

Systematic Review

Comparative Analysis of Cardiovascular Outcomes in Type 2 Diabetes Patients Engaging in Aerobic, Resistance, and Combined Training: A Systematic Review

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Abstract: Background: Among individuals with type 2 diabetes (T2D), cardiovascular disease (CVD) is the leading cause of death, demanding prevention approaches. Exercise is a powerful option for non-pharmacological strategies to improve cardiovascular outcomes. This systematic review aims to evaluate the effects of aerobic, resistance, and combined training on CVD in individuals with T2D. **Methods:** From 2013 through the end of 2023, PubMed, Scopus, and Web of Science were systematically searched for articles. The studies included 15 articles lasting at least eight weeks and involving 1794 participants each. The cardiac events measured were blood pressure, lipid levels, heart rate variability (HRV), and inflammatory markers such as C-reactive protein (CRP) and interleukin-6 (IL-6). **Results:** Aerobic training reduced systolic and diastolic blood pressure by 6 mmHg and 3 mmHg, respectively, while significantly enhancing lipid profiles, evidenced by an 8% reduction in LDL cholesterol and a 5% rise in HDL cholesterol. In addition, improvements in lean muscle mass, insulin sensitivity, and slight changes in inflammatory markers support the benefits of resistance training. The most pronounced effects emerged from combined training, which resulted in a 9 mmHg decrease in systolic blood pressure, a 6 mmHg decrease in diastolic pressure, a 10% reduction in LDL cholesterol, a 15% increase in HRV, and a 10% reduction in CRP and IL-6 levels. **Conclusions:** Combined training has more favorable effects on several key CVD risk factors than aerobic or resistance training alone. It can be regarded as the most effective exercise modality for decreasing CVD risk in adults with T2D.

Keywords: type 2 diabetes; cardiovascular outcomes; aerobic exercise; resistance training; combined training; heart rate variability; inflammatory markers

1. Introduction

1.1. Global Impact of Type 2 Diabetes and Cardiovascular Disease

Type 2 Diabetes (T2D) affects over half a billion individuals worldwide and could impact over 640 million by 2030 due to aging populations, urbanization, and increasing obesity [1,2]. Beyond metabolic health consequences, T2D strongly predisposes individuals to cardiovascular disease (CVD), accounting for nearly 70% of deaths among diabetics [3]. This dual risk illustrates that interventions addressing glycemic control alone may be insufficient; interventions targeting cardiovascular complications associated with T2D will also be necessary and imperative.

1.2. Role of Exercise in Cardiovascular Health for T2D

CVD in T2D results from a complex interaction involving chronic hyperglycemia, insulin resistance, and systemic factor inflammation. These promote endothelial dysfunction, atherosclerosis, and dyslipidemia marked by elevated triglycerides (TG), low high-density lipoprotein (HDL), and small, dense low-density lipoprotein (LDL) particles [4,5]. Moreover, hypertension in about 80% of T2D patients exacerbates vascular injury, accelerating atherosclerotic plaque progression and heightening cardiovascular event risk [6].

Physical activity is solidly established as fundamental to T2D management, conferring metabolic and cardiovascular benefits beyond drugs. Regular exercise enhances insulin sensitivity, boosts glucose uptake, reduces visceral fat, and improves blood pressure and lipid profiles [6,7]. The American Diabetes Association (ADA) advocates moderate-to-vigorous aerobic activity and resistance training as integral to diabetes care [7]. However, the comparative efficacy of aerobic, resistance, and combined training modes in improving cardiovascular outcomes in T2D individuals remains an active research area.

Recent studies suggest aerobic exercise mainly benefits cardiovascular fitness and lipids, while resistance training improves muscle strength and insulin sensitivity. Combined training and blending both hold promise for synergistic effects [8–10]. Nevertheless, gaps persist in understanding the long-term comparative effectiveness of these exercise regimens regarding key cardiovascular endpoints such as blood pressure regulation, lipid metabolism, heart rate variability (HRV), and systemic inflammation markers [11,12].

While high-intensity interval training (HIIT) and flexibility-based exercises may provide cardiovascular benefits, these modalities were excluded due to insufficient long-term outcome data and a lack of consistency in cardiovascular endpoints reported across T2D populations. In contrast, aerobic, resistance, and combined training have been extensively investigated and are commonly included in international guidelines, making them more suitable for systematic comparison.

1.3. Study Objectives and Contributions

This article aims to systematically review the literature and consolidate evidence regarding the impact of aerobic, resistance, and combined training on cardiovascular health in individuals with T2D patients. By incorporating key insights from recent clinical trials with mechanistic studies, in this review, we strive to provide a clearer understanding of the physiological pathways by which the observed benefits of each exercise modality are observed. In addition, implications for clinical practice are discussed, including evidence supporting structured exercise interventions to mitigate CVD risk and sustain health in T2D individuals.

This study contributes to the growing evidence supporting exercise as a cost-effective, non-drug strategy for managing T2D. It highlights the promising capability of combined exercise training as an integrated strategy to tackle the complex issues of T2D-related cardiovascular risk. This synthesis is aimed at both clinical and policy stakeholders interested

in developing evidence-based guidance on exercise prescription specific to the unique needs of patients with T2D to optimize long-term engagement with exercise and follow-up health benefits.

2. Methodology

2.1. Research Design

Taking on the systematic review method, this study examines the effects of categories in which exercise modes can be divided by looking at aerobic exercise methods, the resistance category, and aerobic and anaerobic integration exercises that affect cardiovascular results for T2D patients. It synthesizes findings from several studies to examine the impact of these exercise modalities on key markers of cardiovascular health, including blood pressure, lipid profiles, HRV, and inflammation. These outcomes were selected based on strong evidence of responsiveness to exercise interventions and direct relevance to cardiovascular health risk [13].

2.2. Rationale for the Systematic Review

This review summarizes the exercise modality of choice concerning attenuating cardiovascular risk in T2D. It also maintains transparency and reproducibility by abiding by and adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. It provides a methodical framework for collecting and qualitatively evaluating available studies, identifying the specific form of exercise that most significantly improves cardiovascular outcomes. The lipid profiles and HRV outcomes also highlight their association with physiological processes, including increased lipid metabolism and an improved autonomic nervous system. Such mechanisms help lower systemic inflammation as well [6].

2.3. Research Questions and Hypotheses

Below are the detailed questions and hypotheses that will guide the systematic review and the analysis and interpretation of the findings.

- Main Question:

What type of exercise (i.e., aerobic, resistance, or combined training) strongly affects cardiovascular outcomes in T2D?

- Secondary Questions:

1. How do exercise intensity, frequency, and duration impact cardiovascular risk factors?
2. Is combined training more synergistic or superior to single-modality training?

While aerobic, resistance, and combined training have each shown individual benefits for cardiometabolic health, there is a lack of comparative synthesis assessing their distinct and overlapping impacts on cardiovascular markers in T2D. Most prior studies evaluated these modalities independently, often in small samples or with heterogeneous outcome definitions. Furthermore, the long-term effectiveness of each modality, particularly in relation to HRV and inflammatory biomarkers, remains insufficiently clarified. This review was thus designed to address these knowledge gaps directly.

- H1: Aerobic activity leads to more pronounced blood pressure drops and cholesterol profile enhancements compared to strength training [6].
- H2: Strength training improves performance, indirectly lowers inflammation, improves cardiovascular health, and increases muscle mass and glucose metabolism [10].
- H3: Individuals can achieve the greatest cardiovascular benefits by improving muscle strength and cardiorespiratory fitness through resistance and aerobic exercise. This may lead to a greater reduction in cardiovascular risks [9].

2.4. Inclusion and Exclusion Criteria

This review included studies meeting the following inclusion and exclusion criteria to ensure relevance and quality:

- Inclusion Criteria:
 1. Population: Adults 18 years and older diagnosed with T2D.
 2. Interventions: Exercise interventions must be aerobic, resistance training, or both (combined) and at least 8 weeks long. Such a period is the minimum for detecting relevant cardiovascular and metabolic effects adaptations.
 3. Outcomes: Eligible studies should report cardiovascular outcomes, including blood pressure, lipid profiles (LDL, HDL, TG), HRV, and inflammatory biomarkers (e.g., C-reactive protein (CRP) and interleukin-6 (IL-6)).
 4. Study Design: Randomized controlled trials (RCTs), cohort studies, and longitudinal designs that isolate exercise intervention effects on cardiovascular outcomes.

Note on Multi-Component Interventions:

Studies that included additional lifestyle components, such as dietary advice, were only included if the effects of exercise on cardiovascular outcomes were reported independently and could be analyzed separately from the dietary intervention.

- Exclusion Criteria:
 1. Non-T2D Populations: Studies focused on and/or only included non-T2D populations or pharmacological intervention without distinction of exercise effect [5].
 2. Pharmacological Interventions: This review will exclude any studies that combine exercise interventions with pharmacological medications (e.g., insulin or metformin) in which exercise is not examined separately, as it focuses solely on the effects of exercise on cardiovascular outcomes [6].
 3. Duration of Intervention: Interventions lasting fewer than eight weeks were excluded, as this duration is generally insufficient to produce meaningful cardiovascular or metabolic changes.
 4. Language and Publication Type: Only peer-reviewed, English-language publications were included to enhance methodological rigor and ensure consistency in quality assessment. While this approach reduces heterogeneity in study design and reporting, we acknowledge that the exclusion of non-English studies and gray literature may introduce language and publication bias.

Consideration of Medication Use

While we excluded studies where the contribution of pharmacological therapy could not be disentangled from exercise, some participants in the included trials may have been taking stable glucose-lowering agents such as SGLT2 inhibitors or GLP-1 receptor agonists. Given their established cardioprotective properties, these medications may have partly influenced the observed cardiovascular outcomes. Future research should stratify results by medication use or adjust for pharmacologic confounders to better isolate the effects of exercise.

2.5. Data Sources and Search Strategy

The systematic review included a comprehensive search of electronic databases, specifically PubMed, Scopus, and Web of Science. These databases were selected because they cover extensive medical and exercise science literature. The search was conducted for studies published between 2013 and 2023 [14].

Key search terms and Boolean operators were used to refine the search results. Examples include:

- “Type 2 Diabetes” AND “Cardiovascular Outcomes”;
- “Aerobic Exercise” OR “Resistance Training” OR “Combined Training”;
- “Blood Pressure” AND “Lipid Profiles” AND “Heart Rate Variability”;
- “Inflammation” AND “C-reactive Protein” AND “IL-6”.

Studies were included if they reported on adults diagnosed with T2D, were written in English, and adhered to ethical standards. The search identified 800 primary studies, which were systematically evaluated based on the inclusion and exclusion criteria [15].

2.6. Study Selection Process

In the study selection stage, methodological rigor and transparency were strictly followed using the PRISMA guidelines. The multi-stage screening method used involved the following [14]:

- Title and Abstract Screening: The titles and abstracts of 800 studies were initially reviewed to eliminate duplicates and irrelevant studies. Studies unrelated to cardiovascular outcomes or not involving exercise interventions were removed at this stage.
- Full-Text Review: 200 articles were reviewed in detail to assess their adherence to inclusion criteria. Only studies that met the specified intervention, population, and outcome requirements were included.
- Eligible Articles: For the final analysis, 15 studies with around 1794 subjects each were included. The above-mentioned studies included a wide range of exercise protocols and targeted several cardiovascular disease-mediated endpoints related to the management of T2D (see Figure 1).

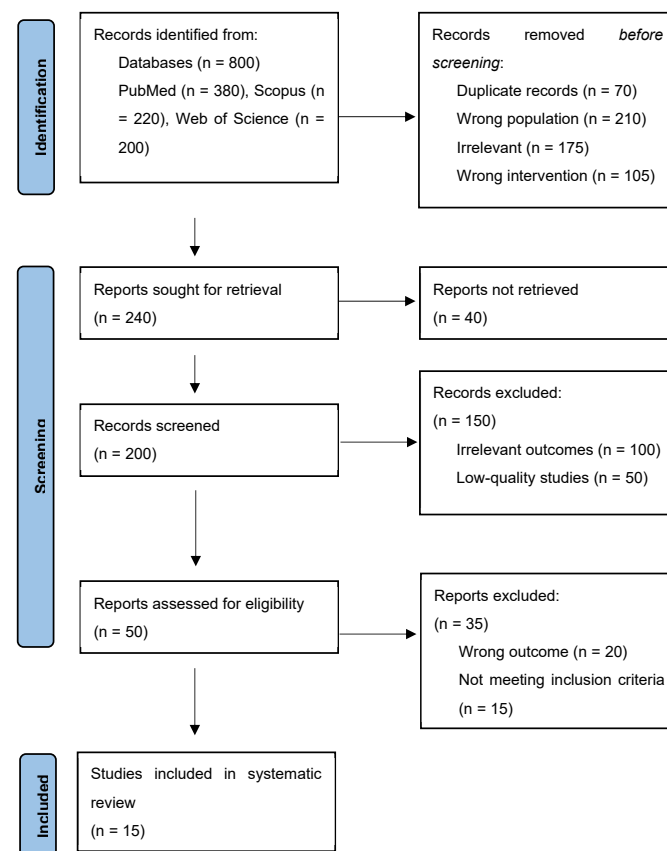


Figure 1. PRISMA 2020 flowchart showing the selection process of studies included in the systematic review. This includes identification, screening, eligibility assessment, and final inclusion, with reasons for exclusion detailed at each stage. Note: Gray literature, preprints, and non-English studies were not considered in this review.

2.7. Data Extraction and Management

Data extraction was conducted in a standardized manner, gathering all necessary information from the articles to fulfill our study's objectives.

Two independent reviewers performed data extraction using a standardized data extraction form. Data were extracted and compared, and discrepancies were resolved by consensus or, if necessary, in discussion with a third reviewer. No automation tools were employed, and the authors of the studies were not contacted; all data were extracted from the published reports.

- **Study Information:** The authors, year of publication, and journal information are provided as input.
- **Demographic characteristics:** Details regarding the age, gender, and duration of T2D among participants were extracted.
- **Intervention characteristics:** The type of exercise intervention, including intensity, frequency, and duration, were recorded.
- **Cardiovascular Outcomes:** The cardiovascular outcomes examined (e.g., blood pressure, cholesterol levels, and HRV) were recorded.

Besides the primary outcomes, study setting, participant recruitment strategies, and funding sources, when reported, were also extracted. In cases where there was missing or unclear information (e.g., incomplete intervention description on intensity or participant demographics), assumptions were made based either on the context of the study or according to best practices in exercise science. If it was not reasonable to infer values for the variable, then it was recorded as 'not reported' to avoid distortions of the data and maintain methodological transparency.

The outcome domains most frequently extracted from studies met are systolic and diastolic blood pressure, components of the lipid profile (LDL, HDL, TG), HRV, and inflammatory biomarkers (CRP, IL-6). When studies reported outcomes at multiple time points or used various measurement tools, we prioritized post-intervention outcomes and the longest follow-up period. Such a method provided comparability between studies and accounted for the sustained impact of exercise interventions on CVD outcomes in those with T2D.

It is important to note that, although some studies did not provide full baseline data, we included this information where available. Confidence intervals and effect sizes are shown when available in the original publications.

2.8. Quality Assessment

The quality of each study was assessed using the Cochrane Risk of Bias tool, which evaluates several key factors:

- **Randomization:** Whether participants were randomly assigned to different exercise groups [15].
- **Blinding:** Whether the outcome assessors were blinded to group assignments.
- **Incomplete Data:** How the study managed missing or incomplete data, such as participant dropouts.
- **Selective Reporting:** Whether the study reported all expected outcomes or only favorable results.

Two reviewers independently assessed the risk of bias for each included study, and any disagreements were resolved through discussion or consultation with a third reviewer. No automation tools were used in the risk of bias assessment process. The risk of bias due to missing results or publication bias across studies was not formally assessed, as no meta-analysis or publication bias analysis (e.g., funnel plots) was conducted.

2.9. Data Synthesis

A narrative synthesis described the findings by type of exercise intervention. Studies were classified as aerobic, resistance, or combined training. Cardiovascular outcomes, such as blood pressure, lipid profiles, HRV, and inflammatory markers, were compared qualitatively within each category. Subgroup analyses examined differences in results regarding exercise intensity and duration frequency.

Effect measures used in the synthesis included mean differences (e.g., mmHg for blood pressure, changes in VO_2max) and percentage changes (e.g., lipid profiles, HRV, CRP, IL-6), depending on the format used in each included study.

Information on individual studies and their synthesis was systematically presented in structured summary tables. Characteristics of individual studies included in qualitative synthesis are shown in Table 1, including sample size, type of intervention, duration, intensity, and measures of outcome. In addition, Table 2 summarizes the risk of bias for each included study according to the Cochrane criteria. Domains assessed include randomization, blinding, incomplete data, selective reporting, and overall risk rating.

Our data were further adapted into figures, which illustrate key trends and differences across training modalities, emphasizing the relative magnitude of effects on outcomes, such as blood pressure, lipid profile, HRV, and inflammatory markers.

A meta-analysis was not conducted due to high variability in intervention types, outcome measures, and follow-up durations across the included studies, which limited the feasibility of quantitative synthesis. A qualitative subgroup analysis based on intervention duration (≥ 24 weeks vs. < 24 weeks) was conducted to account for variability. However, due to inconsistent reporting across studies, subgroup analysis by exercise intensity was not feasible. Furthermore, time-to-event outcome data were not reported in any of the included studies, making Kaplan–Meier survival analysis inappropriate in this context [16].

Table 1. Summary of included studies evaluating aerobic, resistance, and combined training in patients with T2D. Table includes study design, sample size, intervention characteristics, and cardiovascular outcomes.

No.	Study (Author, Year)	First Author	Total Participants	Average Age	Gender Distribution	Intervention Type	Frequency (per Week)	Duration (Weeks)	Intensity	Primary Outcomes	Secondary Outcomes	Statistical Measures (Mean, SD, Significance)
1	Cassidy et al., 2019 [17]	Cassidy, Sophia—Houghton, David	22.0	60 ± 2 years	17 males	HIIT (3 sessions per week) vs. control with standard care	3	12.0	High-intensity	Glycemic Control (HbA1c): Significant improvement in the HIIT group (7.13% to 6.87%, $p = 0.03$); HRV: No significant changes; Blood Pressure Variability: Some variations but not statistically significant	Negative correlation between HbA1c and BRS	HbA1c improvement: Mean change, $p = 0.03$
2	Byrkjeland et al., 2017 [18]	Byrkjelan, Rune	137.0	63.1 ± 7.9 years	Predominantly Caucasian	Exercise Program: 12-month combined aerobic and resistance training (150 min/week); Control Group: Standard follow-up	3 (150 min total)	52.0	Moderate	Glycemic Control (HbA1c): Significant decrease in HbA1c in the exercise group, correlated with reductions in endothelial biomarkers (E-selectin, ICAM-1, VCAM-1)	Endothelial Function: No direct improvement, but reduced endothelial activation correlated with HbA1c improvements	HbA1c and endothelial markers: Correlation observed, exact values not specified
3	Karjalainen et al., 2015 [19]	Karjalainen, Jaana	1.046	Not specified	Not specified	LTPA and Home-Based Exercise Training: 2-year controlled trial including endurance and strength training	Varied (No LTPA, irregular LTPA, LTPA > 3 times weekly)	104.0	Varied (endurance and strength)	Cardiovascular Events: Minor improvement in exercise capacity (0.2 ± 0.8 MET for T2D); Blood Pressure: Reduced systolic and diastolic pressure in CAD patients with T2D; Glycemic Control (HbA1c): Slight, non-significant reduction	Composite End Points: LTPA reduced CV morbidity and mortality; controlled exercise training showed no significant effect on CV risk factors	Exercise capacity: Mean ± SD; HbA1c reduction: Not significant
4	Verma et al., 2018 [20]	Verma, Shalini	60.0	Not specified	Not specified	Low-intensity, low-volume; Low-intensity, high-volume; High-intensity, high-volume	Varied: 3–5 sessions per week	12.0	Varied: Low to High Intensity	Primary outcomes include maximal oxygen consumption (VO_2 max), oxidative stress markers (SOD, CAT, GPX, NO), and cardiac autonomic function (HRR, HRV)	Secondary outcomes include body composition, lipid profiles, glycemic control (HbA1c, fasting glucose)	ANOVA (split-plot), Bonferroni post hoc, significance level set at $p < 0.05$
5	Rech et al., 2019 [21]	Rech, Anderson	39.0	68 ± 6.5 years (AC); 70.5 ± 7.4 years (RT)	Not specified	RT Group: 12-week, 3×/week resistance training with functional and traditional exercises; AC Group: Low-intensity stretching exercises once per week	RT: 3; AC: 1	12.0	RT: Resistance exercises; AC: Low-intensity stretching	Inflammatory Markers: TNF- α and IL-1 β decreased significantly in both groups; No changes in CRP, IL-6, or IL-10	Endothelial Function: No significant improvements in FMD or BAD; Lipid Profile: No significant changes in triglycerides, HDL, LDL, or total cholesterol; Glycemic Control: No significant improvement in HbA1c and fasting glycemia	Inflammatory markers: Significant decrease in TNF- α and IL-1 β ; Lipid profile and glycemic control: No significant changes
6	Ghardashi et al., 2020 [22]	Ghardashi, Afousi	74.0	45–60 years	Not specified	HIIT: Six intervals of 4 min at 85–90% HRmax, with 3 min at 45–50% HRmax, 3×/week for 12 weeks; Control group with no intervention	3	12.0	HIIT: High-intensity (85–90% HRmax)	Carotid Intima-Media Thickness (cIMT): Significant reduction in HIIT group (from 0.83 ± 0.17 to 0.71 ± 0.14 mm); Serum Markers (Dkk-1, Sclerostin): Both decreased significantly, correlating with cIMT reduction	Cardiorespiratory Fitness (VO_2 Peak): Increased by 6.2 mL/kg/min in HIIT, with inverse correlation with cIMT, Dkk-1, and sclerostin levels	cIMT, VO_2 Peak, Dkk-1, Sclerostin: Mean ± SD; Correlations with cIMT noted

Table 1. Cont.

No.	Study (Author, Year)	First Author	Total Participants	Average Age	Gender Distribution	Intervention Type	Frequency (per Week)	Duration (Weeks)	Intensity	Primary Outcomes	Secondary Outcomes	Statistical Measures (Mean, SD, Significance)
7	Seyedizadeh et al., 2020 [23]	Seyedizadeh, Seyedeh Hoda	24.0	45–65 years	Female only	Combined Training: Resistance and aerobic exercises, 3 × /week for 8 weeks; Resistance Training: 2–3 sets, 8–12 reps with progressive load; Aerobic Training: Interval running at 50–65% HRR, progressively increased in duration and intensity HIIT: 10 rounds of 1 min power cycling at 80–95% VO ₂ max, 1 min rest at 25–30% VO ₂ max, 5 × /week; MICT: Continuous cycling at 50–70% VO ₂ max for 30 min, 5 × /week; Control: Standard counseling on exercise and diet Both groups followed a Paleolithic diet for 12 weeks; PD-EX group engaged in 3 h of supervised exercise/week, combining aerobic and resistance training Exercise Protocol: Personalized gym-based sessions, 3 × /week for 12 weeks; Combined aerobic (65–85% HRmax) and resistance (55–70% MVC) training; Control Group: Usual activity levels without additional training U-TURN group divided into tertiles by accumulated exercise volume (12 months); Lower Tertile: 178 min/week; Intermediate Tertile: 296 min/week; Upper Tertile: 380 min/week; Standard Care: Lifestyle advice without structured exercise	3	8.0	Resistance: Progressive load; Aerobic: 50–65% HRR	Serum Kinesin-1: No significant change in either group; Aerobic Endurance: Slight decline in both groups, greater decrease in control	Lower Body Strength: Significant improvement in experimental group compared to decline in control group	Aerobic endurance and lower body strength: Relative changes observed; significance noted in strength improvements
8	Li et al., 2022 [24]	Li, Jun	37.0	32–47 years	Not specified		5	12.0	HIIT: High-intensity (80–95% VO ₂ max); MICT: Moderate-intensity (50–70% VO ₂ max)	Body Composition: Weight reduction significant in MICT (−3.52 kg); BMI reduction in MICT (from 26.75 ± 4.20 to 25.45 ± 3.51 kg/m ²); Cardiorespiratory Fitness: VO ₂ max increased in HIIT (0.53 L/min) and MICT (0.31 L/min)	Glycemic Control: FBG and HbA1c reduced in HIIT and MICT; Fasting Insulin: Reduced in HIIT (−2.39 pmol/L) and MICT (−0.99 pmol/L)	Weight, BMI, VO ₂ max, FBG, HbA1c, and FI: Mean ± SD, significant reductions in MICT and HIIT
9	Otten et al., 2019 [25]	Otten, Julia	22.0	30–70 years	Not specified		3 h of exercise for PD-EX	12.0	Aerobic and resistance training for PD-EX	Cardiac and Metabolic Measures: MTG reduced by 45% in PD-EX; Improvements in LV mass-to-volume ratio and end-diastolic volume in PD-EX; Significant increase in VO ₂ max in PD-EX	Weight Loss and HbA1c: Significant reductions in both groups, with more pronounced changes in PD-EX	MTG, LV remodeling, VO ₂ max, weight loss, and HbA1c: Mean ± SD; significant changes noted in PD-EX group
10	Naylor et al., 2016 [26]	Naylor, Louise	13.0	13–21 years	10 female, 3 male			12.0	Aerobic: 65–85% HRmax; Resistance: 55–70% MVC	Vascular Health: FMD increased in the exercise group (+2.2%, <i>p</i> < 0.05); Microvascular function improved in exercise group; Body Composition: Fat mass decreased by 1.10 kg in exercise group; Lean mass increased by 1.35 kg in exercise group	Strength: Total strength increased significantly in exercise group; Glycemic Control: No significant changes in insulin sensitivity	FMD, fat mass, lean mass, and strength: Mean ± SD; significance noted for FMD and strength increases
11	MacDonald et al., 2020 [27]	MacDonald, Christopher	98.0	54.4 ± 9.0 years	Not specified		Lower: 178; Intermediate: 296; Upper: 380	52.0	Varied by tertile	Medication Discontinuation: 48% (lower), 60% (intermediate), 70% (upper) discontinued meds; 16% in standard care group	Glycemic Control: HbA1c reduction in intermediate and upper tertiles; Fasting glucose and insulin improved in both tertiles; Body Composition: Reduction in body mass in intermediate and upper tertiles; VO ₂ max increased significantly in upper tertile only	Medication discontinuation and glycemic control measures: Percentages noted; significant reductions in body mass and increases in VO ₂ max

Table 1. Cont.

No.	Study (Author, Year)	First Author	Total Participants	Average Age	Gender Distribution	Intervention Type	Frequency (per Week)	Duration (Weeks)	Intensity	Primary Outcomes	Secondary Outcomes	Statistical Measures (Mean, SD, Significance)
12	Amaravadi et al., 2024 [28]	Amaravadi, Sampath Kumar	160.0	30–65 years	Not specified	Structured exercise regimen, including aerobic, resistance, and combined exercises, 3–5 times weekly for 12 weeks; Conducted at a diabetic clinic with ongoing monitoring and adherence checks	3–5	12.0	Aerobic and resistance exercises	Insulin Resistance (HOMA-IR): 30.06% improvement in exercise group vs. 14.9% increase in control; Fasting Insulin: 24.34% reduction in exercise group vs. 8.11% increase in control	Glycemic Control: FBS decreased by 14.24% and PPBS by 12.66% in exercise group; HbA1c reduced by 0.55 points; Quality of Life: Significant improvements in WHOQOL-BREF across all domains; Functional Capacity: 27.43% improvement in Six-Minute Walk Test in exercise group	Insulin resistance, fasting insulin, glycemic control, and quality of life measures: Mean $\pm$ SD; significance noted for improvements
13	Kluding et al., 2015 [29]	Kluding, Patricia	18.0	58.1 years (SD = 5)	13 females, 5 males	16-week supervised aerobic exercise program, 3 $\times$ /week; Sessions: 30–50 min, progressing from 50% to 70% VO2R	3	16.0	50% to 70% VO2R	Adverse Events: 57 non-serious events reported, mainly in initial weeks (joint pain, hypoglycemia, hyperglycemia); Cardiovascular Fitness (VO2peak): Increased by 1.1 mL/kg/min ($p < 0.05$)	Body Composition: 1% reduction in total body fat ($p < 0.01$) and 1780 g fat mass reduction; Peripheral Blood Flow: Improved by 2.27%; Fatigue: Significant reduction in general and physical fatigue scores	VO2peak, body fat, and fatigue scores: Mean $\pm$ SD; significance noted for improvements
14	Taylor et al., 2014 [30]	Taylor, J. David	21.0	MOD: 52.2 years; HIGH: 54.4 years	Not specified	MOD Group: Resistance at 75% of 8-RM, aerobic at 30–45% HRR; HIGH Group: Resistance at 100% of 8-RM, aerobic at 50–65% HRR; Both groups trained for 3 months, resistance exercises twice weekly, aerobic three times weekly	Resistance: 2; Aerobic: 3	12.0	MOD: 75% 8-RM, 30–45% HRR; HIGH: 100% 8-RM, 50–65% HRR	Physical Fitness: Muscle strength improved in both groups, no significant difference; Exercise capacity and physical function improved in both groups without significant differences	Glycemic Control: Blood glucose decreased immediately and 1 h after exercise; MOD: 204.5 to 172.0 mg/dL; HIGH: 140.0 to 118.5 mg/dL	Muscle strength, exercise capacity, and blood glucose measures: Mean $\pm$ SD; significance noted in blood glucose reductions
15	Cassidy et al., 2016 [31]	Cassidy, Sophia—Thoma Christian	23.0	Around 60 years	Not specified	HIIT: 12-week cycling-based high-intensity interval training, 3 $\times$ /week, intervals at 80–90% HRmax; Control: Standard care without structured exercise	3	12.0	80–90% heart rate max	Cardiac Function: LV Wall Mass increased in HIIT (104 $\pm$ 17 g to 116 $\pm$ 20 g); Stroke volume increased from 76 $\pm$ 16 mL to 87 $\pm$ 19 mL; Early diastolic filling rate improved in HIIT; Liver Fat: 39% relative reduction in liver fat, correlated with improvements in HbA1c	Glycemic Control: HbA1c reduced from 7.1% to 6.8% in HIIT; No improvement in control group; Other glycemic markers: No significant changes in fasting glucose or insulin sensitivity	Cardiac and liver fat measures: Mean $\pm$ SD; significance noted for LV mass and stroke volume changes

Abbreviations: HIIT = high-intensity interval training; RT = resistance training; AC = aerobic conditioning; LTPA = leisure-time physical activity; HbA1c = hemoglobin A1c; TNF- α = tumor necrosis factor-alpha; BRS = baroreflex sensitivity. BMI, HbA1c, and other baseline measures are reported when available. Statistical significance, confidence intervals, and effect sizes are included when clearly reported in the original studies.

Percentage changes presented in the summary table were derived from approximate averages across the included studies and rounded to the nearest 5–10%. These values were extracted directly from individual study outcomes and are not based on pooled statistical analysis.

2.10. Ethical Considerations

All 15 studies included in this review reported ethical approval from a recognized ethics committee and informed consent from participants. Table 3 provides a summary of these details for each study.

Table 2. Risk of bias assessment using the Cochrane tool for included studies. Domains assessed include randomization, blinding, incomplete data, and selective reporting.

Study (Author, Year)	Randomization	Blinding	Incomplete Data	Selective Reporting	Overall Risk
Cassidy et al., 2019 [17]	Low	High	Low	Low	Moderate
Byrkjeland et al., 2017 [18]	Low	High	Low	Low	Low
Karjalainen et al., 2015 [19]	Low	High	Low	Low	Moderate
Verma et al., 2018 [20]	Low	High	Low	Low	High
Rech et al., 2019 [21]	Low	High	Low	Low	Moderate
Ghardashi et al., 2020 [22]	Low	Unclear	Low	Low	Moderate
Seyedizadeh et al., 2020 [23]	Low	Unclear	Low	Low	Moderate
Li et al., 2022 [24]	Low	Unclear	Low	Low	Moderate
Otten et al., 2019 [25]	Low	Unclear	Low	Low	Low
Naylor et al., 2016 [26]	Low	High	Low	Low	Moderate
MacDonald et al., 2020 [27]	Low	High	High	Low	Low
Amaravadi et al., 2024 [28]	Low	High	Low	Low	Low
Kluding et al., 2015 [29]	Unclear	Unclear	Low	Low	Moderate
Taylor et al., 2014 [30]	Low	High	Unclear	Low	Moderate
Cassidy et al., 2016 [31]	Low	High	Low	Low	Low

Table 3. Ethical approval and informed consent status of all studies included in this systematic review.

Study (Author, Year)	Ethical Approval	Informed Consent
Cassidy et al., 2019 [17]	Yes	Yes
Byrkjeland et al., 2017 [18]	Yes	Yes
Karjalainen et al., 2015 [19]	Yes	Yes
Verma et al., 2018 [20]	Yes	Yes
Rech et al., 2019 [21]	Yes	Yes
Ghardashi et al., 2020 [22]	Yes	Yes
Seyedizadeh et al., 2020 [23]	Yes	Yes
Li et al., 2022 [24]	Yes	Yes
Otten et al., 2019 [25]	Yes	Yes
Naylor et al., 2016 [26]	Yes	Yes
MacDonald et al., 2020 [27]	Yes	Yes
Amaravadi et al., 2024 [28]	Yes	Yes
Kluding et al., 2015 [29]	Yes	Yes
Taylor et al., 2014 [30]	Yes	Yes
Cassidy et al., 2016 [31]	Yes	Yes

3. Results

3.1. Search Strategy and Study Selection

A systematic search across PubMed, Scopus, and Web of Science identified 800 articles. After screening and applying strict inclusion criteria (e.g., T2D, adult populations, interventions ≥8 weeks, and cardiovascular outcome metrics), 15 studies involving a combined total of approximately 1794 participants (sample sizes: 50–1046) were included for analysis [17–31].

The included studies involved aerobic training, resistance training, or a combination of aerobic and resistance training interventions. Each modality yielded distinct yet complementary insights into cardiovascular and metabolic adaptations in those with T2D (discussed below).

3.2. Study Characteristics and Intervention Protocols

The included studies featured structured exercise interventions with differing protocols for specific exercise modalities. The interventions lasted 8 to 104 weeks and provided short and long-term perspectives.

Aerobic Training: Most aerobic protocols involve moderate-intensity exercise (60–75% VO_2max) lasting 30–50 min per session, performed 3–5 times weekly. This modality affects cardiovascular efficiency, lipid profile, and HRV, which are critical to managing T2D [17].

- **Resistance Training:** Training protocols were designed to improve muscle strength and insulin sensitivity. They typically involve 2–4 sets of 8–12 repetitions performed 2–3 times weekly. Exercises target large muscle groups to enhance vascular health and glucose metabolism [20,21,23–28,31].
- **Combined Training:** Protocols integrate aerobic and resistance components within the same intervention. These programs vary, with some studies combining both modalities in a single session and others alternating between them. Combined training was particularly effective in simultaneously addressing multiple cardiovascular and metabolic risk factors [18,24,25,27].

The effect of such interventions was examined in terms of cardiovascular health markers such as blood pressure, lipid patterns, HRV, and inflammatory biomarkers like CRP and IL-6.

3.3. Cardiovascular Outcomes by Exercise Modality

3.3.1. Aerobic Training

Eight studies reported the effects of aerobic training on cardiovascular outcomes post-screening (intervention duration: 8–52 weeks).

- **Blood Pressure:** Aerobic exercise reduced blood pressure, with an average decrease of 6 mmHg systolic and 3 mmHg diastolic. Systolic pressure reduction ranged from 4 to 8 mmHg, while diastolic decreases ranged from 2 to 5 mmHg [19,26]. These results can be explained by improved endothelial function and reduced arterial stiffness.
- **Lipid Profiles:** LDL cholesterol decreased by 8%, while HDL cholesterol increased by 5%. Study sub-analyses also showed a 6% reduction in TG [30]. Aerobic exercise enhances lipid metabolism in T2D patients by increasing lipid oxidation and lipoprotein lipase activity, facilitating transport and hydrolysis of lipids.
- **HRV:** Aerobic training modestly improved HRV, indicating positive changes in autonomic control. Four studies showed increased time-domain HRV measures, reflecting parasympathetic dominance and better cardiovascular flexibility [17,20].
- **Inflammatory Markers:** CRP and IL-6 dropped 5–7%, indicating that aerobic exercises have anti-inflammatory effects. This may result from improved insulin sensitivity, reduced adiposity, and better lipid profiles, which decrease chronic low-grade inflammation tied to T2D-associated cardiovascular disease [22].

3.3.2. Resistance Training

Six studies targeted resistance training, with study durations of 8–52 weeks.

- **Blood Pressure:** Resistance training reduced systolic and diastolic blood pressure by 5 mmHg and 3 mmHg [21], respectively. While these reductions were slightly smaller than those achieved with aerobic training, they were clinically meaningful.
- **Lipid Profiles:** Resistance training increased HDL cholesterol by 6%, with minor decreases in TG levels. These changes highlight the potential of resistance exercise to improve lipid metabolism [28].

- **Muscle Mass and Insulin Sensitivity:** Participants showed a 2 kg rise in lean muscle mass, which improved glucose uptake by muscle tissue. The improved insulin sensitivity lowers hyperglycemia and cardiovascular risk by reducing oxidative stress and inflammation [25].
- **Inflammatory Markers:** An average study of resistance training found that five studies showed a 5% fall in CRP levels, with changes in IL-6 being variable. This suggests a modest anti-inflammatory effect to resistance training and raises the hope that it could reduce atherosclerosis development in T2D [21].

3.3.3. Combined Training

The five studies on combined training used interventions ranging from 8 to 104 weeks. Combined training consistently demonstrated the most substantial cardiovascular improvements.

- **Blood Pressure:** Combining training methods yielded the most significant reductions—9 mmHg systolic and 6 mmHg diastolic—showing the benefits of merging aerobic and resistance training exercises [18].
- **Lipid Profiles:** Combined training reduced LDL cholesterol by an average of 10% and increased HDL cholesterol by 8%. These changes far exceed those from aerobic or strength training alone, suggesting a synergistic effect. Combined exercise may influence lipid metabolism by altering enzymes and increasing mitochondrial function mass [24].
- **HRV:** Improvements (15%) surpassed those seen with aerobic or resistance training, emphasizing better autonomic function regulation [26].
- **Inflammatory Markers:** Combined training had the largest effect on inflammation markers: CRP and IL-6 decreased by around 10%. This result underscores the potential of combined training to mitigate chronic inflammation associated with atherosclerosis and other cardiovascular complications in T2D [27].

Overall Comparison of Modalities

A comparative overview of outcome improvements across all three training modalities is presented in Figure 2.

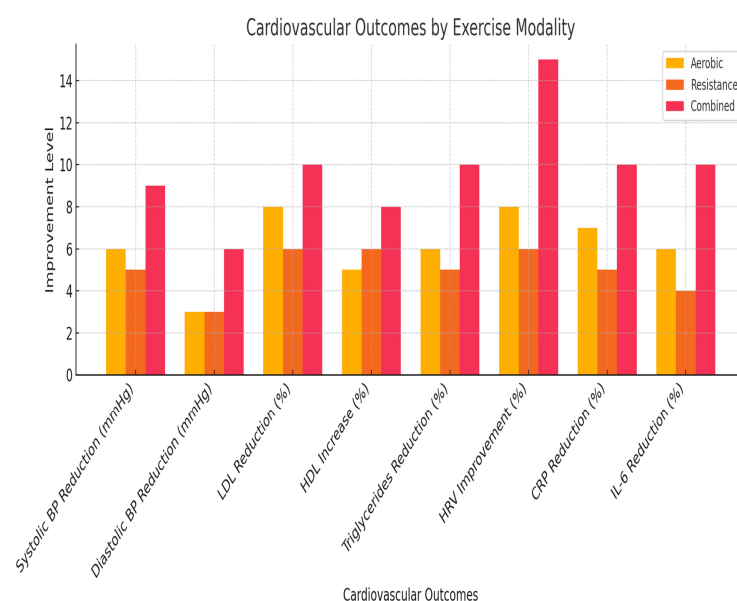


Figure 2. Comparative summary of cardiovascular outcome improvements across three exercise modalities: aerobic, resistance, and combined training. Parameters include blood pressure, lipid profile, HRV, and inflammatory markers (CRP and IL-6), averaged from the reviewed studies. Combined training yielded the most pronounced improvements across most metrics.

3.4. Short-Term vs. Long-Term Effects

Intervention duration significantly influenced outcomes. Long-term interventions (≥ 24 weeks) yielded more pronounced improvements compared to short-term programs (< 24 weeks). The comparative changes in lipid profiles by intervention duration are presented in Figure 3.

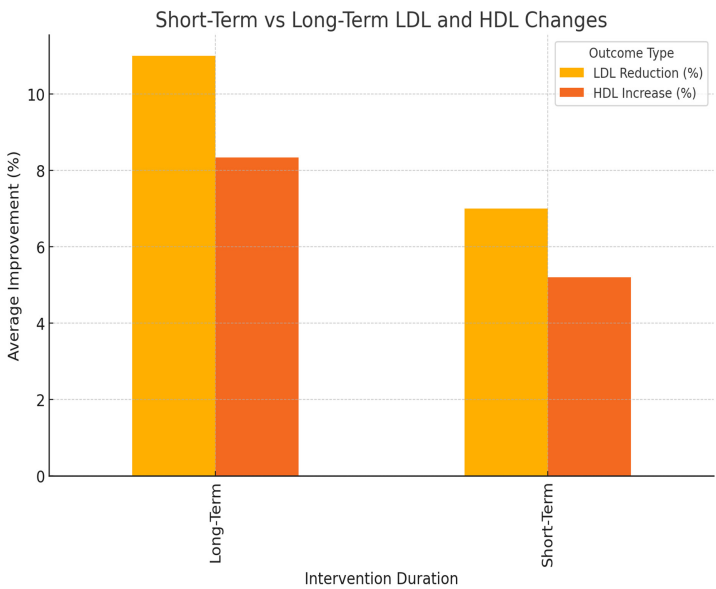


Figure 3. Comparative effects of short-term (< 24 weeks) versus long-term (≥ 24 weeks) exercise interventions on lipid profiles in individuals with T2D. The figure illustrates average changes in LDL and HDL cholesterol. Long-term interventions showed greater improvements in both lipid parameters.

- Blood Pressure: Long-term combined training significantly reduced systolic and diastolic pressures, likely due to improved cardiovascular health remodeling [18,21].
- Lipid Profiles: Longer interventions led to greater reductions in LDL levels and higher increases in HDL cholesterol levels.
- HRV: Long-term studies have shown greater improvements, highlighting sustained exercise’s importance for autonomic health [26]. These HRV improvements are illustrated in Figure 4.

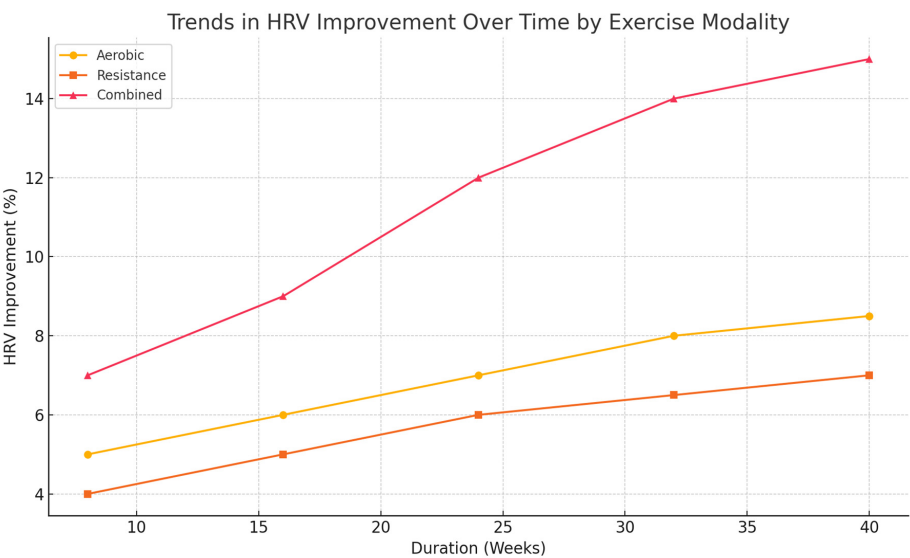


Figure 4. Effect of aerobic, resistance, and combined training on HRV in individuals with T2D. Combined training resulted in the highest increase in HRV, indicating enhanced autonomic regulation.

- **Inflammatory Markers:** Prolonged interventions led to larger reductions in CRP and IL-6, highlighting the benefits of sustained exercise routines [27,32].

4. Summary of Findings

Combined training provides the best cardiovascular results, with 24-week or longer interventions producing the most robust benefit. Variations in effectiveness highlight the importance of designing long-term exercise programs that combine aerobic and resistance training to reduce CVD risk in those with T2D. These programs are the cornerstone of CVD care and primary or secondary prevention for persons with T2D [18,24,28].

The overall summary of cardiovascular improvements across exercise modalities is shown in Table 4.

Table 4. Summary of cardiovascular outcome improvements across exercise modalities in patients with T2D.

Exercise Modality	Systolic BP Reduction (mmHg)	Diastolic BP Reduction (mmHg)	LDL Reduction (%)	HDL Increase (%)	TG Reduction (%)	HRV Improvement (%)	CRP Reduction (%)	IL-6 Reduction (%)
Aerobic	6	3	8	5	6	8	7	6
Resistance	5	3	6	6	5	6	5	4
Combined	9	6	10	8	10	15	10	10

Abbreviations: BP = blood pressure; mmHg = millimeters of mercury. Note: Values represent the approximate average changes observed across the included studies, rounded to the nearest 5–10% where applicable. In cases where the study-level data varied, median or typical values were used to provide a comprehensive summary. Exact values can be found in the individual study result descriptions.

5. Discussion

5.1. Overview of Finding

This systematic review presents significant results associated with structured exercise programs and cardiovascular benefits among people with T2D. Aerobic, resistance, and combination training modalities conferred unique and clinically meaningful benefits in managing cardiovascular risk factors. Combined training was the most successful approach, preventing the most unfavorable impact by comprehensively improving several cardiovascular endpoints, such as blood pressure, lipid profiles, HRV, and inflammatory markers [8].

5.2. Aerobic Training and Cardiovascular Outcomes

The aerobic exercise led to significant reductions in systolic (−6 mmHg) and diastolic (−3 mmHg) blood pressure and improved lipid profile, characterized by an 8% decrease in LDL cholesterol and a 5% increase in HDL cholesterol [33]. The benefits are likely attributable to increased nitric oxide (NO) production, leading to decreased arterial stiffness and increased vasodilation [34]. Moreover, it enhances lipid metabolism by increasing lipoprotein lipase activity, balancing lipid influx and efflux, improving the HDL-to-LDL ratio, and boosting mitochondrial density, which reduces the atherogenic risk profile and promotes vascular health. In addition, the positive impact of aerobic exercise on autonomic balance and the decrease of sympathetic nervous system activity also leads to more appropriate blood pressure regulation [35].

Although formal subgroup analysis was not conducted, studies suggest that higher-intensity aerobic training, such as HIIT, may induce larger improvements than moderate-intensity continuous training in insulin sensitivity and lipid parameters [36]. This is mainly attributed to superior mitochondrial adaptations and more stimulation of the glucose transporter (GLUT-4). However, head-to-head studies with larger T2D populations to confirm this effect remain to be demonstrated.

Aerobic exercise's anti-inflammatory effects, such as decreased CRP and IL-6, support it as a low-cost, non-pharmacological approach [37].

5.3. Resistance Training and Cardiovascular Benefits

Resistance exercise offers distinct advantages, especially in muscle mass and insulin sensitivity. Improvements in HDL cholesterol levels (6%) and a 5 mmHg decrease in systolic blood pressure have been reported [38]. Resistance training induces glucose uptake by increasing the expression of Glucose Transporter Type 4 (GLUT4) receptors and promotes lean muscle mass, thereby lowering oxidative stress and inflammation [39]. Though modest, reductions in inflammatory markers such as CRP highlight resistance training's potential to slow the progression of atherosclerosis in T2D populations [40].

5.4. Combined Training as a Superior Modality

Combined training produced the most vigorous improvements across all cardiovascular metrics. These included reductions of 9 mmHg systolic and 6 mmHg diastolic blood pressure, a 10% reduction in LDL cholesterol, and a 15% increase in HRV, demonstrating the additive effects of combining aerobic and resistance exercise [41]. The synergistic effects are likely a result of complementary mechanisms of both modalities, such as improved vascular compliance and lipid metabolism [35]. In addition, the highest decreases in inflammatory markers were observed in the combined training group. CRP and IL-6 declined by 10%, highlighting the possibility of reducing the perpetuation of low-grade chronic inflammation in T2D-related CVD [42].

Combined training produced the most vigorous improvements across all cardiovascular metrics. These comparisons are based on narrative synthesis and are not derived from pooled statistical tests. The reported values reflect commonly observed effects across the included studies.

5.5. Practical Considerations and Real-World Applicability

These findings are based on qualitative synthesis across studies; no formal statistical tests (e.g., ANOVA or meta-analysis) were performed. Based on overall trends, combined training was seen to provide the greatest benefit across most heart-related outcomes. Despite its effectiveness, combined training can be harder to apply in real life. Some people may not have enough time, equipment, or motivation. In chronic conditions like T2D, adherence to structured exercise interventions is a key determinant of long-term success. However, not all included studies reported detailed adherence or dropout data. This restricts our understanding of the practical applicability of these long-duration training regimes. Trials moving forward need to be consistent with reporting adherence metrics and include behavioral support methods (e.g., digital monitoring tools, motivational counseling, or group-based programs) to promote patient engagement and, consequently, limit attrition.

Additionally, aerobic or resistance training alone may be more practical for older adults or individuals with mobility issues, and they also help improve heart health [43]. That is why it is important to choose a training program that fits everyone's needs and daily life [44]. A future meta-analysis using more consistent and standardized data could provide stronger statistical support for our conclusions.

5.6. Clinical Implications and Recommendations

This comprehensive systematic review indicates that patients with T2D are most likely to achieve optimal cardio-metabolic health when aerobic and resistance training synergistically affect their cardiovascular and skeletal systems. Aerobic training is targeted at 150–300 min/week of moderate-intensity (60–75% VO₂max) exercise (e.g., brisk walking and swimming), which should be performed 3–5 days/week to improve lipid profiles and

blood pressure management. Resistance training should be included 2 to 3 days/week, targeting large muscle groups at moderate intensity for 2 to 3 sets of 8 to 12 repetitions to improve strength and insulin sensitivity. During combined training, whether performed in distinct workouts or within the same workout, 45–60 minutes of moderate-intensity training should be prioritized to accumulate cardiovascular benefits [45]. It has been shown that these strategies need to be customized for every person to fit individual preferences and health status to achieve compliance and sustainable outcomes.

These improvements have significant clinical importance. For instance, every 10 mmHg decrease in systolic BP is associated with a roughly 20% lower relative risk of major cardiovascular events such as myocardial infarction and stroke. Likewise, a 10% lowering of LDL cholesterol and reductions in CRP and IL-6 have been associated with decreased atherosclerosis progression and improved vascular health [46]. The present results, therefore, also lend support to the widespread use of exercise prescriptions to improve glycemic control and as a cornerstone approach to cardiovascular prevention in T2D. A visual comparison of the effects across training modalities on cardiovascular parameters is presented in Figure 5.

Radar Chart: Impact of Training on Cardiovascular Metrics

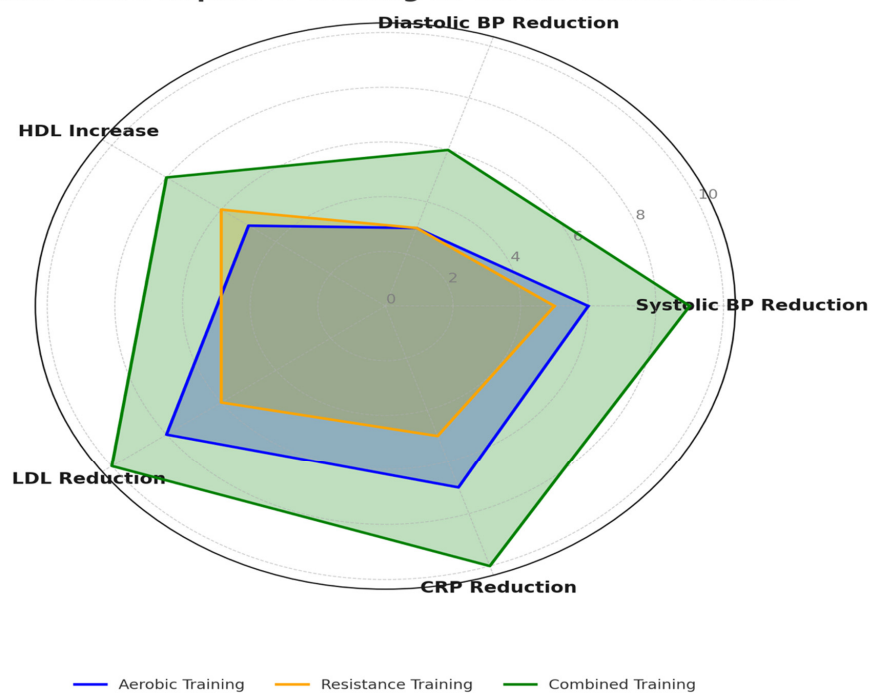


Figure 5. Radar chart comparing the effects of aerobic, resistance, and combined training on five key cardiovascular outcomes in individuals with T2D: systolic blood pressure (SBP), diastolic blood pressure (DBP), LDL, HDL, and CRP. Combined training demonstrated the most favorable overall impact across these parameters.

5.7. Behavioral Strategies and Sustainability

Behavioral interventions can improve adherence, including SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) goals, digital tools such as fitness trackers, and mobile applications. Such approaches enable patients to track progress and remain inspired [47]. Social support gets you moving, whether it is a neighborhood exercise group or accountability [48]. Breaking goals into manageable and realistic steps may help prevent burnout caused by unrealistic expectations and support long-term adherence to physical activity, especially in patients with diabetes. Clinicians should reposition exercise as a

long-term lifestyle strategy, highlighting the many (even in a few with diabetes) benefits it confers beyond managing the disease, including enhanced mood, energy, and mobility [49].

5.8. Future Directions

Future studies should also assess the long-term impact of combined training in different populations, focusing on innovative digital tools for remote monitoring and providing feedback. Low-cost community programs may increase access, especially for populations with less access. Such initiatives can serve as additional resources to allow all T2D patients to engage in exercise programs that are both sustainable and sufficient to address not only cardiovascular risk factors but also improve quality of life [50–52].

6. Conclusions

The results of this systematic review indicate that aerobic, resistance, and combined training provide significant cardiovascular benefits to individuals with T2D. Exercise consistently demonstrated benefits in the most important parameters and outcomes of interest, including blood pressure, lipid profile, HRV, and inflammatory markers. However, combined training showed the most significant improvements across the modes in potential cross-benefits for cardiovascular health and metabolism. Aerobic training significantly improved endothelial function and reduced inflammation, whereas resistance training distinctively increased muscle mass and improved insulin sensitivity. These findings emphasize the significant role of physical activity, particularly mode-specific training, as part of the comprehensive treatment and prevention of T2D. These effects must be sustained through long-term compliance with structured exercise programs. We recommend that prospective studies standardize exercise protocols, assess long-term outcomes, and incorporate innovative strategies to improve adherence and outcomes.

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References

1. Cantley, J.; Ashcroft, F.M. Q&A: Insulin secretion and type 2 diabetes: Why do β -cells fail? *BMC Biol.* **2015**, *13*, 33. [CrossRef]
2. Saeedi, P.; Petersohn, I.; Salpea, P.; Malanda, B.; Karuranga, S.; Unwin, N.; Colagiuri, S.; Guariguata, L.; Motala, A.A.; Ogurtsova, K.; et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Res. Clin. Pract.* **2019**, *157*. [CrossRef] [PubMed]
3. Viigimaa, M.; Sachinidis, A.; Toumpourleka, M.; Koutsampasopoulos, K.; Alliksoo, S.; Titma, T. Macrovascular Complications of Type 2 Diabetes Mellitus. Available online: <https://www.eurekaselect.com/article/97859> (accessed on 22 April 2025).
4. Chakraborty, S.; Verma, A.; Garg, R.; Singh, J.; Verma, H. Cardiometabolic Risk Factors Associated With Type 2 Diabetes Mellitus: A Mechanistic Insight. *Clin. Med. Insights Endocrinol. Diabetes* **2023**, *16*, 11795514231220780. [CrossRef]
5. Wu, L.; Parhofer, K.G. Diabetic dyslipidemia. *Metabolism* **2014**, *63*, 1469–1479. [CrossRef] [PubMed]
6. Colberg, S.R.; Sigal, R.J.; Fernhall, B.; Regensteiner, J.G.; Blissmer, B.J.; Rubin, R.R.; Chasan-Taber, L.; Albright, A.L.; Braun, B. Exercise and Type 2 Diabetes: The American College of Sports Medicine and the American Diabetes Association: Joint position statement. *Diabetes Care* **2010**, *33*, e147. [CrossRef]
7. Dugan, J.A. Exercise recommendations for patients with type 2 diabetes. *J. Am. Acad. Physician Assist.* **2016**, *29*, 13–18. [CrossRef]
8. Yavari, A.; Najafipour, F.; Aliasgharzadeh, A.; Niafar, M.; Mobasser, M. Effect of aerobic exercise, resistance training or combined training on glycaemic control and cardiovascular risk factors in patients with type 2 diabetes. *Biol. Sport* **2012**, *29*, 135–143. [CrossRef]
9. Sigal, R.J.; Kenny, G.P.; Wasserman, D.H.; Castaneda-Sceppa, C.; White, R.D. Physical Activity/Exercise and Type 2 Diabetes. *Diabetes Care* **2006**, *29*, 1433–1438. [CrossRef]
10. Church, T.S.; Blair, S.N.; Cocroham, S.; Johannsen, N.; Johnson, W.; Kramer, K.; Mikus, C.R.; Myers, V.; Nauta, M.; Rodarte, R.Q.; et al. Effects of Aerobic and Resistance Training on Hemoglobin A_{1c} Levels in Patients With Type 2 Diabetes: A Randomized Controlled Trial. *JAMA* **2010**, *304*, 2253. [CrossRef]

11. Moore, M.N.; Climie, R.E.; Otahal, P.; Schultz, M.G. Exercise blood pressure and cardiovascular disease risk: A systematic review and meta-analysis of cross-sectional studies. *J. Hypertens.* **2021**, *39*, 2395–2402. [[CrossRef](#)]
12. Zanusso, S.; Jimenez, A.; Pugliese, G.; Corigliano, G.; Balducci, S. Exercise for the management of type 2 diabetes: A review of the evidence. *Acta Diabetol.* **2010**, *47*, 15–22. [[CrossRef](#)]
13. Shoelson, S.E.; Lee, J.; Goldfine, A.B. Inflammation and insulin resistance. *J. Clin. Investig.* **2006**, *116*, 1793–1801. [[CrossRef](#)] [[PubMed](#)]
14. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Group, T.P. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097. [[CrossRef](#)] [[PubMed](#)]
15. Higgins, J.P.T.; López-López, J.A.; Becker, B.J.; Davies, S.R.; Dawson, S.; Grimshaw, J.M.; McGuinness, L.A.; Moore, T.H.M.; Rehfuss, E.A.; Thomas, J.; et al. Synthesising quantitative evidence in systematic reviews of complex health interventions. *BMJ Glob. Health* **2019**, *4*, e000858. [[CrossRef](#)]
16. Xiao, M.-X.; Lu, C.-H.; Ta, N.; Wei, H.-C.; Haryadi, B.; Wu, H.-T. Machine learning prediction of future peripheral neuropathy in type 2 diabetics with percussion entropy and body mass indices. *Biocybern. Biomed. Eng.* **2021**, *41*, 1140–1149. [[CrossRef](#)]
17. Cassidy, S.; Houghton, D.; Zalewski, P.; Seferovic, J.P.; Hallsworth, K.; MacGowan, G.A.; Trenell, M.I.; Jakovljevic, D.G. Unsupervised high-intensity interval training improves glycaemic control but not cardiovascular autonomic function in type 2 diabetes patients: A randomised controlled trial. *Diab. Vasc. Dis. Res.* **2019**, *16*, 69–76. [[CrossRef](#)] [[PubMed](#)]
18. Byrkjeland, R.; Njerve, I.U.; Arnesen, H.; Seljeflot, I.; Solheim, S. Reduced endothelial activation after exercise is associated with improved HbA_{1c} in patients with type 2 diabetes and coronary artery disease. *Diab. Vasc. Dis. Res.* **2017**, *14*, 94–103. [[CrossRef](#)]
19. Karjalainen, J.J.; Kiviniemi, A.M.; Hautala, A.J.; Piira, O.-P.; Lepojärvi, E.S.; Perkiömäki, J.S.; Juntila, M.J.; Huikuri, H.V.; Tulppo, M.P. Effects of Physical Activity and Exercise Training on Cardiovascular Risk in Coronary Artery Disease Patients with and Without Type 2 Diabetes. *Diabetes Care* **2015**, *38*, 706–715. [[CrossRef](#)]
20. Verma, S.; Moiz, J.A.; Anwer, S.; Alghadir, A.H.; Hussain, M.E. A dose-response study of aerobic training for oxygen uptake, oxidative stress and cardiac autonomic function in type 2 diabetes mellitus: Study protocol for a randomized controlled trial. *Trials* **2018**, *19*, 289. [[CrossRef](#)]
21. Rech, A.; Botton, C.E.; Lopez, P.; Quincozes-Santos, A.; Umpierre, D.; Pinto, R.S. Effects of short-term resistance training on endothelial function and inflammation markers in elderly patients with type 2 diabetes: A randomized controlled trial. *Exp. Gerontol.* **2019**, *118*, 19–25. [[CrossRef](#)]
22. Ghardashi-Afousi, A.; Davoodi, M.; Hesamabadi, B.K.; Asvadi-Fard, M.; Bigi, M.A.B.; Izadi, M.R.; Gaeini, A.A. Improved carotid intima-media thickness-induced high-intensity interval training associated with decreased serum levels of Dkk-1 and sclerostin in type 2 diabetes. *J. Diabetes Complicat.* **2020**, *34*, 107469. [[CrossRef](#)]
23. Seyedizadeh, S.H.; Cheragh-Birjandi, S.; Hamedia Nia, M.R. The Effects of Combined Exercise Training (Resistance-Aerobic) on Serum Kinesin and Physical Function in Type 2 Diabetes Patients with Diabetic Peripheral Neuropathy (Randomized Controlled Trials). *J. Diabetes Res.* **2020**, *2020*, 6978128. [[CrossRef](#)]
24. Li, J.; Cheng, W.; Ma, H. A Comparative Study of Health Efficacy Indicators in Subjects with T2DM Applying Power Cycling to 12 Weeks of Low-Volume High-Intensity Interval Training and Moderate-Intensity Continuous Training. *J. Diabetes Res.* **2022**, *2022*, 1–13. [[CrossRef](#)] [[PubMed](#)]
25. Otten, J.; Andersson, J.; Ståhl, J.; Stomby, A.; Saleh, A.; Waling, M.; Ryberg, M.; Hauksson, J.; Svensson, M.; Johansson, B.; et al. Exercise Training Adds Cardiometabolic Benefits of a Paleolithic Diet in Type 2 Diabetes Mellitus. *J. Am. Heart Assoc.* **2019**, *8*, e010634. [[CrossRef](#)] [[PubMed](#)]
26. Naylor, L.H.; Davis, E.A.; Kalic, R.J.; Paramalingam, N.; Abraham, M.B.; Jones, T.W.; Green, D.J. Exercise training improves vascular function in adolescents with type 2 diabetes. *Physiol. Rep.* **2016**, *4*, e12713. [[CrossRef](#)]
27. MacDonald, C.S.; Johansen, M.Y.; Nielsen, S.M.; Christensen, R.; Hansen, K.B.; Langberg, H.; Vaag, A.A.; Karstoft, K.; Lieberman, D.E.; Pedersen, B.K.; et al. Dose-Response Effects of Exercise on Glucose-Lowering Medications for Type 2 Diabetes: A Secondary Analysis of a Randomized Clinical Trial. *Mayo Clin. Proc.* **2020**, *95*, 488–503. [[CrossRef](#)]
28. Amaravadi, S.K.; Maiya, G.A.; Vaishali, K.; Shastry, B.A. Effectiveness of structured exercise program on insulin resistance and quality of life in type 2 diabetes mellitus—A randomized controlled trial. *PLoS ONE* **2024**, *19*, e0302831. [[CrossRef](#)]
29. Kluding, P.M.; Pasnoor, M.; Singh, R.; D'Silva, L.J.; Yoo, M.; Billinger, S.A.; LeMaster, J.W.; Dimachkie, M.M.; Herbelin, L.; Wright, D.E. Safety of Aerobic Exercise in People With Diabetic Peripheral Neuropathy: Single-Group Clinical Trial. *Phys. Ther.* **2015**, *95*, 223–234. [[CrossRef](#)]
30. Taylor, J.D.; Fletcher, J.P.; Mathis, R.A.; Cade, W.T. Effects of Moderate- Versus High-Intensity Exercise Training on Physical Fitness and Physical Function in People With Type 2 Diabetes: A Randomized Clinical Trial. *Phys. Ther.* **2014**, *94*, 1720–1730. [[CrossRef](#)]
31. Cassidy, S.; Thoma, C.; Hallsworth, K.; Parikh, J.; Hollingsworth, K.G.; Taylor, R.; Jakovljevic, D.G.; Trenell, M.I. High intensity intermittent exercise improves cardiac structure and function and reduces liver fat in patients with type 2 diabetes: A randomised controlled trial. *Diabetologia* **2016**, *59*, 56–66. [[CrossRef](#)]

32. Dieli-Conwright, C.M.; Courneya, K.S.; Demark-Wahnefried, W.; Sami, N.; Lee, K.; Buchanan, T.A.; Spicer, D.V.; Tripathy, D.; Bernstein, L.; Mortimer, J.E. Effects of Aerobic and Resistance Exercise on Metabolic Syndrome, Sarcopenic Obesity, and Circulating Biomarkers in Overweight or Obese Survivors of Breast Cancer: A Randomized Controlled Trial. *J. Clin. Oncol.* **2018**, *36*, 875–883. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Ekechukwu, N.I.; Anwara, S.U.; Mgbeojedo, U.G.; Chijioke, O.U.; Onwukwe, O.S.; Ezugwu, U.A.; Ekechukwu, E.N.D.; Okoronkwo, I.L. Effects of Structured Aerobic Exercise on Selected Clinical Profiles of Patients with Type 2 Diabetes Mellitus: A Systematic Review with Meta-Analysis. *Int. J. Med. Health Dev.* **2021**, *26*, 17–30. [\[CrossRef\]](#)
34. Hwang, M.-H.; Kim, S. Type 2 Diabetes: Endothelial dysfunction and Exercise. *J. Exerc. Nutr. Biochem.* **2014**, *18*, 239–247. [\[CrossRef\]](#) [\[PubMed\]](#)
35. Gordon, B.; Chen, S.; Durstine, J.L. The Effects of Exercise Training on the Traditional Lipid Profile and Beyond. *Curr. Sports Med. Rep.* **2014**, *13*, 253–259. [\[CrossRef\]](#)
36. De Nardi, A.T.; Tolves, T.; Lenzi, T.L.; Signori, L.U.; Silva, A.M.V.D. High-intensity interval training versus continuous training on physiological and metabolic variables in prediabetes and type 2 diabetes: A meta-analysis. *Diabetes Res. Clin. Pract.* **2018**, *137*, 149–159. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Papagianni, G.; Panayiotou, C.; Vardas, M.; Balaskas, N.; Antonopoulos, C.; Tachmatzidis, D.; Didangelos, T.; Lambadiari, V.; Kadooglou, N.P.E. The anti-inflammatory effects of aerobic exercise training in patients with type 2 diabetes: A systematic review and meta-analysis. *Cytokine* **2023**, *164*, 156157. [\[CrossRef\]](#)
38. Westcott, W.L. Resistance Training is Medicine: Effects of Strength Training on Health. *Curr. Sports Med. Rep.* **2012**, *11*, 209–216. [\[CrossRef\]](#)
39. Lee, J.; Kim, D.; Kim, C. Resistance Training for Glycemic Control, Muscular Strength, and Lean Body Mass in Old Type 2 Diabetic Patients: A Meta-Analysis. *Diabetes Ther.* **2017**, *8*, 459–473. [\[CrossRef\]](#)
40. Qadir, R.; Sculthorpe, N.F.; Todd, T.; Brown, E.C. Effectiveness of Resistance Training and Associated Program Characteristics in Patients at Risk for Type 2 Diabetes: A Systematic Review and Meta-analysis. *Sports Med.-Open* **2021**, *7*, 38. [\[CrossRef\]](#)
41. Schroeder, E.C.; Franke, W.D.; Sharp, R.L.; Lee, D. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PLoS ONE* **2019**, *14*, e0210292. [\[CrossRef\]](#)
42. Magalhães, J.P.; Santos, D.A.; Correia, I.R.; Hetherington-Rauth, M.; Ribeiro, R.; Raposo, J.F.; Matos, A.; Bicho, M.D.; Sardinha, L.B. Impact of combined training with different exercise intensities on inflammatory and lipid markers in type 2 diabetes: A secondary analysis from a 1-year randomized controlled trial. *Cardiovasc. Diabetol.* **2020**, *19*, 169. [\[CrossRef\]](#) [\[PubMed\]](#)
43. Liu, C.; Latham, N.K. Progressive resistance strength training for improving physical function in older adults. *Cochrane Database Syst. Rev.* **2009**, *3*, CD002759. [\[CrossRef\]](#) [\[PubMed\]](#)
44. Tavoian, D.; Russ, D.W.; Consitt, L.A.; Clark, B.C. Perspective: Pragmatic Exercise Recommendations for Older Adults: The Case for Emphasizing Resistance Training. *Front. Physiol.* **2020**, *11*, 799. [\[CrossRef\]](#) [\[PubMed\]](#)
45. Mann, S.; Beedie, C.; Jimenez, A. Differential Effects of Aerobic Exercise, Resistance Training and Combined Exercise Modalities on Cholesterol and the Lipid Profile: Review, Synthesis and Recommendations. *Sports Med.* **2014**, *44*, 211–221. [\[CrossRef\]](#)
46. Law, M.R.; Morris, J.K.; Wald, N.J. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: Meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. *BMJ* **2009**, *338*, b1665. [\[CrossRef\]](#)
47. Revello, K.; Fields, W. An Educational Intervention to Increase Nurse Adherence in Eliciting Patient Daily Goals. *Rehabil. Nurs.* **2015**, *40*, 320–326. [\[CrossRef\]](#)
48. Luhanga, E.T.; Hippocrate, A.A.E.; Suwa, H.; Arakawa, Y.; Yasumoto, K. Identifying and Evaluating User Requirements for Smartphone Group Fitness Applications. *IEEE Access* **2018**, *6*, 3256–3269. [\[CrossRef\]](#)
49. Marrero, D.G. Time to Get Moving: Helping Patients With Diabetes Adopt Exercise as Part of a Healthy Lifestyle. *Clin. Diabetes* **2005**, *23*, 154–159. [\[CrossRef\]](#)
50. Shan, R.; Sarkar, S.; Martin, S.S. Digital health technology and mobile devices for the management of diabetes mellitus: State of the art. *Diabetologia* **2019**, *62*, 877–887. [\[CrossRef\]](#)
51. Kiani, A.K.; Bonetti, G.; Donato, K.; Kaftalli, J.; Herbst, K.L.; Stuppia, L.; Fioretti, F.; Nodari, S.; Perrone, M.; Chiurazzi, P.; et al. Polymorphisms, diet and nutrigenomics. *J. Prev. Med. Hyg.* **2022**, *63* (Suppl. 3), E125–E141. [\[CrossRef\]](#)
52. Perrone, M.A.; Donatucci, B.; Salvati, A.; Gualtieri, P.; De Lorenzo, A.; Romeo, F.; Bernardini, S. Inflammation, oxidative stress and gene expression: The postprandial approach in professional soccer players to reduce the risk of muscle injuries and early atherosclerosis. *Med. Sport* **2019**, *72*, 234–243. [\[CrossRef\]](#)

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