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High-Intensity Interval Training Versus Moderate-Intensity Continuous Training for Blood Pressure Reduction and Cardiovascular Quality of Life in Adults With Type 2 Diabetes: A Randomized Controlled Trial

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Abstract: Cardiovascular disease is the leading cause of morbidity and mortality in individuals with type 2 diabetes mellitus, and exercise is a key non-pharmacological intervention. This randomized controlled trial compared the effects of high-intensity interval training and moderate-intensity continuous training on blood pressure and cardiovascular quality of life in adults and older adults with type 2 diabetes mellitus. Seventy-eight participants were randomly assigned to either training group and completed supervised exercise three times per week for 16 weeks. Blood pressure and cardiovascular quality of life were assessed at baseline and post-intervention using validated questionnaires. Both interventions significantly reduced blood pressure and improved cardiovascular quality of life ($p < 0.001$). However, high-intensity interval training produced greater reductions in systolic blood pressure (mean difference −3.0 mmHg; $p = 0.035$) and larger improvements in cardiovascular quality of life, with moderate to large effect sizes. These findings indicate that high-intensity interval training may provide superior cardiovascular and quality of life benefits compared with moderate-intensity continuous training in individuals with type 2 diabetes mellitus.

Keywords: type 2 diabetes mellitus, high-intensity interval training, blood pressure, cardiovascular quality of life, exercise training

1. Introduction

Cardiovascular disease remains the leading cause of morbidity and mortality among individuals with type 2 diabetes mellitus, accounting for more than two thirds of all deaths in this population worldwide [1]. Type 2 diabetes mellitus markedly increases the risk of hypertension, endothelial dysfunction, and impaired cardiac function, even before overt cardiovascular disease becomes clinically apparent [2]. With more than 589 million adults living with diabetes globally in 2024 and prevalence projected to rise substantially by 2050, cardiovascular prevention has become a critical priority in long-term diabetes management [3]. In Indonesia, the growing prevalence of type 2 diabetes mellitus is closely associated with low physical activity levels and obesity, which further exacerbate cardiometabolic risk and impair quality of life, particularly among working-age and older adults [4].

The cardiovascular complications of type 2 diabetes mellitus are driven by interacting pathophysiological mechanisms, including insulin resistance, chronic low-grade inflammation, oxidative stress, and heightened sympathetic nervous system activity [5]. These processes reduce nitric oxide bioavailability, increase arterial stiffness, and promote myocardial structural remodeling, ultimately leading to elevated blood pressure and reduced cardiac functional capacity [6]. Consequently, non-pharmacological interventions that effectively target these mechanisms are essential for reducing cardiovascular risk.

Structured physical exercise is a cornerstone of cardiovascular risk reduction in individuals with type 2 diabetes mellitus. Moderate-intensity continuous training has long been recommended in clinical guidelines because of its safety and its ability to improve metabolic control and cardiorespiratory fitness [7]. However, limited time availability and poor long-term adherence often restrict its effectiveness in real-world settings. In contrast, high-intensity interval training has emerged as a time-efficient exercise modality capable of inducing greater physiological stimuli. By increasing vascular shear stress and activating molecular pathways such as AMP-activated protein kinase and PGC-1α, high-intensity interval training promotes mitochondrial biogenesis, endothelial function, and aerobic capacity [8].

Previous studies generally indicate that high-intensity interval training produces superior improvements in cardiorespiratory fitness compared with moderate-intensity continuous training across various clinical populations [9–12]. Nevertheless, evidence regarding its effects on systolic blood pressure and broader cardiovascular outcomes remains inconsistent, with several meta-analyses reporting no statistically significant differences between training modalities [13]. These discrepancies are likely due to heterogeneity in exercise protocols, participant characteristics, and outcome measures.

Moreover, most comparative studies have focused on individuals with established coronary artery disease or non-diabetic populations in high-income countries. Evidence in individuals with type 2 diabetes mellitus without advanced cardiovascular complications remains limited, particularly regarding patient-reported outcomes such as cardiovascular quality of life. The use of validated disease-specific instruments, including the Kansas City Cardiomyopathy Questionnaire and the Minnesota Living with Heart Failure Questionnaire, is still uncommon in this population, and no controlled studies have directly compared high-intensity interval training and moderate-intensity continuous training in eastern Indonesia.

Therefore, this study aimed to compare the effects of high-intensity interval training and moderate-intensity continuous training on blood pressure and cardiovascular quality of life in adults and older adults with type 2 diabetes mellitus. It was hypothesized that high-intensity interval training would result in greater reductions in blood pressure and greater improvements in cardiovascular quality of life than moderate-intensity continuous training.

2. Results

2.1. Participant Characteristics

A total of 78 participants completed the intervention and were included in the final analysis, with 39 participants assigned to the high-intensity interval training (HIIT) group and 39 to the moderate-intensity continuous training (MICT) group. No significant differences were observed between groups at baseline for age, sex, duration of diabetes, body mass index, blood pressure, resting heart rate, treatment status, or cardiovascular quality of life scores (all $p > 0.05$), indicating good baseline comparability (Table 1).

Table 1. Baseline characteristics of participants in the HIIT and MICT groups.

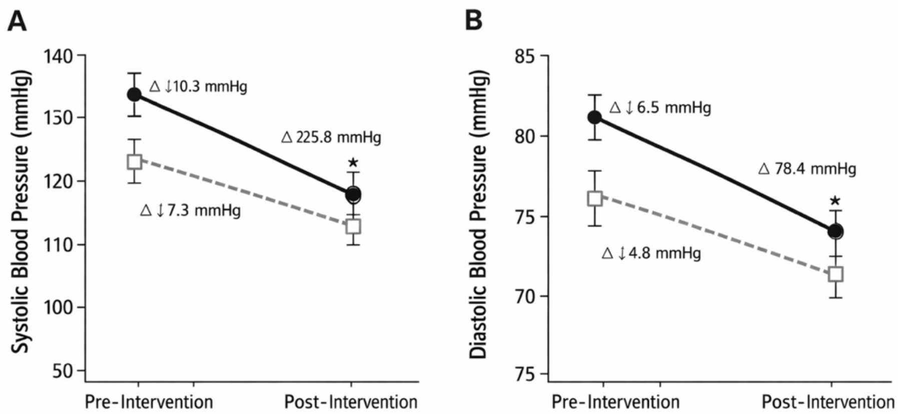
Variable	HIIT (n = 39)	MICT (n = 39)	p-value
Age (years)	54.2 ± 6.1	55.0 ± 5.8	0.56
Sex (male/female), n	21 / 18	22 / 17	0.82
Duration of diabetes (years)	7.8 ± 3.5	8.1 ± 3.2	0.71
Body mass index (kg/m^2)	28.7 ± 3.2	29.1 ± 3.5	0.64
Systolic blood pressure (mmHg)	132.4 ± 11.6	133.1 ± 10.9	0.77
Diastolic blood pressure (mmHg)	82.6 ± 7.8	83.2 ± 8.1	0.73
Resting heart rate (bpm)	78.9 ± 8.4	79.5 ± 7.9	0.75
Oral antidiabetic therapy, n (%)	34 (87.2)	33 (84.6)	0.74
Additional insulin therapy, n (%)	12 (30.8)	13 (33.3)	0.81
Baseline KCCQ total score	62.5 ± 11.3	61.8 ± 10.9	0.78
Baseline MLHFQ total score	48.7 ± 9.6	49.2 ± 10.1	0.83

Data are presented as mean ± standard deviation or number (percentage). No significant baseline differences were observed between groups.

2.2. Effects of HIIT and MICT on Blood Pressure

After 16 weeks of intervention, both systolic and diastolic blood pressure decreased significantly within each group (all p < 0.001). The reduction in systolic blood pressure was greater in the HIIT group (−10.3 ± 6.2 mmHg) than in the MICT group (−7.3 ± 5.9 mmHg). Between-group analysis showed a significant difference favoring HIIT (mean difference −3.0 mmHg; 95% CI −5.8 to −0.2; p = 0.035), with a moderate effect size (Table 2). Reductions in diastolic blood pressure did not differ significantly between groups (p = 0.11). Changes in systolic and diastolic blood pressure are illustrated in Figure 1.

Figure 1. Changes in systolic and diastolic blood pressure following 16 weeks of HIIT and

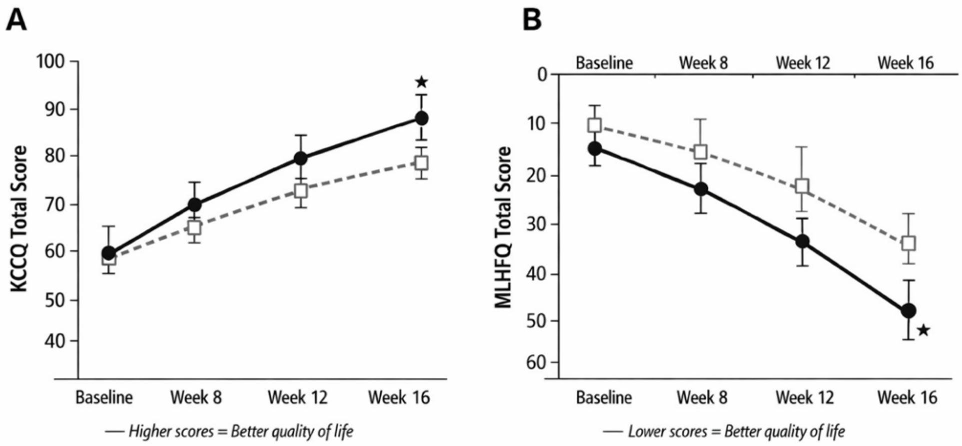


MICT.

2.3. Changes in Cardiovascular Quality of Life

Cardiovascular quality of life improved in both groups over the intervention period. Participants in the HIIT group demonstrated greater increases in Kansas City Cardiomyopathy Questionnaire (KCCQ) scores and greater reductions in Minnesota Living with Heart Failure Questionnaire (MLHFQ) scores compared with the MICT group. At week 16, KCCQ scores increased by 16.4 ± 8.1 points in the HIIT group and by 10.6 ± 7.5 points in the MICT group, while MLHFQ scores decreased by 17.2 ± 7.9 and 10.6 ± 7.4 points, respectively. Between-group differences were significant for both KCCQ (p = 0.001) and MLHFQ ($p < 0.001$), with moderate to large effect sizes (Table 2). Longitudinal changes in cardiovascular quality of life are shown in Figure 2.

Figure 2. Longitudinal changes in cardiovascular quality of life during 16 weeks of HIIT and MICT.



2.4. Between-Group Comparison of Outcome Changes

Comparative analyses of change scores indicated that HIIT produced greater improvements than MICT in systolic blood pressure and both cardiovascular quality of life outcomes. Effect sizes were moderate for systolic blood pressure and large for KCCQ and MLHFQ outcomes (Table 2). Analysis of covariance adjusting for baseline values confirmed significantly lower systolic blood pressure and more favorable cardiovascular quality of life scores in the HIIT group at post-intervention.

A significantly higher proportion of participants in the HIIT group achieved the minimal clinically important difference for systolic blood pressure, KCCQ, and MLHFQ outcomes (all $p < 0.05$). Number needed to treat analysis indicated that approximately five to six individuals would need to undergo HIIT for one additional participant to achieve a clinically meaningful improvement compared with MICT.

Table 2. Between-group comparison of changes in blood pressure and cardiovascular quality of life after 16 weeks of intervention.

Outcome	Δ HIIT (Mean ± SD)	Δ MICT (Mean ± SD)	Mean Difference (HIIT–MICT)	95% CI	p-value	Effect Size (Cohen's d)
Systolic blood pressure (mmHg)	−10.3 ± 6.2	−7.3 ± 5.9	−3.0	−5.8 to −0.2	0.035	0.49
Diastolic blood pressure (mmHg)	−6.5 ± 4.8	−4.8 ± 4.5	−1.7	−3.8 to 0.4	0.11	0.36
KCCQ total score	+16.4 ± 8.1	+10.6 ± 7.5	+5.8	2.4 to 9.2	0.001	0.74
MLHFQ total score	−17.2 ± 7.9	−10.6 ± 7.4	−6.6	−10.0 to −3.2	<0.001	0.86

Δ indicates change from baseline to week 16. Positive values indicate improvement for KCCQ, whereas negative values indicate improvement for blood pressure and MLHFQ.

3. Discussion

The principal finding of this study is that high-intensity interval training produced greater reductions in systolic blood pressure and more pronounced improvements in cardiovascular quality of life than moderate-intensity continuous training in individuals with type 2 diabetes mellitus. These findings support the study hypothesis and underscore the importance of exercise intensity as a key determinant of clinically meaningful cardiovascular adaptation and patient-perceived health benefits in populations at high cardiometabolic risk.

From a physiological perspective, the superiority of high-intensity interval training is consistent with established principles of overload and intensity specificity. Repeated exposure to high-intensity exercise induces substantial increases in endothelial shear stress, stimulating nitric oxide bioavailability, improving endothelial function, and reducing peripheral vascular resistance more effectively than continuous moderate-intensity exercise [15,16]. Given that endothelial dysfunction and arterial stiffness are central mechanisms linking type 2 diabetes mellitus to hypertension and cardiovascular disease, stronger hemodynamic stimuli may be required to overcome the blunted vascular responsiveness commonly observed in this population.

The present findings are broadly consistent with previous meta-analyses reporting superior effects of high-intensity interval training on cardiorespiratory fitness and selected hemodynamic outcomes in individuals with cardiovascular disease [17–19]. However, earlier studies have reported inconsistent effects on systolic blood pressure, likely due to heterogeneity in intervention duration, training intensity, and participant characteristics. By employing a longer, supervised intervention and focusing on individuals with type 2 diabetes mellitus without advanced cardiovascular complications, this study extends existing evidence and helps clarify the conditions under which high-intensity interval training confers additional benefit.

Beyond blood pressure, a key contribution of this study is the demonstration of significantly greater improvements in cardiovascular quality of life following high-intensity interval training, as assessed using validated disease-specific instruments. Cardiovascular quality of life reflects not only physiological change but also perceived functional capacity, symptom burden, and overall well-being. Although high-intensity exercise involves greater exertion, it may enhance engagement and self-efficacy and produce more rapid functional gains, thereby translating physiological improvements into perceptible benefits for daily living [20,21]. These findings support theoretical models suggesting that exercise intensity influences both the magnitude of cardiovascular adaptation and its translation into patient-reported outcomes.

The clinical relevance of these results is reinforced by analyses of minimal clinically important difference and number needed to treat, which demonstrated that a greater proportion of participants in the high-intensity interval training group achieved meaningful improvements in blood pressure and cardiovascular quality of life. These findings indicate that the observed benefits are not only statistically significant but also clinically meaningful, supporting the integration of appropriately supervised high-intensity interval training into exercise prescriptions for individuals with type 2 diabetes mellitus.

Several limitations should be acknowledged. The modest sample size and single-center design may limit generalizability. In addition, the study did not assess other cardiometabolic outcomes, such as glycemic control or cardiorespiratory fitness, which restricts mechanistic interpretation. The absence of long-term follow-up also precludes conclusions regarding the sustainability of training-induced benefits.

Future research should include larger, multicenter trials with longer follow-up periods to evaluate the durability of cardiovascular and quality of life improvements and their impact on clinical events. Further investigation into behavioral and psychological mechanisms underlying improvements in patient-reported outcomes, as well as the development of individualized and scalable high-intensity interval training protocols, is warranted.

4. Materials and Methods

4.1. Study Design

This study employed a randomized controlled trial design to compare the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on blood pressure and cardiovascular quality of life in individuals with type 2 diabetes mellitus. The intervention was conducted over 16 weeks and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Outcome assessments were performed using a single-blind design, in which assessors were blinded to group allocation.

4.2. Participants and Eligibility Criteria

Participants were recruited from a chronic disease management program. Of 96 individuals screened, 78 completed the intervention and were included in the final analysis. Inclusion criteria were: physician-diagnosed type 2 diabetes mellitus, age ≥40 years, stable clinical condition without acute complications during the previous three months, controlled blood pressure or prehypertension with or without stable medication, no participation in structured moderate- to high-intensity exercise during the previous six months, and medical clearance for exercise. Exclusion criteria included severe cardiovascular disease, uncontrolled hypertension, musculoskeletal limitations to aerobic exercise, advanced diabetes-related complications, or non-adherence to the prescribed exercise protocol. All participants provided written informed consent prior to participation.

4.3. Randomization and Adherence

Eligible participants were randomly assigned to the HIIT or MICT group using simple randomization after baseline assessment, with 39 participants allocated to each group. Exercise adherence was monitored through attendance records, and only participants who completed at least 75% of prescribed sessions were included in the final analysis.

4.4. Intervention Protocols

Both groups participated in supervised exercise sessions three times per week for 16 weeks, using the same exercise modality and location. Exercise intensity was prescribed based on age-predicted maximal heart rate.

The HIIT protocol consisted of a 5-minute warm-up, repeated high-intensity intervals at 85–95% of predicted maximal heart rate interspersed with active recovery periods at 60–70%, and a 5-minute cool-down, with total session duration of 30–40 minutes. The interval structure was progressively adjusted throughout the intervention.

The MICT protocol involved continuous aerobic exercise at 60–70% of predicted maximal heart rate for 40–50 minutes per session, including warm-up and cool-down. Exercise volume was designed to be broadly comparable between groups. All sessions were supervised by trained exercise instructors to ensure safety and protocol adherence.

4.5. Outcome Measures

Primary outcomes were systolic and diastolic blood pressure and cardiovascular quality of life. Blood pressure was measured using a calibrated digital sphygmomanometer (Omron HEM-7600T) in a seated position after at least five minutes of rest at baseline and post-intervention. Cardiovascular quality of life was assessed using validated Indonesian versions of the Kansas City Cardiomyopathy Questionnaire (KCCQ) and the Minnesota Living with Heart Failure Questionnaire (MLHFQ). Both instruments demonstrated satisfactory validity and high internal consistency (Cronbach's alpha >0.88). Cardiovascular quality of life assessments were conducted at baseline and at weeks 8, 12, and 16.

4.6. Statistical Analysis

Data were analyzed using Jamovi software version 2.6. Normality testing indicated that all variables were normally distributed. Within-group changes were analyzed using paired t tests, while between-group comparisons of change scores were performed using independent t tests. Analysis of covariance was applied to compare post-intervention outcomes while adjusting for baseline values. Chi-square tests were used to compare the proportion of participants achieving the minimal clinically important difference. Effect sizes were calculated using Cohen's d, and clinical effectiveness was evaluated using the number needed to treat. Statistical significance was set at $p < 0.05$.

4.7. Ethical Approval

The study protocol was approved by the Health Research Ethics Committee of Poltekkes Sorong (approval number: DP.04.03/F.LIII.13.a/114/2025). All procedures were conducted in accordance with the Declaration of Helsinki. Participant confidentiality was maintained using coded identifiers, and participation was voluntary with the right to withdraw at any time.

5. Conclusions

This study provides robust evidence that High-Intensity Interval Training yields superior improvements in systolic blood pressure and cardiovascular quality of life compared with Moderate-Intensity Continuous Training among adults with type 2 diabetes mellitus, thereby directly fulfilling the study objective and extending the current evidence base for exercise-based cardiovascular prevention. The central novelty of this research lies in demonstrating that exercise intensity operates not only as a determinant of physiological adaptation but also as a critical mechanism through which such adaptations are translated into clinically meaningful, patient-perceived cardiovascular well-being, as reflected by clinically important differences and low numbers needed to treat. These findings advance theoretical understanding by reinforcing intensity-guided exercise prescription as a key construct in cardiometabolic care and provide practical support for the integration of structured HIIT protocols into supervised, non-pharmacological management strategies for clinically stable individuals with type 2 diabetes mellitus. Nonetheless, the single-center design, moderate sample size, and absence of long-term follow-up and direct cardiometabolic biomarkers limit the generalizability and mechanistic interpretation of the findings. Future investigations should therefore prioritize multicenter trials with larger cohorts, extended follow-up durations, and comprehensive physiological and psychosocial assessments to clarify the durability of benefits and further refine individualized HIIT prescriptions for sustainable cardiovascular risk reduction.

6. Patents

The authors declare that there are no patents resulting from the work reported in this manuscript.

Supplementary Materials: The following supporting information can be downloaded online: Figure S1: Flow diagram of participant recruitment and allocation; Table S1: Detailed exercise protocols for the HIIT and MICT interventions.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript." Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Health Research Ethics Committee of Poltekkes Sorong (protocol code: DP.04.03/F.LIII.13.a/114/2025).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request. The data are not publicly available due to ethical and privacy considerations.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Appendix A provides supplementary methodological details related to the progression of exercise intensity and session structure across the 16-week intervention period.

Figure A1. Progression of exercise intensity during the HIIT and MICT intervention.
Table A1. Weekly distribution of exercise workload.

Appendix B

Appendix B presents additional analyses supporting the main findings, including sensitivity analyses excluding participants with medication changes during the intervention period.

Table B1. Sensitivity analysis of blood pressure outcomes.

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