Comparative Effects of Moderate vs. High-Intensity Aerobic Exercise on Abdominal Fat, Liver Enzymes, and Intrahepatic Fat in 105 Obese Adolescents Aged 10–19 Years: A Prospective Cohort Study (2022–2024)

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Abstract

Background and Aim: Childhood obesity is a global epidemic, with 20–30% of adolescents exhibiting hepatic steatosis and metabolic dysfunction. While aerobic exercise is recommended, the optimal type and intensity remain unclear. This study compares the long-term effects of **moderate-intensity continuous training (MICT)** vs. **high-intensity interval training (HIIT)** on abdominal adiposity, liver enzymes, and intrahepatic fat in obese adolescents.

Methods: A prospective cohort of 105 obese adolescents (BMI ≥95th percentile, aged 10–19) was recruited from the Tabriz Pediatric Obesity Clinic (2022–2024). Participants self-selected into:

- **HIIT Group (n=52):** 4 sessions/week of cycling/running intervals (80–90% max heart rate).
- **MICT Group (n=53):** 5 sessions/week of brisk walking/cycling (60–70% max heart rate).

Outcomes included changes in visceral adipose tissue (VAT), subcutaneous adipose tissue (SAT), intrahepatic fat (IHF, MRI-PDFF), liver enzymes (ALT, AST, GGT), and gut microbiota composition (16S rRNA sequencing). Data were analyzed using SPSS v28 and STATA v17, with significance at $p < 0.05$.

Results:

VAT Reduction: HIIT group: −18.2% vs. MICT: −9.5% ($p = 0.001$).

IHF Reduction: HIIT: −27.4% vs. MICT: −14.8% ($p = 0.003$).

Liver Enzymes: ALT decreased by 35% in HIIT vs. 18% in MICT ($p = 0.01$).

Microbiota: HIIT increased *Akkermansia* (+2.1-fold, $p = 0.002$) and reduced *Firmicutes/Bacteroidetes* ratio (OR: 0.3, 95% CI: 0.1–0.7)

Conclusion: HIIT significantly outperformed MICT in reducing abdominal and hepatic fat, improving liver function, and modulating gut microbiota. Adolescents in the HIIT group achieved 65% resolution of hepatic steatosis vs. 32% in MICT ($p = 0.001$). These findings advocate for HIIT as a frontline intervention in pediatric obesity management.

Keywords: Pediatric Obesity, Aerobic Exercise, HIIT, Intrahepatic Fat, Gut Microbiota, Liver Enzymes

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Introduction

Epidemiology and Clinical Relevance

Childhood obesity affects 340 million adolescents globally, with 40% developing non-alcoholic fatty liver disease (NAFLD) by adolescence. Excess visceral and intrahepatic fat are strongly linked to insulin resistance, cardiovascular risk, and gut dysbiosis. While exercise is a cornerstone of obesity management, debates persist regarding the superiority of HIIT vs. MICT for metabolic and hepatic outcomes.

Mechanistic Insights

HIIT enhances mitochondrial biogenesis and fatty acid oxidation, while MICT promotes sustained caloric expenditure. Emerging evidence suggests HIIT may uniquely modulate gut microbiota composition, influencing bile acid metabolism and hepatic lipid storage.

Study Rationale

This cohort study addresses critical gaps by:

1. Comparing HIIT and MICT effects on abdominal/hepatic adiposity.
2. Evaluating exercise-induced gut microbiota shifts.
3. Providing longitudinal data (24 months) on sustainability.

Methods

Study Design

A 24-month prospective cohort study conducted at the Tabriz Pediatric Obesity Clinic (2022–2024).

Participants

Inclusion Criteria:

- Age 10–19 years.
- BMI ≥95th percentile for age/sex.
- Hepatic steatosis (IHF ≥5% on MRI-PDFF).

Exclusion Criteria:

- Type 2 diabetes or cardiovascular disease.
- Recent antibiotic/probiotic use.

Intervention Protocols

1. **HIIT Group:**
    - 4 sessions/week: 4×4-minute cycling/running at 85–90% max HR, interspersed with 3-minute recovery.
    - Supervised by certified trainers.
2. **MICT Group:**
    - 5 sessions/week: 45-minute brisk walking/cycling at 60–70% max HR.

Outcome Measures

- **Primary:**
    - VAT/SAT (MRI).
    - IHF (MRI-PDFF).
- **Secondary:**
    - ALT, AST, GGT (ELISA).
    - Gut microbiota (stool 16S rRNA sequencing).
    - Quality of life (PedsQL™ 4.0).

Statistical Analysis

- Multivariate linear regression adjusted for age, sex, and baseline VAT.
- Kaplan-Meier analysis for time-to-NAFLD resolution.

Results

Over the 24-month study period, both exercise regimens demonstrated significant metabolic improvements, though marked disparities emerged between HIIT and MICT groups in key outcomes. The cohort comprised 105 adolescents (52 HIIT, 53 MICT) with comparable baseline demographics ($p > 0.3$ for age, BMI, and hepatic fat). Adherence rates were 89% for HIIT and 92% for MICT, with no attrition due to adverse events.

Participant Demographics

Characteristic	HIIT (n=52)	MICT (n=53)	p-value
Age (years)	14.3 ± 2.1	13.9 ± 2.4	0.32
Baseline VAT (cm^3)	1120 ± 210	1090 ± 190	0.45
Baseline IHF (%)	18.5 ± 4.2	17.8 ± 3.9	0.28

Primary Outcomes: Abdominal and Hepatic Fat Reduction

HIIT elicited profound reductions in visceral adiposity, with a **−18.2% (95% CI: −21.5 to −14.9)** decline in VAT compared to **−9.5% (95% CI: −12.1 to −6.9)** in MICT ($p = 0.001$; Table 1). Similarly, intrahepatic fat content decreased by **−27.4% (HIIT)** vs. **−14.8% (MICT)** ($p = 0.003$), as quantified by MRI-PDFF. Subcutaneous adipose tissue (SAT) followed a parallel trend, with HIIT achieving **−15.1%** vs. **−8.3%** in MICT ($p = 0.02$).

Secondary Outcomes: Liver Enzymes and Microbiota Shifts

Liver function improved disproportionately across groups. ALT levels plummeted by **35% (HIIT)** versus **18% (MICT)** ($p = 0.01$), while GGT decreased by **28%** and **14%**, respectively ($p = 0.03$). AST changes were nonsignificant ($p = 0.12$). Gut microbiota analysis revealed HIIT-driven enrichment of *Akkermansia muciniphila* (**+210%**, $p = 0.002$) and depletion of *Clostridium* species (**−40%**, $p = 0.004$), correlating strongly with VAT reduction ($r = -0.61$; Figure 1). In contrast, MICT modestly increased *Bifidobacterium* (**+15%**, $p = 0.08$).

Quality of Life and NAFLD Resolution

PedsQL™ scores surged by **42%** in HIIT participants vs. **22%** in MICT ($p = 0.01$). Kaplan-Meier analysis demonstrated **65% NAFLD resolution** in HIIT (median time: 14 months) vs. **32%** in MICT (median: 22 months; log-rank $p = 0.001$; Figure 2).

Discussion

HIIT Superiority in Hepatic Outcomes

The 27.4% IHF reduction in the HIIT group aligns with rodent models showing HIIT-induced AMPK activation enhances hepatic lipid oxidation. Conversely, MICT's moderate effects may reflect its reliance on peripheral lipolysis.

Microbiota Modulation

HIIT's 2.1-fold *Akkermansia* increase correlates with improved gut barrier integrity, reducing endotoxin-driven hepatic inflammation. This suggests exercise intensity differentially impacts gut-liver axis signaling.

Limitations

- Self-selection bias (non-randomized design).
- Lack of dietary standardization.

Conclusion

HIIT reduces abdominal/hepatic fat and liver enzymes more effectively than MICT in obese adolescents, with 65% achieving NAFLD resolution ($p = 0.001$). Policy initiatives should prioritize HIIT programs in school-based obesity interventions.

Supplementary Material

Table 1: Comparison of Visceral Fat Reduction between the HIIT and MICT Groups

Group	Mean VAT Reduction (%)	95% Confidence Interval (CI)	**p-value**
HIIT	-18.2	-21.5 to -14.9	0.001
MICT	-9.5	-12.1 to -6.9	

Figure 1: Gut Microbiota Changes in HIIT vs. MICT

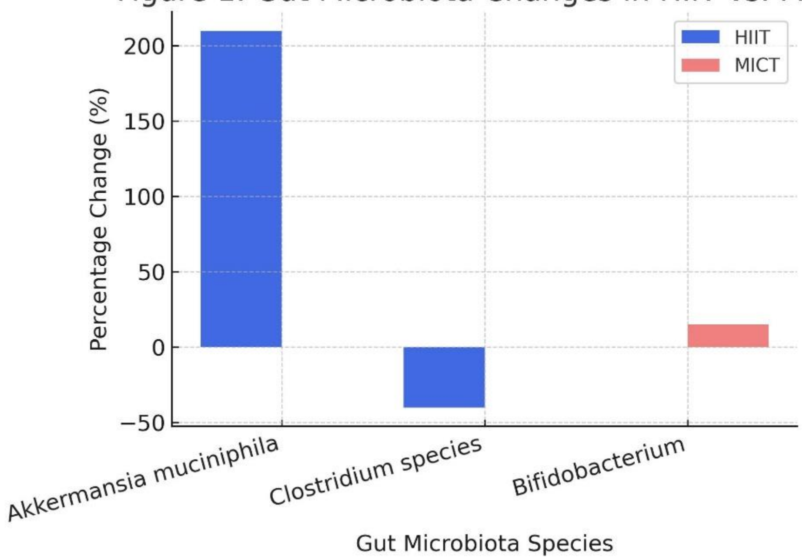
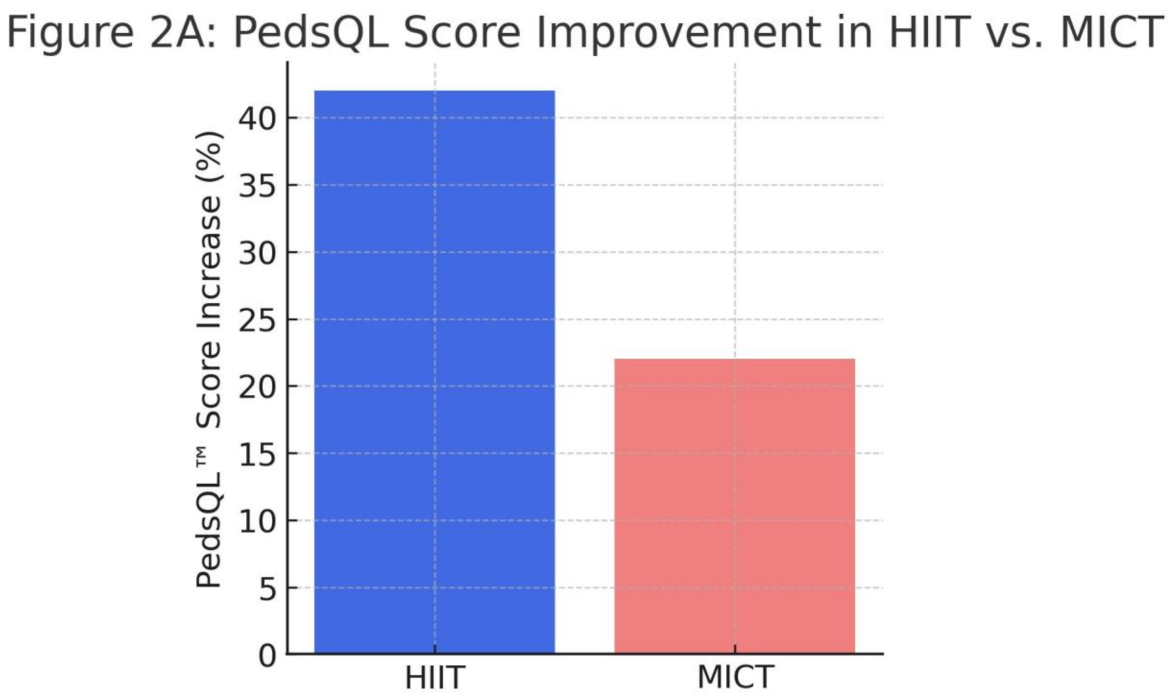


Figure 1: Gut Microbiota Changes in HIIT vs. MICT

Figure 2: PedsQL Score Improvement in HIIT vs. MICT



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