Original Article

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Physiotherapy Section

Effect of Four Weeks of Mat Pilates versus Swiss Ball Pilates on Blood Profile and Body Composition Elements in Sedentary Type 2 Diabetes Mellitus Population: A Randomised Clinical Trial

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ABSTRACT

Introduction: Type 2 Diabetes Mellitus (T2DM) is a common metabolic disorder among mid-aged adults. Physical fitness is a measure approach for maintaining Blood Glucose Levels (BGL) within the ranges. Pilates is a low-impact exercise and easy to perform. Mat Pilates (MP) and Swiss Ball Pilates (SBP) were the two interventions used in the current study.

Aim: To determine and compare the effect of four weeks of MP and SBP on blood profile and body composition elements in sedentary T2DM.

Materials and Methods: The present randomised controlled trial was conducted over a period of 12 months at Karnataka Lingayat Education Society's (KLES) Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi, Karnataka, India. A total of 30 participants were enrolled and randomly assigned into two groups during the study period with each group of 15 participants; Group A received MP, while Group B received SBP. Outcome measures included Blood Lactate (BL) levels, body composition elements, and BGLs were recorded on day 1 and after four weeks of intervention.

Results: Statistical analysis was done using Statistical Package for the Social Sciences (SPSS). Within-group analysis demonstrated significant improvement in BL with Group A (p-value <0.001) and for Group B (p-value <0.001), blood glucose both the groups p-value being <0.001 and body composition elements like fat (Group A, p-value=0.003) (Group B, p-value <0.001), skeletal muscle mass, water content, Waist to Hip Ratio (WHR), physical age, and overall Health Assessment Score (HAS).

Conclusion: Both MP and SBP led to significant improvements in body composition, metabolic function, and overall physical health. By successfully reducing BL, blood glucose, and body fat while raising skeletal muscle mass, water content, and HAS, both strategies showed their effectiveness in fostering fitness and well-being.

Keywords: Blood glucose, Blood lactate, Exercise therapy

INTRODUCTION

Dysregulation of the metabolism of carbohydrates, fats, and proteins is a hallmark of T2DM, which can be caused by either insulin resistance, inadequate insulin secretion, or a combination of the two. Out of the three primary forms of diabetes, type 2 diabetes is far more prevalent, making up over 90% of all cases [1,2]. In India, the prevalence of diabetes increased from 7.1% in 2009 to 8.9% in 2019. Those over the age of 45 are the ones most likely to develop Diabetes [3]. For years, epidemiologists have seen a definitive connection between sedentary behaviour and the progression of T2DM [3]. The connections between type 2 diabetes and lactate in the blood a significant, linear, and expanding relationship between lactate and the prevalence of type 2 diabetes [4].

The MP is a form of low-impact exercise that is performed on the floor using a mat, rather than on specialised Pilates equipment like reformers. The exercises in MP are designed to strengthen muscles, improve flexibility, and enhance postural alignment. It emphasises controlled movements, breathing, and core stabilisation, making it accessible to people of various fitness levels, including those with chronic conditions such as diabetes mellitus. Benefits of MP in diabetes mellitus are blood glucose management, strengthening muscular and enhancing core stability, improving flexibility of the joint, improving circulation.

The SBP, often referred to as stability ball pilates, is a dynamic type of exercise that uses an exercise ball, or Swiss ball, in conjunction with the classic pilates concepts. The workouts become increasingly unstable due to the huge, inflatable ball, requiring the body to use more muscles in order to maintain control and balance. Because SBP focuses specifically on enhancing balance, strength, and flexibility all of which are linked to improved general health and more successful diabetes management it can be especially helpful for those with diabetes mellitus.

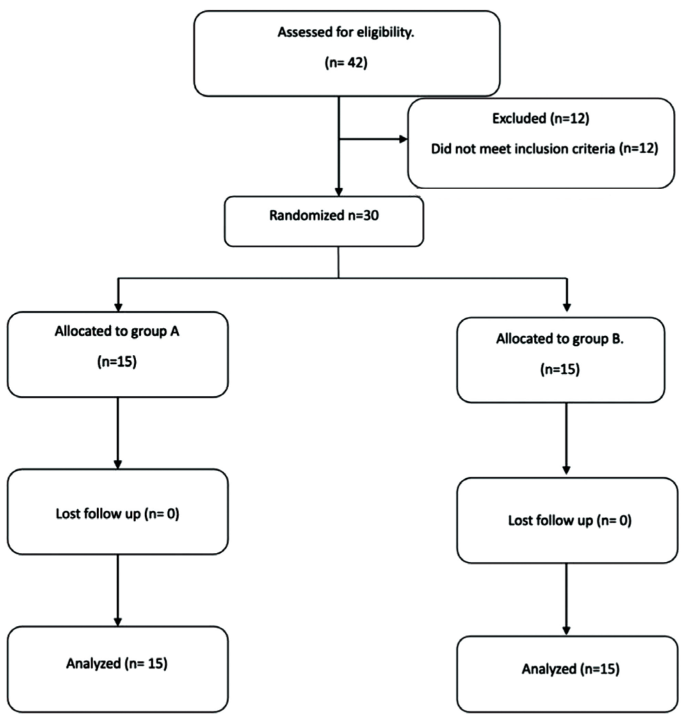
MP and SBP both have been shown to improve physical functions, strengthening the core muscles, and increasing equilibrium, posture, and muscular balance. Pilates has been shown to improve oxidative capability in type 2 diabetes patients [5].

Studies examining changes in BL levels and aspects of body composition in people with type 2 diabetes have not been reported. Furthermore, there is a dearth of research comparing SBP with MP methods for individuals with diabetes. As a result, the purpose of this research was to evaluate the effect of four weeks of MP vs SBP on blood profile and body composition elements in sedentary T2DM. The null hypothesis states no significant effect of MP or SBP on the blood profile and body composition of sedentary individuals with T2DM. Additionally, there is no significant difference between the effects of SBP and MP on these variables. The alternative hypothesis was that there would be significant effect of SBP or MP on the blood profile and body composition of sedentary individuals with T2DM. Also there would be significant difference between the effects of SBP and MP on these variables.

MATERIALS AND METHODS

The present randomised controlled trial was conducted over a period of 12 months from April 2022 to March 2023 at Karnataka Lingayat Education Society's (KLES) Dr. Prabhakar Kore Hospital and Medical Research Centre, Belagavi, Karnataka, India.

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and the study was conducted in accordance with the ethical standards and received ethical clearance from the Research and Ethical Committee KLEU Institute of Physiotherapy Belagavi- Karnataka, India under approval number 764/29/06/2022. For better reporting of the trial, the CONSORT (Consolidated Standards of Reporting Trials) 2010 statement - with extension to pilot studies and feasibility trial guidelines [Table/Fig-1], and the TiDier (Template for Intervention Description and Replication) checklist to maintain the quality of reporting of interventions were used.



[Table/Fig-1]: CONSORT flow chart.

Sample size calculation: In the study, the total sample size consisted of 30 participants, divided into two groups of 15 each. Group A included six male and nine female participants, while Group B had five male and 10 female participants.

Sample size calculation was done using formula [6]:

$$n = \frac{2(Z\alpha + Z\beta) * \sigma^2}{d^2}$$

n = Sample size

$Z\alpha$ = Alpha Value (Probability of falsely rejecting a true null hypothesis) (1.96)

$Z\beta$ = Beta Value (power of the test) (0.84).

σ = Standard deviation of the outcome (6.5)

d = Size of the effect that is clinically worthwhile to detect (6.5)

With two tailed sample analysis there would be 15 participants in each group.

Inclusion criteria: Participants of all genders between 45-65 years of age with sedentary lifestyle according to International Physical Activity Questionnaire - Short Form (IPAQ-SF) (low-inactive) [7]; with Body Mass Index (BMI) between 24 to 27.5 kg/m^2 and diagnosed cases of diabetes mellitus for five years or more [8].

Exclusion criteria: Subjects with musculoskeletal injury; hemodynamic instability; bleeding disorders; serious pathology such as cancer and bed ridden [9].

Study Procedure

A total of 42 participants were initially screened for eligibility. Of these, 12 were excluded for not meeting the inclusion criteria. Resulting in 30 participants were recruted and completed the intervention [Table/Fig-1]. The study objectives were clearly explained to all participants, and written informed consent was obtained. Participants were not blinded and were randomly assigned to two groups using the chit-draw method.

To record demographic characteristics and collect baseline measurements, each participant underwent a comprehensive evaluation. BL levels, random BGLs, and body composition analysis were all part of these assessments. After evaluation of the baseline data participants were treated face to face in the physiotherapy outpatient department under the guidance of a qualified physiotherapist on 1:1 basis (one therapist attending one patient at a time) and were all individually performed by patient and hence adherence was ensured.

Intervention: In pilates pre-protocol training, participants were instructed to maintain three foundational positions: scoop, imprinting, and nod throughout all exercises. The scoop involved engaging the deep abdominal muscles by drawing them inward and upward, stabilising the core and supporting spinal alignment. Imprinting entailed gently pressing the lower back toward the mat, creating a slight posterior pelvic tilt to support the spine during exercises where the legs were lifted or extended. The nod referred to a subtle chin tuck, aligning the cervical spine and preparing the neck for movements like curling the head and shoulders off the mat. These positions were emphasised to ensure proper form and optimal muscle engagement.

- **Mat Pilates (MP):** The MP included 10 different exercises. Each exercise was performed for 10 reps * 2 sets. Participants were asked to lie down on a Yoga mat while performing exercises. Total protocol was for 40 minutes. MP Protocol included exercises like the hundred, single leg stretch, single leg circle, double leg stretch, roll down, roll back, side-kicks, single leg kicks, plank, side plank [6].
- **Swiss Ball Pilates (SBP):** All Swiss ball exercises were performed (Cosco fitness Swiss ball) with same sized ball of 75 cm. While performing Swiss ball exercises participants asked to perform lower abdominal muscle along with complete straight spinal curve and neck flexion. They were instructed to hold the ball with distal part of lower leg. SBP require good balance to perform, so progression of these exercise is difficult. SBP included exercises like the hundred, single leg stretch, double leg stretch, single leg circle, plank, shoulder bridge, spinal twist, bridging [10].

Pilates exercises consisted of a four week protocol. Performed on alternate days, including one session of 40 minutes, the exercise protocol began with a 5-minute warm-up, followed by the main exercise protocol and ended with cool-down session. Each exercise was performed 10 times and two sets in one session. Post outcome measures were taken after four weeks of protocol.

Outcome measures: Prior to treatment on Day 1 and following the conclusion of four weeks of training, all objective outcomes were evaluated. A certified and experienced physiotherapist took and documented all of the results, and the assessor was blinded to the study groups.

- **Blood Lactate (BL) levels:** The BL levels were measured using the Lactate Plus® analyser, a handheld, portable device designed for rapid and accurate point-of-care testing (Nova Biomedical, USA). A sterile finger prick was carried out using a lancet to remove a small drop of capillary blood after the participant's fingertip had been cleaned with an alcohol swab. The blood sample was placed onto a disposable test strip that had been inserted into the analyser. The device provided a lactate concentration reading in roughly 13 seconds. Both at baseline and immediately following the intervention, measurements were made [11].
- **Blood Glucose Levels (BGL):** Random BGLs were measured by an accredited pathology laboratory to assess the physiological effects of the intervention. Venipuncture was used to draw venous blood samples in accordance with standard aseptic protocols. The samples were placed in the appropriate tubes, such as sodium fluoride/citrate buffer tubes, to stop glycolysis and ensure accurate glucose measurement. The concentrations of glucose were measured using standardised laboratory methods, including the hexokinase method, which is considered the gold standard for measuring glucose. Measurements were taken both at baseline and immediately following the intervention to assess changes in glucose levels [12].
- **Body composition:** Body composition was measured using a multifrequency bioelectrical impedance analyser (InBody, Co., Ltd., South Korea), a tool authorised for use in clinical and research settings. Prior to measurement, participant-specific demographic data, including name, age, height, weight, and sex, was entered into the system to ensure accurate analysis. The evaluation process produced a comprehensive report on several body composition metrics and took around 30 seconds to complete. Skeletal muscle mass, total body fat, protein content, total body water, WHR, Impedance Score (IS), and a physical HAS were among them [13].

STATISTICAL ANALYSIS

Data gathered fed into MS-Excel 2013 and were statistically calculated using the Statistical Package for the Social Sciences (SPSS) version 23. Normality of the data was assessed using the Shapiro-Wilk test. As all p-values were >0.05, the assumption of normality was not violated, indicating that the distribution of each variable in both groups was normally distributed within group analysis of the outcomes were done using paired samples t-test and the between group analysis was done using independent samples t-test. Level of significance was considered at $p<0.05$.

RESULTS

The distribution of participants across the two study groups was even, with each group comprising 15 individuals. [Table/Fig-2] shows the normality test of age, height, weight and BMI for individuals in MP group and SBP group, respectively. Results showed no significant deviations from normality ($p>0.05$) in both groups, supporting the application of parametric statistical tests in further data analysis.

Variables	Group	Shapiro-Wilk statistic (W)	p-value	Normality assumption
Age (years)	Group A	0.973	0.420	Normal
	Group B	0.969	0.367	Normal
Height (cm)	Group A	0.958	0.212	Normal
	Group B	0.982	0.582	Normal
Weight (kg)	Group A	0.965	0.305	Normal
	Group B	0.955	0.181	Normal
BMI (kg/m²)	Group A	0.951	0.145	Normal
	Group B	0.960	0.227	Normal

[Table/Fig-2]: Assessment of normality using Shapiro-Wilk test.

Within group analysis: In Group A, the within-group analysis revealed statistically significant improvements across several parameters following the intervention. Significant reductions were observed in BGL ($p<0.001$), fat mass ($p=0.003$), and BL ($p<0.001$). Additionally, water content ($p=0.022$), skeletal muscle mass ($p=0.001$), WHR ($p=0.049$), IS ($p=0.042$), and physical score ($p=0.008$) also showed significant changes. However, changes in protein content ($p=0.355$) and HAS ($p=0.096$) were not statistically significant [Table/Fig-2].

In Group B, significant improvements were observed in fewer parameters. Notably, there were significant reductions in BGL ($p=0.006$), fat mass ($p=0.001$), and BL ($p<0.001$), indicating favourable metabolic changes. However, no significant differences were found in protein content ($p=0.511$), water content ($p=0.374$), skeletal muscle mass ($p=0.089$), WHR ($p=0.336$), IS ($p=0.178$), physical score (no change), or HAS ($p=0.336$) [Table/Fig-3].

Between group analysis: The between-group comparison of pre- and post-intervention values revealed no statistically significant differences between Group A and Group B for most outcome variables. At pre-test, parameters including BGL ($p=0.875$), fat mass ($p=0.324$), protein content ($p=0.159$), water content ($p=0.686$), skeletal muscle mass ($p=0.974$), WHR ($p=0.687$), IS (IS) ($p=0.656$), physical score ($p=0.197$), HAS ($p=0.315$), and BL ($p=0.563$) showed no significant difference between the groups [Table/Fig-4].

Following the intervention (post-test), most variables continued to show no significant between-group differences, including BGL ($p=0.803$), fat mass ($p=0.701$), protein content ($p=0.496$), water content ($p=0.255$), skeletal muscle mass ($p=0.749$), WHR ($p=0.284$), IS ($p=0.469$), HAS ($p=0.426$), and BL ($p=0.989$). However, a statistically significant difference was observed in the physical score at post-test ($p=0.040$), indicating a greater improvement in Group B compared to Group A [Table/Fig-5].

DISCUSSION

In the current randomised clinical study, sedentary individuals with T2DM were asked to examine the effects on body composition and blood profile indicators of a four week MP versus SBP intervention. While several metabolic markers improved with both training modalities, the results showed that MP produced more comprehensive and statistically significant benefits across a larger range of outcomes, thus accepting the alternative hypothesis.

Group A (Mat Pilates)

In the MP group, participants' BGL, fat mass, BL, skeletal muscle mass, water content, WHR, IS, and physical performance ratings all changed statistically significantly. Based on these findings, MP may be able to quickly and efficiently address several pathophysiological features of type 2 diabetes.

One plausible explanation is that MP incorporates both isometric and isotonic exercises that target major muscle groups while promoting neuromuscular coordination, flexibility, and core stability. These characteristics may promote improved insulin sensitivity and enhance glucose absorption by the skeletal muscles. This finding confirms previous research suggesting neuromuscular exercise and moderate-intensity resistance help diabetics maintain their blood sugar levels and enhance their body composition [14,15].

Since the skeletal muscle is the main location for insulin-mediated glucose elimination, the increase in skeletal muscle mass and decrease in fat mass are especially noticeable. Mat with resistance pilates exercises may improve glycaemic management by increasing mitochondrial density, activating insulin receptors, and recruiting more muscle fibre [16,17].

Improvements in electrical conductance and cellular hydration are correlated with increases in IS and body water content, which could be related to better metabolic health. Lower abdominal obesity and better physical function are implied by higher WHR and physical

Variables		Group A				Group B			
		Mean	SD	"t"	p-value	Mean	SD	"t"	p-value
BGL	Pre	203.8	25.0	5.06	<0.001*	199.5	43.2	3.3	0.006*
	Post	176.9	15.3			174.7	25.4		
Fat	Pre	22.4	6.0	3.81	0.003*	20.5	2.9	4.15	0.001*
	Post	20.3	5.2			19.7	2.7		
Protein	Pre	11.8	3.3	0.97	0.355	11.0	1.4	0.68	0.511
	Post	11.5	2.8			10.9	1.5		
Water	Pre	31.3	5.7	-2.70	0.022*	29.9	4.0	-0.92	0.374
	Post	32.1	5.3			30.0	3.8		
Skeletal	Pre	24.1	4.9	-4.59	0.001*	23.9	3.8	-1.84	0.089
	Post	24.9	4.8			24.4	3.7		
WHR	Pre	0.9	0.1	2.24	0.049*	0.9	0.1	1	0.336
	Post	0.9	0.1			0.9	0.1		
IS	Pre	2.7	0.4	2.34	0.042*	2.7	0.4	1.42	0.178
	Post	2.6	0.4			2.7	0.4		
Physical	Pre	56.5	6.4	3.32	0.008*	59.6	3.6	0	1.000
	Post	55.1	6.7			59.6	3.6		
HAS	Pre	68.2	10.7	1.84	0.096	70.6	6.3	1	0.336
	Post	67.7	10.7			70.5	6.3		
BL	Pre	6.7	1.8	6.79	<0.001*	6.2	1.0	5.11	<0.001*
	Post	5.6	1.7			5.6	1.0		

[Table/Fig-3]: Comparison of BGL, body composition, and Blood Lactate (BL) within the groups.
("t"=Paired t-test; *Significant) p<0.005, SD: Standard deviation; BGL: Blood glucose level; WHR: Waist-hip ratio; IS: Impedance score; HAS: Health assessment score; BL: Blood lactate

Variables		Pretest				Post-test			
		Mean	S.D.	"t"	p-value	Mean	S.D.	"t"	p-value
BGL	Group A	199.5	24.2	-0.16	0.875	176.9	15.3	0.25	0.803
	Group B	201.5	42.3			174.7	25.4		
Fat	Group A	22.2	5.2	1.00	0.324	20.3	5.2	0.39	0.701
	Group B	20.6	2.9			19.7	2.7		
Protein	Group A	12.5	3.4	1.45	0.159	11.5	2.8	0.69	0.496
	Group B	11.1	1.5			10.9	1.5		
Water	Group A	30.3	5.7	0.41	0.686	32.1	5.3	1.17	0.255
	Group B	29.5	4.1			30.0	3.8		
Skeletal	Group A	23.9	4.2	0.03	0.974	24.9	4.8	0.32	0.749
	Group B	23.8	3.7			24.4	3.7		
WHR	Group A	0.9	0.1	-0.41	0.687	0.9	0.1	-1.10	0.284
	Group B	0.9	0.1			0.9	0.1		
IS	Group A	2.7	0.5	-0.45	0.656	2.6	0.4	-0.74	0.469
	Group B	2.7	0.4			2.7	0.4		
Physical	Group A	57.5	5.9	-1.32	0.197	55.1	6.7	-2.18	0.040*
	Group B	59.8	3.5			59.6	3.6		
HAS	Group A	67.7	9.3	-1.02	0.315	67.7	10.7	-0.81	0.426
	Group B	70.6	6.0			70.5	6.3		
BL	Group A	6.5	1.6	0.59	0.563	5.6	1.7	-0.01	0.989
	Group B	6.2	0.9			5.6	1.0		

[Table/Fig-4]: Within-group comparison of Blood Glucose Level (BGL), body composition variables, and Blood Lactate (BL) before and after intervention using paired t-test.
("t"=Paired t-test; *Significant) p<0.005, SD: Standard deviation; BGL: Blood glucose level; WHR: Waist-hip ratio; IS: Impedance score; HAS: Health assessment score; BL: Blood lactate

Variables	Time	Group A Mean±SD	t	p-value	Group B Mean±SD	t	p-value
BGL (mg/dL)	Pre	203.8±25.0	5.06	<0.001 *	199.5±43.2	3.30	0.006 *
	Post	176.9±15.3			174.7±25.4		
Fat (%)	Pre	22.4±6.0	3.81	0.003 *	20.5±2.9	4.15	0.001 *
	Post	20.3±5.2			19.7±2.7		
Protein (%)	Pre	11.8±3.3	0.97	0.355	11.0±1.4	0.68	0.511
	Post	11.5±2.8			10.9±1.5		

Water (%)	Pre	31.3±5.7	-2.70	0.022 *	29.9±4.0	-0.92	0.374
	Post	32.1±5.3			30.0±3.8		
Skeletal mass	Pre	24.1±4.9	-4.59	0.001 *	23.9±3.8	-1.84	0.089
	Post	24.9±4.8			24.4±3.7		
WHR	Pre	0.9±0.1	2.24	0.049 *	0.9±0.1	1.00	0.336
	Post	0.9±0.1			0.9±0.1		
IS	Pre	2.7±0.4	2.34	0.042 *	2.7±0.4	1.42	0.178
	Post	2.6±0.4			2.7±0.4		
Physical score	Pre	56.5±6.4	3.32	0.008 *	59.6±3.6	t=0.000	0.040
	Post	55.1±6.7			59.6±3.6		
HAS	Pre	68.2±10.7	1.84	0.096	70.6±6.3	1.00	0.336
	Post	67.7±10.7			70.5±6.3		
BL (mmol/L)	Pre	6.7±1.8	6.79	<0.001 *	6.2±1.0	5.11	<0.001 *
	Post	5.6±1.7			5.6±1.0		

[Table/Fig-5]: Comparison of Blood Glucose Level (BGL), body composition, and Blood Lactate (BL) between groups.

score, both of which are important in lowering cardiovascular risk in people with type 2 diabetes.

Group B (Swiss Ball Pilates)

The SBP group had significant reductions in BGL, fat mass, and BL, suggesting that this method might be advantageous for metabolic health. However, there was no statistically significant change in skeletal muscle mass, WHR, water content, or functional outcomes like IS or physical score as a result of the intervention.

The SBP emphasises core stability, coordination, and dynamic balance. Compared to MP, this exercise may need less overall muscle activity, nevertheless being beneficial for improving neuromuscular control. Its effect on systemic metabolic markers may be limited by this. Even though posture and balancing exercises help older persons improve their proprioception and lower their risk of falling, they may need to be combined with strength or aerobic activities for more comprehensive metabolic effects [18,19].

Even though the majority of physical and biochemical markers did not alter considerably, Group B's post-test physical score shown a statistically significant improvement when compared to Group A. This suggests that enhanced neuromuscular function or a greater perception of physical capacity may be the outcome of the functional requirements of Swiss ball workouts, which include dynamic balance, core control, and continuous muscle engagement.

The between-group investigation found no discernible variations in baseline (pre-test) values for any outcome variables, confirming effective randomisation and homogeneity between groups. After the intervention, both groups improved, but Group A continuously exhibited higher statistical significance over a larger range of traits.

The only post-intervention metric that revealed a significant difference between groups was the physical score, which favoured the SBP group. This is likely due to the proprioceptive and balance-enhancing properties of Swiss ball exercises, which require continuous postural adjustments and may enhance neuromuscular coordination and dynamic stability [20].

These findings suggest that both strategies have benefits, but mat SBP may be more helpful for improving physical functionality, especially in populations at risk for falls and functional decline, while pilates appears to be better at addressing metabolic and compositional concerns.

These findings have important clinical ramifications for the treatment of sedentary people with type 2 diabetes. First, any form of pilates is a safe, practical, and low-impact exercise technique that may be used in both clinical and community settings. Second, SBP may be saved for functional rehabilitation and balance training, whereas MP might be the better option when the main objective is body composition improvement and metabolic optimisation. Because Pilates is dynamic and non threatening, this study also supports its inclusion in structured diabetic treatment programs, which may lessen reliance on pharmaceutical therapies while increasing patient involvement and adherence.

Limitation(s)

It's critical to acknowledge certain restrictions despite the benefits. The four-week trial timeframe may have made it more challenging to document sustainable benefits or long-term changes. The limited sample size (n=30) reduced the generalisability of the results. Moreover, biochemical markers like HbA1c and inflammatory cytokines that can provide additional insight into systemic inflammation and long-term glycaemic control were not included in the study. Lack of post-intervention tracking of participant activity, nutrition, and adherence may have had an impact on the results. Future research should aim to increase sample sizes, extend study durations, and conduct more comprehensive biomarker analysis.

Future research should examine hybrid exercise models that combine Pilates with Swiss balls and mats to improve their functional and metabolic impacts. Research on how Pilates affects the cardiovascular fitness, mental health, and quality of life in diabetic people may be beneficial. To support the body of evidence, longitudinal studies that monitor the impact of therapies for a minimum of three to six months would be beneficial.

CONCLUSION(S)

In conclusion, a four-week pilates intervention significantly improved important metabolic and body composition metrics in inactive individuals with type 2 diabetes. MP was especially successful for most of the outcomes. Despite its lower metabolic effectiveness, SBP may be more advantageous for functional performance. Because these strategies are realistic and helpful tools in the multidisciplinary care of type 2 diabetes, they ought to be further examined in bigger, longer-term trials.

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