 and F (with df 2, 38) = 4.857, p = .020, η_p^2 = .204 for T2DM stage 2. This result suggests that there were significant changes in SpO_2 of all groups across the three measurement periods. The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 13.727, p = .000, η_p^2 = .462 for pre-diabetes; F (with df 2, 36) = 22.235, p = .000, ηp^2 = .553 for T2DM stage 1 and F (with df 2, 42) = 3.615, p = .036, η_p^2 = .147 for T2DM stage 2. It may be interpreted that there were significant changes in SpO_2 of all groups across the three measurement periods.

4.4.1 Heart Rate:

Table 34: Repeated Measure ANOVA of Heart Rate of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
MALE	Within subjects factor (Time: pretest, midtest, and posttest)	1052.752	2	526.376	15.371*	.000	.243
	Between subjects factors (Groups: A, B, C)	4899.834	2	2449.917	10.779*	.000	.310
	Interaction Time * group	75.559	4	18.890	.552	.698	.022
	Error (within subjects factor)	3287.447	96	34.244			
	Error (between subjects factor)	10910.140	48	227.295			
FEMALE	Within subjects factor (Time: pretest, midtest, and posttest)	3353.950	2	1771.608	62.100*	.000	.530
	Between subjects factors (Groups: A, B, C)	81.686	2	40.843	.172	.843	.006
	Interaction Time * group	38.897	4	10.273	.360	.826	.013
	Error (within subjects factor)	2970.506	110	28.528			
	Error (between subjects factor)	13081.670	55	237.849			

* p-value ≤ 0.05 indicates the significant changes

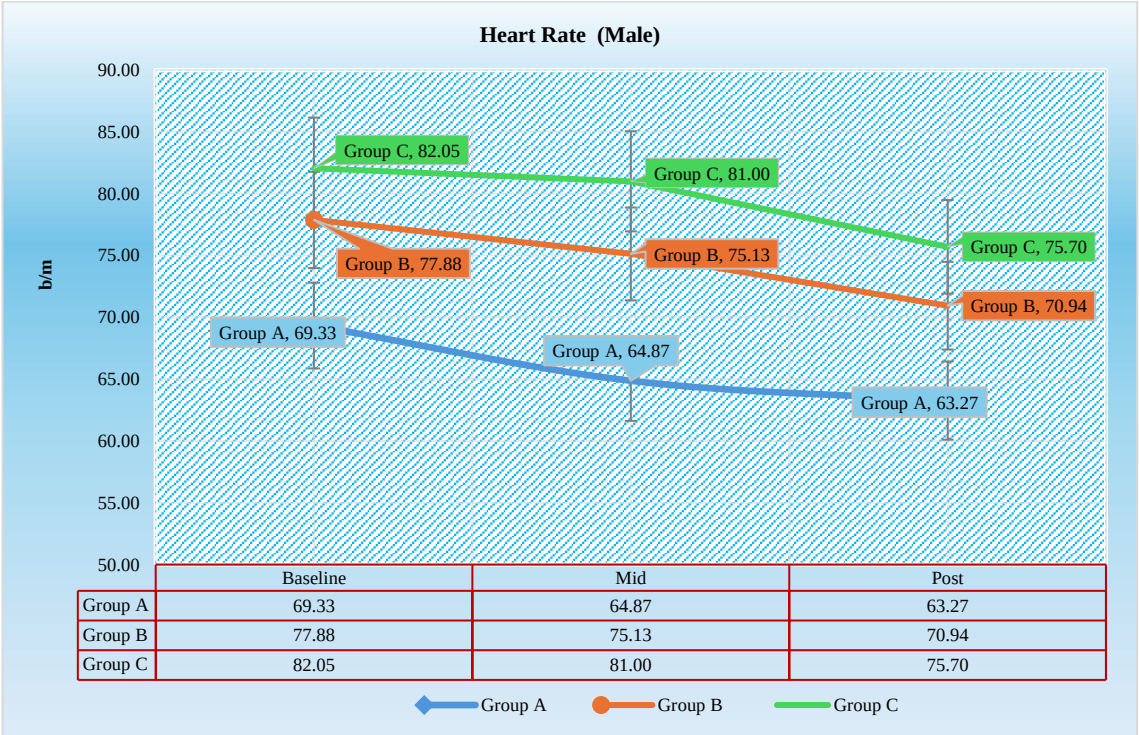
Statistical differences of heart rate in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 34. After that Bonferroni post hoc test indicated that there was a significant difference of heart rate in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 35.

Table 35: Multiple comparisons (Bonferroni Post Hoc) of Heart Rate in three time point of all groups

Heart Rate	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Post	6.451*	1.031	.000	3.894	9.009
	Mid	Post	3.696*	1.301	.020	.467	6.925
Female	Pre	Mid	5.584*	1.102	.000	2.862	8.305
		Post	10.812*	.989	.000	8.371	13.254
	Mid	Post	5.229*	.795	.000	3.264	7.193

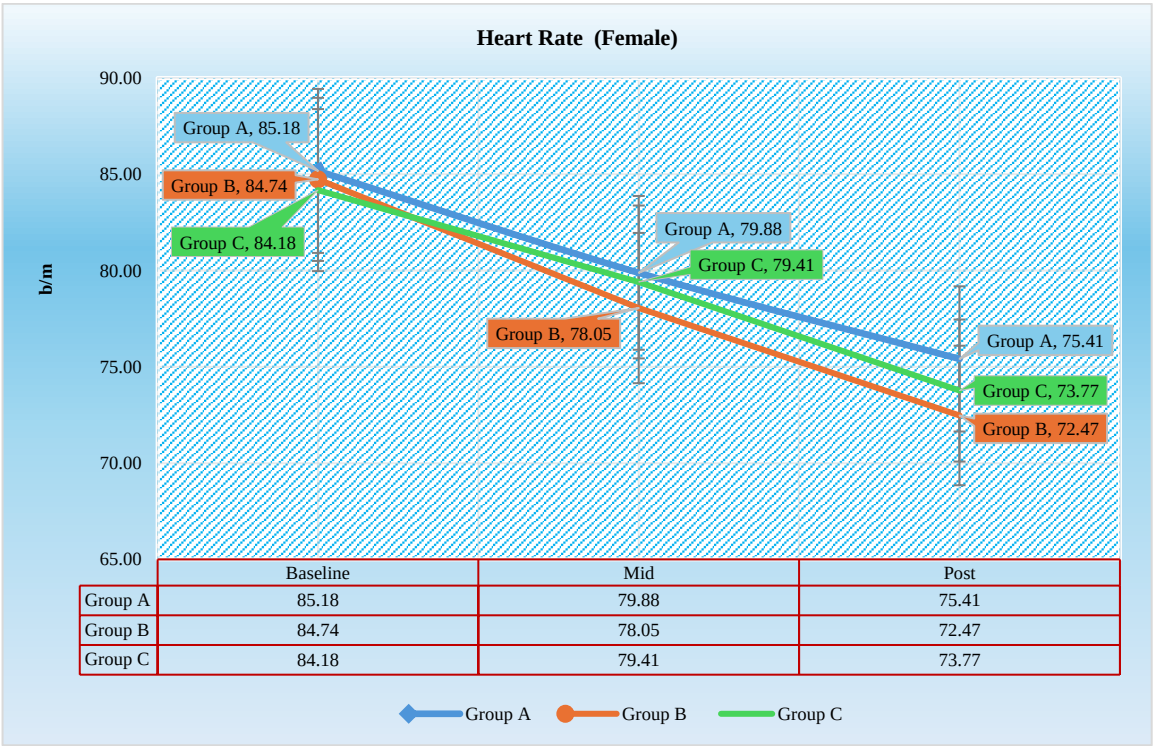
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	69.33	64.87	63.27
Group B	77.88	75.13	70.94
Group C	82.05	81.00	75.70

Figure 36: The Results of changes of Heart Rate in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	85.18	79.88	75.41
Group B	84.74	78.05	72.47
Group C	84.18	79.41	73.77

Figure 37: The Results of changes of Heart Rate in three time points (Pre, Mid & Post) of all female participants groups

4.4.2 Systolic Blood Pressure (SBP)

Table 36: Repeated Measure ANOVA of SBP of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	4331.365	2	2487.299	26.404*	.000	.355
	Between subjects factors (Groups: A, B, C)	1486.715	2	743.357	2.206	.121	.084
	Interaction Time * group	335.202	4	96.245	1.022	.395	.041
	Error (within subjects factor)	7873.922	96	94.200			
	Error (between subjects factor)	16173.494	48	336.948			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	4390.188	2	2527.249	28.034*	.000	.338
	Between subjects factors (Groups: A, B, C)	299.521	2	149.760	.257	.775	.009
	Interaction Time * group	652.528	4	187.817	2.083	.098	.070
	Error (within subjects factor)	8613.173	110	90.150			
	Error (between subjects factor)	32106.002	55	583.745			

* p-value ≤ 0.05 indicates the significant changes

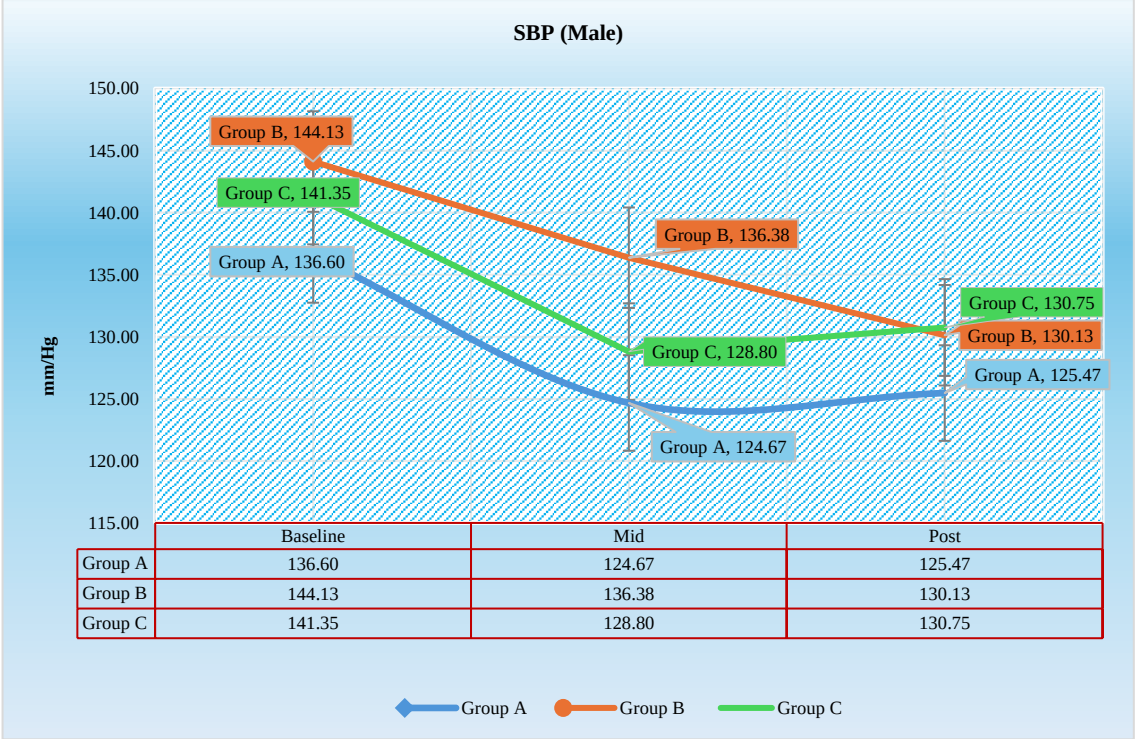
Statistical differences of SBP in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 36. After that Bonferroni post hoc test indicated that there was a significant difference of SBP in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 37.

Table 37: Multiple comparisons (Bonferroni Post Hoc) of SBP in three time point of all groups

SBP	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Post	10.744*	1.906	.000	6.017	15.472
	Mid	Post	11.911*	2.031	.000	6.872	16.950
Female	Pre	Mid	8.202*	1.709	.000	3.983	12.422
		Post	12.123*	1.882	.000	7.477	16.769
	Mid	Post	3.921*	1.315	.013	.672	7.169

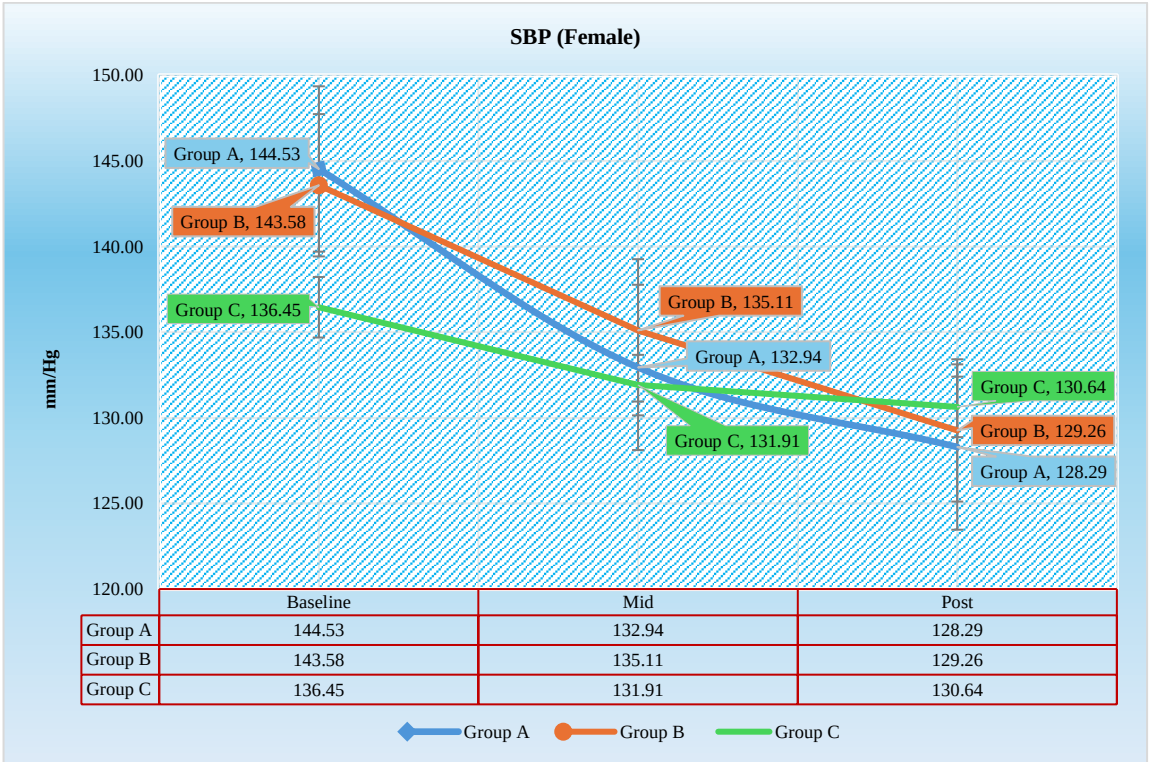
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	136.60	124.67	125.47
Group B	144.13	136.38	130.13
Group C	141.35	128.80	130.75

Figure 38: The Results of changes of SBP in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	144.53	132.94	128.29
Group B	143.58	135.11	129.26
Group C	136.45	131.91	130.64

Figure 39: The Results of changes of SBP in three time points (Pre, Mid & Post) of all female participants groups

4.4.3 Diastolic Blood Pressure (DBP)

Table 38: Repeated Measure ANOVA of DBP of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	999.048	2	499.524	16.495*	.000	.256
	Between subjects factors (Groups: A, B, C)	712.447	2	356.223	2.921	.064	.109
	Interaction Time * group	279.462	4	69.865	2.307	.064	.088
	Error (within subjects factor)	2907.192	96	30.283			
	Error (between subjects factor)	5853.762	48	121.953			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	1010.052	2	505.026	15.466*	.000	.219
	Between subjects factors (Groups: A, B, C)	372.580	2	186.290	2.229	.117	.075
	Interaction Time * group	27.205	4	6.801	.208	.933	.008
	Error (within subjects factor)	3591.979	110	32.654			
	Error (between subjects factor)	4596.461	55	83.572			

* p-value ≤ 0.05 indicates the significant changes

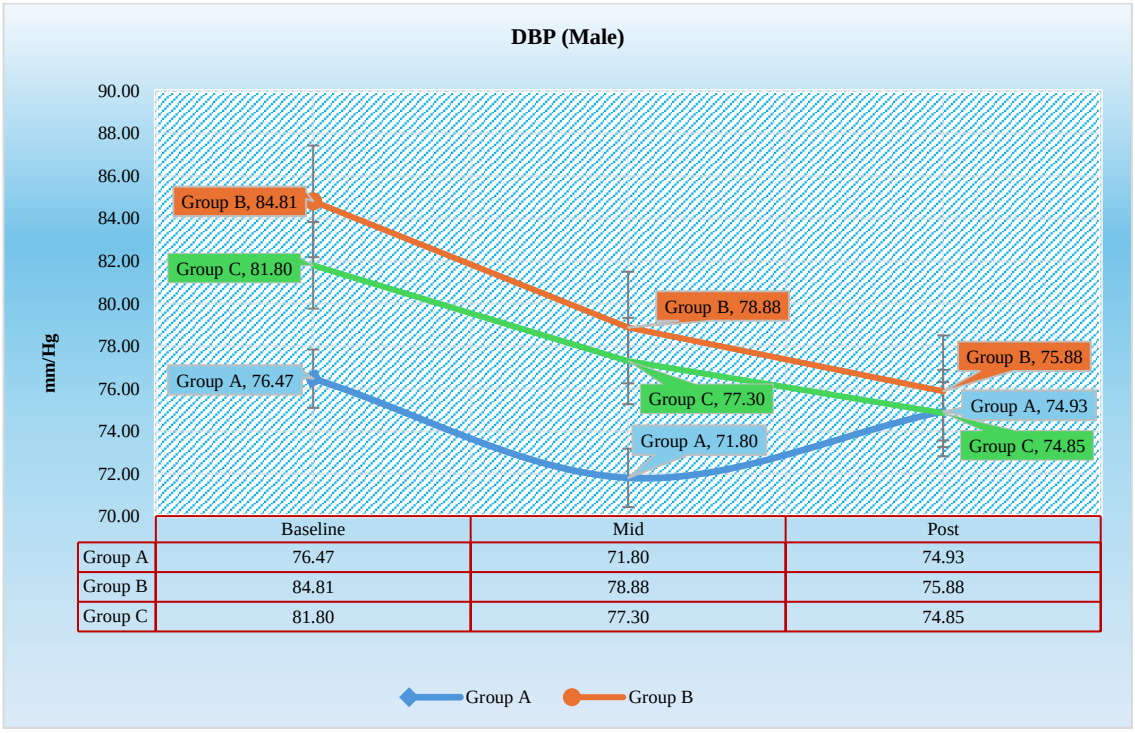
Statistical differences of DBP in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 38. After that Bonferroni post hoc test indicated that there was a significant difference of DBP in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 39.

Table 39: Multiple comparisons (Bonferroni Post Hoc) of DBP in three time point of all groups

DBP	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Post	Pre	5.035*	1.162	.000	2.152	7.917
		Mid	5.807*	1.168	.000	2.908	8.705
Female	Pre	Mid	4.658*	1.107	.000	1.924	7.392
		Post	5.514*	1.142	.000	2.694	8.333

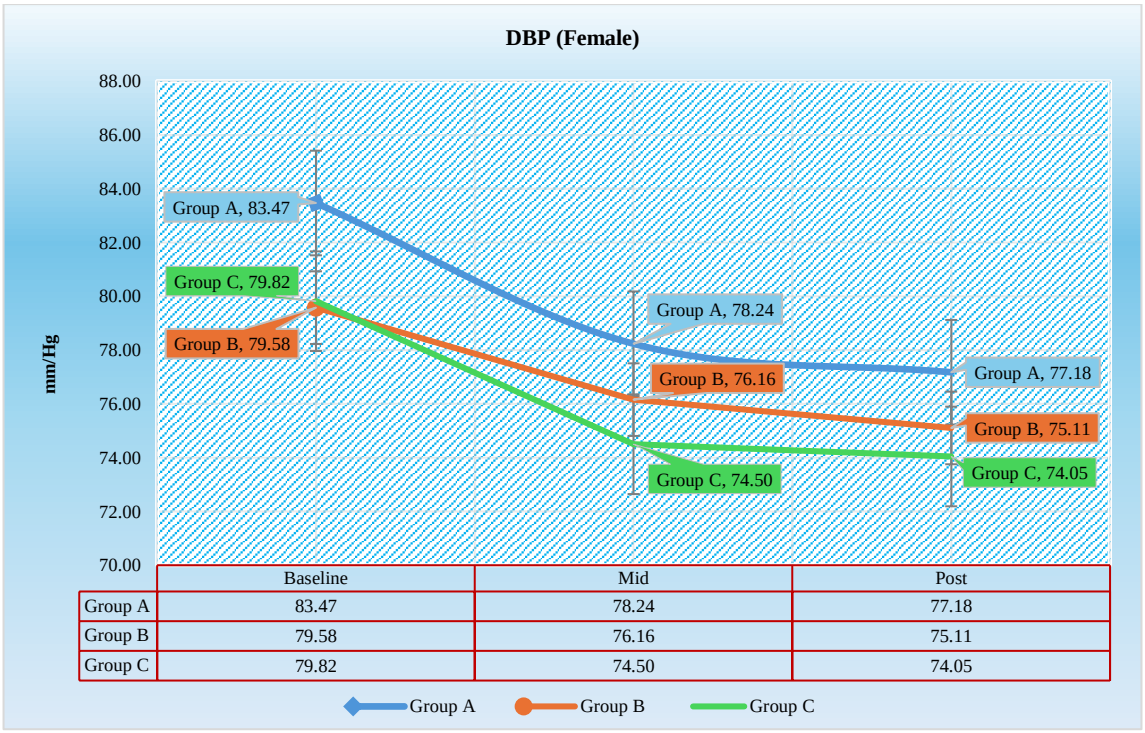
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons



	Baseline	Mid	Post
Group A	76.47	71.80	74.93
Group B	84.81	78.88	75.88
Group C	81.80	77.30	74.85

Figure 40: The Results of changes of DBP in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	83.47	78.24	77.18
Group B	79.58	76.16	75.11
Group C	79.82	74.50	74.05

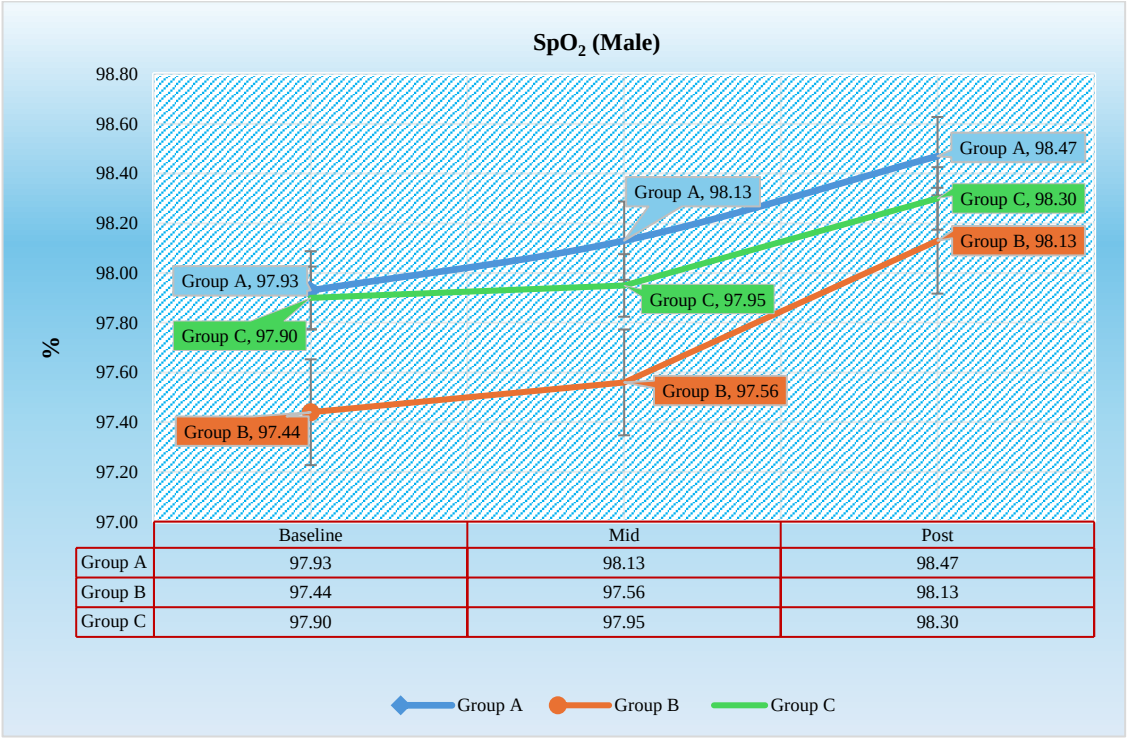
Figure 41: The Results of changes of DBP in three time points (Pre, Mid & Post) of all female participants groups

4.4.4 SpO_2

Table 40: Repeated Measure ANOVA of SpO_2 of all groups							
Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	8.037	2	4.018	17.301*	.000	.265
	Between subjects factors (Groups: A, B, C)	5.597	2	2.798	1.799	.176	.070
	Interaction Time * group	.487	4	.122	.524	.718	.021
	Error (within subjects factor)	22.297	96	.232			
	Error (between subjects factor)	74.678	48	1.556			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	21.258	2	10.629	33.899*	.000	.381
	Between subjects factors (Groups: A, B, C)	1.616	2	.808	.511	.603	.018
	Interaction Time * group	3.613	4	.903	2.881*	.026	.095
	Error (within subjects factor)	34.491	110	.314			
	Error (between subjects factor)	86.936	55	1.581			
* p-value ≤ 0.05 indicates the significant changes							

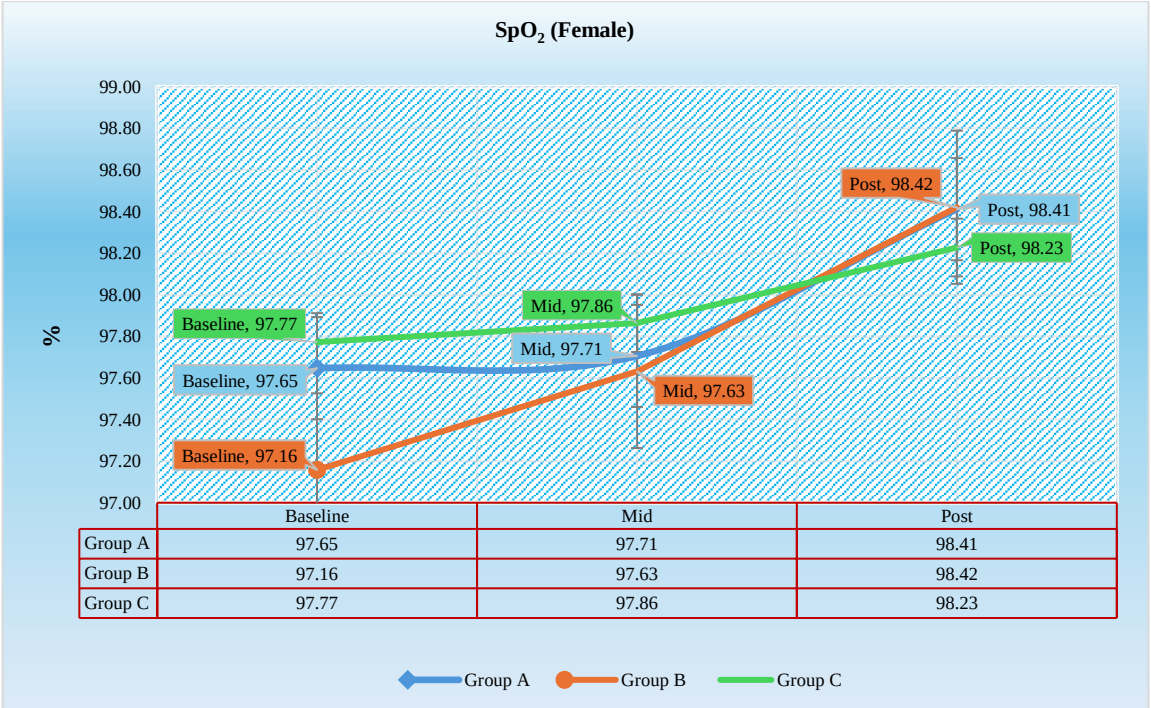
Statistical differences of SpO_2 in time points, groups, interaction between time points and groups, and errors of male and female were shown in table 40. After that Bonferroni post hoc test indicated that there was a significant difference of SpO_2 in three time points (pre, mid and post) (p=.000) in both male and female that is illustrated in table 41.

Table 41: Multiple comparisons (Bonferroni Post Hoc) of SpO_2 in three time point of all groups							
SpO_2	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig. [b]	95% Confidence Interval for Difference [b]	
						Lower Bound	Upper Bound
Male	Pre	Post	-.540*	.100	.000	-.788	-.293
	Mid	Post	-.415*	.095	.000	-.651	-.179
Female	Post	Pre	-.827*	.116	.000	-1.113	-.542
		Mid	-.620*	.090	.000	-.843	-.396
*. The mean difference is statistically significant at the .05 level.							
b. Bonferroni method was used for multiple comparisons							



	Baseline	Mid	Post
Group A	97.93	98.13	98.47
Group B	97.44	97.56	98.13
Group C	97.90	97.95	98.30

Figure 42: The Results of changes of SpO_2 (%) in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	97.65	97.71	98.41
Group B	97.16	97.63	98.42
Group C	97.77	97.86	98.23

Figure 43: The Results of changes of SpO_2 (%) in three time points (Pre, Mid & Post) of all female participants groups

Table 42: percentage interchanges within time points (Pre, Mid & Post) of Physiological variables

Variables	Groups	Male			Female		
		Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)	Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)
Heart Rate (b/m)	Pre-Diabetes [n=15(m), 17(f)]	6.22	2.23	8.55	6.40	5.09	11.42
	T2DM stage 1 [n=16(m), 19(f)]	3.17	5.68	9.05	7.58	6.94	14.11
	T2DM stage 2 [n=20(m), 22(f)]	0.46	5.69	7.46	5.24	6.38	11.71
Systolic Blood Pressure (mm/Hg)	Pre-Diabetes [n=15(m), 17(f)]	7.89	0.62	7.53	7.17	3.51	10.15
	T2DM stage 1 [n=16(m), 19(f)]	4.89	4.09	9.15	5.84	3.78	9.49
	T2DM stage 2 [n=20(m), 22(f)]	8.27	1.82	6.61	2.90	0.40	3.91
Diastolic Blood Pressure (mm/Hg)	Pre-Diabetes [n=15(m), 17(f)]	5.47	4.93	1.42	5.25	0.76	6.54
	T2DM stage 1 [n=16(m), 19(f)]	6.80	3.34	10.09	3.78	1.26	5.06
	T2DM stage 2 [n=20(m), 22(f)]	4.95	3.08	8.11	6.50	0.08	7.02
SpO_2 (%)	Pre-Diabetes [n=15(m), 17(f)]	0.21	0.34	0.55	0.07	0.72	0.79
	T2DM stage 1 [n=16(m), 19(f)]	0.13	0.58	0.71	0.49	0.81	1.31
	T2DM stage 2 [n=20(m), 22(f)]	0.06	0.36	0.41	0.10	0.38	0.47

From table 42 it was observed that **heart rate (b/m)** of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 6.22%, 2.23% & 8.55% for pre-diabetes group (A), 3.17%, 5.68% & 9.05% for T2DM stage 1 group (B) and 0.46%, 5.69% & 7.46% for T2DM stage 2 group (C) respectively where T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants. Heart rate of female participants was also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 6.40%, 5.09% & 11.42% for pre-diabetes group, 7.58%, 6.94% & 14.11% for T2DM stage 1 group and

5.24%, 6.38% & 11.71% for T2DM stage 2 group where T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction and nearly similar to T2DM stage 2 group of female participants.

Systolic blood pressure (mm/Hg) of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 7.89%, 0.62% & 7.53% for pre-diabetes group (A), 4.89%, 4.09% & 9.15% for T2DM stage 1 group (B) and 8.27%, *1.82*% & 6.61% for T2DM stage 2 group (C) respectively where T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants. Systolic blood pressure of female participants was also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 7.17%, 3.51% & 10.15% for pre-diabetes group, 5.84%, 3.78% & 9.49% for T2DM stage 1 group and 2.90%, 0.40% & 3.91% for T2DM stage 2 group where T2DM stage 2 group showed less reduction and pre-diabetes group showed more reduction of female participants.

Diastolic blood pressure (mm/Hg) of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 5.47%, *4.93*% & 1.42% for pre-diabetes group (A), 6.80%, 3.34% & 10.09% for T2DM stage 1 group (B) and 4.95%, 3.08% & 8.11% for T2DM stage 2 group (C) respectively where T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction of male participants. Diastolic blood pressure of female participants was also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 5.25%, 0.76% & 6.54% for pre-diabetes group, 3.78%, 1.26% & 5.06% for T2DM stage 1 group and 6.50%, 0.08% & 7.02% for T2DM stage 2 group where T2DM stage 2 group showed more reduction and T2DM stage 1 group showed less reduction of female participants.

SpO_2 (%) of male participants were improved (increases) at the end of first 3 months, last 3 months and 6 months intervention 0.21%, 0.34% & 0.55% for pre-diabetes

group (A), 0.13%, 0.58% & 0.71% for T2DM stage 1 group (B) and 0.06%, 0.36% & 0.41% for T2DM stage 2 group (C) respectively where T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction of male participants. SpO_2 of female participants was also improved (increases) after first 3 months, last 3 months & 6 months intervention, 0.07%, 0.72% & 0.79% for pre-diabetes group, 0.49%, 0.81% & 1.31% for T2DM stage 1 group and 0.10%, 0.38% & 0.47% for T2DM stage 2 group where T2DM stage 1 group increased maximum and T2DM stage 2 group increased minimum in female participants.

4.5 Results of Glycemic control:

4.5.1 Fasting Plasma Glucose level:

Fasting Plasma Glucose (FPG) level plays a crucial role in glycaemic control, providing valuable information for diabetes management. In this study Repeated Measures ANOVA were performed for time points (baseline, after three months and six months of Yog-vyayama intervention) and groups (Pre-Diabetes, T2DM stage 1 and T2DM stage 2).

Table 43: Repeated Measure ANOVA of Fasting Plasma Glucose level (mg/dL) of individual group

Groups		Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig. (P–value)	η_p^2
Male	Pre-Diabetes (n=15)	120.35±12.54	112.47±13.71	104.06±10.37	2, 28	69.076	.000	.831
	T2DM stage 1 (n=16)	146.52±19.40	126.31±10.42	118.59±7.99	2, 30	28.446	.000	.655
	T2DM stage 2 (n=20)	185.56±45.07	158.85±39.05	134.3±32.26	2, 38	42.026	.000	.689
Female	Pre-Diabetes (n=17)	114.69±8.05	101.20±13.52	96.08±9.87	2, 32	27.739	.000	.634
	T2DM stage 1 (n=19)	140.18±18.69	123.68±18.14	110.15±15.44	2, 36	73.746	.000	.804
	T2DM stage 2 (n=22)	199.10±53.75	159.83±47.45	131.10±29.84	2, 42	46.693	.000	.690

Note: η_p^2 = partial eta square (effect size)

Statistical differences of Fasting Plasma Glucose level in three time points of each group of male and female are shown in Table 43. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 69.076, p = .000, η_p^2 = .831 for pre-diabetes; F (with df 2, 30) = 28.446, p = .000, η_p^2 = .655 for T2DM stage 1 and F (with df 2, 38) = 42.026, p = .000, η_p^2 = .689 for T2DM stage 2. This result suggests that there were significant changes in FPG level of all groups across the three measurement periods.

The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 27.739, p = .000, η_p^2 = .634 for pre-diabetes; F (with df 2, 36) = 73.746, p = .000, η_p^2 = .804 for T2DM stage 1 and F (with df 2, 42) = 46.693, p = .000, η_p^2 = .690 for T2DM stage 2. It may be interpreted that there were significant changes in FPG level of all groups across the three measurement periods.

Table 44: Repeated Measure ANOVA of Fasting Plasma Glucose level (mg/dL) of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
MALE	Within subjects factor (Time: pretest, midtest, and posttest)	25576.222	2	15839.898	77.912*	.000	.619
	Between subjects factors (Groups: A, B, C)	60123	2	30061.782	16.746*	.000	.411
	Interaction Time ∗ group	5841	4	1809.028	8.898*	.000	.270
	Error (within subjects factor)	15757.004	96	203.305			
	Error (between subjects factor)	86166.029	48	1795.126			
FEMALE	Within subjects factor (Time: pretest, midtest, and posttest)	43869.117	2	21934.558	89.447*	.000	.619
	Between subjects factors (Groups: A, B, C)	107638.825	2	53819.413	24.324*	.000	.469
	Interaction Time ∗ group	13527.965	4	3381.991	13.791*	.000	.334
	Error (within subjects factor)	26974.705	110	245.225			
	Error (between subjects factor)	121692.404	55	2212.589			

* The F value is significant at the .05 level.

Statistical differences of fasting plasma glucose (FPG) level in time points, groups, interaction between time points and groups, and errors of male and female are shown in

Table 44. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 77.912, p = .000, η_p^2 = .619. This tabulated value suggests that there were significant changes in FPG level across the three measurement periods. Additionally, there was a significant effect of Groups, F (with df 2, 48) = .16.746, p = .000, η_p^2 = .411, indicating that the FPG level significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 96) = 8.898, p = .000, η_p^2 = .270. This interaction suggests that the changes in FPG level across time differed between the three groups of male participants.

Therefore, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 89.447, p = .000, η_p^2 = .619. This obtained value suggests that there were significant changes in FPG level around the three measurement periods. There was a significant effect of Groups, F (with df 2, 55) = 24.324, p = .000, η_p^2 = .469, indicating that the FPG level significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 110) = 13.791, p = .000, η_p^2 = .334. This interaction suggests that the changes in FPG level across time differed between the three groups.

Table 45: Multiple comparisons (Bonferroni Post Hoc) of Fasting Plasma Glucose level in three time point of all groups

FPG level	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	18.266*	2.214	.000	12.774	23.758
		Post	31.794*	3.119	.000	24.056	39.531
	Mid	Post	13.527*	2.231	.000	7.993	19.062
Female	Pre	Mid	23.091*	2.800	.000	16.175	30.006
		Post	38.883*	3.150	.000	31.106	46.661
	Mid	Post	15.793*	2.809	.000	8.856	22.729

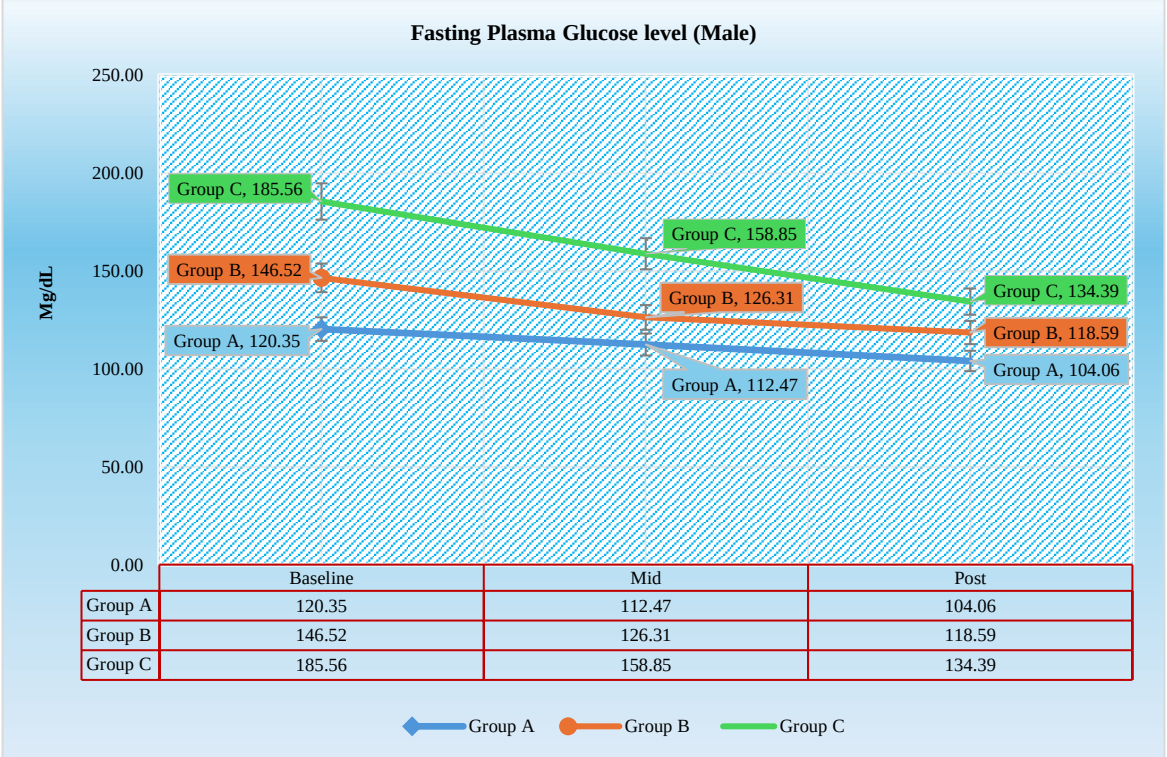
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons

From table 45, the Bonferroni post hoc test indicated that there was a significant difference of FPG level in three time points (pre, mid and post) (p=.000) in both male and female.

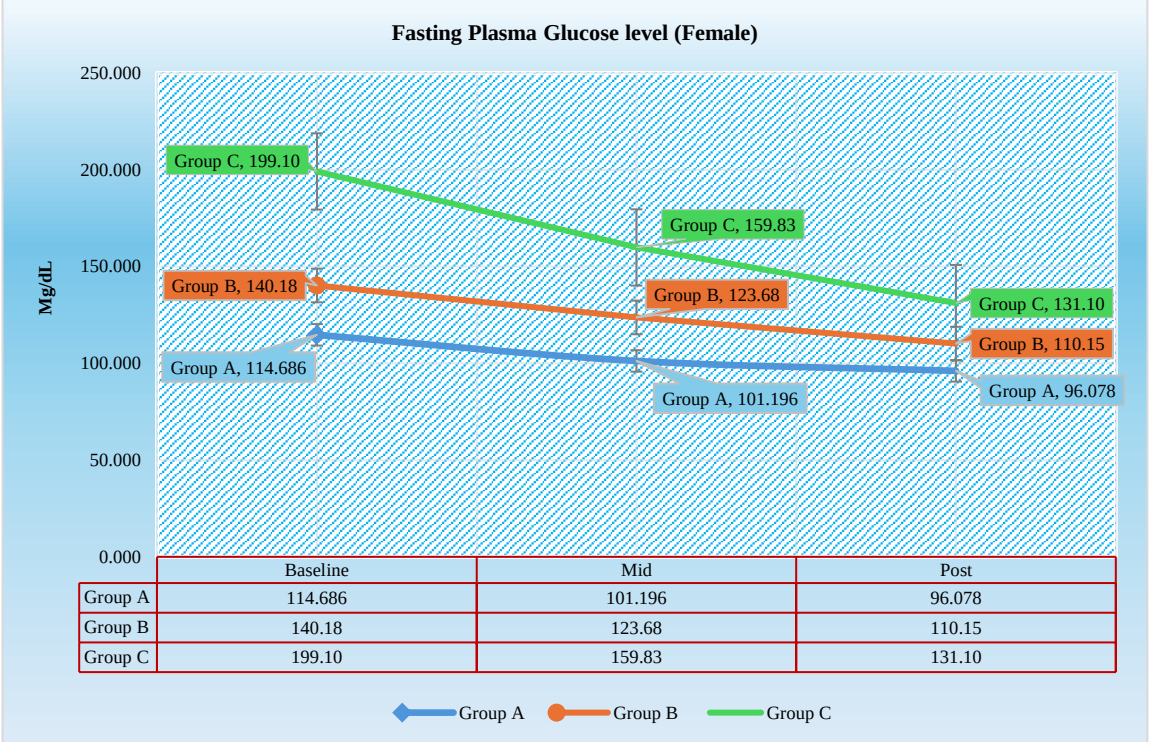
Table 46: Percentage interchanges within time points (Pre, Mid & Post) of Fasting Plasma Glucose levels (mg/dL)				
Groups		Pre to Mid [First three months] (%)	Mid to Post [Last three month] (%)	Pre to Post [Six Months] (%)
Male	Pre-Diabetes (A) (n=15)	6.65	7.18	13.40
	T2DM stage 1 (B) (n=16)	12.87	5.85	18.11
	T2DM stage 2 (C) (n=20)	13.76	14.05	25.86
Female	Pre-Diabetes (A) (n=17)	11.94	3.86	16.06
	T2DM stage 1 (B) (n=19)	11.71	10.62	21.14
	T2DM stage 2 (C) (n=22)	18.97	15.71	32.64

From table 46, it was observed that FPG level of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 6.65%, 7.18% & 13.40% for pre-diabetes group (A), 12.87%, 5.85% & 18.11% for T2DM stage 1 group (B) and 13.76%, 14.05% & 25.86% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of male participants. FPG level of female participants were also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 11.94%, 3.86% & 16.06% for pre-diabetes group, 11.71%, 10.62% & 21.14% for T2DM stage 1 group and 18.97%, 15.71% & 32.64% for T2DM stage 2 group where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of female participants.



	Baseline	Mid	Post
Group A	120.35	112.47	104.06
Group B	146.52	126.31	118.59
Group C	185.56	158.85	134.39

Figure 44: The Results of changes of FPG levels (mg/dL) in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	114.686	101.196	96.078
Group B	140.18	123.68	110.15
Group C	199.10	159.83	131.10

Figure 45: The Results of changes of FPG levels (mg/dL) in three time points (Pre, Mid & Post) among the groups of female participants

4.5.2 HbA1c:

Table 47: Repeated Measure ANOVA of HbA1c (%) of individual group

Groups		Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig. (P–value)	η_p^2
Male	Pre-Diabetes (n=15)	**6.28±0.30**	**5.41±1.54**	**5.38±0.33**	2, 28	5.189	.036	.270
	T2DM stage 1 (n=16)	**7.40±0.45**	**6.81±0.52**	**6.00±0.70**	2, 30	72.109	.000	.828
	T2DM stage 2 (n=20)	**11.03±2.33**	**9.33±2.23**	**7.73±1.72**	2, 38	56.770	.000	.749
Female	Pre-Diabetes (n=17)	**6.15±0.24**	**5.83±0.39**	**5.37±0.41**	2, 32	66.855	.000	.807
	T2DM stage 1 (n=19)	**7.35±0.41**	**6.67±0.47**	**6.25±0.63**	2, 36	45.284	.000	.716
	T2DM stage 2 (n=22)	**10.55±1.78**	**9.37±1.82**	**7.96±1.35**	2, 42	42.004	.000	.667

Note: η_p^2 = partial eta square (effect size)

Statistical differences of HbA1c in three time points of each group of male and female are shown in Table 47. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 5.189, p = .036, η_p^2 = .270 for pre-diabetes; F (with df 2, 30) = 72.109, p = .000, η_p^2 = .828 for T2DM stage 1 and F (with df 2, 38) = 56.770, p = .000, η_p^2 = .749 for T2DM stage 2. This result suggests that there were significant changes in HbA1c of all groups across the three measurement periods.

The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 66.855, p = .000, η_p^2 = .807 for pre-diabetes; F (with df 2, 36) = 45.284, p = .000, η_p^2 = .716 for T2DM stage 1 and F (with df 2, 42) = 42.004, p = .000, η_p^2 = .667 for T2DM stage 2. It may be interpreted that there were significant changes in HbA1c of all groups across the three measurement periods.

Table 48: Repeated Measure ANOVA of HbA1c (%) of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	87.975	2	43.987	69.581	.000	.592
	Between subjects factors (Groups: A, B, C)	383.028	2	191.514	37.750	.000	.611
	Interaction Time ∗ group	30.457	4	7.614	12.044	.000	.334
	Error (within subjects factor)	60.689	96	.632			
	Error (between subjects factor)	243.513	48	5.073			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	63.361	2	41.180	81.485	.000	.597
	Between subjects factors (Groups: A, B, C)	393.993	2	196.997	71.784	.000	.723
	Interaction Time ∗ group	19.346	4	6.287	12.440	.000	.311
	Error (within subjects factor)	42.767	110	.389			
	Error (between subjects factor)	150.987	55	2.744			

* The F value is significant at the .05 level.

Statistical differences of HbA1c in time points, groups, interaction between time points and groups, and errors of male and female are shown in Table 48. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 69.581, p = .000, η_p^2 = .592. This tabulated value suggests that there were significant changes in HbA1c across the three measurement periods. Additionally, there was a significant effect of Groups, F (with df 2, 48) = 37.750, p = .000, η_p^2 = .611, indicating that the HbA1c significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 96) = 12.044, p = .000, η_p^2 = .334. This interaction suggests that the changes in HbA1c across time differed between the three groups of male participants.

Therefore, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 81.485, p = .000, η_p^2 = .579. This obtained value suggests that there were significant changes in HbA1c around the three measurement periods. There was a significant effect of Groups, F (with df 2, 55) = 71.784, p = .000, η_p^2 = .723, indicating that the HbA1c significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 110) = 12.440, p = .000, η_p^2 = .311. This interaction suggests that the changes in HbA1c across time differed between the three groups.

Table 49: Multiple comparisons (Bonferroni Post Hoc) of HbA1c in three time point of all groups

	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	1.052*	.175	.000	.617	1.487
		Post	1.867*	.153	.000	1.487	2.246
	Mid	Post	.815*	.146	.000	.452	1.177
Female	Pre	Mid	.723*	.125	.000	.415	1.030
		Post	1.486*	.137	.000	1.148	1.825
	Mid	Post	-.764*	.080	.000	-.961	-.566

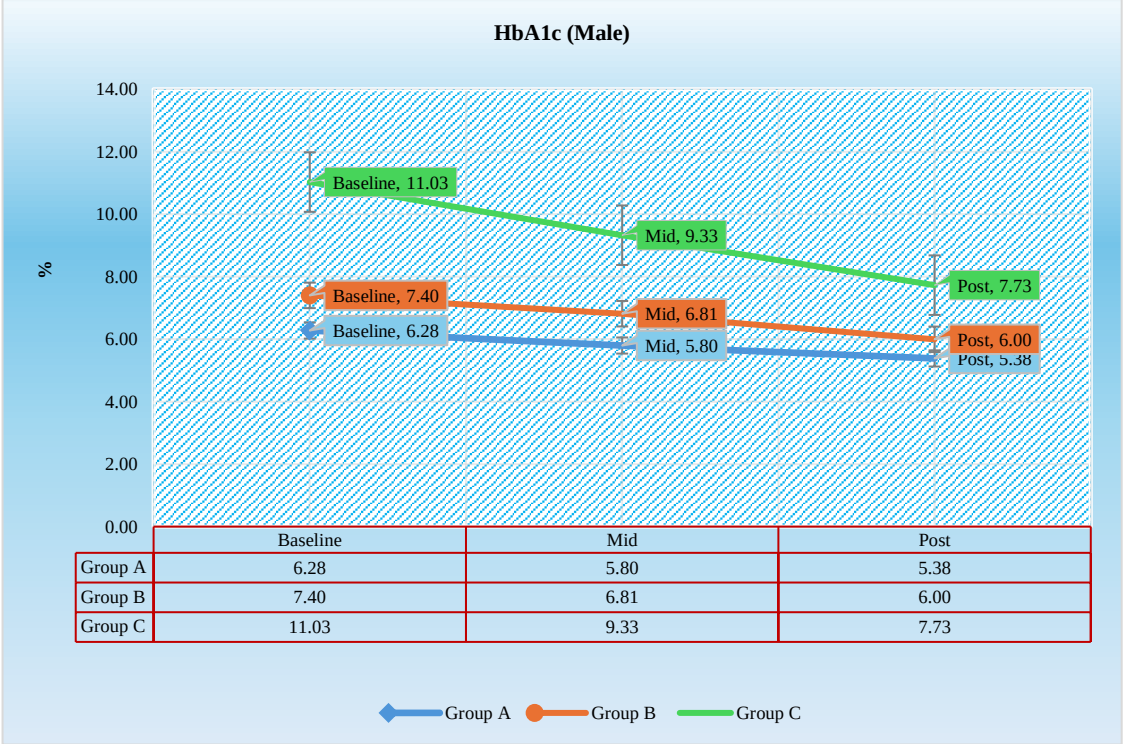
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons

From table 49, the Bonferroni post hoc test indicated that there was a significant difference of HbA1c in three time points (pre, mid and post) (p=.000) in both male and female.

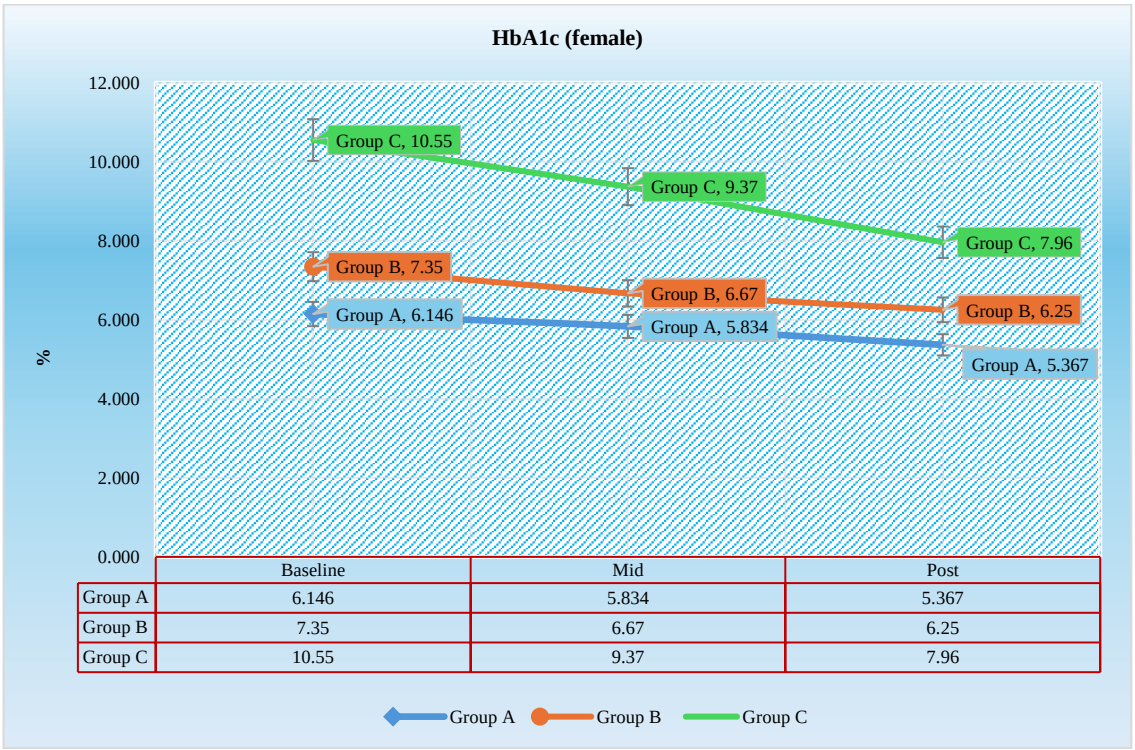
Table 50: percentage interchanges within time points (Pre, Mid & Post) of HbA1c (%)				
Groups		**Pre to Mid (% of First three months)**	**Mid to Post (% of Last three months)**	**Pre to Post (% of Six Months)**
Male	Pre-Diabetes (A) (n=15)	7.78	6.90	14.17
	T2DM stage 1 (B) (n=16)	7.90	11.98	19.14
	T2DM stage 2 (C) (n=20)	15.00	16.49	29.08
Female	Pre-Diabetes (A) (n=17)	5.12	7.99	12.68
	T2DM stage 1 (B) (n=19)	9.09	6.30	14.74
	T2DM stage 2 (C) (n=22)	10.61	14.41	23.61

In table 50, it was observed that HbA1c of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 7.78%, 6.90% & 14.17% for pre-diabetes group (A), 7.90%, 11.98% & 19.14% for T2DM stage 1 group (B) and 15.00%, 16.49% & 29.08% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of male participants. HbA1c of female participants were also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 5.12%, 7.99% & 12.68% for pre-diabetes group, 9.09%, 6.30% & 14.74% for T2DM stage 1 group and 10.61%, 14.41% & 23.61% for T2DM stage 2 group where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of female participants.



	Baseline	Mid	Post
Group A	6.28	5.80	5.38
Group B	7.40	6.81	6.00
Group C	11.03	9.33	7.73

Figure 46: The Results of changes of HbA1c in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	6.146	5.834	5.367
Group B	7.35	6.67	6.25
Group C	10.55	9.37	7.96

Figure 47: The Results of changes of HbA1c in three time points (Pre, Mid & Post) of all female participants groups

4.5.3 Fasting Insulin:

Table 51: Repeated Measure ANOVA of Fasting Insulin (μIU/mL) of individual group

Groups		Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig. (P–value)	η_p^2
Male	Pre-Diabetes (n=15)	**19.08± 5.81**	**14.31± 3.68**	**10.01± 4.99**	2, 28	66.327	.000	.826
	T2DM stage 1 (n=16)	**29.18± 8.71**	**19.43± 8.21**	**13.87± 6.31**	2, 30	58.578	.000	.796
	T2DM stage 2 (n=20)	**33.93± 9.72**	**19.5± 7.51**	**13.08± 6.28**	2, 38	106.499	.000	.849
Female	Pre-Diabetes (n=17)	**23.49± 8.61**	**14.46± 4.09**	**10.02± 2.65**	2, 32	41.090	.000	.720
	T2DM stage 1 (n=19)	**28.97± 6.90**	**18.48± 6.77**	**13.53± 6.94**	2, 36	110.594	.000	.860
	T2DM stage 2 (n=22)	**34.60± 8.19**	**20.0± 7.11**	**13.23± 5.19**	2, 42	112.586	.000	.843

Note: η_p^2 = partial eta square (effect size)

Table 51 shows the statistical differences of Fasting Insulin in three time points of each group of male and female. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 66.327, p = .000, η_p^2 = .826 for pre-diabetes; F (with df 2, 30) = 58.578, p = .000, η_p^2 = .796 for T2DM stage 1 and F (with df 2, 38) = 106.499, p = .000, η_p^2 = .849 for T2DM stage 2. This result suggests that there were significant changes in Fasting Insulin of all groups across the three measurement periods.

The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 66.855, p = .000, η_p^2 = .807 for pre-diabetes; F (with df 2, 36) = 45.284, p = .000, η_p^2 = .716 for T2DM stage 1 and F (with df 2, 42) = 42.004, p = .000, η_p^2 = .667 for T2DM stage 2. It may be interpreted that there were significant changes in Fasting Insulin of all groups across the three measurement periods.

Table 52: Repeated Measure ANOVA of Fasting Insulin (μIU/mL) of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
MALE	Within subjects factor (Time: pretest, midtest, and posttest)	5856.674	2	4044.773	195.870	.000	.803
	Between subjects factors (Groups: A, B, C)	1657.972	2	828.986	6.700	.003	.218
	Interaction Time * group	675.021	4	233.755	11.288	.000	.320
	Error (within subjects factor)	1435	96	20.650			
	Error (between subjects factor)	5938.584	48	123.720			
FEMALE	Within subjects factor (Time: pretest, midtest, and posttest)	8398.425	2	5082.009	232.477	.000	.809
	Between subjects factors (Groups: A, B, C)	1275.685	2	637.843	6.790	.002	.198
	Interaction Time * group	356.553	4	107.878	4.935	.002	.152
	Error (within subjects factor)	1986.918	110	21.86			
	Error (between subjects factor)	5166.268	55	93.932			

* The F value is significant at the .05 level.

Statistical differences of Fasting Insulin in time points, groups, interaction between time points and groups, and errors of male and female are shown in Table 52. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 195.870, p = .000, η_p^2 = .803. This tabulated value suggests that there were significant changes in Fasting Insulin across the three measurement periods. Additionally, there was a significant effect of Groups, F (with df 2, 48) = 6.700, p = .003, η_p^2 = .218, indicating that the Fasting Insulin significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 96) = 11.288, p = .000, η_p^2 = .320. This interaction suggests that the changes in Fasting Insulin across time differed between the three groups of male participants.

Therefore, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 232.477, p = .000, η_p^2 = .809. This obtained value suggests that there were significant changes in Fasting Insulin around the three measurement periods. There was a significant effect of Groups, F (with df 2, 55) = 6.790, p = .002, η_p^2 = .198, indicating that the Fasting Insulin significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 110) = 4.935, p = .002, η_p^2 = .152. This interaction suggests that the changes in Fasting Insulin across time differed between the three groups.

Table 53: Multiple comparisons (Bonferroni Post Hoc) of Fasting Insulin (μIU/mL) in three time point of all groups

	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	9.632*	.819	.000	7.601	11.664
		Post	15.078*	.932	.000	12.765	17.391
	Mid	Post	5.445*	.496	.000	4.215	6.676
Female	Pre	Mid	11.371*	.821	.000	9.343	13.399
		Post	13.742*	3.514	.001	5.065	22.420

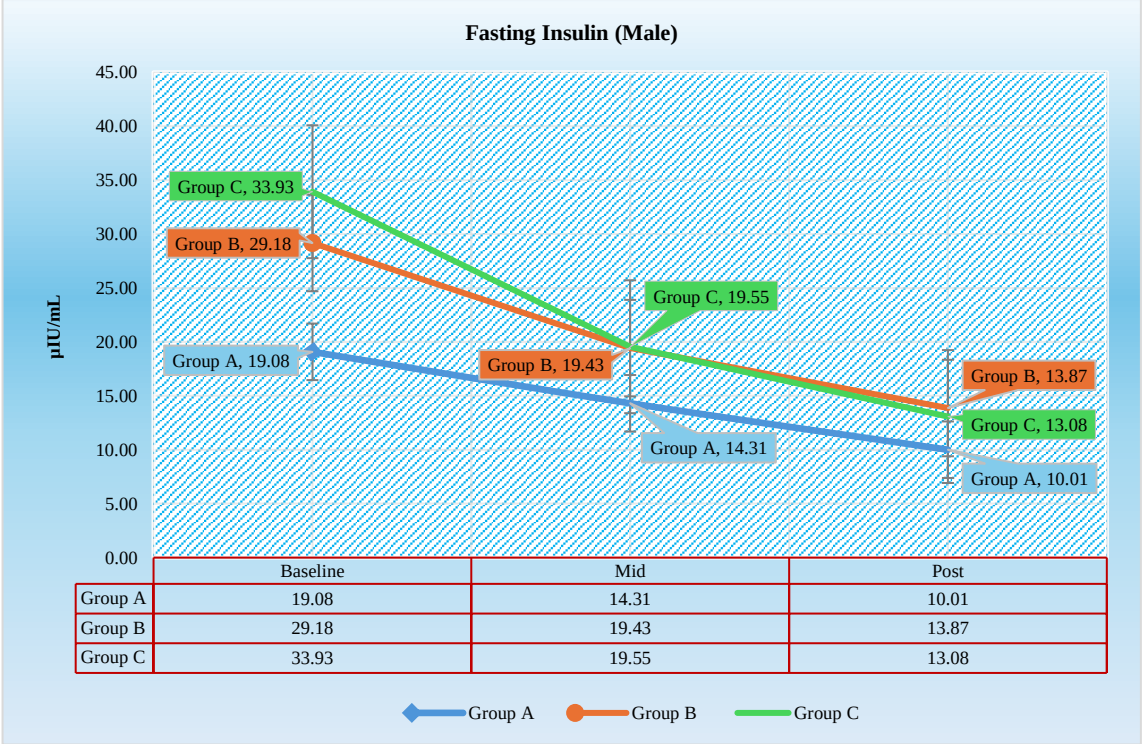
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons

From table 53, the Bonferroni post hoc test indicate that there was significance difference of Fasting Insulin in three time points (pre, mid and post) (p=.000) in both male and female.

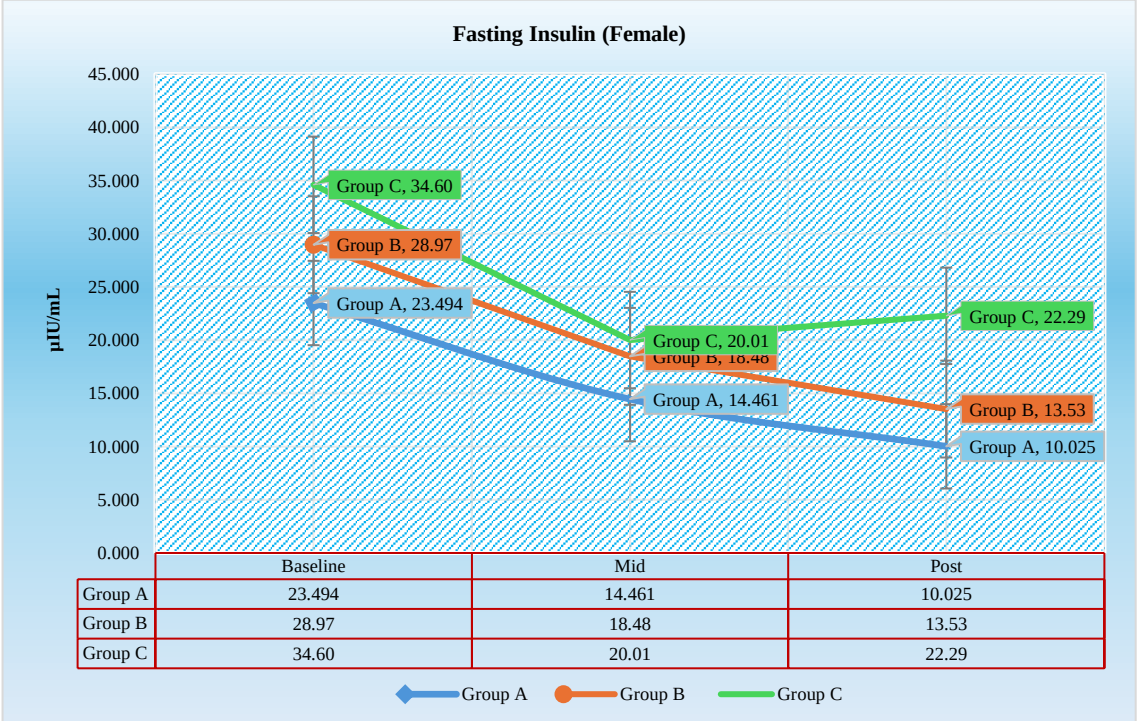
Table 54: Percentage interchanges within time points (Pre, Mid & Post) of Fasting Insulin (μIU/mL)				
Groups		**Pre to Mid (% of First three months)**	**Mid to Post (% of Last three months)**	**Pre to Post (% of Six Months)**
Male	Pre-Diabetes (A) (n=15)	23.51	32.31	49.10
	T2DM stage 1 (B) (n=16)	34.27	28.90	53.34
	T2DM stage 2 (C) (n=20)	42.44	32.38	61.20
Female	Pre-Diabetes (A) (n=17)	33.78	29.27	54.65
	T2DM stage 1 (B) (n=19)	36.66	28.35	58.60
	T2DM stage 2 (C) (n=22)	41.80	31.52	61.19

In table 54, it was observed that Fasting Insulin of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 23.51%, 32.31% & 49.10% for pre-diabetes group (A), 34.27%, 28.90% & 53.34% for T2DM stage 1 group (B) and 42.44%, 32.38% & 61.20% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of male participants. Fasting Insulin of female participants were also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 33.78%, 29.27% & 54.65% for pre-diabetes group, 36.66%, 28.35% & 58.60% for T2DM stage 1 group and 41.80%, 31.52% & 61.19% for T2DM stage 2 group where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of female participants.



	Baseline	Mid	Post
Group A	19.08	14.31	10.01
Group B	29.18	19.43	13.87
Group C	33.93	19.55	13.08

Figure 48: The Results of changes of Fasting Insulin (µIU/mL) in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	23.494	14.461	10.025
Group B	28.97	18.48	13.53
Group C	34.60	20.01	22.29

Figure 49: The Results of changes of Fasting Insulin (µIU/mL) in three time points (Pre, Mid & Post) of all female participants groups

4.5.4 Insulin Resistance:

Table 55: Repeated Measure ANOVA of Insulin Resistance (μU/mL x mmol/L) of individual groups

Groups		Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig. (P–value)	η_p^2
Male	Pre-Diabetes (n=15)	5.76± 2.18	4.00± 1.23	2.58± 1.38	2, 28	65.299	.000	.823
	T2DM stage 1 (n=16)	10.50± 3.47	6.03± 2.54	4.08± 1.92	2, 30	60.056	.000	.800
	T2DM stage 2 (n=20)	16.06± 7.62	8.19± 5.62	4.70± 3.91	2, 38	74.594	.000	.797
Female	Pre-Diabetes (n=17)	6.60± 2.35	3.60± 1.06	2.36± 0.60	2, 32	49.128	.000	.754
	T2DM stage 1 (n=19)	10.04± 2.97	5.68± 2.44	3.70± 2.07	2, 36	153.807	.000	.895
	T2DM stage 2 (n=22)	17.29± 7.19	8.03± 4.36	7.69± 16.43	2, 42	7.864	.008	.272

Note: η_p^2 = partial eta square (effect size)

Table 55 shows the statistical differences of Insulin Resistance in three time points of each group of male and female. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 65.299, p = .000, η_p^2 = .823 for pre-diabetes; F (with df 2, 30) = 60.056, p = .000, η_p^2 = .800 for T2DM stage 1 and F (with df 2, 38) = 74.594, p = .000, η_p^2 = .797 for T2DM stage 2. This result suggests that there were significant changes in Insulin Resistance of all groups across the three measurement periods.

The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 49.128, p = .000, η_p^2 = .754 for pre-diabetes; F (with df 2, 36) = 153.807, p = .000, η_p^2 = .895 for T2DM stage 1 and F (with df 2, 42) = 78.64, p = .008, η_p^2 = .272 for T2DM stage 2. It may be interpreted that there were significant changes in Insulin Resistance of all groups across the three measurement periods.

Table 56: Repeated Measure ANOVA of Insulin Resistance (μU/mL x mmol/L) of all groups

Groups	Source of variation	Type III Sum of squares	Df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	1273.440	2	1028.703	136.547	.000	.740
	Between subjects factors (Groups: A, B, C)	793.270	2	396.635	9.556	.000	.285
	Interaction Time * group	321.721	4	129.945	17.249	.000	.418
	Error (within subjects factor)	447.649	96	7.534			
	Error (between subjects factor)	1992.332	48	41.507			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	1479.829	2	1251.554	22.662	.000	.292
	Between subjects factors (Groups: A, B, C)	1428.795	2	714.397	9.778	.000	.262
	Interaction Time * group	250.787	4	106.051	1.920	.147	.065
	Error (within subjects factor)	3591.520	110	55.227			
	Error (between subjects factor)	4018.347	55	73.061			

* The F value is significant at the .05 level.

Statistical differences of Insulin Resistance in time points, groups, interaction between time points and groups, and errors of male and female are shown in Table 56. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 136.547, p = .000, η_p^2 = .740. This tabulated value suggests that there were significant changes in Insulin Resistance across the three measurement periods. Additionally, there was a significant effect of Groups, F (with df 2, 48) = 9.556, p = .000, η_p^2 = .285, indicating that the Insulin Resistance significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 96) = 17.249, p = .000, η_p^2 = .418. This interaction suggests that the changes in Insulin Resistance across time differed between the three groups of male participants.

Therefore, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 22.662, p = .000, η_p^2 = .292. This obtained value suggests that there were significant changes in Insulin Resistance around the three measurement periods. There was a significant effect of Groups, F (with df 2, 55) = 9.778, p = .000, η_p^2 = .262, indicating that the Insulin Resistance significantly differed between the three groups. The interaction between time and group was not significant, F (with df 4, 110) = 1.920, p = .147, η_p^2 = .065. This interaction suggests that the changes in Insulin Resistance across time not differed between the three groups.

Table 57: Multiple comparisons (Bonferroni Post Hoc) of Insulin Resistance (μU/mL x mmol/L) in three time point of all groups

	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	4.698*	.443	.000	3.600	5.796
		Post	6.983*	.553	.000	5.610	8.356
	Mid	Post	2.285*	.234	.000	1.705	2.865
Female	Pre	Mid	5.541*	.443	.000	4.446	6.636
		Post	6.729*	1.301	.000	3.516	9.942

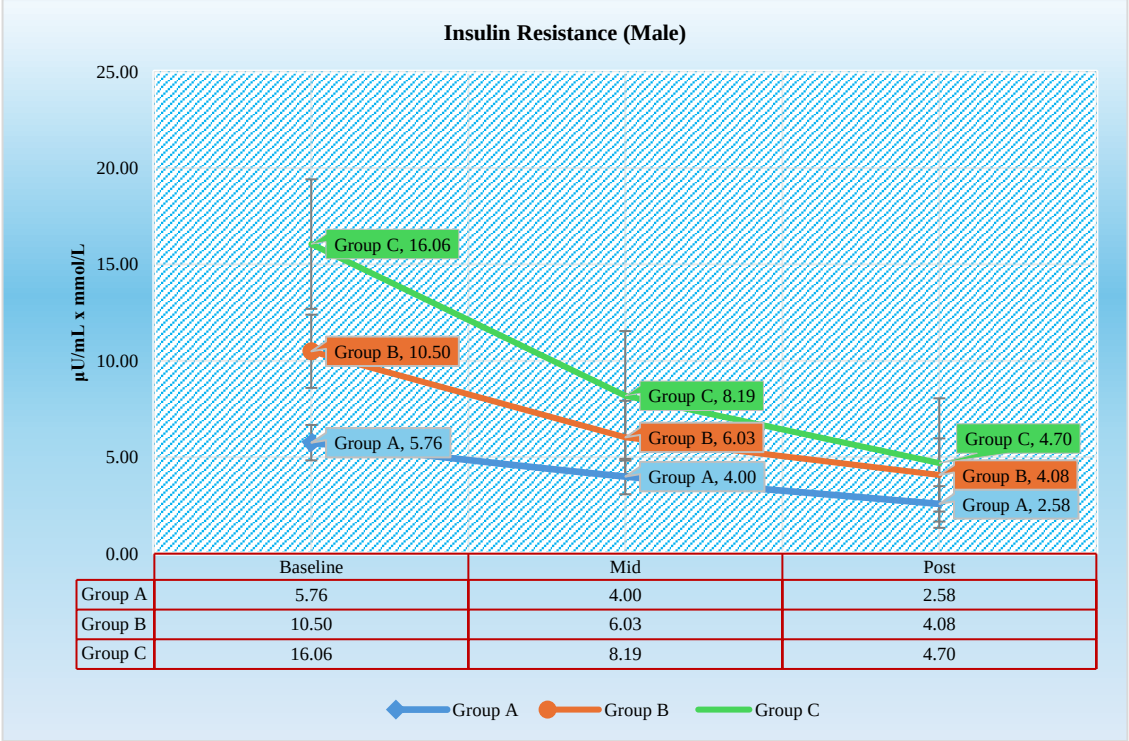
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons

From table 57, the Bonferroni post hoc test indicated that there was a significant difference of Insulin Resistance in three time points (pre, mid and post) (p=.000) in both male and female.

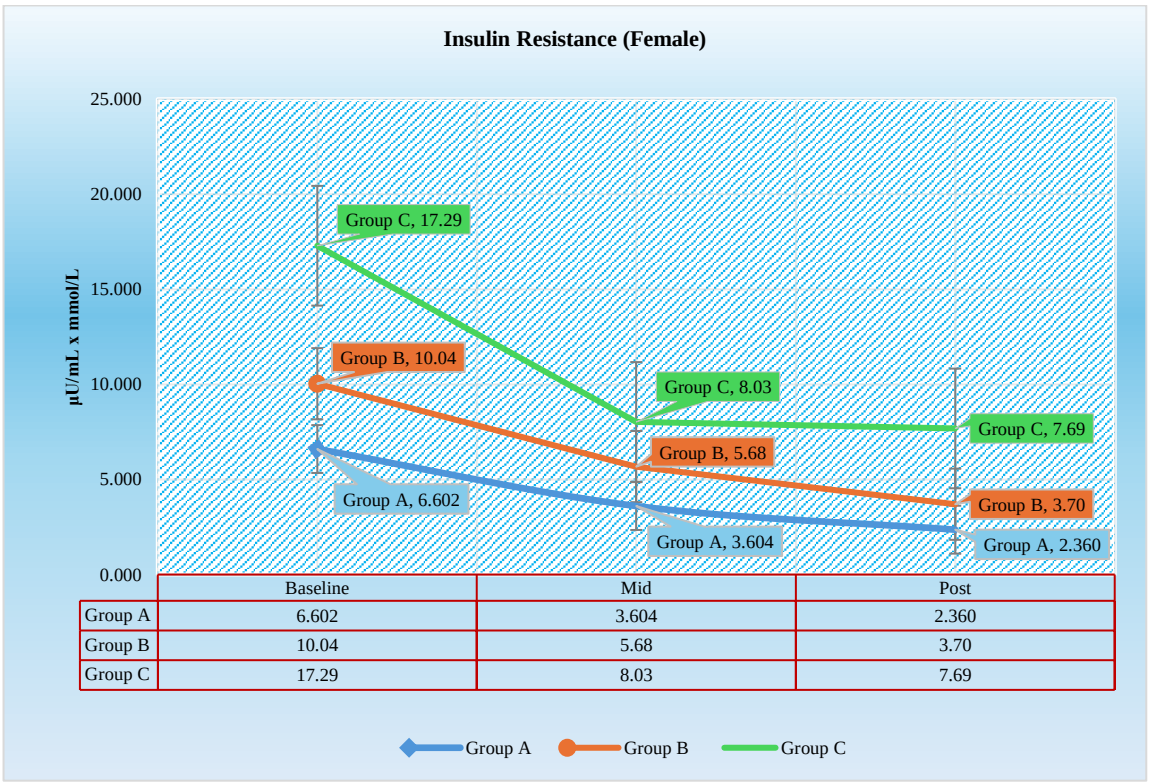
Table 58: Percentage interchanges within time points (Pre, Mid & Post) of Insulin Resistance (μU/mL x mmol/L)				
Groups		Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)
Male	Pre-Diabetes (A) (n=15)	28.57	37.02	56.15
	T2DM stage 1 (B) (n=16)	42.49	33.14	61.47
	T2DM stage 2 (C) (n=20)	50.19	41.44	70.97
Female	Pre-Diabetes (A) (n=17)	41.20	31.98	61.99
	T2DM stage 1 (B) (n=19)	43.91	36.29	63.79
	T2DM stage 2 (C) (n=22)	52.48	41.58	73.75

In table 58, it was observed that Insulin Resistance of male participants were improved (decreases) at the end of first 3 months, last 3 months and 6 months intervention 28.57%, 37.02% & 56.15% for pre-diabetes group (A), 42.49%, 33.14% & 61.47% for T2DM stage 1 group (B) and 50.19%, 41.44% & 70.97% for T2DM stage 2 group (C) respectively where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of male participants. Insulin Resistance of female participants were also improved (decreases) after first 3 months, last 3 months & 6 months intervention, 41.20%, 31.98% & 61.99% for pre-diabetes group, 43.91%, 36.29% & 63.79% for T2DM stage 1 group and 52.481%, 41.58% & 73.75% for T2DM stage 2 group where T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction of female participants.



	Baseline	Mid	Post
Group A	5.76	4.00	2.58
Group B	10.50	6.03	4.08
Group C	16.06	8.19	4.70

Figure 50: The Results of changes of Insulin Resistance (µU/mL x mmol/L) in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	6.602	3.604	2.360
Group B	10.04	5.68	3.70
Group C	17.29	8.03	7.69

Figure 51: The Results of changes of Insulin Resistance (µU/mL x mmol/L) in three time points (Pre, Mid & Post) of all female participants groups

4.5.5 Insulin Sensitivity:

Table 59: Repeated Measure ANOVA of Insulin Sensitivity of individual group

Groups		Pre (Mean± SD)	Mid (Mean± SD)	Post (Mean± SD)	df	F	Sig. (P–value)	η_p^2
Male	Pre-Diabetes (n=15)	0.30±0.01	0.31±0.01	0.34±0.03	2, 28	45.052	.000	.763
	T2DM stage 1 (n=16)	0.28±0.01	0.30±0.02	0.32±0.03	2, 30	53.943	.000	.782
	T2DM stage 2 (n=20)	0.27±0.01	0.29±0.02	0.31±0.02	2, 38	113.700	.000	.857
Female	Pre-Diabetes (n=17)	0.29±0.01	0.32±0.01	0.34±0.01	2, 32	97.478	.000	.859
	T2DM stage 1 (n=19)	0.28±0.01	0.30±0.02	0.32±0.02	2, 36	83.550	.000	.823
	T2DM stage 2 (n=22)	0.26±0.01	0.29±0.02	0.31±0.03	2, 42	62.453	.000	.748

Note: η_p^2 = partial eta square (effect size)

Table 59 shows the statistical differences of insulin sensitivity in three time points of each group of male and female. The results of male subjects indicated a significant effect on measurement time, F (with df 2, 28) = 65.299, p = .000, η_p^2 = .823 for pre-diabetes; F (with df 2, 30) = 60.056, p = .000, η_p^2 = .800 for T2DM stage 1 and F (with df 2, 38) = 74.594, p = .000, η_p^2 = .797 for T2DM stage 2. This result suggests that there were significant changes in Insulin sensitivity of all groups across the three measurement periods.

The results of female subjects indicated a significant effect on measurement time, F (with df 2, 32) = 49.128, p = .000, η_p^2 = .754 for pre-diabetes; F (with df 2, 36) = 153.807, p = .000, η_p^2 = .895 for T2DM stage 1 and F (with df 2, 42) = 78.64, p = .008, η_p^2 = .272 for T2DM stage 2. It may be interpreted that there were significant changes in insulin sensitivity of all groups across the three measurement periods.

Table 60: Repeated Measure ANOVA of insulin sensitivity of all groups

Groups	Source of variation	Type III Sum of squares	df	Mean square	F	Sig. (P–value)	Partial eta square (η_p^2)
Male	Within subjects factor (Time: pretest, midtest, and posttest)	.047	2	.030	195.216	.000	.803
	Between subjects factors (Groups: A, B, C)	.020	2	.010	9.941	.000	.293
	Interaction Time * group	.001	4	.000	1.692	.147	.066
	Error (within subjects factor)	.011	96	.000			
	Error (between subjects factor)	.048	48	.001			
Female	Within subjects factor (Time: pretest, midtest, and posttest)	.059	2	.036	210.339	.000	.793
	Between subjects factors (Groups: A, B, C)	.024	2	.012	19.141	.000	.410
	Interaction Time * group	.000	4	6.847	.398	.771	.014
	Error (within subjects factor)	.015	110	.000			
	Error (between subjects factor)	.034	55	.001			

* The F value is significant at the .05 level.

Statistical differences of insulin sensitivity in time points, groups, interaction between time points and groups, and errors of male and female are shown in table 60. The results of male participants indicated a significant effect on measurement time, F (with df 2, 96) = 136.547, p = .000, η_p^2 = .740. This tabulated value suggests that there were significant changes in insulin sensitivity across the three measurement periods. Additionally, there was a significant effect of Groups, F (with df 2, 48) = 9.556, p = .000, η_p^2 = .285, indicating that the insulin sensitivity significantly differed between the three groups. The interaction between different time and group was also significant, F (with df 4, 96) = 17.249, p = .000, η_p^2 = .418. This interaction suggests that the changes in insulin sensitivity across time differed between the three groups of male participants.

Therefore, the results of female subjects indicated a significant effect on measurement time, F (with df 2, 110) = 22.662, p = .000, η_p^2 = .292. This obtained value suggests that there were significant changes in insulin sensitivity around the three measurement periods. There was a significant effect of Groups, F (with df 2, 55) = 9.778, p = .000, η_p^2 = .262, indicating that the insulin sensitivity significantly differed between the three groups. The interaction between time and group was not significant, F (with df 4, 110) = 1.920, p = .147, η_p^2 = .065. This interaction suggests that the changes in insulin sensitivity across time did not differ between the three groups.

Table 61: Multiple comparisons (Bonferroni Post Hoc) of Insulin Sensitivity in three time point of all groups

	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Male	Pre	Mid	-.021*	.002	.000	-.025	-.017
		Post	-.043*	.003	.000	-.050	-.037
	Mid	Post	-.022*	.002	.000	-.028	-.017
Female	Pre	Mid	-.024*	.002	.000	-.028	-.020
		Post	-.045*	.003	.000	-.052	-.039
	Mid	Post	-.021*	.002	.000	-.027	-.015

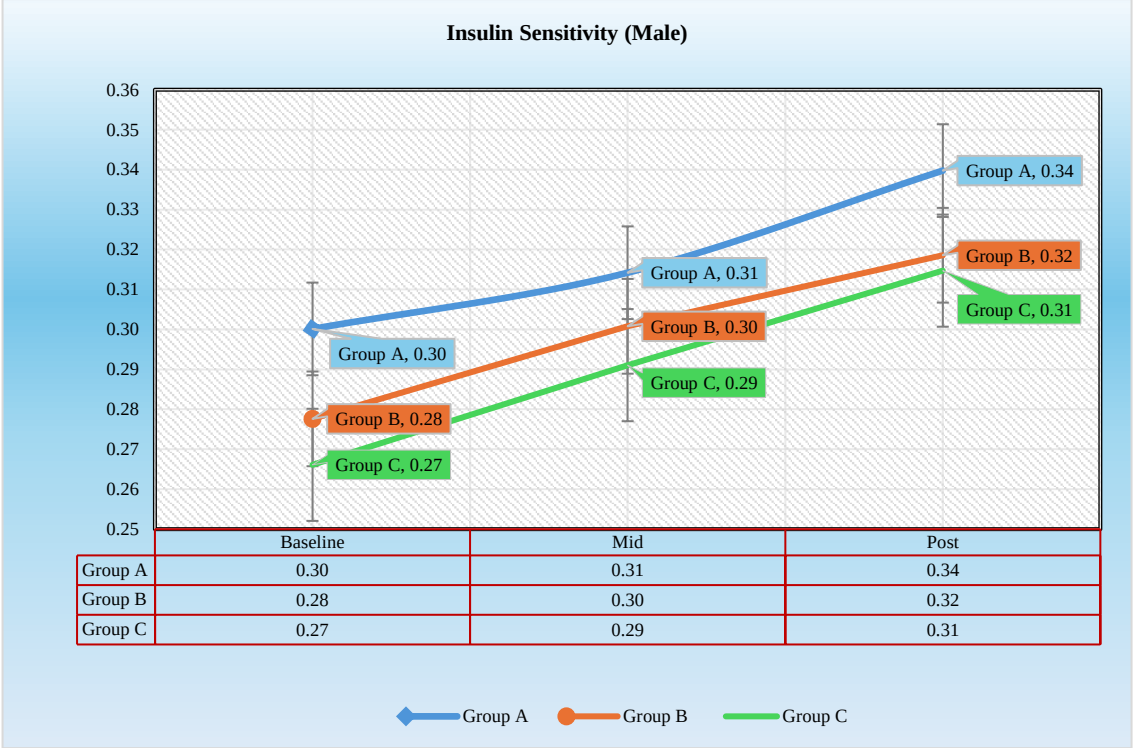
*. The mean difference is statistically significant at the .05 level.

b. Bonferroni method was used for multiple comparisons

From table 61, the Bonferroni post hoc test indicated that there was a significant difference of insulin sensitivity in three time points (pre, mid and post) (p=.000) in both male and female.

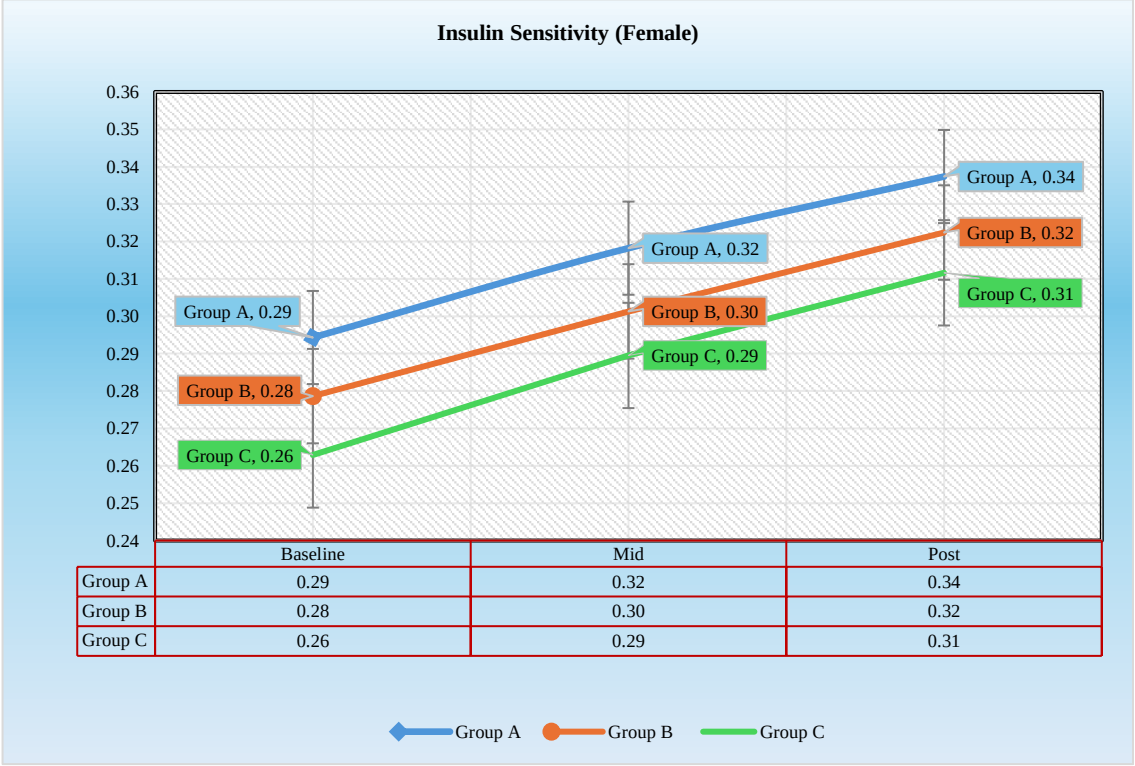
Table 62: Percentage interchanges within time points (Pre, Mid & Post) of Insulin Sensitivity				
Groups		Pre to Mid (% of First three months)	Mid to Post (% of Last three months)	Pre to Post (% of Six Months)
Male	Pre-Diabetes (A) (n=15)	4.72	8.10	13.13
	T2DM stage 1 (B) (n=16)	8.30	5.84	14.65
	T2DM stage 2 (C) (n=20)	9.33	8.20	18.28
Female	Pre-Diabetes (A) (n=17)	8.25	6.10	14.73
	T2DM stage 1 (B) (n=19)	8.11	6.96	15.67
	T2DM stage 2 (C) (n=22)	10.16	8.71	19.64

In table 62, it was observed that Insulin Sensitivity of male participants were improved (increases) at the end of first 3 months, last 3 months and 6 months intervention 4.72%, 8.10% & 13.13% for pre-diabetes group (A), 8.30%, 5.84% & 14.65% for T2DM stage 1 group (B) and 9.33%, 8.20% & 18.28% for T2DM stage 2 group (C) respectively where T2DM stage 2 group increased maximum and pre-diabetes group increased fewer in male participants. Insulin Sensitivity of female participants were also improved (increases) after first 3 months, last 3 months & 6 months intervention, 8.25%, 6.10% & 14.73% for pre-diabetes group, 8.11%, 6.96% & 15.67% for T2DM stage 1 group and 10.16%, 8.71% & 19.64% for T2DM stage 2 group where T2DM stage 2 group increased more and pre-diabetes group increased less in female participants.



	Baseline	Mid	Post
Group A	0.30	0.31	0.34
Group B	0.28	0.30	0.32
Group C	0.27	0.29	0.31

Figure 52: The Results of changes of Insulin Sensitivity in three time points (Pre, Mid & Post) of all male participants groups



	Baseline	Mid	Post
Group A	0.29	0.32	0.34
Group B	0.28	0.30	0.32
Group C	0.26	0.29	0.31

Figure 53: The Results of changes of Insulin Sensitivity in three time points (Pre, Mid & Post) of all female participants groups

4.6 Discussion on Anthropometric and physical variables:

On the basis of results, it may be interpreted that there were significant changes in BMI, waist circumference, hip circumference, left hand grip strength, right hand grip strength and flexibility of all groups across the three assessment periods of both male and female subjects. In the present study BMI, waist circumference and hip circumference of both male and female participants was improved (decreases) after six months Yog-vyayama intervention. Among the three groups BMI of pre-diabetes group (A) showed more reduction and T2DM stage 2 group (C) showed less reduction of male participants; T2DM stage 1 group showed less reduction and pre-diabetes group showed more reduction in female participants. Waist circumference of T2DM stage 2 group (C) showed more reduction and pre-diabetes group showed less reduction in male participants; and pre-diabetes group (A) showed more reduction and the T2DM stage 2 group (C) showed less reduction in female participants. Hip circumference of pre-diabetes group showed more reduction and T2DM stage 2 group showed less reduction in male participants; and the T2DM stage 1 group (B) showed more reduction and the T2DM stage 2 group (A) showed more reduction in female participants.

Grip strength and flexibility of both male and female participants increased after six months Yog-vyayama intervention. Where left grip strength of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction in male participants; and in case of female participants pre-diabetes group showed more reduction and T2DM stage 1 group showed less reduction. Right grip strength of T2DM stage 1 group showed with maximum increase and pre-diabetes group showed minimum increase in male participants. In case of female participants right grip strength T2DM stage 2 group increased less and pre-diabetes group increased more. Flexibility of pre-diabetes group increased more and T2DM stage 1 group increased fewer in male participants. In case of

female participants flexibility of T2DM stage 2 group increased less and pre-diabetes group increased more in this present study.

4.7 Discussion on physiological variables:

Results of the present study suggests that there were significant changes in heart rate, blood pressure and SpO_2 of all groups across the three measurement periods. Heart rate and blood pressure of both male and female participants was decreased after six months Yog-vyayama intervention. where heart rate of T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants. In case of female participants heart rate of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction and nearly similar to T2DM stage 2 group. Systolic blood pressure of T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants; pre-diabetes group showed more reduction and T2DM stage 2 group showed less reduction of female participants. Diastolic blood pressure of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction of male participants; T2DM stage 2 group showed more reduction and T2DM stage 1 group showed less reduction of female participants. SpO2 of both male and female participants was increased after six months Yog-vyayama intervention. SpO_2 of T2DM stage 1 group increased more and pre-diabetes group increased less in male participants; T2DM stage 1 group increased maximum and T2DM stage 2 group increased minimum in female participants.

4.8 Discussion on Glycemic control:

On the basis of results of the present study, it may be interpreted that there were significant changes in all Glycemic variables in all groups across the three measurement periods of both male and female subjects. It was observed that fasting plasma glucose

level, HbA1c, fasting insulin and insulin resistance of both male and female participants was improved (reduced) after the end of six months Yog-vyayama intervention where of T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction in both male and female participants. Insulin Sensitivity of both male and female participants was also improved (increased) after the end of six months Yog-vyayama intervention where the T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction in both male and female participants.

In the present study, the substantial drop in fasting blood glucose levels after Yog-vyayama in three groups (Pre-diabetes, T2DM Stage 1 and T2DM Stage 2) suggests that yoga may have a potential role in T2DM prevention and control. Fasting blood glucose levels were shown to be significantly lower in T2DM patients on oral hypoglycemic agents (OHA) who participated in yoga training compared to those who simply took OHA. [11, 113] Similarly, yoga training has been shown to significantly lower fasting blood glucose levels in T2DM patients on OHA.[153]

Previous studies have suggested that the practice of yoga may lower Insulin Resistance Syndrome, which is a distinctive combination of risk factors for the development of T2DM and has shown beneficial outcomes in terms of relieving symptoms, prognosis, and minimizing complications.[41, 54, 75, 103, 142, 156, 162] Some studies have shown that regular physical exercise like yoga or aerobic exercise may delay the occurrence of diabetes from the prediabetic state [53, 103, 154, 166, 170] Vaishali, K found that implementation of Yoga along with conventional therapy, on long term basis would convey proper control of glycosylated haemoglobin (HbA1c), blood sugar, lipid profile in elderly subjects with long duration diabetes.[199]

Yogic practice along with standard treatment may reduce the direct effect of hyperinsulinemia on the hypothalamus, reducing sympathetic activity and increasing

parasympathetic activity, improving insulin sensitivity at target tissues, and increasing peripheral glucose utilization, ultimately lowering glucose levels.[214]

The beneficial effect of yoga on T2DM has been related to enhanced insulin sensitivity in target tissues, which reduces insulin resistance and, as a result, promotes peripheral glucose utilization [Sahay BK.2007]. Additionally, there have also been statements that yogic exercise may regenerate or rejuvenate beta cells inside the pancreas. [48, 163]

Positive benefits of Yoga may be transmitted via neurohormonal pathways, lowering stress and anxiety while increasing autonomic balance towards parasympathetic activity. Furthermore, insulin receptor-expressing regions of the hypothalamus and striatum, as well as the amygdala, hippocampus, and prefrontal cortex, have a role in the pathophysiology of illness disorders affecting mood and behaviour.[109] Yoga may improve quality of life and well-being by establishing correct insulin signalling in these regions, which regulates dopaminergic and serotonin neural pathways that increase mood and behaviour. [108]

The most significant factor in lowering the likelihood of chronic Diabetes Mellitus complications is improved glycemic control. Home-based resistance tube training may help lower FBS and HbA1c levels in aged T2DM patients.[139] Elastic-band resistance exercise may lower FBS, HbA1c, and fasting insulin levels in Type 2 Diabetes Mellitus patients.[145] Yogic exercise increases blood flow to muscles, which improves insulin receptor expression and lowers blood sugar. Yoga decreases insulin resistance while increasing insulin receptors, resulting in changes in peak insulin levels.[182]

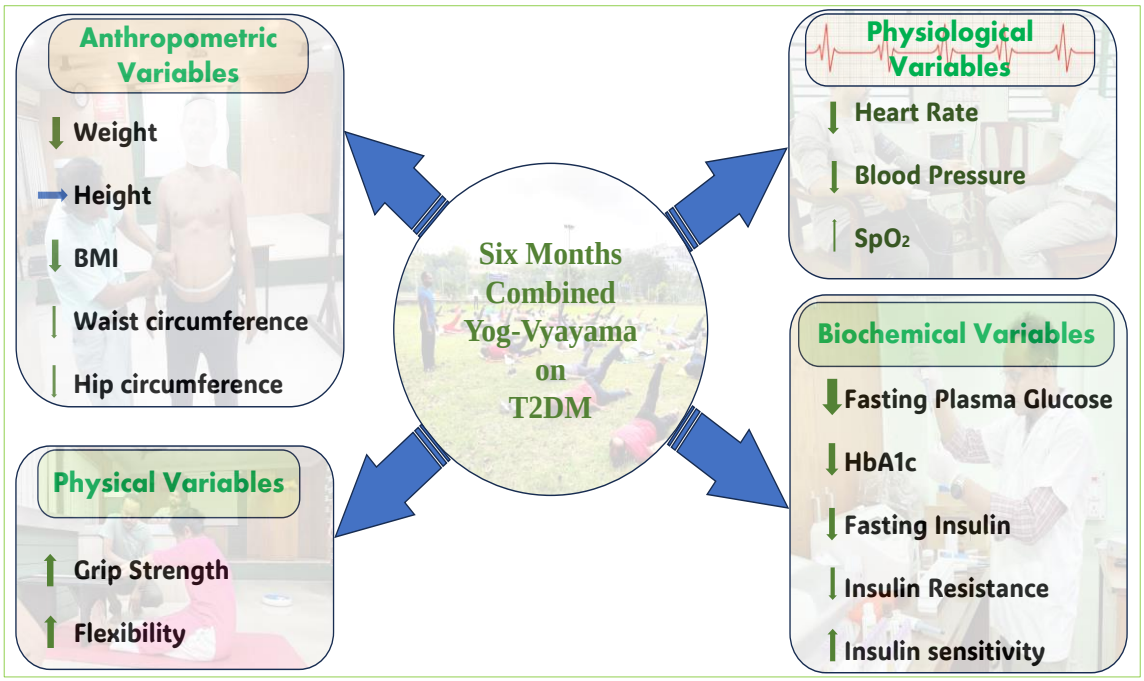


Figure 54: Effect of six months Yog-vyayama on T2DM

Within the limitations of the study, the researcher would like to present the prospective mechanisms of yoga for improving glycemic control and insulin resistance of type 2 diabetes patients after regular graded combined Yog-vyayama practices for 24 weeks. Mind and body are not separate entity in yoga. The practice of Kriya, Suryanamaskara and Asana (physical level), Pranayama (psychophysiological level), and Meditation (psychoneurological level) integrate and harmonise mind and body to provide an ideal neuroglandular adjustment within the individual and may positively stimulate the insulin secretion pattern in the aged type 2 diabetes patients.

Kriya (Kapalbhati) and Pranayama (Bhastrika) bring in control over the autonomic nervous system' function.[128] Kapalbhati kriya and Bhastrika pranayama give vigorous abdominal movements and an automatic abdominal massage may preserve the effective functioning of pancreas and thus improve insulin concentration in the blood. Autonomic and proprioceptive neuromuscular reactions seem to have an important bearing in bringing about these results.[76]

Suryanamaskara or salutation to the sun is an important yogic practice which is a series of dynamic movements (12 counts) of forward and backward spinal bends and stretches with body and breathing awareness improve major muscle group in the body, strengthen joint structure and range of motion, digestion, circulation, aerobic capacity, body's circadian rhythms, nourishment, and stimulation of the nerves.[46, 49, 50, 51, 79] With this it is also equally activate and stimulates all the glands in the body including pancreas to get positive neuroendocrine feedback for maintaining a healthy secretion of insulin.

Cultural asanas (static physical posture with internal body awareness) provide a constant supply of proper nutrition to the tissues and the internal secretion of the endocrine glands.[116] Twisting asana and some asanas extensively compresses and squeezes the abdomen such as Vakrasana, Uttanapadasana, Ardha Halasana, Pavanmuktasana, Parivrtta Trikonasana poses not only massage the pancreas but also stimulate the surrounding organs, promoting overall digestive health and metabolic balance, promoting pancreatic secretions.

Regular practice of different forms of Pranayama (Nadisodhan & Bhramari) increases psychophysiological relaxation by quieting and calming the mind, decreases sympathetic tone, and enhances parasympathetic activation.[190, 191, 203]

Meditation is believed to gradually diminish sympathetic dominance, resulting in a better balance between the sympathetic and the parasympathetic activity.[14] It also brings about a hypometabolic state.[12] By modifying the state of tension and anxiety, mediation reduces stress induced sympathetic over reactivity.[13, 14, 63] Thus, a decrease in sympathetic response and ability to overcome stress can be a possible reason for the improvement in glucose level in the plasma blood.

Sukshma Vyayama, a subtle yoga practice, offers numerous benefits, including improved flexibility, relaxation, balance, and coordination.[95] Regular practice reduces

stress and anxiety, [114] enhances concentration and emotional balance,[181] and promotes energy balance and spiritual growth. [168] Additionally, Sukshma Vyayama alleviates chronic pain,[130] improves sleep quality,[114] and boosts the immune system.[59] Overall, this practice cultivates physical, mental, and spiritual well-being.

Regular physical exercise leads to better glycemic control. The American Diabetes Association prescribes 150 minutes of physical exercise per week to lower HbA1c over time.[19, 30, 197] Increasing the length of exercise over the prescribed 150 minutes per week leads to an even higher decrease in HbA1c by 0.89%. The combination of weight and endurance training had a stronger impact on HbA1c than weight training alone. Adults with diabetes should perform resistance workouts 2-3 times per week on non-consecutive days. Flexibility and balancing activities for the elderly, such as yoga and tai chi, are advised 2-3 times per week. [197]

4.9 Physiological mechanism:

Yogic activities stimulate the muscles to absorb excess glucose in the bloodstream, thereby reducing blood sugar levels. They help the pancreas and liver work properly, regulating blood sugar levels. Asanas aid to rejuvenate pancreatic cells, hence improving insulin production. The physical exercises or Vayayama also aid to lower blood sugar levels. Asanas promote relaxation, which is also essential for the proper functioning of the body's internal organs. Since the soul is essentially spiritual, yogic activities may be the only ones that help us get closer to it. Yoga, pranayama, and meditation practitioners typically experience a change in their outlook on life.

Changes in Fasting Blood Glucose level and HbA1c observed in this present study may be a consequence of increased workload during Asanas, Surya namaskar, and different dynamic and static stretching, which is associated with enhanced insulin sensitivity and glucose absorption. [165, 176] Slow breathing during pranayama has been related with

decreased Hypothalamo-Pituitary-Adrenocortical (HPA axis) activation, which is associated with lowered cortisol, and lower cortisol is associated with decreased hepatic glycolysis. [143, 184]

Insulin resistance in Type 2 Diabetes Mellitus may occur due to excessive production of a large number of adipocytes in the body.[100] Adiposity is associated with impaired production and differentiation capacity of adipocytes.[137] Physical activity is involved in decreased production of large sized adipocytes, which may be via correcting the impairment in proliferation of differential capacity of mesenchymal cells.[135, 144]

Prediabetes is a stage in the progression from normal glucose tolerance to impaired glucose tolerance, as seen in type 2 diabetes. According to research, even a slight rise in blood glucose in prediabetes might cause oxidative stress.[36, 40] Thus, oxidative stress gradually increases from prediabetes to diabetes, both without and with consequences.[40] Many controlled trials in type 2 diabetes have indicated an improvement in oxidative stress indicators and glycemic control following yoga therapy.[78, 85, 119, 178] The duration of the yoga intervention provided in these studies ranged from 6 weeks to 6 months.

It has been suggested that yoga decreases oxidative stress with two different mechanisms.[152, 206] The first one involves lowering overactivation of the hypothalamic-pituitary-adrenal axis and the sympathoadrenal medullary axis. These systems may produce high levels of stress hormones such as cortisol and epinephrine, which can elevate heart rate, blood pressure, metabolic, and inflammatory responses. The second mechanism is that yoga emphasizes on extended exhalations and deliberate slow breathing, which reactivates the parasympathetic nervous system, which results in these effective enhancements to them.

CHAPTER – V

Summary, Conclusion and Recommendations

5. Summary, Conclusion and Recommendations

5.1 Summary

5.2 Conclusion

5.3 Recommendations

5.4 Clinical Implications

5.5 Constraints

5.6 Future Directions

CHAPTER - V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5. Summary, Conclusion and Recommendations

This is the final and most important part of the thesis. It summarizes the study findings and provides a concise essence of the entire study.

5.1 Summary:

Research on Yoga and Vyayama's individual benefits for type 2 diabetes patients is sufficient, but regarding the combined effect of Yog-vyayama for type 2 diabetes patients is unsatisfactory, particularly on different HbA1c levels. To address this gap the researcher intended to determine the combined effect of Yog-vyayama on Body mass index, Waist circumference, Hip circumference, Grip Strength, Trunk flexibility, Heart Rate, Blood Pressure, glycemic control, insulin resistance and insulin sensitivity in patients with type 2 diabetes mellitus, and to determine its efficacy in improving glycemic control across different HbA1c levels.

The present study was conducted in the exercise and sports physiology laboratory and Yoga Centre of the Department of physical education, Jadavpur University, Jadavpur, Kolkata. A total of 162 members were purposively divided into three groups: Group A (pre-diabetes - HbA1c Level 5.7% to 6.4%) n=54 (M-24, F-30) without taking oral hypoglycemic agent, Group B (T2DM Stage 1 - HbA1c Level 6.5% to 8%) n=54 (M-24, F-30) with taking oral hypoglycemic agent, and Group C (T2DM Stage 2 - HbA1c Level > 8%) n=57 (M-27, F-30) with taking oral hypoglycemic agent for the study. 109 of the 162 people who enrolled stayed until the end of the study and received the specified intervention. The Yog-vayayama intervention regimen was designed specifically for the

individuals' health and physical conditions. Participants started practicing a specific Yog-vyayama intervention. The yoga intervention included prayer, yogic suksma vyayama, surya namaskara, brisk walking, dynamic stretching and deep breathing, asana, kriya, pranayama, and meditation. 50-75 minutes (200-280 minutes per week) per day and four (4) days per week for six (6) months of structured Yog-vyayama intervention module were considered in this current study. For the participants all variables were measured at the time of enrolment (Baseline), after 3 months and after 6 months of intervention.

Normality tests were used before parametric tests to examine the normal distribution of the data. In the current study the RM ANOVA was used for significant differences between the assessments in three different time points, followed by Post hoc analysis with Bonferroni adjustment to determine which of the paired means difference was significant at 0.05 level. Percentage changes were calculated to establish the effect or outcomes of treatment on both male and female of every group of the study.

The results of entire variables indicated a significant effect in three time points ($p = .000$) in both male and female participants. On the basis of results, it may be interpreted that there were significant changes in BMI, waist circumference, hip circumference, left grip strength, right grip strength and flexibility of all groups across the three measurement periods of both male and female subjects. In this present study BMI, waist circumference and hip circumference of both male and female participants was improved (decreases) after six months Yog-vyayama intervention. Among the three groups BMI of pre-diabetes group (A) showed more reduction and T2DM stage 2 group (C) showed less reduction of male participants; in case of female participants, T2DM stage 1 group showed less reduction and pre-diabetes group showed more reduction. Waist circumference of T2DM stage 2 group (C) showed more reduction and pre-diabetes group showed less reduction in male participants; and pre-diabetes group (A) showed more reduction and the T2DM stage 2

group (C) showed less reduction in female participants. Hip circumference of pre-diabetes group showed more reduction and the T2DM stage 2 group showed less reduction in male participants; and the T2DM stage 1 group (B) showed more reduction and the T2DM stage 2 group (A) showed more reduction in female participants.

Grip strength and flexibility of both male and female participants increased after six months Yog-vyayama intervention. Where left grip strength of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction in male participants; and in case of female participants pre-diabetes group showed more reduction and T2DM stage 1 group showed less reduction. Right grip strength of T2DM stage 1 group showed with maximum increase and pre-diabetes group showed minimum increase in male participants. In case of female participants right grip strength T2DM stage 2 group increased less and pre-diabetes group increased more. Flexibility of pre-diabetes group increased more and T2DM stage 1 group increased fewer in male participants. In case of female participants flexibility of T2DM stage 2 group increased less and pre-diabetes group increased more in this present study.

Results of the present study suggests that there were significant changes in heart rate, blood pressure and SpO2 of all groups across the three measurement periods. Heart rate and blood pressure of both male and female participants was decreased after six months Yog-vyayama intervention. where heart rate of T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants. In case of female participants heart rate of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction and nearly similar to T2DM stage 2 group. Systolic blood pressure of T2DM stage 1 group showed more reduction and T2DM stage 2 group showed less reduction of male participants; pre-diabetes group showed more reduction and T2DM stage 2 group showed less reduction of female participants. Diastolic blood

pressure of T2DM stage 1 group showed more reduction and pre-diabetes group showed less reduction of male participants; T2DM stage 2 group showed more reduction and T2DM stage 1 group showed less reduction of female participants. SpO2 of both male and female participants was increased after six months Yog-vyayama intervention. SpO2 of T2DM stage 1 group increased more and pre-diabetes group increased less in male participants; T2DM stage 1 group increased maximum and T2DM stage 2 group increased minimum in female participants.

There were significant changes in all Glycemic variables in all groups across the three measurement periods of both male and female subjects (p=.000). It was observed that fasting plasma glucose level, HbA1c, fasting insulin and insulin resistance of both male and female participants was improved (reduced) after the end of six months Yog-vyayama intervention where of T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction in both male and female participants. Insulin Sensitivity of both male and female participants was also improved (increased) after the end of six months Yog-vyayama intervention where of the T2DM stage 2 group showed more reduction and pre-diabetes group showed less reduction in both male and female participants.

From the above discussion it may be concluded that the combined effect of Yog-vyayama determines a significant benefit in improving (reducing) BMI, Waist circumference, Hip circumference, Heart Rate, Blood Pressure, Fasting blood glucose level, HbA1c levels, fasting insulin level and insulin resistance; improving (increasing) SpO_2, insulin sensitivity and enhancing strength and flexibility in patients with T2DM.

5.2 Conclusion:

From the above discussion and based on the objectives of the study it may be concluded that Yog-vyayama has a positive impact on:

- **Reducing Anthropometric characteristics:** Significant reductions in BMI, waist-hip circumference was observed.
- **Enhancing Muscular fitness**: Improvements in hand grip strength and trunk flexibility were noted.
- **Improving Vitals:** Decreases in heart rate and blood pressure; and increases SpO_2 were observed.
- **Improving glycemic control:** Reduced HbA1c levels and fasting blood glucose level.
- **Decreasing insulin level and insulin resistance:** Lowered fasting insulin level and Homeostatic Model Assessment insulin resistance (HOMA-IR) scores.
- **Enhancing insulin sensitivity**: Increased the value of Quantitative Insulin Sensitivity Check Index (QUICKI).
- **Improvement on Pre-diabetes Group (A) (HbA1c-5.7%-6.4%):** Yog-vyayama improved BMI of both male and female, Waist circumference of female, Hip circumference of male, Grip Strength of female, Flexibility of male, Systolic Blood Pressure of male participants.
- **Improvement on T2DM Stage 1 Group (B) (HbA1c-6.5%-8%):** Yog-vyayama improved Hip circumference of female, Grip Strength of male, Heart Rate of both male and female, Blood Pressure of male, Diastolic Blood Pressure of female,
- **Improvement on T2DM Stage 2 Group (C) (HbA1c->8%):** Yog-vyayama demonstrated moderate improvements of Waist circumference of male, Flexibility of female, Diastolic Blood Pressure of female, SpO2 of both male and female, Fasting

plasma glucose levels, HbA1c, Fasting Insulin, insulin resistance and Insulin Sensitivity of both male and female participants.

- Greatest improvements in Glycemic control, insulin resistance and Insulin Sensitivity were observed in the severe HbA1c group (HbA1c->8%).

5.3 Recommendations:

- Patients with T2DM should incorporate Yog-vyayama into their lifestyle management plan.
- Healthcare providers should consider integrating Yog-vyayama into diabetes management programs.
- Yog-vyayama training programs should accommodate various HbA1c levels.
- Future research should explore the molecular mechanisms underlying Yog-vyayama's effects.
- Future research should explore personalized Yog-vyayama protocols for different HbA1c levels.
- Future studies should investigate Yog-vyayama's effects on other chronic diseases.
- Patients with T2DM should consult healthcare providers to determine optimal Yog-vyayama regimens.
- Healthcare providers should consider HbA1c stratification when recommending Yog-vyayama.

5.4 Clinical Implications:

- Healthcare professionals may consider recommending Combined Yog-vyayama as a valuable adjunctive therapy for the management of T2DM.
- Large-scale, randomized controlled trials are necessary to confirm these findings.
- Yog-vyayama may be use as complementary and alternative Medicine for the management of type 2 diabetes.
- Patients with poor glycemic control (HbA1c ≥ 8%) may benefit most considering combined Yog-vyayama treatment.
- Combination into existing treatment plans of Yog-vyayama may improve overall outcomes.

5.5 Constraints:

- Unrestricted Diet patterns
- Overall Biological clock of the subjects
- Non-residential training camp
- More Drop out participants from the intervention
- Adverse weather condition

5.6 Future Directions:

- Long-term follow-up studies.
- Investigation of Yog-vyayama's effects on other T2DM-related outcomes.
- Development of standardized Yog-vyayama protocols for different HbA1c levels.

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Annexure – 1

(Plagiarism Repots)

"Combined effect of Yog-vyayama on different levels of HbA1c in patients with Type 2 Diabetes Mellitus" by Biswajit Dhali

ORIGINALITY REPORT

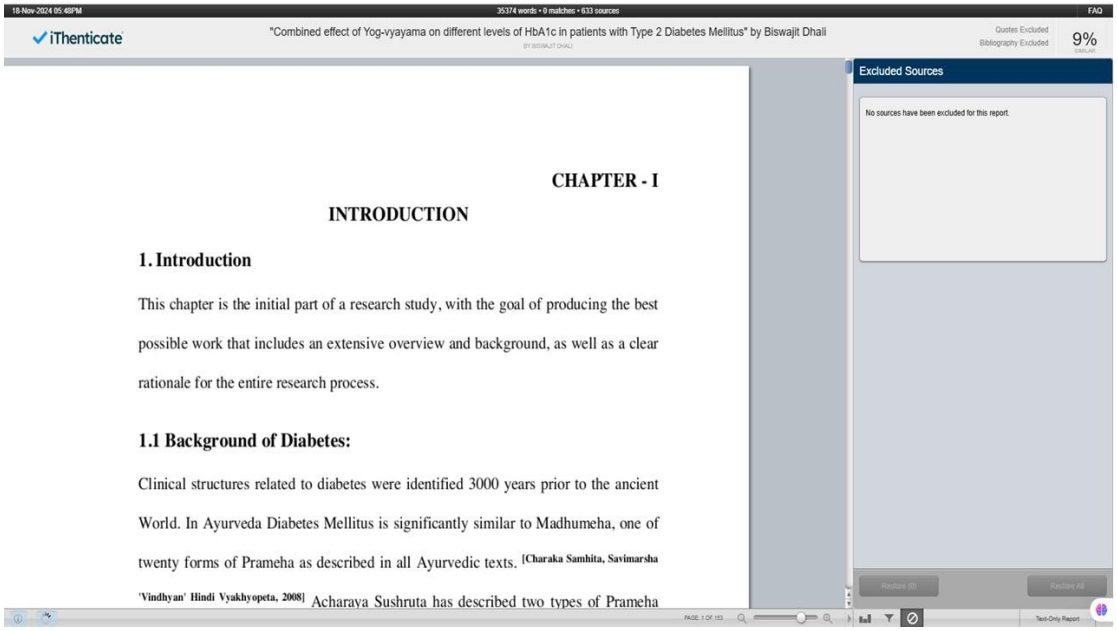
9%
SIMILARITY INDEX

PRIMARY SOURCES

1	elib.uni-stuttgart.de Internet	300 words — 1%
2	Varma, Vandana. "Association of Markers of Acute Phase Response to Serum Total Sialic Acid Levels in Type II Diabetic Patients with and Without Nephropathy and Its Correlation with the Antioxidant Levels.", Devi Ahilya Vishwavidyalaya, 2019 ProQuest	294 words — 1%
3	www.ejmste.com Internet	240 words — 1%
4	"Posters", The Journal of nutrition, health and aging, 2009 Crossref	136 words — < 1%
5	Debopriya Ghosh, Utpal sanyal, Dr. Anup Adhikari. "Effect of physical training on gender difference in trained personal", International Journal of Research in Hospital and Clinical Pharmacy, 2020 Crossref	136 words — < 1%
6	www.ncbi.nlm.nih.gov Internet	123 words — < 1%

This Report is Authentic

Dr. [illegible] Das
Professor & Supervisor
Department of Physical Education
Jadavpur University
Kolkata - 700 032



CHAPTER - I

INTRODUCTION

1. Introduction

This chapter is the initial part of a research study, with the goal of producing the best possible work that includes an extensive overview and background, as well as a clear rationale for the entire research process.

1.1 Background of Diabetes:

Clinical structures related to diabetes were identified 3000 years prior to the ancient World. In Ayurveda Diabetes Mellitus is significantly similar to Madhumeha, one of twenty forms of Prameha as described in all Ayurvedic texts. **[Charaka Samhita, Savimarsha 'Vindhyan' Hindi Vyakhyopeta, 2008]** Acharaya Sushruta has described two types of Prameha

This Report is Authentic
Professor & Supervisor
Department of Physical Education
Jadavpur University
Kolkata - 700 032

Annexure – 2

(Ethical information and Trial registration)

যাদবপুর বিশ্ববিদ্যালয়
কলকাতা-৭০০০৩২, ভারত

*JADAVPUR UNIVERSITY
KOLKATA-700 032, INDIA

Prof. Sudip Sundar Das
Dept. of Physical Education
Jadavpur University

Ref No: IEC/27/C/23
Date: 06.07.2023

Dear Sir/ Madam,

Institutional Ethics Committee (IEC) Approval

Title of the Study: COMBINED EFFECT OF YOGA AND VYAYAMA ON DIFFERENT LEVELS OF HBA1C IN PATIENTS WITH TYPE 2 DIABETES MELLITUS

The above application of **Biswajit Dhali** has been considered on behalf of the Jadavpur University Institutional Ethics Committee in accordance with the procedures laid down by the University for ethical approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to the Jadavpur University Institutional Ethics Committee, the proposed research has been judged as per meeting appropriate ethical standards, and accordingly approval has been granted in the meeting dated 15.03.2023.

Should there be any subsequent changes to the project, which raise ethical issues not covered in the original application, P.I. should submit details to the Jadavpur University Institutional Ethics Committee for consideration.

Hope this will serve your purpose.

Thanking You,

(Prof.Pritha Mukhopadhyay)
CHAIRPERSON
Professor,
Department of Psychology,
University of Calcutta
92, A.P.C. Road, Kolkata-700009

(Shri Indrajit Banerjee)
CONVENER
Secretary Faculty Council of Arts
Jadavpur University
Kolkata-32

Clinical Trial Details (PDF Generation Date :- Fri, 23 Aug 2024 06:55:29 GMT)

CTRI Number	CTRI/2024/08/072487 [Registered on: 13/08/2024] - **Trial Registered Prospectively**
Last Modified On	10/08/2024
Post Graduate Thesis	Yes
Type of Trial	Interventional
Type of Study	Yoga & Naturopathy
Study Design	Non-randomized, Multiple Arm Trial
Public Title of Study	Effect of Yog-Vyayama on Type 2 Diabetes Mellitus
Scientific Title of Study	Combined Effect of Yoga and Vyayama on Different Levels of HbA1c in Patients with Type 2 Diabetes Mellitus

Secondary IDs if Any

Secondary ID	Identifier
NIL	NIL

Details of Principal Investigator or overall Trial Coordinator (multi-center study)

Details of Principal Investigator	
Name	Dr Sridip Chatterjee
Designation	Associate Professor
Affiliation	Jadavpur University
Address	Department of Physical Education, Jadavpur University, 188, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032 Kolkata WEST BENGAL 700032 India
Phone	9674764085
Fax	
Email	sridipchatterjee.ped@jadavpuruniversity.in

Details Contact Person (Scientific Query)

Details Contact Person (Scientific Query)	
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Designation	Associate Professor
Affiliation	Jadavpur University
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Designation	Research Scholar
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	India
Phone	9647121103
Fax	
Email	biswajitdhali.pe.rs@jadavpuruniversity.in

Source of Monetary or Material Support

Source of Monetary or Material Support
> Jadavpur University, 188, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032

Primary Sponsor

Primary Sponsor Details	
Name	University Grant Commission
Address	University Grants Commission Bahadur Shah Zafar Marg, New Delhi - 110002
Type of Sponsor	Government funding agency

Details of Secondary Sponsor

Name	Address
NIL	NIL

Countries of Recruitment

List of Countries
India

Sites of Study

Name of Principal Investigator	Name of Site	Site Address	Phone/Fax/Email
Dr Sridip Chatterjee	Jadavpur University	Department of Physical Education, Jadavpur University, 188, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032 Kolkata WEST BENGAL Kolkata WEST BENGAL	9675764085 sridipchatterjee.ped@jadavpuruniversity.in

Details of Ethics Committee

Name of Committee	Approval Status	Date of Approval	Is Independent Ethics Committee?
IEC - Jadavpur University	Approved	06/07/2023	No

Regulatory Clearance Status from DCGI

Status	Date
Not Applicable	No Date Specified

Health Condition / Problems Studied

Health Type	Condition
Patients	Type 2 diabetes mellitus with unspecified complications

Intervention / Comparator Agent

Type	Name	Details
Intervention	Yogvyayama Training Within group comparison	There are three type II diabetes mellitus group with following HbA1C levels 1. Pre Diabetes Group A - 5.7 - 6.4 % 2. Diabetes Mellitus Group B - 6.5 - 10 % 3. Diabetes Mellitus Group C - above 10 %

Inclusion Criteria

Inclusion Criteria	
Age From	40.00 Year(s)
Age To	70.00 Year(s)
Gender	Both
Details	1. Type 2 Diabetes Mellitus with a history of diabetes for 0-10 years

	were selected as subjects. 2. HbA1c level of Subjects were above 5.7 % 3. Age ranging from 40 to 70 from both genders 4. The selected activities were Yoga and Vyayama. 5. 65 Minutes Yoga and Vyayama was take place for 24 weeks and five days per week. 6. Willingness to give written consent for participation in the study

Exclusion Criteria

Exclusion Criteria	
Details	1. Patients with type-1 Diabetes, gestational diabetes. 2. Below 5.7% HbA1c Level of Patients 3. Alcoholic Patients, or addiction to any forms of drug usage 4. Patients previously performing yoga or any other regular Physical exercise. 5. Uncontrolled diabetes, Morbid obesity 6. Recent major trauma or surgery that would interfere with participation 7. Pregnant women 8. Participation in any interventional study within the past 6 months 9. Persons identified with any other serious problem that can confound the outcome 10. Diagnosed with cardiovascular diseases, cancer 11. Diagnosed with neurological or psychological disorders 12. Mobility restrictions or inability to do yoga practices

Method of Generating Random Sequence	Not Applicable
Method of Concealment	Other
Blinding/Masking	Participant, Investigator, Outcome Assessor and Date-entry Operator Blinded

Primary Outcome

Outcome	Timepoints
Blood Glucose level, Fasting Insulin, HbA1c	Baseline, three months and six months

Secondary Outcome

Outcome	Timepoints
Lipid Profile, Blood Pressure, Heart Rate, Flexibility, SpO2, Waist circumference, Hip circumference, Grip Strength	Baseline, three months & six months

Target Sample Size	**Total Sample Size=**100 **Sample Size from India=**100 **Final Enrollment numbers achieved (Total)=**Applicable only for Completed/Terminated trials **Final Enrollment numbers achieved (India)=**Applicable only for Completed/Terminated trials
Phase of Trial	Phase 3
Date of First Enrollment (India)	26/08/2024
Date of First Enrollment (Global)	26/08/2024
Estimated Duration of Trial	**Years=**0 **Months=**6 **Days=**0
Recruitment Status of Trial (Global)	Not Applicable
Recruitment Status of Trial (India)	Not Yet Recruiting
Publication Details	N/A
Brief Summary	The proposed study tries to examine how yoga influences insulin Resistance in different HbA1c level of type-2 diabetic patients, alongside its effect on anthropometric parameters with minimum 65 hrs of yoga and vyayama practice spanning over 24 weeks

Annexure – 3

(Permission and Yog-vyayama Programme)

RECEIVED
DOCKET NO: 02
DATE: 19/12/23
Vice-Chancellor's Office
JADAVPUR UNIVERSITY
Kolkata - 700032

To,
The Vice Chancellor,
Jadavpur University,
Jadavpur, Kolkata – 700032

(Through proper channel)

Subject: Permission to conduct a Yog-Vyayama training camp in the University premises.

Respected Sir,

We are eager to appraise that a diabetes management camp based on yog-vyayama in Jadavpur University premises (Small Area Games Arena) for the fulfillment of the research work of Mr. Biswajit Dhali, a senior PhD scholar, Dept. of Physical Education, Jadavpur University.

We have already got an Ethical permission from Jadavpur University Institutional Ethics Committee (JUIEC) on the 6th July, 2023. We want to start yog-vyayama camp on and from January, 2024 to April, 2024. Our target population is Pre-diabetes and diabetes participants of university community and some other those who are residing near the university campus.

Considering the security of the university, and for smooth management of the camp, an identification through campus entry pass need to be issued to the participants as well. It may be issued jointly by the supervisor of the Ph.D scholar, joint coordinator of the yoga centre and head of the Department concerned.

So, we are here with a request to consider the above mentioned issue and allow us to conduct the said program which may be helpful to accomplish this research work smoothly.

Thanking you.

Date:

Sincerely Yours

13.12.23
Prof. Sudip Sundar Das,
Supervisor concerned
Professor
Physical Education
Jadavpur University
Kolkata - 700032

13/12/23
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Biswajit Dhali 13/12/23
Biswajit Dhali,
PhD Scholar,
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Enclosures:
1. Copy of the Ethical Approval
2. Sample copy of camp flyer
3. Sample copy of campus entry pass

Forwarded for Consideration
14/12/2023
HEAD
DEPT. OF PHYSICAL EDUCATION
JADAVPUR UNIVERSITY
KOLKATA-32

VC, Sir
Forwarded for favourable consideration
— Udaya Bhattacharya
14/12/23
DEAN
FACULTY OF ARTS
JADAVPUR UNIVERSITY
KOLKATA-32

Approved.
19/12/2023

Permission from University Authority

Initial advertisement of Yog-vyayama training camp

Registration of Yog-vyayama training camp

Orientation program of Yog-vyayama training camp

Pre-Check-up of Participant by the Diabetologist before Yog-vyayama training intervention

Dr. CONSULTING DOCTOR - NANO HEALTH/ READY KARE - 6

Nano Health/ Ready Kare - 6
CONTACT:

TEST DATE: **04/Mar/2024 14:36**

NAME: **DOLA BHATTACHARYA** PATIENT ID: **1A3ED2** GENDER: CONTACT: **9433936757** DOB: **04-Mar-1967**

AGE: **57** CONSULTATION ID: REPORT ID: **REP131378** DIABETIC: **Yes** HbA1c:

OVERVIEW

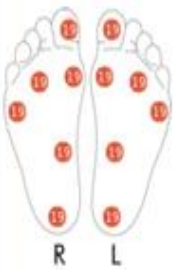
Diabetic Peripheral Neuropathy is the most common cause leading to foot ulceration, and can result in limb amputation. Diabetic patients are recommended to undergo comprehensive foot examination annually. In case of abnormal test results, patients are recommended to undergo a comprehensive foot assessment at least once in 3 months. If a patient is diagnosed with Peripheral Neuropathy, the patient's feet need to be inspected daily for corns, calluses, cuts, blisters, sores, signs of infection and changes in colour or temperature of the skin. It is recommended the patient consults the doctor immediately if any of the above signs are noticed.

RESULTS

MONOFILAMENT

Low Risk of Peripheral Neuropathy: Tactile sensation is felt using a 10 gram monofilament at Hallux, 1st, 3rd, and 5th Metatarsal Heads bilaterally

High Risk of Peripheral Neuropathy: Value greater than 10 grams at any one of the 4 points - Hallux, 1st, 3rd, and 5th Metatarsal Heads



VIBRATION PERCEPTION

Intermediate Risk of Peripheral Neuropathy

Low Risk of Peripheral Neuropathy: Vibration detected below 15V

Intermediate Risk of Peripheral Neuropathy: Vibration detected between 16 V to 24 V at any one of the test points

High Risk of Peripheral Neuropathy: Value detected above 25V at any one of the test points

Reference - International Diabetes Federation. Clinical Practice Recommendation on the Diabetic Foot: A guide for healthcare professionals: International Diabetes Federation, 2017.

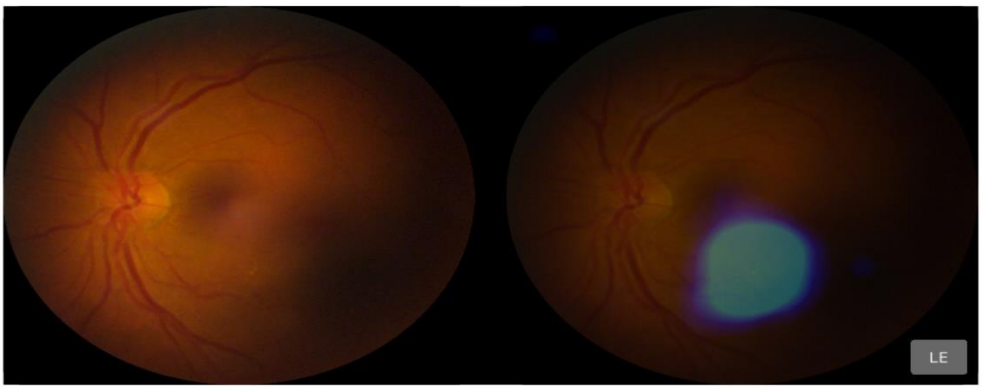
Foot Neuropathy test with one Sample copy of Report

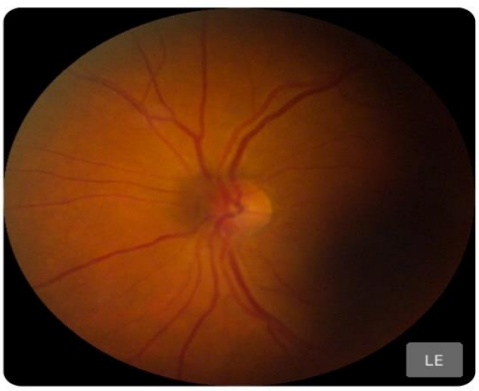
ReadyKare
Device-2389

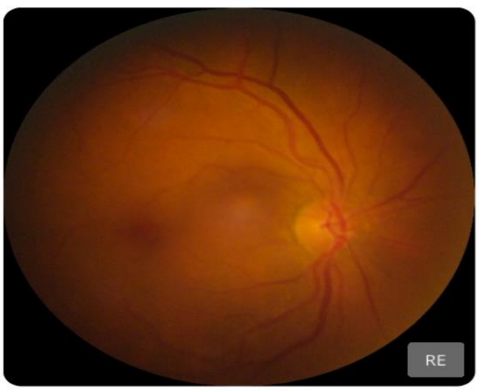
Diabetic Retinopathy Report

Patient MRN:	D10DBC	Gender:	Female	Age:	61
Patient Name:	Nivedita Chatterji	Doctor:	Mary D Cruz	Date:	04 Mar 2024

Result: Signs of Retinopathy detected. Examples of lesions are highlighted.







Medios AI is a physician assist software, not a replacement for an ophthalmologist's diagnosis. The results are only indicative of a high probability of Moderate NPDR or more severe disease. This report does not screen for any medical or vision conditions apart from Diabetic Retinopathy. The images on this report are only thumbnails and must not be used for diagnostic purposes. Any heat maps shown are only indicative of some probable areas of abnormality.

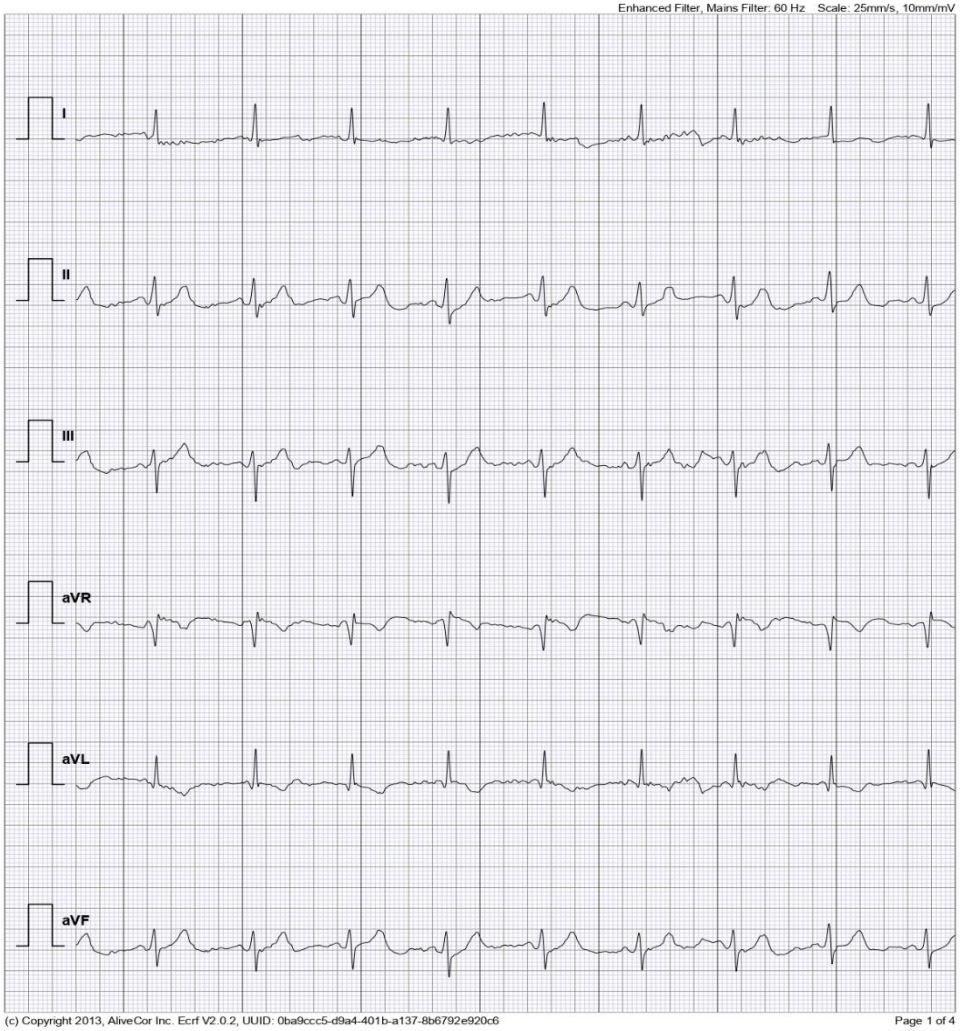
remidio medios

Retinopathy test with one Sample copy of Report

Patient: Pradip Sankar Moulik
ID: IECGR_2346-133
Recorded: Monday, 04 Mar, 2024, 5:14:03 pm
Heart Rate: 80 bpm **Duration:** 30s

Instant Analysis: Normal
* Instant Analysis is done on Lead I.

Enhanced Filter, Mains Filter: 60 Hz Scale: 25mm/s, 10mm/mV



Instant 30sec ECG test with one Sample copy of Report

Six months Yog-vyayama intervention for the study

Annexure - 4

INFORMED CONSENT FORM

Research Information:

Study title: "Combined effect of Yog-vyayama on different levels of HbA1c in patients with Type 2 Diabetes Mellitus".

Name of the research scholar: Biswajit Dhali, Dept. of Physical Education, Jadavpur University.

Purpose: To investigate the combined effect of Yog-vyayama on glycemic control in patients with type 2 diabetes mellitus, and to determine its efficacy in improving glycemic control across different HbA1c level.

Duration: 50-75 minutes and four days for Six months

Subject's name : …… Age : ……..…..… Sex : ……..……

I confirm that I have read and understood/have been explained the information given by the researcher/moderator and I had an opportunity to ask questions.

I understand that the participation in the study is voluntary and I am free to withdraw at any time without giving any reason and without being my medical care and legal rights being affected.

I understand that my identity will not be revealed to any third party or in publication.

I understand that the researchers/ regulatory authorities/ ethics committee will not need my permission to access my health records if necessary for the current study.

I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).

I agree to take part in the above study.

Signature of the subject :……..…… Date:…….

Name of the Investigator (printed)……..

Signature of the investigator……Date…….

Name and signature of the impartial witness with date if required

…….

Signature of the Researcher……Date…….

Annexure – 5

(Journal Publication and Seminar Presentation)

1

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Effect of Yoga on Insulin Resistance in Type 2 Diabetes: A Systematic Review and Meta-Analysis

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Save all to author list

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Abstract

Objective: We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to observe the efficacy of yoga on insulin resistance in type 2 diabetes (T2D). Materials and methods: The present systematic review and meta-analysis were done following the PRISMA guidelines. Data were collected through specific keyword searches from eminent databases. The risk of bias in included studies was assessed, using the revised Cochrane risk-of-bias tool. Meta-analysis was performed using RevMan software. Forest plots were used to illustrate the study findings and meta-analysis results. Results: A total of six studies were finally included in this systematic review, where 375 participants were allocated to a yoga intervention with the control group, and the age range of participants was 15–75 years. In the yoga group compared to the control, there was a significant reduction in fasting blood glucose (FBG) by 33.02 mg/dL, post-prandial blood glucose (PPBG) by 62.54 mg/dL, fasting insulin by 4.95 µIU/mL and insulin resistance (HOMA-IR) by 2.81 in the meta-analysis. Conclusions: Regular yogic practice with oral hypoglycemic agents (OHA) have positive effects on insulin resistance compared to the control group (no regular exercise with OHA) in patients with type 2 diabetes. (Clin Diabetol 2023; 12; 3: 201–208)

Author keywords

insulin resistance; meta-analysis; type 2 diabetes; yoga

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Effect of Yoga on Insulin Resistance in Type 2 Diabetes: A Systematic Review and Meta-Analysis

ABSTRACT

Objective: We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to observe the efficacy of yoga on insulin resistance in type 2 diabetes (T2D).

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Conclusions: Regular yogic practice with oral hypoglycemic agents (OHA) have positive effects on insulin resistance compared to the control group (no regular exercise with OHA) in patients with type 2 diabetes. (Clin Diabetol 2023; 12; 3: 201–208)

Keywords: meta-analysis, yoga, type 2 diabetes, insulin resistance

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Introduction

Yoga originated in ancient India more than 5000 years ago and is a means of balancing and harmonizing the body, mind, and emotions. The yogic practice embraces moral observances (Yama), self-disciplines (Niyama), physical postures (asana), voluntarily controlled breathing (Pranayama), sensory withdrawal (Pratyahara), concentration (Dharana), meditation (Dhyana), self-realization (Samadhi), and certain philosophical principles [1]. Yoga, as part of Vedic philosophy, emphasizes the unity of mind, body, and soul in the human body [2].

Yoga practice is useful in controlling numerous lifestyle diseases, including type 2 diabetes (T2D). Psycho-neuro-endocrine and immune mechanisms are convoluted in the beneficial effects of yoga on diabetes. Regular yogic practice with proper guidance is beneficial for controlling numerous lifestyle diseases, including type 2 diabetes. The various postures during yoga practice help to improve the sensitivity of ß-cells to glucose, thereby refining insulin secretion, and surging the blood supply to the muscle, thereby promoting glucose uptake [3].

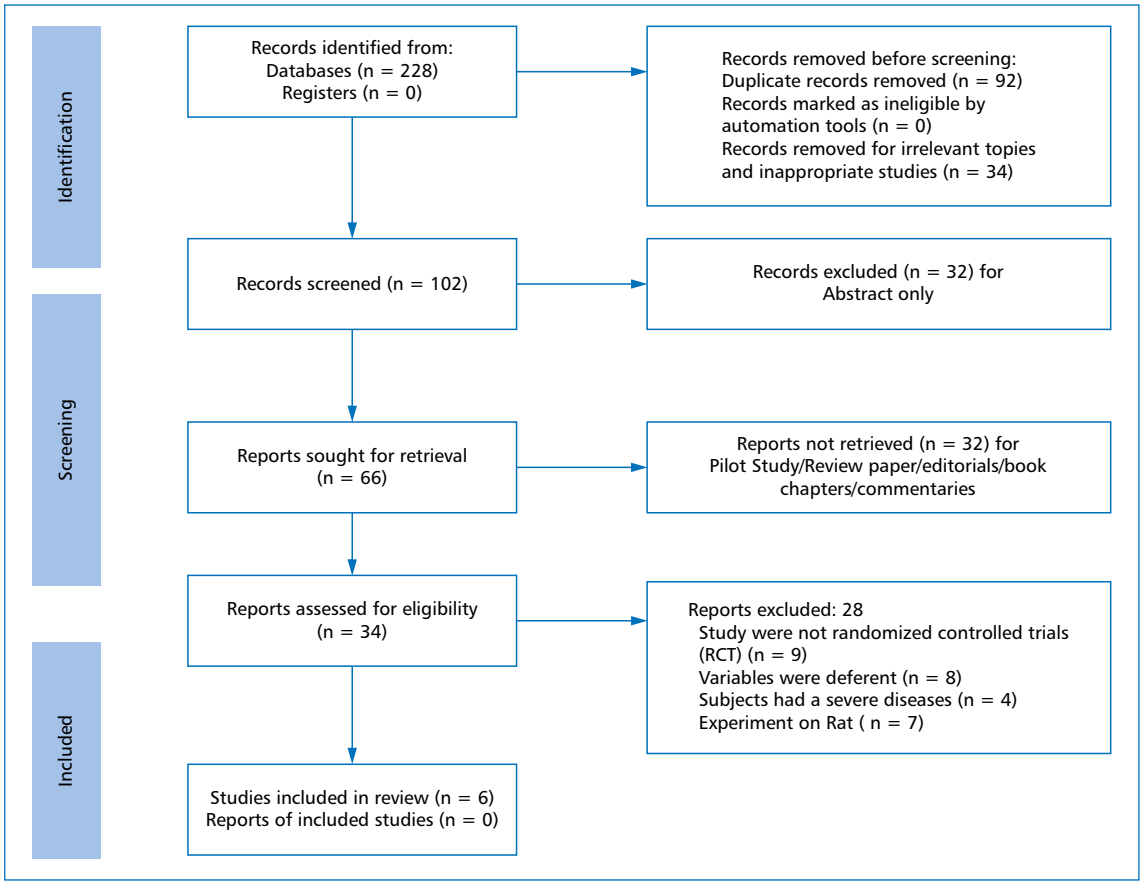

Figure 1. Flow Diagram of the Present Study Prepared as per PRISMA Guidelines

There are several systematic reviews and meta-analyses examining the benefits of yoga for diabetes management, but there is no study directly conducted to observe the effect of yoga on insulin resistance in type 2 diabetes. Hence, the present study aims to systematically evaluate the literature and conduct meta-analyses of randomized controlled trials (RCTs) to evaluate the effectiveness of yoga on insulin resistance in type 2 diabetes.

Materials and Methods

This systematic review and meta-analysis was conducted in accordance with PRISMA guidelines [4].

Search strategies

The data were gathered by searching the online databases Scopus, Web of Science, PubMed, Science Direct, MDPI, BioMed Central, and Medline to find appropriate articles using the keywords "type 2 diabetes", "T2D", "yoga", "yoga and type 2 diabetes", "insulin resistance", "yoga and insulin resistance". Proper articles, restricted to human subjects and written in English were included in this study. After obtaining related articles from the above databases, duplicates and some unsatisfactory studies were screened and excluded through the process of identification, screening, and inclusion as followed by the PRISMA guidelines. After the final assessment, appropriate studies were included in this systematic review and meta-analysis. Figure 1 illustrates the complete selection process.

Eligibility criteria

Inclusion criteria

The existing studies followed the PICOS criteria [5], including:

1. (P) Participants: type 2 diabetes mellitus patients;
2. (I) Intervention: Yogic exercise;
3. (C) Control: without any regular exercise;
4. (O) Outcomes: fasting blood glucose (FBG), post-prandial blood glucose (PPBG), glycated hemoglobin (HbAlc), fasting insulin level and homeostatic model assessment for insulin resistance (HOMA-IR);
5. (S) Study design: randomized controlled trials (RCT).

Exclusion criteria

1. Participants: adolescents with T2D (under 15 years of age) and geriatric age groups (above 75 years of age); those who had any severe diseases; those who were pregnant; and those who were participating in another regular physical exercise program at the same time;
2. Non-randomized controlled trials (NRCT) were excluded;
3. Pilot studies, review studies, duplicate studies, only abstracts, conference proceedings, editorials, book chapters and commentaries were excluded.

Data extraction

Data were withdrawn from the included articles [6–11] by the first reviewer (BD) using a structured form on MS Excel and it was cross-checked for precision by the second reviewer (SC). The data were extracted from every study based on six categories: (a) Study Details (first author and publication year), (b) Participants (sample size along with male/female and age), (c) Details of Intervention: (type of yoga: frequency, duration, time and intensity) (d) Details of the Control Group (no exercise with or without standardised care (medication), (e) Outcomes (FBG, PPBG, HbA1c, fasting insulin and HOMA-IR) and (f) Study Design (randomized controlled trials) that is summarized in Table 1, some differences in the extracted data were determined by discussion, with a contribution of the second, third and fourth reviewer (SC, SSD and MD) when necessary.

Risk of bias assessment

The risk of bias in the involved articles was assessed by the revised Cochrane risk-of-bias tool for randomized controlled trials (RoB-2) [12]. Using this tool, the risk of bias in this study was evaluated through the 5 domain. 1) Risk of bias arising from the randomization procedure; 2) Risk of bias due to deviances from the suggested interventions (effect of assignment to intervention and adhering to intervention); 3) Risk of bias caused by missing outcomes; 4) Risk of bias in quantity of the outcomes and 5) Risk of bias in the collection of the stated result. The risk of bias is classified as "Low risk", "Some concerns" and "High risk".

Statistical analysis

Numerical results were accumulated from the included studies for the statistical meta-analysis using RevMan statistical software (version 5.4.1). The effect size was measured by taking the difference in mean and standard deviation of FBG, PPBG, fasting insulin and HOMA-IR in the subjects of pre- and post-intervention in both the experimental group and the control group. If the study failed to report this data, the effect size of the mean difference and SD difference was calculated by the following formula [13, 14] *Mean difference* = = Baseline Mean – Final Mean

$$SD\ difference = \sqrt{SD^2\ baseline + SD^2\ final - (2 \times r \times \times\ baseline\ SD \times final\ SD)}$$

where r equals 0.7. Gowri et al. [6] reported only the median and interquartile range (upper and lower value) in their study so in that case from median (m), first quartile (q1), and third quartile (q3) sample mean ($\bar{x}$) and SD were calculated using this formula [15] $\bar{x} = \frac{q_1 + m + q_3}{3}$ and $SD = \frac{q_3 - q_1}{1.35}$. Mean difference and 95% confidence intervals were used as the summary statistic for the overall effect sizes. The I^2 statistic was used to test for heterogeneity of the effect size among studies included in the meta-analysis. Forest plots were used to express the outcomes of the study and meta-analysis results (Fig. 2). FBG and PPBG were stated as mg/dL, and for studies which stated these parameters as mmol/L, a numerical conversion to mg/dL was done. Fasting insulin was specified as μIU/mL, and for studies specified this parameter as pmol/L or ug/dL, a numerical conversion to μIU/mL was done. Funnel plots were used to illustrate the publication bias in the meta-analysis of the efficacy of yoga and the control group (no exercise) on FBG, PPBG, HbA1c, fasting insulin and HOMA-IR (Fig.3). In order to measure insulin resistance, HOMA-IR formula was employed. This formula is HOMA-IR = fasting insulin (μIU/mL) × fasting glucose (mmol/L)/22.5 [8, 16].

Results

Literature search

Literature search was shown according to the searching criterion that is illustrated in Figure 1. There were a total of 228 articles identified through keyword searches from across the seven databases. Every single article was individually screened by title resulting in 92 duplicate records removed and 34 records removed for irrelevant topics and inappropriate studies before screening. After screening the 102 studies 36 studies were excluded for Abstract only. Following this, 32 studies were excluded because they fell into one of the following categories: pilot study, review article, conference proceedings, editorial, book chapter, and commentary. The remaining 28 studies were not eligible for our meta-analysis because they were non-randomized controlled trials, and due to different variables, severe diseases of subjects and experiments conducted on rats.

Study characteristics

After the removal of duplicates, screening of studies and excluding some studies, six studies (randomized

Table 1. Characteristics of Included Studies of Yoga Intervention and Control Group

Sl. No.	Authors and year	Participants (recruited, sex and age)	Intervention (type, intensity and duration)	Comparison condition	Outcomes	Study design
	Gowri et al., 2022	Yoga: M/F 14/21 54 ± 13 years Control: M/F 23/12 52.5 ± 11.2 years	Yoga 60 min/day, 2 days/week for 16 weeks	Control group with standard medication	BMI, FBG, PPBG, HbA1c, insulin, HOMA-IR	RCT
2	Danasegaran et al., 2021	Yoga: M/F 40/0 51.95 ± 6.17 years Control: M/F 40/0 51.48 ± 8.47 years	Yoga 40 min/day, 5 days/week for 12 weeks with medication	Control group with standard medication	BMI, SBP, DBP, FPG, Insulin, HOMA-IR, lipids.	RCT
3	Pahlevaninejad,, 2019	Yoga: M/F 0/8 47.37 ± 3.62 years Control: M/F 0/8 44.62 ± 3.24 years	Yoga 75 min/day, 3 days/week for 8 weeks	Control group	BMI, WHR, FBG, insulin, HOMA-IR, creatinine	RCT
4	Keerthi et al. 2017	Yoga: M/F 31/29 37.28 ± 6.21 years Control: M/F 32/27 36.72 ± 6.12 years	Yoga 38–45 min/day, 3 days/week for 12 weeks	Control group	WHR, FPG, insulin, HOMA-IR,	RCT
5	Chen et al. 2016	Yoga: M/F 0/15 18–25 years Control: M/F 0/15 18–25 years	Yoga 60 min/day, 2 days/week for 8 weeks	Control group	Insulin, FPG, HOMA-IR, lipids, SBP, DBP, BMI	RCT
6	Singh et al. 2008	Yoga: M/F 30/0 35–60 years Control: M/F 30/0 35-60 years	Yoga 45 min/day, 7 days/week for 6 weeks	Control group with standard medication	BMI, FBG, PPBG, lipids, insulin	RCT

BMI — body mass index; DBP — diastolic blood pressure; FBG — fasting blood glucose; FPG — fasting plasma glucose; HbA1c — glycated hemoglobin; HOMA-IR — Homeostatic Model Assessment for Insulin Resistance; IR — insulin resistance; PPBG — postprandial blood glucose; RCT — randomized controlled trial; SBP — systolic blood pressure; WHR — waist–hip ratio

controlled trials) were finally included in this systematic review as yoga intervention group with control group that is summarized in Table 1. In total, 375 participants (male — 240 and female — 135) were assigned to yoga with control group and the age range of subjects was 15–75 years.

In this study, yoga intervention involved loosening exercises, breathing exercises, asanas, pranayama, kriya and relaxation techniques also included meditation, prayer and Savasana. Maximum articles used yoga interventions like Tadasana, Trikonasana, Ardha-Matsyendrasana, Pawanmuktasana, Paschimottanasana, Savasana; Anulom-Vilom pranayama, Bhamri pranayama; Kapalbhati kriya; OM mantra. The majority of the studies used 40–60 minutes per day; 2–3 days per week and 8–12 weeks yoga intervention.

Risk of bias analysis

According to the criteria of the revised Cochrane risk-of-bias tool for randomized controlled trials that is illustrated in Table 2, five studies showed 'low risk of biases, because these five studies were considered to be at low risk of bias for all domains for these outcomes. One study showed 'some concerns' as this study was judged to raise some concerns in a minimum of one domain for this result, but not to be at high risk of bias in any domain.

Fasting blood glucose

The effect of fasting blood glucose was considered in six studies (6 interventions, n = 375) [6–11] involved in the meta-analysis. Forest plots for FBG in Figure 2A show that there was a significant decrease in FBG in the yoga group compared to the control group. The collective mean difference for FBG of the yoga group and the control groups from random effects analysis was 33.02 mg/dL (95% CI: –54.91, –11.13) and the statistical heterogeneity as stated by I^2 = 97% was statistically significant ($p < 0.00001$).

Post-prandial blood glucose

There were two studies (2 interventions, n = 130) [6, 11] where the effect of yoga on post-prandial blood glucose (PPBG) was considered. Forest plots for PPBG in Figure 2B showed a significant reduction in PPBG in the yoga group compared to the control group. The pooled mean-difference of PPBG between the yoga group and the control groups of the random effects analysis was 62.54 mg/dL (95% CI: –86.67, –38.42 and the statistical heterogeneity was indicated by I^2 = 37%, p = 0.21).

Fasting insulin

Fasting insulin level was assessed in six studies (6 interventions, n = 375) [6–11]. Forest plots for fasting

Table 2. Risk of Bias Assessment of the Included Studies

Sl. No	Author and year	Domain 1 (Randomization process)	Domain 2 (Assignment to intervention)	Domain 2 (Adhering to intervention)	Domain 3 (Missing outcome data)	Domain 4 (Measurement of the outcome)	Domain 5 (Reported result)	Overall risk of bias
1	Gowri et al., 2022	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
2	Danasegaran et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
3	Pahlevaninejad, 2019	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
4	Keerthi et al., 2017	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
5	Chen et al., 2016	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
6	Singh et al., 2008	Low risk	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns

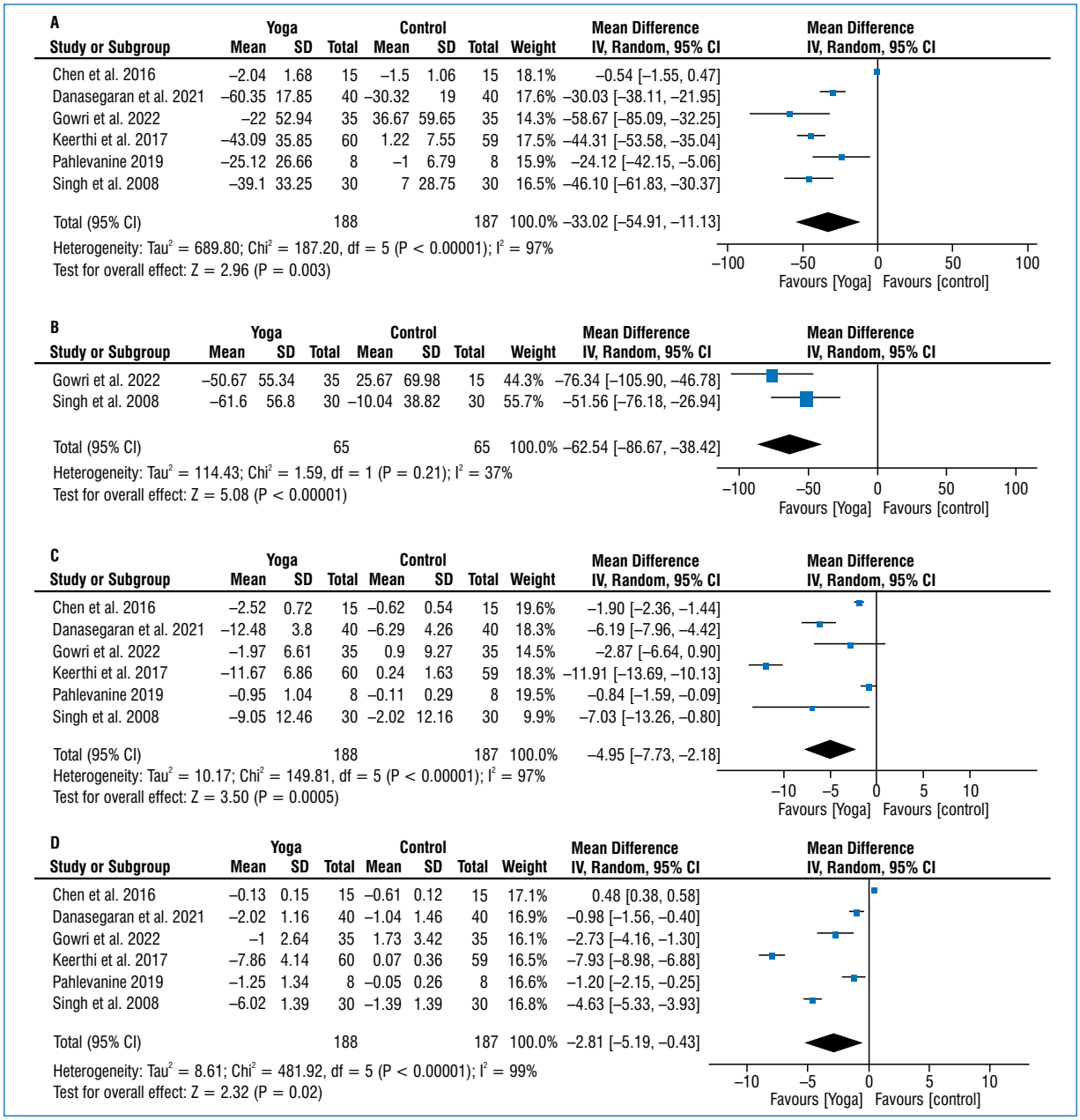

Figure 2. Forest Plots Presenting the Effect of Yoga Compared to Control Group on (**A.**) Fasting Blood Glucose (**B.**) Postprandial Blood Glucose, (**C.**) Fasting Insulin and (**D.**) Insulin Resistance
CI — confidence interval; df — degrees of freedom, I — indicates the level of heterogeneity, SD — standard deviation

insulin in Figure 2C showed the pooled mean difference in fasting insulin level between the yoga group and the control group of the random effects analysis was 4.95 μIU/mL (95% CI: –7.73, –2.18 and the statistical heterogeneity was indicated by $I^2 = 97\%$, $p < 0.00001$).

Homeostatic Model Assessment for Insulin Resistance (HOMA-IR)

HOMA-IR was assessed in six studies included in the meta-analysis (6 interventions, n = 375) [6–11]. Forest plots for HOMA-IR in Figure 2D showed the pooled mean-difference in HOMA-IR between the yoga group and the control groups of the random effects analysis was 2.81 (95% CI: –5.19, -3.93) and the statistical heterogeneity of the data as indicated by $I^2 = 99\%$ was significant ($p < 0.00001$).

Discussion

Yoga and insulin resistance in patients with type 2 diabetes were investigated in this meta-analysis. Six studies with 375 adults (male — 240 and female — 135) comparing the yoga intervention to a control

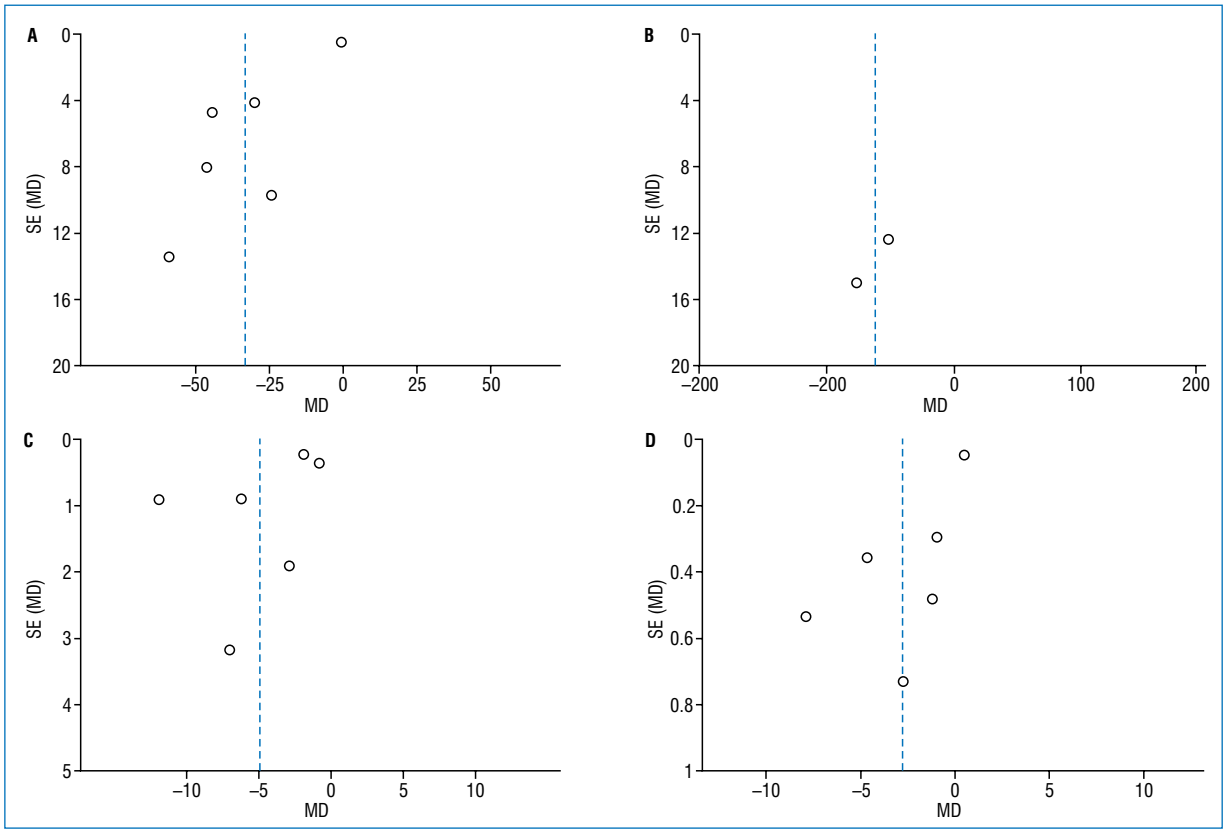

Figure 3. Funnel plots of estimate of publication bias in meta-analysis of the efficacy of Yoga compared to Control group (no exercise) on (**A.**) Fasing Blood Glucose, (**B.**) Postprandial Blood Glucose, (**C.**) Fasting Insulin and (**D.**) Insulin Resistance

group were evaluated. Yoga interventions improved FBG, PPBG, fasting insulin and HOMA-IR compared to the control group. Our results showed a significant reduction in FBG (33.02 mg/dL), PPBG (62.54 mg/dL), fasting insulin (4.95 μIU/mL) and HOMA-IR (2.81) in the yoga intervention compared to the control group (no exercise) in the meta-analysis. Only one study by Gowri et al. [6] evaluated the HbA1c and there was a significant fall in HbA1c level in the yoga group compared to the control group.

Keerthi et al. [9] showed that 12 weeks of yoga given along with standard treatment improved quality of life and reduced diabetes risk scores in patients with diabetes. Gowri et al. [6] showed that the management of combined yoga therapy for individuals with diabetes leads to a significant improvement in glycemic control, insulin resistance, and key biochemical parameters. Yoga helps improve glucose tolerance and insulin sensitivity, anthropometric characteristics, lipid profiles, and blood pressure in diabetes [17]. Some studies showed a reduction in FBG, PPBG, and HbA1c in the control group when comparing the pre- and post-intervention data, which was due to taking of OHA and was not statistically significant [18]. Diabetes is a psychosomatic disease that involves both mind and body, so psycho-neuro-endocrine and immune mechanisms are involved in the beneficial effects of yoga on diabetes [19].

According to the results of this study, the following yoga poses may be recommended: asanas such as Tadasana, Trikonasana, Ardha-Matsyendrasana, Pawanmuktasana, Paschimottanasana, Savasana; Kapalbhati kriya; Anulom-Vilom pranayama and OM mantra meditation for 45–60 minutes per day, five days per week, were more beneficial for type 2 diabetes patients by improving insulin resistance. Asanas, pranayama, kriya, and meditation should be the focus of future studies, with an emphasis on the effects of different intensities of yoga interventions.

Conclusions

In conclusion, this systematic review and meta-analysis delivers a strong indication to conclude whether yoga with oral hypoglycemic agent (OHA) has positive effects on insulin resistance and glycemic control compared to the control group (no regular exercise) with taking OHA in patients with T2D.

Funding

None.

Conflict of interest

None declared.

Acknowledgments

Not applicable.

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Effect of Yoga and Walking on Glycemic Control for the Management of Type 2 Diabetes: A Systematic Review and Meta-analysis

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Abstract

Background: A daily habit of yogic practice or walking, along with an oral hypoglycemic agent (OHA) could be beneficial for better control of type 2 diabetes mellitus (T2DM). We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to find out the efficiency of yoga or walking on glycemic control in T2DM.

Methodology: The present systematic review and meta-analysis were completed according to the PRISMA guidelines. The risk of bias in included studies was evaluated, by using the revised Cochrane risk-of-bias tool for randomized trials. Meta-analysis was implemented using RevMan software. Forest plots were used to illustrate the study findings and meta-analysis results.

Results: Sixteen studies were included in this systematic review, where 1820 participants were allocated to one of the following interventions: yoga, walking, and without any regular exercise (control group). Participants were between 17-75 years of age. Compared to the control group, the yoga group had a significant reduction in fasting blood glucose (FBG) by 31.98 mg/dL (95% CI = -47.93 to -16.03), postprandial blood glucose (PPBG) by 25.59 mg/dL (95% CI = -44.00 to -7.18], glycosylated hemoglobin (HbAlc) by 0.73% (95% CI = -1.24 to -0.22), fasting insulin by 7.19 µIU/mL (95% CI = -12.10 to -2.28), and homeostatic model assessment for insulin resistance (HOMA-IR) by 3.87 (95% CI = -8.40 to -0.66). Compared to the control group, the walking group had a significant reduction in FBG by 12.37 mg/dL (95% CI = -20.06 to -4.68) and HbA1c by 0.35% (95% CI = -0.70 to -0.01). Compared to the walking group, the yoga group had a significant reduction in FBG by 12.07 mg/dL (95% CI = -24.34 to - 0.20), HbA1c by 0.20% (95% CI = -0.37 to -0.04), fasting insulin by 10.06 µIU/mL (95% CI = -23.84 to 3.71) and HOMA-IR by 5.97 (95% CI = -16.92 to 4.99).

Conclusions: Yoga or walking with OHA has positive effects on glycemic control. For the management of T2DM, yoga has relatively more significant effects on glycemic control than walking.Review registration number: PROSPERO registration number CRD42022310213.

Keywords: glycemic control; insulin resistance; type 2 diabetes; walking; yoga.

REVIEW ARTICLE

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Conclusions. Yoga or walking with OHA has positive effects on glycemic control. For the management of T2DM, yoga has relatively more significant effects on glycemic control than walking.

Review registration number: PROSPERO registration number CRD42022310213

Key words: yoga, walking, type 2 diabetes, glycemic control, insulin resistance

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a common metabolic disorder characterized by chronic hyperglycemia.[1] It is affected by a combination of two primary factors: defective insulin secretion of pancreatic β-cells and the inability of insulin-sensitive tissues to respond appropriately to insulin.[2] Poor glycemic control among T2DM patients is a major community health problem and is a significant risk factor for the advancement of diabetic complications. Glycemic control is the key healing objective for the prevention of organ damage and other health-related problems from diabetes. A rapid change in people's lifestyle in terms of physical inactivity collectively increases metabolic complications and gives rise to the problems related to T2DM.[3]

Yoga is an ancient pre-Vedic science and a way of life. Yoga originated in ancient India over 5000 years ago. It mainly aims to develop the psychophysiological health of an individual. The practice of yoga embraces moral observances *(Yama)*, self-disciplines *(Niyama)*, physical postures *(Asana)*, voluntarily controlled breathing *(Pranayama)*, Sensory withdrawal *(Pratyahara)*, Concentration *(Dharana)*, Meditation *(Dhyana)*, and self-realization *(Samadhi)* and certain philosophical principles.[4] Regular yogic practice

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with proper scientific dose is beneficial for controlling numerous lifestyle diseases, including type 2 diabetes.[5] Walking is a natural and primitive exercise pattern that an individual follows from childhood. It is the fundamental base of locomotion and good exercise for the whole body.[6]

A daily habit of yogic practice reduces mental and oxidative stress and is beneficial to attain glycemic control.[5,7] A growing body of evidence reports that regular physical activity like walking or yoga has a beneficial effect on metabolic activity by helping to promote better glycemic control.[7,8] Scientific research on walking suggests that walking is one of the safest cardiovascular activities that improves glycemic control and insulin sensitivity.[6,8]

Walking and yoga have an impact on glycemic control and insulin resistance for type 2 diabetes patients. The aim of this systematic review and meta-analysis was to pool all experimental results of randomized control trials (RCTs) to update and consolidate the evidence on the effect of yoga and walking on glycemic control in patients with T2DM.

METHODOLOGY

The present systematic review and meta-analysis was completed following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[9]

Search strategies

Data were collected by searching the online databases PubMed, Scopus, Web of Science, BioMed Central, ClinicalTrials.gov, and International Clinical Trials Registry Platform (ICTRP) to find out appropriate RCTs. The following keywords were used: 'type 2 diabetes,' 'T2DM,' 'yoga,' 'walking,' 'yoga and Type 2 diabetes,' and 'walking and Type 2 diabetes,' which is illustrated in Table 1. Appropriate trials were limited to human subjects and only trials published with the full text in the last 10 years (2012 to 2022) and written in English were included in this study. The related studies acquired from the above databases were assembled and duplicates were removed; some inappropriate studies were further screened and excluded by reading the title, abstract, and selected manuscripts. After the final assessment, eligible articles were included in the systematic review and meta-analysis. The total selection process is illustrated in Figure 1.

Eligibility criteria

Inclusion criteria

The existing studies followed the PICOS criteria,[10] including:

1. (P) Participants: patients with type 2 diabetes mellitus with standard medication (OHA).
2. (I) Intervention: walking and yoga.
3. (C) Control: without any regular exercise.
4. (O) Outcomes: fasting blood glucose (FBG), postprandial blood glucose (PPBG) and glycosylated hemoglobin (HbAlc), fasting insulin level and homeostatic model assessment for insulin resistance (HOMA-IR).
5. (S) Study design: randomized controlled trials (RCT).

Exclusion criteria

1. Participants: adolescents with T2DM (under 17 years of age) and geriatric age groups (above 75 years of age); those with severe diseases or any severe illness; pregnancy; those who were participating in another physical exercise program at the same time.
2. Study design: articles that were not RCTs were not included in the study;
3. Review studies, duplicate studies, only abstracts, conference proceedings, editorials, book chapters, and commentaries were excluded.
4. Studies published before the year 2012 were excluded.

Risk of bias assessment

The risk of bias in included studies was evaluated by using the revised Cochrane risk-of-bias tool for randomized controlled trials (RoB-2)[11] which is illustrated in Table 5. According to this tool, the risk of bias in the study was assessed through five Domains. 1. Risk of bias arising from the randomization procedure; 2. Risk of bias due to deviances from the intended interventions (effect of assignment to intervention and adhering to intervention); 3. Risk of bias due to missing results data; 4. Risk of bias in the measurement of the outcome; and 5. Risk of bias in the selection of the reported outcome. The risk of bias is classified as "Low risk," "Some concerns," and "High risk".

Statistical analysis

Quantitative outcomes were collected from the included studies[3,6,12-25] for the statistical meta-analysis was performed by using RevMan statistical software (version 5.4.1). In order to pool the measures of treatment effect, a random effects model based on the inverse variance method was

Table 1. Articles identified according to search sequence and database used for the systematic review

Bibliographic databases↓	Search strategies			
	Yoga vs control on T2DM	Walking vs control on T2DM	Yoga vs walking on T2DM	Other exercises on T2DM
PubMed = 154	64	52	16	22
Scopus = 113	40	38	17	18
Web of Science = 99	28	29	18	24
BioMed Central = 79	28	29	13	9
ClinicalTrials.gov (United States National Library of Medicine) = 27	12	8	4	3
International Clinical Trials Registry Platform (ICTRP) = 26	6	8	0	12

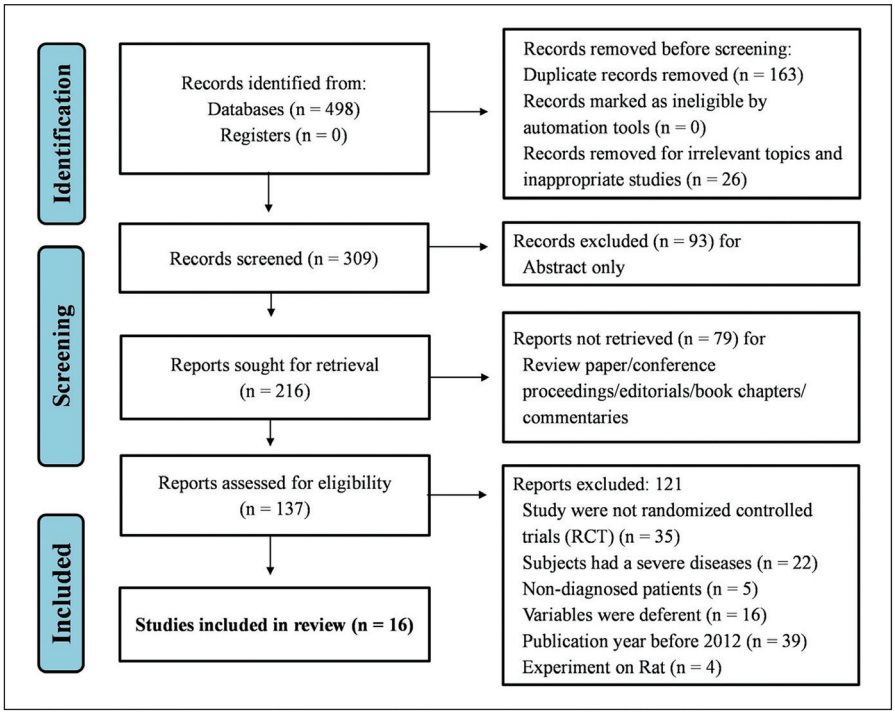

Figure 1. Flow diagram of the present study prepared as per PRISMA guidelines.

used. The effect size was calculated by taking the difference from mean and standard deviation (SD) of FBG, PPBG, HbA1c levels, fasting insulin, and HOMA-IR in the subjects before and after the intervention in both the experimental group and the control group. If the study failed to report this data, the effect size of the mean difference and SD difference was calculated by the following formula:[26,27]

$$\text{Mean difference} = \text{BaselineMean} - \text{FinalMean},$$

$$\text{SD difference} = \sqrt{\text{SD}^2\text{baseline} + \text{SD}^2\text{final} - (2 \times r \times \text{baselineSD} \times \text{finalSD})}$$

where r=0.7. Gowri et al., reported only the Median and interquartile range (upper and lower value) in their study so in that case from Median (m), First quartile (q1), and Third quartile (q3) sample Mean ($\bar{x}$) and SD was calculated by using this formula $x = \frac{q_1 + m + q_3}{3}$ and $SD = \frac{q_3 - q_1}{1.35}$.[28]

Mean difference and 95% confidence intervals were used as the summary statistic for the overall effect sizes. The I^2 statistic was used to test for heterogeneity of effect size among studies included in the meta-analysis. Forest plots were used to illustrate the study findings and meta-analysis results. FBG and PPBG are stated as mg/dL. HbA1c is stated as a percentage (%). Fasting insulin is stated as μIU/mL.

RESULTS

Study characteristics

After the removal of duplicates, screening of studies, and excluding some studies, 16 RCTs were finally included in this systematic review. Nine studies were included as a comparison of the yoga intervention group with the control group. They are summarized in Table 2. Seven studies were included as a comparison of the walking intervention group with the control group. They are summarized in Table 3. Six studies were included as a comparison of the yoga intervention group with the walking group. They are summarized in Table 4. Three studies were included as a comparison of yoga and walking with the control group.[6,12,13] These three studies were analyzed in three sub-groups (yoga vs control, walking vs control, and yoga vs walking). A total of 1820 participants (1054 males, 766 females) were included, and the age range of participants was 17–75 years.

In this review study, included articles used yoga interventions like Trikonasana, Paschimottanasana, Ardha-Matsyendrasana, Dhanurasana, Pawanmuktasana, Vakrasana, Bhujangasana, Anulom-vilom and Bhamri Pranayama, and relaxation techniques such as meditation, prayer, and Savasana. In the majority of the included studies, yoga interventions involved 30-60 minutes per day and five days per week (5 d/w) for twelve weeks (12 w). Subjects of every included study joined the yoga practice in the morning; these practices were facilitated by a yoga expert from the day of recruitment. Included studies had selected similar kinds of OHA: metformin and glimepiride.

This review study included articles that used walking interventions for 30-60 minutes, three days per week (3 d/w) for 8-12 weeks with moderate intensity (brisk walking) on a plane ground surface.

Risk of bias analysis

According to the criteria of the revised Cochrane risk-of-bias tool for randomized controlled trials that is illustrated in Table 5, eleven studies showed 'low risk of bias' because

these eleven studies were judged to be at low risk of bias for all domains. Four studies showed 'some concerns' as these studies were judged to raise some concerns in at least one domain for this effect, but not to be at high risk of bias for any domain. Two studies failed to maintain the criteria of RoB-2 for low risk of bias due to deviances from the intended interventions (intervention assignment).[12,14] One study failed to maintain the criteria of low risk of bias due to deviations from the intended interventions (adhering to intervention),[15] and one study failed to maintain the criteria of low risk of bias due to missing result data.[6] One study showed a 'high risk of bias'; this study was judged to be at high risk of bias in at least one domain for this outcome or the study is judged to have some concerns for multiple domains in a way that substantially lowers confidence in the result. This study was judged to be at 'high risk of bias' due to deviances from the intended interventions (intervention assignment), measurement of the outcome, and selection of the reported result.[24]

Effect of yoga on glycemic control

Glycemic control was determined by measuring FBG, PPBG, and HbA1c along with fasting insulin level and HOMA-IR. The effect on FBG was studied in nine studies (9 interventions, n = 1199)[3,6,12,13,16,17] included in the meta-analysis. Forest plots for FBG in Figure 2(I) show that there was a significant reduction in FBG in the yoga group in comparison to the control group. The pooled mean difference for FBG between the yoga group and control groups from random effects analysis was 31.98 mg/dL (95% CI = –47.93 to–16.03), and the statistical heterogeneity of the data as indicated by I^2 = 96% was statistically significant (p <0.00001). There were five studies (5 interventions, n = 899)[3,16-19] in which the effect of yoga on PPBG was studied. The pooled mean difference for PPBG between the yoga group and control groups from random effects analysis was 25.59 mg/dL (95% CI = –44.00 to –7.18; I^2 = 87%, p <0.00001) in Figure 2(II). HbA1c was assessed in four of the studies[3,16-18] included in the meta-analysis (4 interventions, n = 795). The pooled mean difference from

Table 2. Characteristics of included studies on yoga intervention and control group

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Intervention (Type, intensity and duration)	Comparison condition	Outcomes	Study design
1	Gowri et al., 2022	Yoga – M/F 14/21, Age 54 ± 13 Control – M/F 23/12, Age 52.5 ± 11.2	Yoga 60 min/day, 2 days/week for 16 weeks	Control group with standard medication	FBG, PPBG, HbA1c, BMI, HOMA-IR, Lipids	RCT
2	Kaur et al., 2021	Yoga – M/F 19/72, Age 47.77 ± 9.59 Control – M/F 30/63, Age 49.24 ± 10.53	Yoga 60 min/day, 5 days/week for 12 weeks	Control group with standard medication	FBG, PPBG, HbA1c, BMI, WC, Lipids	RCT
3	Danasegaran et al., 2021	Yoga – M/F 40/0, Age 51.95 ± 6.17 Control – M/F 40/0, Age 51.48 ± 8.47	Yoga 40 min/day, 5 days/week for 12 weeks with medication	Control group with standard medication	FPG, BP, Insulin, BMI, Lipids	RCT
4	Viswanathan et al., 2021	Yoga – M/F 93/57, Age 50.8 ± 8.3 Control – M/F 103/47, Age 52.8 ± 7.0	Yoga 50 min/day, 5 days/week for 12 weeks	Control group with standard medication	FPG, PPPG, HbA1c, Lipids	RCT
5	Yuniartika et al., 2021	Yoga – M/F 7/11, Age 51.66 Control – M/F 8/10, Age 51.11	Yoga 60 min/day, 3 days/week for 12 weeks	Control group with standard medication	FBG, Lipids	RCT
6	Saberipour et al., 2020	Yoga – M/F 32/0, Age 48.25 ± 7.14 Control – M/F 33/0, Age 51.66 ± 11.06	Yoga 60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, Lipids, BP, BMI	RCT
7	Sharma et al., 2020	Yoga – M/F 32/20, Age 50.8 ± 8.3 Control – M/F 25/27, Age 52.8 ± 7.0	Yoga 40 min/day, 5 days/week for 24 weeks	Control group with standard medication	FBG, PPBG, HbA1c, Lipids, WHR	RCT
8	Keerthi et al., 2017	Yoga – M/F 31/29, Age 37.28 ± 6.21 Control – M/F 32/27, Age 36.72 ± 6.12	Yoga 38-45 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
9	Kumpatla et al., 2015	Yoga – M/F 87/44, Age 41.0 ± 8.7 Control – M/F 71/39, Age 44.2 ± 7.4	Yoga 30 min/day, 7 days/week for 12 Weeks	Control group with standard medication	FPG, PPPG, HbA1c, BP, Lipids, BMI	RCT

FPG – Fasting Plasma Glucose; PPBG – Post-prandial Blood Glucose; HbA1c – Glycosylated hemoglobin; BMI – Body Mass Index; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; BMI – Body Mass Index; WC – Waist Circumference; PPPG – Post-prandial Plasma Glucose; FBG – Fasting Blood Glucose; RCT – Randomized Controlled Trial; WHR – Waist Hip Ratio, QoL – Quality of Life

Table 3. Characteristics of included studies of walking intervention and control group

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Intervention (Type, intensity and duration)	Comparison condition	Outcomes	Study design
1	Leischik 2021	Waking – M/F 17/0, Age 60.4 ± 5.9 Control – M/F 16/0, Age 59.1 ± 8.5	Walking 40 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, HbA1c, Lipids	RCT
2	Yuniartika et al., 2021	Walking – M/F 5/13, Age 61.33 Control – M/F 8/10, Age 51.11	Walking 30 min/day, 3 days/week for 12 weeks	Control group with standard medication	FBG, Lipids	RCT
3	Saberipour et al., 2020	Walking – M/F 33/0, Age 49.83 ± 9.58 Control – M/F 33/0, Age 51.66 ± 11.06	Walking 60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, Lipids, BP, BMI	RCT
4	Rafii et al., 2018	Waking – M/F 15/18, Age 53.18 ± 4.99 Control – M/F 14/20, Age 51.85 ± 7.83	Walking 30 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, BMI	RCT
5	Akbarina et al., 2018	Waking – M/F 0/12, Age 61.92 ± 3.63 Control – M/F 0/12, Age 61.92 ± 3.63	Walking 45-60 min/day, 3 days/week for 8 weeks	Control group with standard medication	FBG, BMI, HbA1c, Lipids	RCT
6	Keerthi et al., 2017	Walking – M/F 30/28, Age 37.28 ± 6.21 Control – M/F 32/27, Age 36.72 ± 6.12	Walking 45 min/day, 3 days/week for 12 weeks	Control group with standard medication	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
7	Karstoft et al., 2013	Waking – M/F 4/8, Age 60.8 ± 2.2 Control – M/F 3/5, Age 57 ± 3.0	Walking 60 min/day, 5 days/week for 16 weeks	Control group with standard medication	FBG, Fasting Insulin, HbA1c, BP, Lipids.	RCT

FPG – Fasting Plasma Glucose; FBG – Fasting Blood Glucose; BP – Blood Pressure; BMI – Body Mass Index; HbA1c – Glycosylated hemoglobin; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; IDRS – Indian Diabetes Risk Score; RCT – Randomized Controlled Trial

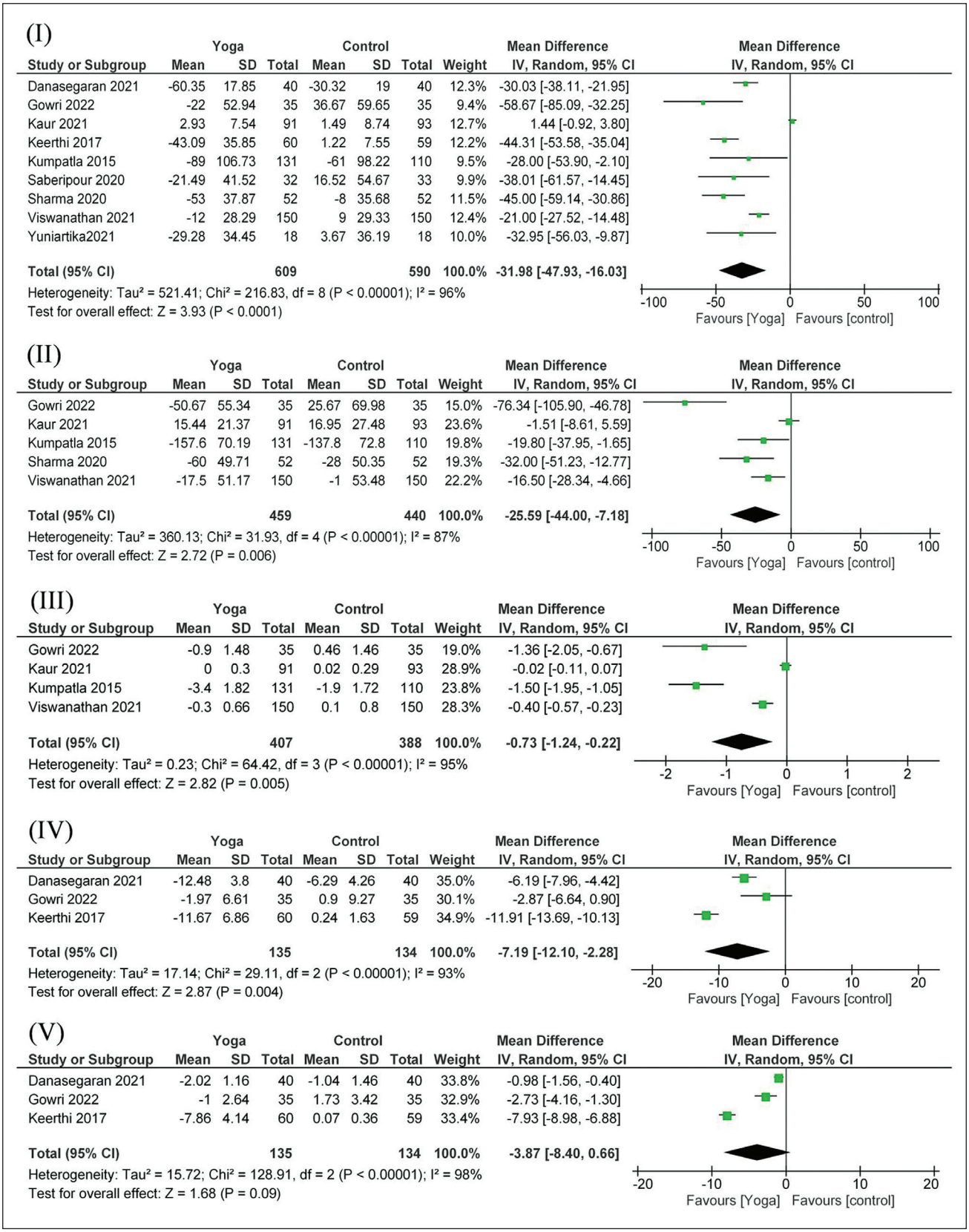

Figure 2. Forest plots presenting the effect of Yoga compared to Control group on **(I)** Fasting Blood Glucose, **(II)** Postprandial Blood Glucose, **(III)** Glycosylated Hemoglobin, **(IV)** Fasting Insulin and **(V)** Insulin Resistance.

Table 4. Characteristics of included studies on yoga intervention and walking intervention

Sl. No.	Authors and year	Participants (Recruited, age and sex)	Yoga (Type, intensity and duration)	Walking (Type, intensity and duration)	Outcomes	Study design
1	Yuniartika et al., 2021	Yoga – M/F 7/11, Age 51.66 Walking – M/F 5/13, Age 61.33	Yoga 60 min/day, 3 days/week for 12 weeks	Walking 30 min/day, 3 days/week for 12 weeks	FBG, Lipids	RCT
2	Gupta et al., 2020	Yoga – M/F 21/19, Age 51.1 ± 8.6 Walking – M/F 24/17, Age 50.2 ± 8.6	Yoga 45 min/day, 5 days/week for 16 weeks	Walking 30 min/day, 5 days/week for 16 weeks	FPG, SBP, DBP, HbA1c, Lipids, BMI, WC	RCT
3	Saberipour et al., 2020	Yoga – M/F 32/0, Age 48.25 ± 7.14 Walking – M/F 33/0, Age 49.83 ± 9.58	Yoga 60 min/day, 3 days/week for 8 weeks	Walking 60 min/day, 3 days/week for 8 weeks	FBG, SBP, DBP, Lipids, BMI	RCT
4	Singh et al., 2020	Yoga – M/F 41/60, Age 50.3 ± 9.1 Walking – M/F 49/50, Age 49.4 ± 8.7	Yoga 38-115 min/day, 5 days/week for 12 weeks	Walking 30 min/day, 5 days/week for 12 weeks	HbA1c, SSAI, STAI, BDI, ESE	RCT
5	Keerthi et al., 2017	Yoga – M/F 31/29, Age 37.28 ± 6.21 Walking – M/F 30/28, Age 37.28 ± 6.21	Yoga 38-45 min/day, 3 days/week for 12 weeks	Walking 45 min/day, 3 days/week for 12 weeks	FPG, Fasting Insulin, HOMA-IR, QoL, IDRS	RCT
6	McDermott et al., 2014	Yoga – M/F 9/12, Age 47.0 ± 9.7 Control – M/F 7/13, Age 47.2 ± 9.1	Yoga 75 min/day, 3-6 days/week for 8 weeks	Walking 30 min/day, 3-6 days/week for 8 weeks	FBG, PPBG, HbA1c, HOMA-IR, BP, Lipids	RCT

FBG – Fasting Blood Glucose; FPG – Fasting Plasma Glucose; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure; HbA1c – Glycosylated hemoglobin; BMI – Body Mass Index; WC – Waist Circumference; SSAI – Spielberger's State Anxiety Inventory; STAI – Spielberger's Trait Anxiety Inventory; BDI – Beck Depression Inventory; ESE – Exercise Self-Efficacy; HOMA-IR – Homeostatic Model Assessment for Insulin Resistance; BP – Blood Pressure

Table 5. Risk of bias assessment of the included studies

Sl. No	Authors and year	Domain 1 (randomization process)	Domain 2 (assignment to intervention)	Domain 2 (adhering to intervention)	Domain 3 (missing outcome data)	Domain 4 (measurement of the outcome)	Domain 5 (selection of the reported result)	Overall risk of bias
1	Gowri et al., 2022	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
2	Kaur et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
3	Danasegaran et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
4	Viswanathan et al., 2021	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
5	Sharma et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
6	Kumpatla et al., 2015	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
7	Leischik 2021	Low risk	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
8	Rafii et al., 2018	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
9	Akbarina et al., 2018	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
10	Karstoft et al., 2013	Low risk	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
11	Yuniartikaet et al., 2021	Low risk	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
12	Gupta et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
13	Saberipour et al., 2020	Low risk	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
14	Singh et al., 2020	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
15	Keerthi et al., 2017	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
16	McDermott et al., 2014	Low risk	High risk	Low risk	Some concerns	High risk	High risk	High risk

random effects analysis was 0.73% (95% CI = –1.24 to -0.22; I^2 = 95%, p <0.00001) in Figure 2(III). There were three studies (3 interventions, n = 269)[3,13,20] for fasting insulin between the yoga group and control groups. The pooled mean difference from random effects analysis was 7.19 μIU/mL (95% CI = –12.10 to –2.28; I^2 = 93%, p <0.00001) in Figure 2(IV). HOMA-IR was assessed in 3 of the studies included in the meta-analysis (3 interventions, n = 269).[3,13,20] The pooled mean difference for HOMA-IR between the yoga group and control groups from random effects analysis was 3.87 (95% CI = –8.40 to -0.66) in Figure 2(V), and the statistical heterogeneity of the data as indicated by I^2 = 98% was significant (p <0.00001).

Effect of walking on glycemic control

Glycemic control was determined in the same way by measuring FBG, PPBG, and HbA1c along with fasting insulin and HOMA-IR. The effect on FBG was studied in 7 studies (7 interventions, n = 363)[6,12-15,21,22] included in the meta-analysis. There was a statistically significant reduction in FBG in the walking group in comparison to the control group. Forest plots for FBG Figure 3(I) show that there was a significant reduction in FBG in the walking group. The pooled mean difference for FBG between the walking group and control groups from random effects analysis was 12.37 mg/dL (95% CI = –20.06 to –4.68), and the statistical heterogeneity of the data as indicated by I^2 = 52% was statistically significant (p = 0.05). There were three studies (3 interventions, n = 77)[14,15,22] in which the effect of walking on HbA1c was studied. The pooled mean difference for HbA1c from random effects analysis was 0.35% (95% CI = –0.70 to –0.01; I^2 = 69%, p = 0.04) Figure 3(II). The change of HbA1c by 0.35% and FBG of 12.37 mg/dL in the walking group in comparison to the control group is statistically significant but may not be clinically significant.

Comparative effect of yoga and walking on glycemic control

The effect on FBG was studied in five studies (5 interventions, n = 335)[6,12,13,23,24] included in the meta-analysis. There was a statistically significant reduction in FBG in the yoga group in comparison to the walking group.

Forest plots for FBG in Figure 4(I) showed that there was a significant reduction in FBG in the yoga group. The pooled mean difference from random effects analysis was 12.07 mg/dL (95% CI = –24.34 to – 0.20; p = 0.03, I^2 = 62%). There were two studies (2 interventions, n = 278)[23,25] in which the effect of yoga and walking on HbA1c was studied. The pooled mean difference for HbA1c between the yoga group and walking group from random effects analysis was 0.20% (95% CI = –0.37 to –0.04; I^2 = 0%, p <0.90) in Figure 4(II). The effect on fasting insulin was studied in two studies (n = 156)[13,24] included in the meta-analysis. The pooled mean difference for fasting insulin between the yoga group and walking group from random effects analysis was 10.06 μIU/mL (95% CI = –23.84 to 3.71; I^2 = 98%, p <0.00001) in Figure 4(III). There were two studies (2 interventions, n = 159)[13,24] in which the effect of yoga and walking on HOMA-IR was studied. The pooled mean difference for HOMA-IR between the yoga group and walking group from random effects analysis was 5.97 (95% CI = –16.92 to 4.99; I^2 = 99%, p <0.00001) in Figure 4 (IV).

DISCUSSION

This meta-analysis observed either the effects of yoga or walking on glycemic control among patients with T2DM. Nine studies with 1197 adults (719 males, 478 females) comparing the yoga intervention to a control group were evaluated. Yoga interventions improved glycemic control by reducing HbA1c, FBG, PPBG, fasting insulin, and HOMA-IR compared to the control group. Seven studies with 365 adults (211 males, 154 females) comparing the walking intervention to a control group were evaluated. Walking interventions improved glycemic control by reducing HbA1c and FBG compared to the control group. Six studies with 541 adults (289 males, 252 females) comparing the yoga intervention to a walking intervention were evaluated. Yoga interventions improved glycemic control by reducing HbA1c, FBG, fasting insulin, and HOMA-IR compared to the walking intervention. Three studies were included comparing yoga and walking with control groups; these were analyzed in three sub-groups (yoga vs control, walking vs control, and yoga vs walking).[6,12,13]

Our results demonstrate a significant reduction in FBG (31.98 mg/dL), PPBG (25.59 mg/dL), HbA1c (0.73%), fasting insulin (7.19 μIU/mL), and HOMA-IR (3.87) in the yoga intervention compared to the control group (no exercise) in the pooled analysis. In the case of walking intervention compared to the control group (no exercise), the significant reduction of FBG was 12.37 mg/dL and HbA1c was 0.35% in the pooled analysis, but they did not evaluate the PPBG. Only Keerthi et al., evaluated fasting insulin and insulin resistance.[13] Similarly our results show a significant reduction in FBG (12.07 mg/dL), HbA1c (0.20%), fasting insulin (10.06 μIU/mL) and HOMA-IR (5.97) in the yoga intervention compared to the walking group in the pooled analysis. Kour et al., showed that after yoga intervention, the mean difference of glycemic control (FBG, PPBG, and HbA1c) decreased in a smaller amount than the control group in patients with type 2 diabetes mellitus.[16] McDermott showed that walking has more significant effects on FBG in comparison to yoga in type 2 diabetes mellitus patients.[24]

Viswanathan et al., revealed that there was a significant reduction in blood glucose levels and HbA1c in the yoga group as compared to the non-yoga group.[18] Kumpatla

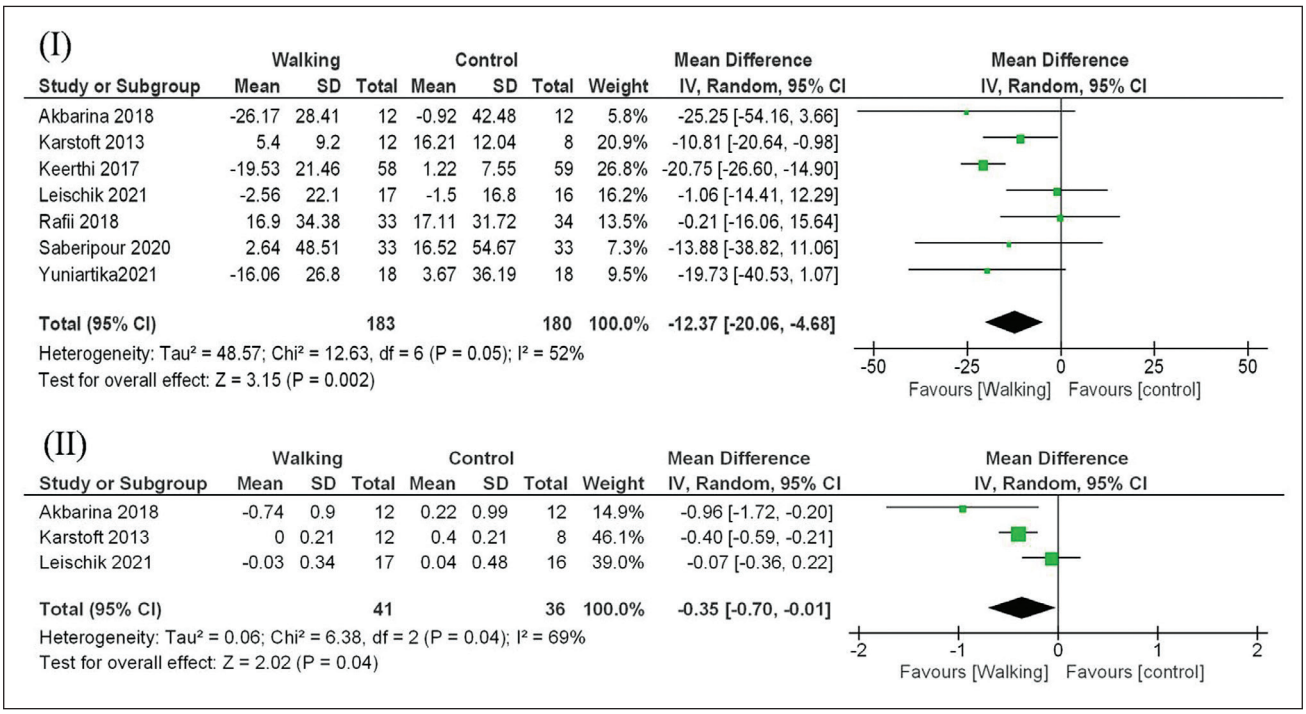

Figure 3. Forest plots presenting the effect of Walking compared to Control group on **(I)** Fasting Blood Glucose and **(II)** Glycosylated Hemoglobin.

et al., showed that the regular practice of yoga along with conventional medicines could be beneficial for better control of diabetes.[17] Saberipour et al., showed that yoga and walking had a positive effect on improving the laboratory indicators in men with type 2 diabetes, but yoga had more significant effects in diabetic patients as compared to walking.[12] Some studies exhibited a reduction in FBG, PPBG and HbA1c in the control group compared to the baseline and post-intervention due to the taking of oral hypoglycemic drugs (OHD),[15,17-20,22] but this change was not statistically significant. Diabetes is a psychosomatic disease related to both mind and body so psychoneuroendocrine and immune mechanisms are involved in the benefits of yoga on diabetes.[5]

Diabetes is a growing epidemic among lifestyle-associated cardiometabolic risk syndromes. It is accompanied by insulin resistance.[29] The idea of positive health was first introduced by Charaka, the father of the ancient Indian medical system called Ayurveda. He is the composer of the Ayurvedic foundational text, "Charaka Samhita." According to Charaka, body, mind, and soul are like a tripod.[30] In the Vasistha Samhita, we find two types of disease. One is mental (Adhija Vyadhi) and the other is physical (Anadhija Vyadhi).[31,32] Disease can germinate in either body or mind. Psychosomatic diseases are those that manifest in the mind and creep into the body, while in somatopsychic it is reversed. Yoga is a therapy that is a mind–body medicine.[33] Yoga as a part of Vedic philosophy that regards the human body as a combination of the mind, body, and soul.[34]

From this study, it may be recommended that Trikonasana, Paschimattanasana, Pawanmuktasana, Vakrasana,

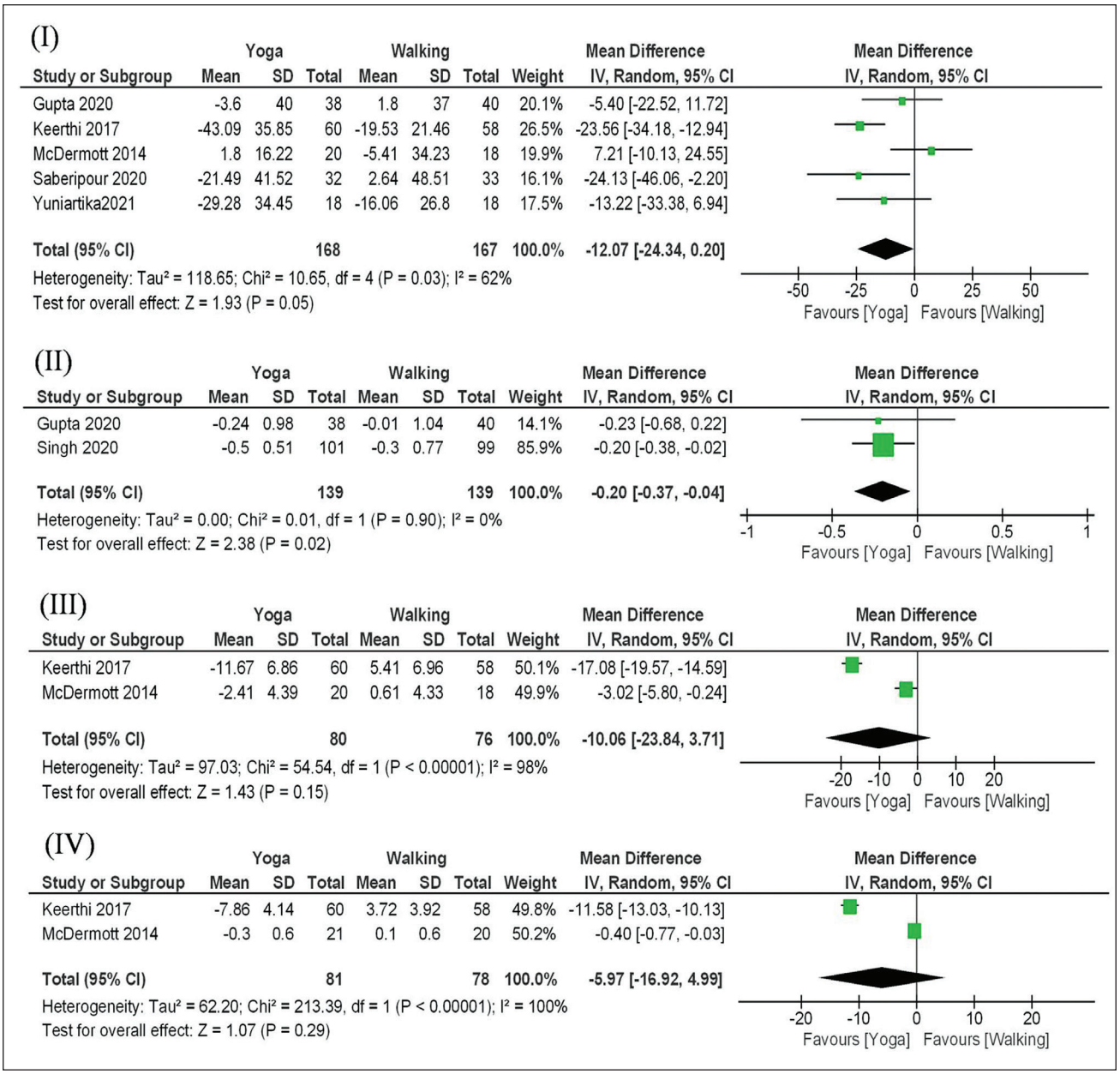

Figure 4. Forest plots presenting the effect of Yoga compared to Walking intervention on **(I)** Fasting Blood Glucose, **(II)** Glycosylated Hemoglobin, **(III)** Fasting Insulin and **(IV)** Insulin Resistance.

Bhujangasana, Ardha-Matseyendrasana, Dhanurasana, Sabasana, Kapalbhati, Anulom-Vilom and meditation for at least 45-60 minutes for five days per week can be beneficial for patients with diabetes. Walking five days per week and at least 45 minutes daily for people with diabetes can realize benefits to improve glycemic control. Additionally, concentration towards walking (Buddhist walking meditation) has a more favorable effect than the traditional walking program in patients with type 2 diabetes.[35] Future studies should emphasize the effects of different parameters of walking exercise on glycemic control of diabetes patients, such as walking frequency, walking time, and intensity.

CONCLUSIONS

In conclusion, this systematic review and meta-analysis provides evidence that either yoga or walking has positive effects on glycemic control and insulin resistance in comparison to the control group (no regular exercise) in patients with type 2 diabetes taking oral hypoglycemic agents. The change of HbA1c and FBG in the walking group compared to the control group is statistically significant but may not be clinically significant. Comparatively, yoga has more significant effects on glycemic control and insulin resistance in comparison to walking for the management of type 2 diabetes.

Statement of Authorship
The authors certified fulfillment of ICMJE authorship criteria.

CRediT Author Statement
BD: Methodology, Software, Validation, Formal analysis, Investigation, resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Visualization, Project administration; **SC:** Conceptualization, Methodology, Validation, Investigation, Resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Visualization, Supervision, Project administration; **SSD:** Validation, Writing – review and editing, Supervision, Project administration; **MC:** Validation, Writing – review and editing, Supervision.

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E-Certificate of Appreciation

This is to certify that Biswajit Dhali, Ph.D. Scholar of Jadavpur University presented his/her paper entitled Immediate Effect of Surya-Namaskar on Blood Glucose Level in Patients with Type 2 Diabetes Mellitus in the two-day I.C.P.R. Sponsored International Seminar on "Yoga for Health, Happiness and Harmony" organized by the Departments of Sanskrit, Philosophy & Physical Education, Swarnamoyee Jogendranath Mahavidyalaya in Collaboration with Department of Physical Education, Mugberia Gangadhar Mahavidyalaya, held on 24th & 25th July, 2023 at Swarnamoyee Jogendranath Mahavidyalaya .

Dr.Parimal Mandal	Dr.Aninda Kisor Bhaumik	Dr.Swapan Kumar Mishra	Dr.Ratan Kr. Samanta
Coordinator	Chief Patron	Principal	Principal
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Annexure – 6

(List of Common Oral Hypoglycemic Agents)

Common Oral Hypoglycemic Agents used by the T2DM patients in the present study

1. Metformin (Zomet, Glyciphage)

2. Gliclazide (Diamicron, Gliclad)

3. Glipizide (Glucotrol, Glimpid)

4. Pioglitazone (Actos, Pioz)

5. Sitagliptin (Januvia, Sitaglu)