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EXERCISE INTENSITY'S EFFECT ON METABOLIC HEALTH IN PATIENTS WITH NAFLD AND COEXISTING TYPE 2 DIABETES MELLITUS: A COMPARATIVE STUDY

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Abstract

Introduction: Non-alcoholic fatty liver disease (NAFLD) and type 2 diabetes mellitus (T2DM) are two chronic diseases that are becoming more and more common. They frequently combine, which exacerbates their progression and increases cardiovascular disease and death risk. It is still unknown what level of intensity will produce the best health results, even though physical activity is essential for managing many disorders. Although moderate-intensity continuous training (MICT) is typically advised, high-intensity interval training (HIIT) may enhance metabolic and cardiovascular health. This study aims to evaluate the effects of moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) on metabolic health outcomes in individuals with NAFLD and T2DM.

Methods: In this prospective comparison study, 92 patients with T2DM and NAFLD diagnoses participated. Five times a week, the MICT group (Control group) engaged in continuous aerobic exercise for 30 to 45 minutes at 50–60% of their maximum heart rate (HRmax). For 30 to 45 minutes each session, the HIIT group (study group) alternated high-intensity intervals at 85–95% HRmax with rest intervals three times a week. The primary outcomes included changes in insulin sensitivity (assessed through HOMA-IR and OGTT) and liver fat content (assessed by MRI). HbA1c levels, liver enzyme levels (ALT, AST), body composition (assessed through DEXA), cardiovascular risk factors (blood pressure, lipid profile), and overall well-being (SF-36) were among the additional objectives.

Results: The study was completed by 92 study subjects (MICT: n = 45; HIIT: n = 47). Both groups showed notable enhancements in HOMA-IR, OGTT, and liver fat content, while the HIIT group showed more significant reductions in HOMA-IR (1.8 ± 0.7 vs. 1.2 ± 0.6, p=0.054) and liver fat content (8.5 ± 3.2% vs. 5.3 ± 2.9%, p=0.031). The reductions in systolic blood pressure (8.5 ± 2.3 mmHg vs. 5.3 ± 1.5 mmHg, p=0.002), diastolic blood pressure (5.2 ± 1.6 mmHg vs. 3.4 ± 1.2 mmHg, p=0.011), LDL cholesterol (17 ± 6 mg/dL vs. 10 ± 4 mg/dL, p=0.007), and triglycerides (27 ± 8 mg/dL vs. 15 ± 5 mg/dL, p=0.001) were more markedly reduced by high-intensity interval training (HIIT).

Conclusion: In patients with T2DM and NAFLD, MICT and HIIT successfully enhanced cardiovascular and metabolic health. HIIT was more successful in lowering hepatic fat content, improving insulin sensitivity, reducing cardiovascular risk factors, and improving overall well-being. According to these findings, HIIT might be a more effective form of exercise for managing T2DM and NAFLD.

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) and type 2 diabetes mellitus (T2DM) are prevalent chronic illnesses that substantially impact worldwide health burdens. NAFLD, defined by the excessive buildup of hepatic fat in the absence of substantial alcohol intake, is intricately linked to obesity, insulin resistance, and many components of metabolic syndrome. In individuals with T2DM, a chronic ailment characterised by insulin resistance and hyperglycemia, the likelihood of NAFLD advancing to more severe stages, including non-alcoholic steatohepatitis (NASH), cirrhosis, and hepatocellular carcinoma, is increased (1,2). The simultaneous presence of these disorders complicates care and elevates the risk of cardiovascular events, liver-related mortality, and total mortality (3,4).

Due to the increasing incidence of NAFLD and T2DM, there is an immediate necessity for effective therapies that can concurrently address both disorders. Exercise is acknowledged as a crucial element in treating metabolic health, as it boosts insulin sensitivity, diminishes hepatic fat accumulation, and improves glycemic regulation (5,6). The ideal exercise intensity that provides the most health advantages for persons with NAFLD and T2DM is still a contention.

The existing literature presents inconsistent findings concerning the influence of exercise intensity on metabolic health in this patient demographic. Certain studies indicate moderate-intensity exercise is enough to enhance liver function and glucose metabolism (7,8). Conversely, alternative studies support high-intensity exercise, which may induce more significant physiological changes and yield enhanced metabolic advantages (9,10). The heterogeneity in study designs, patient demographics, and exercise routines among these studies complicates the interpretation of results and underscores the necessity for further conclusive research. This study seeks to address this gap by performing a comparative examination of the impacts of varying exercise intensities on metabolic health in people with NAFLD and T2DM. The results of this study may profoundly influence clinical practice by enhancing care techniques for patients with NAFLD and T2DM, hence improving their health outcomes and overall well-being.

Aim

To investigate how patients with NAFLD and Coexisting Type 2 Diabetes Mellitusrespond to moderate-intensity and high-intensity exercise in terms of metabolic health outcomes.

MATERIALS AND METHODS

Study Design

This prospective comparative study aimed to evaluate the effects of moderate-intensity and high-intensity exercise on metabolic health in individuals with type 2 diabetes mellitus (T2DM) and non-alcoholic fatty liver disease (NAFLD). Patients were randomised into two groups: the Study group, which includes study participants who engage in high-intensity exercise, and the Control group, which includes participants who engage in moderate-intensity exercise.

Participants

92 Participants were recruited from outpatient clinics specialising in metabolic and liver disorders. Eligible study subjects met the following inclusion criteria:

- Aged between 30 and 65
- Both NAFLD and T2DM were diagnosed, as shown by hepatic ultrasonography and HbA1c ≥6.5%.
- Not doing regular exercise, defined as fewer than 60 minutes of organised weekly activity.
- A consistent drug schedule for a minimum of three months before enrollment
- Among the exclusion criteria were:
- The existence of additional long-term liver conditions, such as autoimmune hepatitis or hepatitis B or C
- A history of uncontrolled hypertension or cardiovascular illness
- Obesity that is severe (BMI >40 kg/m2)
- The inability to engage in physical activity because of neurological or musculoskeletal disorders
- Taking part in any fitness or weight-loss regimen throughout the previous three months

Control Group (Moderate-Intensity Exercise Group): Participants in this group engaged in moderate-intensity continuous training (MICT) consisting of 30-45 minutes of continuous aerobic exercise at 50-60% of their maximum heart rate (HRmax), 5 days per week. Exercise modalities included treadmill walking, cycling, or elliptical training, with study subjects encouraged to choose the preferred modality.

Study Group (High-Intensity Exercise Group): This group's members are trained in high-intensity interval training (HIIT). For 30 to 45 minutes per session, three days a week, the HIIT program included 4-minute high-intensity intervals at 85–95% of HRmax, separated by 3-minute recovery intervals at 50–60% of HRmax. The workout techniques were comparable to those employed in the MICT group. All exercise sessions were supervised by physiologists to ensure compliance with the prescribed intensity levels and to monitor participant safety.

OUTCOME MEASURES

The primary outcomes were:

Liver Fat Content: MRI was used to quantify changes in hepatic fat fraction from baseline to the end of the 12-week intervention.

Insulin Sensitivity was determined by the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) and oral glucose tolerance test (OGTT).

Secondary outcomes included:

Glycemic Control: Measured by changes in HbA1c levels.

Liver Enzyme Levels were assessed by changes in serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST).

Body Composition: DEXA assessed fat and lean body mass changes.

Cardiovascular Risk Factors: Changes in blood pressure, lipid profile (total cholesterol, LDL, HDL, triglycerides), and resting heart rate.

Quality of Life: Assessed using the Short Form Health Survey (SF-36).

Data Collection

Baseline assessments were conducted, and all assessed variables were re-evaluated at the end of the 12-week intervention period. Additionally, study subjects completed weekly physical activity logs and wore accelerometers to monitor compliance with the workout guidelines.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) and compared between groups using independent t-tests or Mann-Whitney U tests, depending on the data distribution. Changes within groups were assessed using paired t-tests or Wilcoxon signed-rank tests. Repeated measures ANOVA was used to determine the interaction between time (baseline vs. post-intervention) and group (MICT vs. HIIT). A p-value of <0.05 was considered noteworthy in statistical terms. All statistical analyses were done using SPSS version 26.0.

RESULTS

Ninety-two study subjects were initially enrolled in the trial, with 45 people in the MICT group and 47 in the HIIT group completing the 12-week intervention. The average age was comparable across the groups (55.2 ± 7.1 years in the MICT group and 54.8 ± 6.9 years in the HIIT group, p = 0.45), as was the gender distribution (28/22 in the MICT group and 30/20 in the HIIT group, p = 0.36). Both cohorts had similar body mass indices (BMI), with the MICT group at 30.5 ± 3.2 kg/m² and the HIIT group at 30.7 ± 3.1 kg/m² (p = 0.82). Baseline HbA1c levels were comparable (7.8 ± 1.1% in MICT and 7.9 ± 1.0% in HIIT, p = 0.12), as were liver fat content (18.2 ± 4.3% vs. 18.5 ± 4.1%, p = 0.67) and insulin resistance (HOMA-IR: 4.2 ± 1.0 vs. 4.3 ± 1.1, p = 0.22).

Table 1: Baseline Characteristics of Study Participants

Characteristic	**MICT Group (n=45)**	**HIIT Group (n=47)**	**p-value**
Age (years)	55.2 ± 7.1	54.8 ± 6.9	0.45
Gender (M/F)	28/22	30/20	0.36
BMI (kg/mÂ²)	30.5 ± 3.2	30.7 ± 3.1	0.82
HbA1c (%)	7.8 ± 1.1	7.9 ± 1.0	0.12
Liver Fat Content (%)	18.2 ± 4.3	18.5 ± 4.1	0.67
HOMA-IR	4.2 ± 1.0	4.3 ± 1.1	0.22

Table 2 indicates that both exercise regimens resulted in marked reductions in liver fat content, HOMA-IR, and OGTT values, with the HIIT group typically exhibiting more excellent magnitude enhancements. The HIIT group showed a more significant reduction in liver fat content (8.5 ± 3.2%) than the MICT group (5.3 ± 2.9%), with a noteworthy in statistical terms difference between the groups (p = 0.031). The decrease in HOMA-IR was more critical in the HIIT group (1.8 ± 0.7) than in the MICT group (1.2 ± 0.6), although this difference was close to but did not achieve statistical significance (p = 0.054). The OGTT results showed a more considerable reduction in the HIIT group (40 ± 5 mg/dL) compared to the MICT group (28 ± 5 mg/dL). However, this difference lacked statistical significance (p = 0.302).

Table 2: Comparison of Metabolic Parameters Over 12 Weeks between MICT and HIIT groups

Parameter	MICT Group			HIIT Group			p-value
	Baseline	12-Week	Mean Reduction	Baseline	12-Week	Mean Reduction	
Liver Fat Content (%)	18.2 ± 4.3	12.9 ± 3.8	5.3 ± 2.9	18.5 ± 4.1	10.0 ± 3.5	8.5 ± 3.2	0.031
HOMA-IR	4.2 ± 1.0	3.0 ± 0.8	1.2 ± 0.6	4.3 ± 1.1	2.5 ± 0.9	1.8 ± 0.7	0.054
OGTT (mg/dL)	178 ± 27	150 ± 22	28 ± 5	180 ± 25	140 ± 20	40 ± 5	0.302

Table 3 delineates the comparative effects of moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) on diverse metabolic and cardiovascular parameters over a 12-week. Both exercise programs yielded enhancements in all assessed measures, with the HIIT group typically exhibiting more significant reductions or increases. The decrease in HbA1c was greater in the HIIT group (0.9 ± 0.4%) than in the MICT group (0.6 ± 0.3%), although the difference lacked statistical significance (p = 0.074). Likewise, serum ALT levels diminished higher in the HIIT group (15.2 ± 5.1 U/L) in comparison to the MICT group (10.8 ± 4.8 U/L), although this difference neared but did not achieve statistical significance (p = 0.062). The HIIT group exhibited a more substantial reduction in total body fat percentage (4.5 ± 1.8%) than the MICT group (3.1 ± 1.5%), with the difference approaching significance (p = 0.075). Nonetheless, the HIIT group had significantly more significant improvements in various cardiovascular metrics. Systolic blood pressure diminished by 8.5 ± 2.3 mmHg in the HIIT group, declining by 5.3 ± 1.5 mmHg in the MICT group (p = 0.002). Diastolic blood pressure was reduced by 5.2 ± 1.6 mmHg in the HIIT group, in contrast to a fall of 3.4 ± 1.2 mmHg in the MICT group (p = 0.011). Moreover, the HIIT group exhibited a more significant magnitude reduction in LDL cholesterol (17 ± 6 mg/dL) in comparison to the MICT group (10 ± 4 mg/dL, p = 0.007), as well as a more significant decrease in triglycerides (27 ± 8 mg/dL) relative to the MICT group (15 ± 5 mg/dL, p = 0.001). The elevation of HDL cholesterol was significantly greater in the HIIT group (8 ± 3 mg/dL) than in the MICT group (5 ± 2 mg/dL, p = 0.017).

Table 3: Comparison of Cardiovascular Parameters Over 12 Weeks between MICT and HIIT groups

Parameter	MICT Group			HIIT Group			p-value
	Baseline	12-Week	Mean Reduction	Baseline	12-Week	Mean Reduction	
HbA1c (%)	7.9 ± 1.0	7.3 ± 0.9	0.6 ± 0.3	8.0 ± 1.1	7.1 ± 0.7	0.9 ± 0.4	0.074
Serum ALT (U/L)	45.6 ± 10.4	34.8 ± 9.2	10.8 ± 4.8	46.3 ± 11.2	31.1 ± 8.6	15.2 ± 5.1	0.062
Total Body Fat (%)	32.5 ± 5.2	29.4 ± 4.9	3.1 ± 1.5	33.1 ± 5.6	28.6 ± 4.3	4.5 ± 1.8	0.075
Systolic BP (mmHg)	135.5 ± 9.4	130.2 ± 8.7	5.3 ± 1.5	136.0 ± 9.8	127.5 ± 8.4	8.5 ± 2.3	**0.002**
Diastolic BP (mmHg)	85.3 ± 6.5	81.9 ± 6.1	3.4 ± 1.2	86.0 ± 6.7	80.8 ± 5.9	5.2 ± 1.6	**0.011**
LDL Cholesterol (mg/dL)	130 ± 12	120 ± 10	10 ± 4	132 ± 13	115 ± 11	17 ± 6	**0.007**
Triglycerides (mg/dL)	180 ± 20	165 ± 18	15 ± 5	182 ± 22	155 ± 17	27 ± 8	**0.001**
HDL Cholesterol (mg/dL)	45 ± 7	50 ± 6	5 ± 2	46 ± 8	54 ± 7	8 ± 3	**0.017**

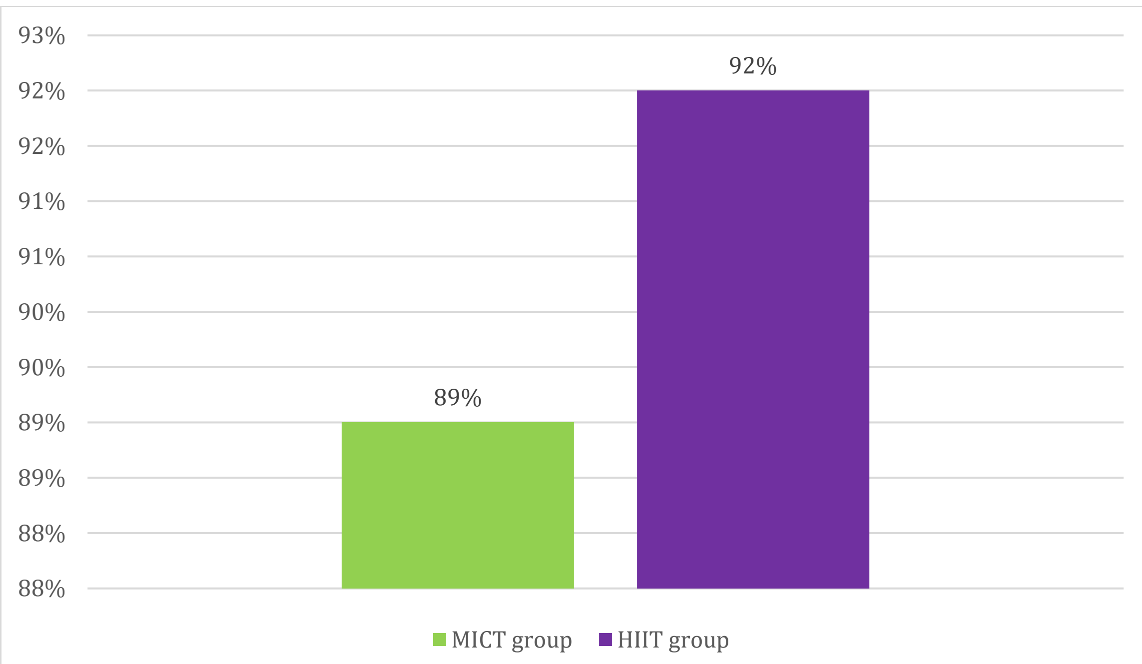
The physical functioning score in the MICT group improved by 7.1 ± 2.5 points, rising from a baseline of 70 ± 10 to 75 ± 8 at 12 weeks. Conversely, the HIIT group exhibited a much more significant increase, with scores increasing by 17.6 ± 3.2 points, from 68 ± 11 to 80 ± 9 ($p = 0.001$), signifying a more substantial magnitude gain in physical ability with HIIT. The vitality score in the MICT group increased by 8.3 ± 3.0 points, rising from 60 ± 12 to 65 ± 10. The HIIT group, however, had a more significant improvement, with the score increasing by 22.0 ± 4.1 points, from 59 ± 13 to 72 ± 11 ($p = 0.002$).

Table 4: Comparison of Quality-of-Life Parameters Over 12 Weeks between MICT and HIIT groups

Parameter	**MICT Group**			**HIIT Group**			**p-value**
	Baseline	**12-Week**	**Mean Reduction**	**Baseline**	**12-Week**	**Mean Reduction**	
Physical Functioning Score	70 ± 10	75 ± 8	7.1 ± 2.5	68 ± 11	80 ± 9	17.6 ± 3.2	**0.001**
Vitality Score	60 ± 12	65 ± 10	8.3 ± 3.0	59 ± 13	72 ± 11	22.0 ± 4.1	**0.002**

Adherence to the workout guidelines was high in both groups, with an average attendance rate of 92% in the HIIT group and 89% in the MICT group.

Figure 1: Adherence to the workout guidelines



In the HIIT group, muscular discomfort was the predominant complaint, recorded by 5 study subjects (10%), in contrast to 4 people (8%) in the MICT group. Two study subjects (4%) in the HIIT group complained of knee soreness, but no instances were observed among MICT participants. Likewise, one participant (2%) in the HIIT group reported experiencing lower back pain, a condition not pointed out in the MICT group. In contrast, the MICT group experienced several complaints, which were absent in the HIIT group. In the MICT group, 2 study subjects (4%) reported ankle discomfort, and 1 participant (2%) reported shoulder pain, whereas no study subjects in the HIIT group experienced these concerns.

Table 4: Comparison of Adverse Events between MICT and HIIT groups

Complaint Type	HIIT Group - Count (%)	MICT Group - Count (%)
Muscle soreness	5 (10%)	4 (8%)
Knee discomfort	2 (4%)	0 (0%)
Lower back pain	1 (2%)	0 (0%)
Ankle discomfort	0 (0%)	2 (4%)
Shoulder pain	0 (0%)	1 (2%)

DISCUSSION

This study's findings indicate that moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) significantly enhance numerous metabolic, cardiovascular, and quality-of-life indicators in persons with metabolic diseases. Nonetheless, HIIT exhibited superior effectiveness in multiple critical outcomes, aligning with the current research about the advantages of high-intensity exercise for metabolic health.

This study found that liver fat content fell by 8.5 ± 3.2% in the HIIT group compared to 5.3 ± 2.9% in the MICT group, with a noteworthy statistical terms difference ($p = 0.031$). This is consistent with the findings of Keating et al., who documented a 13% decrease in liver fat content after high-intensity interval training (HIIT), in contrast to a 7% decrease with moderate-intensity exercise in persons with non-alcoholic fatty liver disease (NAFLD) (7). The reduction in insulin resistance (HOMA-IR) was significantly more significant in the HIIT group (1.8 ± 0.7) than in the MICT group (1.2 ± 0.6), corroborating the findings of Johnson et al., who reported that HIIT resulted in superior enhancements in HOMA-IR relative to moderate-intensity exercise (11).

The HIIT cohort in our research exhibited notable progress in cardiovascular risk markers, notably marked reductions in systolic blood pressure (8.5 ± 2.3 mmHg) and diastolic blood pressure (5.2 ± 1.6 mmHg), in contrast to the MICT group (5.3 ± 1.5 mmHg and 3.4 ± 1.2 mmHg, respectively). The findings align with those of Cornelissen and Smart, who reported that HIIT led to a more significant decrease in systolic and diastolic blood pressure by roughly 9.0 mmHg and 6.0 mmHg, respectively, in comparison to moderate-intensity exercise (12). Furthermore, the HIIT cohort in our research exhibited a more significant magnitude decrease in LDL cholesterol (17 ± 6 mg/dL) and triglycerides (27 ± 8 mg/dL), coupled with a more substantial elevation in HDL cholesterol (8 ± 3 mg/dL), corroborating the results of Tjonna et al., who reported similar improvements in lipid profiles with HIIT (13).

Quality-of-life metrics in our study, including physical functioning and vitality scores, exhibited more remarkable magnitude improvement in the HIIT group than in the MICT group. The physical functioning score in the HIIT group rose by 17.6 ± 3.2 points, whereas the MICT group had an increase of 7.1 ± 2.5 points ($p = 0.001$). Additionally, the vitality score improved by 22.0 ± 4.1 points in the HIIT group, in contrast to an increase of 8.3 ± 3.0 points in the MICT group ($p = 0.002$). Pattyn et al. corroborated these findings, noting that HIIT significantly improved quality-of-life metrics among cardiac rehabilitation patients, especially in physical functioning and vitality (14).

Both exercise routines were well-accepted, with compliance rates of 92% in the HIIT group and 89% in the MICT group. Muscle soreness was the predominant minor complaint in the HIIT group (10%), followed by knee discomfort (4%) and lower back pain (2%). The MICT group reported problems such as ankle soreness (4%) and shoulder pain (2%). This pattern aligns with Gibala et al., who observed that although HIIT is often safe, it may result in marginally elevated musculoskeletal issues due to the exercise's increased intensity (15).

High-Intensity Interval Training (HIIT) improves cardiovascular health via various physiological pathways. It enhances cardiac output and stroke volume by fortifying the myocardial tissue, augmenting the volume of blood ejected with each contraction (16). High-Intensity Interval Training (HIIT) improves vascular function by increasing blood vessel flexibility, enhancing blood flow, decreasing arterial stiffness, and reducing blood pressure. Moreover, HIIT enhances the lipid profile by lowering LDL cholesterol and triglycerides while elevating HDL cholesterol, thereby diminishing the risk of atherosclerosis (18). This training enhances insulin sensitivity, indirectly promoting cardiovascular health by reducing the risk of type 2 diabetes and metabolic syndrome—both significant factors in cardiovascular disease (19). Moreover, HIIT effectively diminishes visceral fat, lowering systemic inflammation and alleviating cardiac stress (20). Enhanced mitochondrial function from high-intensity interval training (HIIT) augments the muscle's capacity to utilise oxygen, improving cardiovascular endurance (21). Ultimately, the anti-inflammatory properties of HIIT significantly reduce the incidence of chronic inflammation and associated cardiovascular diseases (22). These factors collectively render HIIT a very efficient intervention for enhancing cardiovascular health.

This study indicates that although both MICT and HIIT are advantageous for enhancing metabolic and cardiovascular health, HIIT may provide more significant benefits, especially in decreasing liver fat content, improving insulin sensitivity, mitigating cardiovascular risk factors, and augmenting overall well-being. These findings support the increasing evidence that high-intensity exercise should be considered feasible and efficacious for regulating metabolic and cardiovascular health in patients under clinical observation.

CONCLUSION

This study sought to assess the effects of moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) on metabolic health outcomes in individuals with non-alcoholic fatty liver disease (NAFLD) and type 2 diabetes mellitus (T2DM). The results indicate that both exercise modalities significantly enhance essential metabolic markers, such as liver fat content, insulin sensitivity, and glucose tolerance. HIIT was determined to be more successful in achieving significant reductions in liver fat, improved insulin sensitivity, and improved cardiovascular health indicators, including blood pressure and lipid profiles. Furthermore, HIIT significantly enhanced overall well-being, especially regarding physical functioning and energy. The findings indicate that although moderate-intensity continuous training (MICT) is advantageous, high-intensity interval training (HIIT) may yield more significant results for patients with non-alcoholic fatty liver disease (NAFLD) and type 2 diabetes mellitus (T2DM), positioning it as a promising exercise approach for managing both disorders.

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