e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(3); 301-306

Original Research Article

Assessment of Exercise Capacity and Cardiovascular Response in Patients with Type 2 Diabetes Mellitus

Akansha Agrawal[1], Deepika Bohra[2], Manisha Gupta[3]

[1]2nd year MD Physiology, Department of Physiology, Batch 23-24, Santosh Medical College, Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India

[2]PhD Scholar, Department of Physiology, Santosh Medical college, Santosh Deemed to be university, Ghaziabad, Uttar Pradesh, India

[3]Professor, Department of Physiology, Santhosh Medical College, Santosh deemed to be university, Ghaziabad, Uttar Pradesh, India

Received: 09-01-2026 / Revised: 07-02-2026 / Accepted: 08-03-2026

Corresponding Author: Dr. Akansha Agrawal

Conflict of interest: Nil

Abstract:

Background: Assessment of exercise capacity and cardiovascular response during physical exertion can provide valuable information regarding functional status in patients with diabetes. The present study aimed to evaluate exercise capacity and cardiovascular responses in patients with Type 2 Diabetes Mellitus in comparison with healthy individuals.

Material and Methods: A hospital-based cross-sectional study was conducted among 120 participants, including 60 patients with Type 2 Diabetes Mellitus and 60 age- and sex-matched healthy controls. Demographic data, clinical parameters, and laboratory investigations including fasting blood glucose, glycated hemoglobin (HbA1c), and lipid profile were recorded. Exercise capacity and cardiovascular responses were assessed using a treadmill exercise test following the Bruce protocol. Parameters evaluated included exercise duration, maximum heart rate achieved, metabolic equivalents (METs), blood pressure response during exercise, heart rate recovery, and rate pressure product. Statistical analysis was performed using SPSS version 25.0, with a p-value <0.05 considered statistically significant.

Results: The mean age of diabetic participants was 54.3 ± 8.1 years, with comparable age and sex distribution between groups. Body mass index and baseline blood pressure were significantly higher in the diabetic group. Laboratory parameters revealed significantly elevated fasting blood glucose (158.6 ± 32.4 mg/dL) and HbA1c levels (8.1 ± 1.2%) among diabetic patients. Exercise testing demonstrated significantly shorter exercise duration (7.2 ± 2.1 minutes vs 9.4 ± 2.5 minutes), lower maximum heart rate achieved (146.3 ± 15.2 beats/min vs 154.7 ± 14.8 beats/min), and reduced METs (7.8 ± 1.9 vs 10.1 ± 2.2) in patients with diabetes compared with controls. Heart rate recovery at 1 minute was significantly lower in diabetic participants (16.8 ± 5.2 beats/min vs 22.4 ± 6.1 beats/min). Poor exercise capacity (<5 METs) was observed in 23.3% of diabetic patients compared with 5.0% of controls.

Conclusion: Patients with Type 2 Diabetes Mellitus demonstrate reduced exercise capacity and impaired cardiovascular response during exertion. These findings emphasize the importance of early cardiovascular evaluation and lifestyle interventions to improve functional capacity and reduce cardiovascular risk in individuals with diabetes.

Keywords: Type 2 Diabetes Mellitus, Exercise Capacity, Treadmill Test, Cardiovascular Response, Metabolic Equivalents, Heart Rate Recovery.

DOI: 10.25258/ijcpr.18.3.48

Introduction

Type 2 Diabetes Mellitus (T2DM) is one of the most prevalent metabolic disorders worldwide and is associated with significant cardiovascular morbidity and mortality. The condition is characterized by insulin resistance, chronic hyperglycemia, and multiple metabolic abnormalities that affect various organ systems, particularly the cardiovascular and musculoskeletal systems. These alterations contribute to reduced physical performance and diminished cardiorespiratory fitness in individuals with diabetes [1]. Impaired exercise capacity has been recognized as an important clinical indicator because it reflects the integrated function of the cardiovascular, respiratory, and muscular systems during physical activity.

Exercise capacity is widely regarded as a strong predictor of cardiovascular health and overall mortality. Reduced cardiorespiratory fitness has been consistently reported in patients with T2DM compared with healthy individuals, even after adjusting for age, body composition, and physical activity levels [2]. A recent meta-analysis demonstrated that individuals with T2DM exhibit significantly lower peak oxygen uptake (VO_2 peak), indicating reduced aerobic capacity and functional performance compared with non-diabetic populations [3]. These impairments may arise from a combination of metabolic disturbances, endothelial dysfunction, and abnormalities in skeletal muscle oxygen utilization.

In addition to reduced exercise tolerance, patients with T2DM often demonstrate altered cardiovascular responses during physical activity. Studies evaluating functional exercise tests have shown that individuals with T2DM may exhibit exaggerated heart rate and blood pressure responses during exertion, reflecting increased cardiac workload and impaired cardiovascular regulation [4]. Such abnormal responses may be related to autonomic dysfunction, impaired vascular reactivity, and abnormalities in peripheral circulation commonly observed in diabetes [5].

Cardiac autonomic neuropathy is a well-recognized complication of diabetes and is associated with abnormalities in heart rate variability and impaired heart rate recovery following exercise. These abnormalities contribute to reduced exercise tolerance and may increase the risk of adverse cardiovascular outcomes [6]. Therefore, assessment of cardiovascular responses during exercise testing provides valuable insights into functional capacity and autonomic regulation in individuals with diabetes.

Exercise stress testing, particularly treadmill testing using standardized protocols, is a practical and widely used method to evaluate exercise capacity and cardiovascular responses. Parameters such as exercise duration, metabolic equivalents (METs), heart rate response, and blood pressure changes during exercise can provide important information about cardiovascular performance and functional limitations [7]. Despite the growing burden of T2DM, data evaluating exercise capacity and cardiovascular responses in diabetic populations remain limited in many clinical settings.

Therefore, the present study was undertaken to assess exercise capacity and cardiovascular responses in patients with Type 2 Diabetes Mellitus and to compare these parameters with those of healthy individuals.

Material and Methods

Study Design and Setting: A hospital-based cross-sectional observational study was carried out at a tertiary care teaching hospital. The objective of the study was to evaluate exercise capacity and cardiovascular responses among patients diagnosed with Type 2 Diabetes Mellitus.

Study Population: The study included adult patients with previously diagnosed Type 2 Diabetes Mellitus attending the outpatient and inpatient services of the Department of Medicine. Age- and sex-matched apparently healthy individuals without diabetes were recruited as controls for comparison.

Sample Size: The sample size was determined based on previous studies evaluating exercise tolerance and cardiovascular responses among patients with Type 2 Diabetes Mellitus, which reported a moderate difference in exercise capacity parameters between diabetic and non-diabetic populations [8,9]. Assuming a confidence level of 95%, power of 80%, and an expected moderate effect size, a minimum sample size of 90 participants was calculated. To account for potential incomplete tests and exclusions, a total of 120 participants were enrolled in the study.

The study population was divided into two groups:

- **Group A:** 60 patients with Type 2 Diabetes Mellitus
- **Group B:** 60 age- and sex-matched healthy controls

Inclusion Criteria: Participants were included in the study if they met the following criteria:

1. Adults aged between 30 and 65 years.
2. Patients with established Type 2 Diabetes Mellitus diagnosed according to standard clinical and biochemical criteria.
3. Duration of diabetes of at least one year.
4. Individuals who were able to perform treadmill-based exercise testing.

For the control group, individuals without diabetes, cardiovascular disease, or other chronic systemic illness were included.

Exclusion Criteria: Participants were excluded if they had:

1. Known ischemic heart disease, heart failure, or significant valvular heart disease.
2. Uncontrolled hypertension (blood pressure ≥180/110 mmHg).
3. Severe respiratory disorders that could interfere with exercise testing.
4. Musculoskeletal or neurological conditions limiting physical activity.
5. Acute illness or infection at the time of assessment.
6. Pregnancy.

Data Collection: After obtaining informed written consent, demographic and clinical information was recorded using a structured data collection form. Data included age, sex, duration of diabetes, body mass index (BMI), blood pressure, and current medications. Laboratory investigations included fasting blood glucose and glycated hemoglobin (HbA1c) levels to assess glycemic status.

Assessment of Exercise Capacity: Exercise capacity was evaluated using a standardized treadmill exercise test (TMT) performed according to the Bruce protocol. Participants were instructed to avoid heavy meals, caffeine intake, and vigorous physical activity for at least 12 hours before the test. During the test, the following parameters were recorded:

- Resting heart rate and blood pressure
- Maximum heart rate achieved during exercise
- Duration of exercise
- Metabolic equivalents (METs) achieved
- Time to onset of fatigue
- Recovery heart rate at 1 and 3 minutes post-exercise

Exercise capacity was primarily assessed based on the total exercise duration and METs achieved.

Cardiovascular Response Assessment: Cardiovascular responses during exercise were evaluated by measuring:

- Heart rate response to exercise
- Systolic and diastolic blood pressure changes during exertion
- Heart rate recovery after exercise
- Rate-pressure product (heart rate × systolic blood pressure)

Electrocardiographic monitoring was performed continuously throughout the exercise test to identify any arrhythmias or ischemic changes.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons between diabetic patients and controls were performed using the independent sample t-test for continuous variables and the chi-square test for categorical variables. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 120 participants were included in the study, comprising 60 patients with Type 2 Diabetes Mellitus and 60 age- and sex-matched healthy controls. The baseline demographic and clinical characteristics of the study population are presented in Table 1. The mean age of patients with Type 2 Diabetes Mellitus was 54.3 ± 8.1 years, while the control group had a mean age of 52.7 ± 7.6 years. The gender distribution was comparable between the two groups, with 34 males and 26 females in the diabetic group and 32 males and 28 females in the control group. Body mass index was significantly higher among patients with diabetes compared with controls (27.8 ± 3.9 kg/m² vs 25.6 ± 3.4 kg/m², $p = 0.002$). Additionally, systolic and diastolic blood pressures were significantly elevated in the diabetic group compared with controls ($p < 0.05$) (Table 1).

Laboratory parameters of the study participants are summarized in Table 2. Patients with Type 2 Diabetes Mellitus demonstrated significantly higher fasting blood glucose levels compared with controls (158.6 ± 32.4 mg/dL vs 92.3 ± 10.7 mg/dL, $p < 0.001$). Similarly, glycated hemoglobin (HbA1c) levels were markedly higher in the diabetic group (8.1 ± 1.2%) compared with the control group (5.3 ± 0.5%) ($p < 0.001$). Lipid profile analysis revealed significantly elevated total cholesterol, low-density lipoprotein cholesterol, and triglyceride levels in diabetic participants, whereas high-density lipoprotein cholesterol levels were significantly lower when compared with the control group ($p < 0.05$) (Table 2).

Exercise capacity parameters obtained from the treadmill exercise test are presented in Table 3. The resting heart rate was significantly higher in patients with Type 2 Diabetes Mellitus compared with controls (82.4 ± 9.6 beats/min vs 76.8 ± 8.7 beats/min, $p = 0.001$). Diabetic patients demonstrated a significantly shorter exercise duration (7.2 ± 2.1 minutes) compared with healthy controls (9.4 ± 2.5 minutes, $p < 0.001$). Furthermore, the maximum heart rate achieved during exercise was lower in the diabetic group (146.3 ± 15.2 beats/min) than in controls (154.7 ± 14.8 beats/min, $p = 0.004$). The metabolic equivalents (METs) achieved were also significantly reduced in patients with diabetes (7.8 ± 1.9) compared with the control group (10.1 ± 2.2, $p < 0.001$). Similarly, time to fatigue was shorter among diabetic patients ($p < 0.001$) (Table 3).

The blood pressure response during exercise testing is shown in Table 4. Resting systolic blood pressure was significantly higher in the diabetic group compared with controls (132.6 ± 14.2 mmHg vs 124.3 ± 11.5 mmHg, $p = 0.001$). Peak systolic blood pressure during exercise was slightly lower among diabetic patients compared with controls (178.4 ± 18.6 mmHg vs 186.7 ± 17.4 mmHg, $p = 0.011$). However, no statistically significant difference was observed in peak diastolic blood pressure between the two groups ($p = 0.132$) (Table 4).

Heart rate recovery and rate pressure product during exercise are presented in Table 5. Patients with Type 2 Diabetes Mellitus demonstrated significantly

impaired heart rate recovery at both 1 minute and 3 minutes following exercise when compared with controls ($p < 0.001$). In addition, the rate pressure product at peak exercise was significantly lower among diabetic patients (26052 ± 3840) compared with the control group (28914 ± 4126) ($p < 0.001$) (Table 5).

The distribution of exercise capacity based on metabolic equivalents achieved is shown in Table 6. Poor exercise capacity (<5 METs) was observed in 23.3% of patients with Type 2 Diabetes Mellitus compared with 5.0% of controls. Moderate exercise capacity (5–8 METs) was noted in 53.3% of diabetic patients and 30.0% of controls, whereas good exercise capacity (>8 METs) was observed in only 23.3% of diabetic participants compared with 65.0% of the control group. The difference in exercise capacity distribution between the two groups was statistically significant ($p < 0.001$) (Table 6).

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Parameter	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Age (years)	54.3 ± 8.1	52.7 ± 7.6	0.238
Male/Female	34 / 26	32 / 28	0.703
Body Mass Index (kg/m²)	27.8 ± 3.9	25.6 ± 3.4	0.002
Duration of Diabetes (years)	7.4 ± 3.6	—	—
Systolic BP (mmHg)	132.6 ± 14.2	124.3 ± 11.5	0.001
Diastolic BP (mmHg)	82.7 ± 9.4	78.1 ± 7.6	0.004

Table 2: Laboratory Parameters of Study Participants

Parameter	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Fasting Blood Glucose (mg/dL)	158.6 ± 32.4	92.3 ± 10.7	<0.001
HbA1c (%)	8.1 ± 1.2	5.3 ± 0.5	<0.001
Total Cholesterol (mg/dL)	196.4 ± 34.7	178.5 ± 29.6	0.003
LDL Cholesterol (mg/dL)	121.7 ± 28.1	105.3 ± 24.8	0.002
HDL Cholesterol (mg/dL)	40.6 ± 6.5	46.2 ± 7.1	<0.001
Triglycerides (mg/dL)	168.2 ± 46.9	132.7 ± 38.5	<0.001

Table 3: Exercise Capacity Parameters During Treadmill Exercise Test

Parameter	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Resting Heart Rate (beats/min)	82.4 ± 9.6	76.8 ± 8.7	0.001
Exercise Duration (minutes)	7.2 ± 2.1	9.4 ± 2.5	<0.001
Maximum Heart Rate Achieved (beats/min)	146.3 ± 15.2	154.7 ± 14.8	0.004
METs Achieved	7.8 ± 1.9	10.1 ± 2.2	<0.001
Time to Fatigue (minutes)	6.9 ± 2.0	9.0 ± 2.3	<0.001

Table 4: Blood Pressure Response During Exercise

Parameter	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Resting Systolic BP (mmHg)	132.6 ± 14.2	124.3 ± 11.5	0.001
Peak Systolic BP (mmHg)	178.4 ± 18.6	186.7 ± 17.4	0.011
Resting Diastolic BP (mmHg)	82.7 ± 9.4	78.1 ± 7.6	0.004
Peak Diastolic BP (mmHg)	88.9 ± 10.2	86.3 ± 8.7	0.132

Table 5: Heart Rate Recovery and Rate Pressure Product

Parameter	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Heart Rate Recovery at 1 min (beats/min)	16.8 ± 5.2	22.4 ± 6.1	<0.001
Heart Rate Recovery at 3 min (beats/min)	34.6 ± 8.9	42.1 ± 9.3	<0.001
Rate Pressure Product at Peak Exercise	26052 ± 3840	28914 ± 4126	<0.001

Table 6: Distribution of Exercise Capacity Based on METs Achieved

Exercise Capacity	Type 2 Diabetes Mellitus (n=60)	Controls (n=60)	p-value
Poor (<5 METs)	14 (23.3%)	3 (5.0%)	<0.001
Moderate (5–8 METs)	32 (53.3%)	18 (30.0%)	
Good (>8 METs)	14 (23.3%)	39 (65.0%)	

Discussion

The present study evaluated exercise capacity and cardiovascular responses in patients with Type 2 Diabetes Mellitus and compared these findings with those of healthy controls. The results demonstrated that patients with diabetes had significantly reduced exercise duration, lower metabolic equivalents (METs), and diminished maximal heart rate during treadmill exercise testing. In addition, diabetic participants showed impaired heart rate recovery and altered blood pressure responses during exertion, indicating compromised cardiovascular adaptability.

In the present study, patients with Type 2 Diabetes Mellitus demonstrated significantly lower exercise capacity compared with the control group, as reflected by reduced exercise duration and METs achieved. These findings are consistent with previous research indicating that individuals with T2DM frequently exhibit reduced cardiorespiratory fitness and impaired exercise tolerance. A systematic review and meta-analysis reported that adults with T2DM have significantly lower peak oxygen uptake (VO_2 peak), reflecting reduced aerobic capacity when compared with non-diabetic individuals [10]. Similarly, other studies have shown that the presence of T2DM is independently associated with reduced peak aerobic capacity and poorer functional performance [11].

The reduced exercise capacity observed in diabetic patients may be attributed to multiple physiological mechanisms. Previous studies suggest that exercise intolerance in T2DM results from a combination of impaired cardiac output response, reduced skeletal muscle oxygen utilization, endothelial dysfunction, and abnormalities in peripheral circulation during physical activity [12]. In addition, chronic hyperglycemia and insulin resistance may lead to structural and metabolic changes in skeletal muscle that contribute to early fatigue and diminished physical performance [13].

Another important finding of the present study was the significantly higher resting heart rate and impaired heart rate recovery following exercise in patients with T2DM. Heart rate recovery after exercise reflects autonomic nervous system function, particularly parasympathetic reactivation. Previous studies have demonstrated that delayed heart rate recovery is commonly observed in individuals with diabetes and is strongly associated with cardiac autonomic neuropathy [14]. Reduced heart rate recovery has also been reported as an important predictor of cardiovascular morbidity and mortality in patients with T2DM [15].

The present study also observed differences in blood pressure response during exercise between diabetic patients and healthy controls. Abnormal cardiovascular responses during exertion have been reported in individuals with diabetes, possibly due to autonomic dysfunction and impaired vascular regulation. A study evaluating cardiovascular responses during functional exercise testing reported higher heart rate and systolic blood pressure responses among individuals with T2DM compared with healthy subjects, suggesting increased cardiovascular workload during physical activity [16].

Furthermore, our findings showed that a greater proportion of diabetic participants had poor exercise capacity (<5 METs) compared with controls. Reduced exercise capacity is clinically important because it has been associated with increased cardiovascular risk and adverse outcomes. Previous research has demonstrated that lower exercise capacity and abnormal heart rate recovery are associated with higher incidence of cardiovascular events in individuals with metabolic disorders and diabetes [17].

Overall, the findings of the present study support existing evidence that Type 2 Diabetes Mellitus is associated with impaired functional capacity and abnormal cardiovascular responses during exercise. These alterations may reflect underlying autonomic dysfunction, impaired peripheral oxygen utilization, and reduced cardiovascular efficiency. Early identification of these abnormalities through exercise testing may help in risk stratification and guide interventions aimed at improving cardiovascular fitness. Lifestyle modifications including regular aerobic exercise, improved glycemic control, and cardiovascular risk management may play an important role in improving exercise tolerance and reducing long-term complications in patients with Type 2 Diabetes Mellitus [18].

Conclusion

Patients with Type 2 Diabetes Mellitus demonstrated significantly reduced exercise capacity and altered cardiovascular responses compared with healthy individuals. Diabetic participants showed shorter exercise duration, lower metabolic equivalents achieved and reduced maximum heart rate during treadmill testing. In addition, impaired heart rate recovery and differences in blood pressure response during exercise were observed, suggesting underlying autonomic dysfunction and diminished cardiovascular adaptability. These findings indicate that Type 2 Diabetes Mellitus is associated with decreased functional exercise capacity and suboptimal cardiovascular performance, highlighting the importance of early cardiovascular evaluation and targeted lifestyle interventions, including regular physical activity and optimal

glycemic control, to improve cardiovascular fitness and overall clinical outcomes in this population.

References

1. Zaki S, Alam MF, Sharma S, El-Ashker S, Ahsan M, Nuhmani S. Impact of Concurrent Exercise Training on Cardiac Autonomic Modulation, Metabolic Profile, Body Composition, Cardiorespiratory Fitness, and Quality of Life in Type 2 Diabetes with Cardiac Autonomic Neuropathy: A Randomized Controlled Trial. Journal of Clinical Medicine. 2024; 13(13):3910. https://doi.org/10.3390/jcm13133910
2. Anderson KC, Weeldreyer NR, Leicht ZS, Angadi SS, Liu Z. Exercise Intolerance in Type 2 Diabetes: A Systematic Review and Meta-Analysis. J Am Heart Assoc. 2025;14(5):e035721. doi:10.1161/JAHA.124.035721
3. Anand V, Garg S, Garg J, Bano S, Pritzker M. Impact of Exercise Training on Cardiac Function Among Patients with Type 2 Diabetes: A SYSTEMATIC REVIEW AND META-ANALYSIS. J Cardiopulm Rehabil Prev. 2018;38(6):358-365. doi:10.1097/HCR.0000000000000353
4. Senefeld JW, D'Astice SE, Harmer AR, Hunter SK. Increased Cardiovascular Response to a 6-Minute Walk Test in People with Type 2 Diabetes. Diabetes Spectr. 2020;33(1):104-110. doi:10.2337/ds19-0002
5. Poitras VJ, Hudson RW, Tschakovsky ME. Exercise intolerance in Type 2 diabetes: is there a cardiovascular contribution? J Appl Physiol (1985). 2018;124(5):1117-1139. doi:10.1152/japplphysiol.00070.2017
6. Picard M, Tauveron I, Magdasy S, et al. Effect of exercise training on heart rate variability in type 2 diabetes mellitus patients: A systematic review and meta-analysis. PLoS One. 2021;16(5):e0251863. Published 2021 May 17. doi: 10.1371/journal.pone.0251863
7. Adekunle AE, Akintomide AO. Gender differences in the variables of exercise treadmill test in type 2 diabetes mellitus. Ann Afr Med. 2012;11(2):96-102. doi:10.4103/1596-3519.93532.
8. Kanaley JA, Colberg SR, Corcoran MH, et al. Exercise/Physical Activity in Individuals with Type 2 Diabetes: A Consensus Statement from the American College of Sports Medicine. Med Sci Sports Exerc. 2022;54(2):353-368. doi:10.1249/MSS.0000000000002800
9. Baldi JC, Aoina JL, Oxenham HC, Bagg W, Doughty RN. Reduced exercise arteriovenous O2 difference in Type 2 diabetes. J Appl Physiol (1985). 2003;94(3):1033-1038. doi:10.1152/japplphysiol.00879.2002
10. Nesti L, Pugliese NR, Sciuto P, et al. Mechanisms of reduced peak oxygen consumption in subjects with uncomplicated type 2 diabetes. Cardiovasc Diabetol. 2021;20(1):124. Published 2021 Jun 22. doi:10.1186/s12933-021-01314-6
11. Abe T, Yokota T, Fukushima A, et al. Type 2 diabetes is an independent predictor of lowered peak aerobic capacity in heart failure patients with non-reduced or reduced left ventricular ejection fraction. Cardiovasc Diabetol. 2020; 19:142. doi:10.1186/s12933-020-01114-4.
12. Ishihara K, Morisawa T, Kawada J, et al. Influence of Complications of Diabetes Mellitus on Exercise Tolerance of Patients with Heart Failure: Focusing on autonomic nervous activity and heart rate response during cardiopulmonary exercise tests. Phys Ther Res. 2019;22(2):81-89. doi:10.1298/ptr.E9979
13. Poole DC, Hirai DM, Copp SW, Musch TI. Muscle oxygen transport and utilization in heart failure: implications for exercise (in)tolerance. Am J Physiol Heart Circ Physiol. 2012;302(5):H1050-H1063. doi:10.1152/ajpheart.00943.2011
14. Sacre JW, Jellis CL, Coombes JS, Marwick TH. Diagnostic accuracy of heart-rate recovery after exercise in the assessment of diabetic cardiac autonomic neuropathy. Diabet Med. 2012;29(9):e312-e320. doi:10.1111/j.1464-5491.2012. 03719.x
15. Chacko KM, Bauer TA, Dale RA, Dixon JA, Schrier RW, Estacio RO. Heart rate recovery predicts mortality and cardiovascular events in patients with type 2 diabetes. Med Sci Sports Exerc. 2008;40(2):288-295. doi:10.1249/mss.0b013e31815c4844
16. Senefeld JW, D'Astice SE, Harmer AR, Hunter SK. Increased Cardiovascular Response to a 6-Minute Walk Test in People With Type 2 Diabetes. Diabetes Spectr. 2020;33(1):104-110. doi:10.2337/ds19-0002
17. Spies C, Otte C, Kanaya A, Pipkin SS, Schiller NB, Whooley MA. Association of metabolic syndrome with exercise capacity and heart rate recovery in patients with coronary heart disease in the heart and soul study. Am J Cardiol. 2005;95(10):1175-1179. doi:10.1016/j.amjcard.2005.01.045
18. Amare F, Kiflu A, Taddese A. Effects of concurrent continuous aerobic and short rest resistance exercise training on metabolic biomarkers in type 2 diabetes patients: a systematic review and meta-analysis. Diabetol Metab Syndr. 2025;17:290. doi:10.1186/s13098-025-01838-x.