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COMPARATIVE EFFICACY OF CONTINUOUS AEROBIC EXERCISE, MODERATE-INTENSITY INTERVAL TRAINING, AND HIGH-INTENSITY INTERVAL TRAINING IN ADULTS WITH CARDIOMETABOLIC AND PSYCHIATRIC RISK: A SYSTEMATIC REVIEW WITH EMPHASIS ON MENTAL HEALTH AND MUSCULOSKELETAL ADAPTATIONS

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ABSTRACT

Background and Aim: Aerobic exercise is a widely recommended non-pharmacological therapy for preventing and managing metabolic and cardiovascular diseases, as well as promoting psychological well-being. Interval training—especially high-intensity interval training (HIIT) and moderate-intensity interval training (mHIT)—has gained attention as a time-efficient alternative to moderate-intensity continuous training (MICT). Furthermore, emerging evidence indicates potential musculoskeletal adaptations that may influence adherence and performance, as well as the possibility of reducing medication dosage in certain psychiatric and hypertensive populations. This systematic review synthesizes global evidence comparing these exercise modalities in adults (≥18 years), focusing on cardiometabolic risk factors, mental health, and musculoskeletal responses.

Methods: Following PRISMA guidelines, we searched PubMed, Web of Science, and Scopus (2008–2023) for randomized controlled trials (RCTs) and meta-analyses investigating MICT, mHIT, or HIIT in adults with or at risk for cardiometabolic or psychiatric conditions. Primary outcomes included blood lipids, insulin sensitivity, blood pressure, endothelial function, inflammatory markers, VO_2max, mental health parameters, and musculoskeletal adaptations. Secondary outcomes included potential changes in medication usage.

Results: A total of 78 RCTs and 14 meta-analyses were included. Both MICT and interval training improved blood lipids, insulin sensitivity, and blood pressure significantly. HIIT was often associated with more pronounced or time-efficient gains in VO_2max and endothelial function. Regarding mental health, aerobic exercise (whether continuous or interval-based) consistently reduced depressive and anxiety symptoms, and several studies noted a possibility of tapering psychiatric medication in stable patients. Some evidence hinted that higher-intensity intervals might confer slightly larger acute mood benefits, though differences were modest. Preliminary reports also suggested that improvements in muscle strength and bone density markers could further optimize outcomes, especially in mHIT protocols.

Conclusion: Regular aerobic exercise—whether delivered continuously or via intervals—confers significant benefits for cardiometabolic, musculoskeletal, and mental health outcomes in adults. HIIT may offer superior physiological benefits in less total exercise time, whereas MICT is widely accessible and well-tolerated. Future research should address long-term adherence, medication tapering in psychiatric and hypertensive populations, and the synergy between skeletal muscle adaptations and overall health.

KEYWORDS

Aerobic Exercise, High-Intensity Interval Training, Mental Health, Depression, Anxiety, Musculoskeletal Adaptations, Medication Tapering, Cardiometabolic Disease, PRISMA

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1. Introduction

Cardiovascular and metabolic disorders (e.g., hypertension, obesity, and type 2 diabetes) remain pressing global health issues, often exacerbated by co-existing mental health conditions such as depression and anxiety [1]. This interplay can lead to poorer adherence to treatment regimens and overall lower quality of life [2]. Aerobic exercise is consistently recommended to mitigate these risks, with public health guidelines advocating a minimum of 150 minutes per week of moderate-intensity aerobic activity [3]. Traditional moderate-intensity continuous training (MICT) is safe, accessible, and evidence-based [4].

Interval-based modalities—specifically moderate-intensity interval training (mHIT) and high-intensity interval training (HIIT)—have shown promising results in time-efficiently improving VO_2max, insulin sensitivity, and mental well-being [5,6]. Additionally, growing literature suggests beneficial musculoskeletal adaptations, including positive effects on bone density and muscle strength, which may reduce injury risk and improve adherence [7,8].

Meanwhile, individuals with psychiatric conditions (e.g., depression) and hypertension often struggle with medication side effects. Evidence indicates that structured exercise interventions could, under clinical supervision, facilitate medication tapering or dosage reductions, particularly for selected antihypertensives and some psychotropics [9,10].

This systematic review examines data from randomized trials and meta-analyses on MICT, mHIT, and HIIT in adults (≥18 years) with or at risk of cardiometabolic diseases or psychiatric conditions. Outcomes of interest include cardiometabolic measures (lipids, glucose/insulin regulation, blood pressure, endothelial function, VO_2max, inflammation), mental health (depression, anxiety, quality of life, potential for medication reduction), and musculoskeletal changes relevant to exercise compliance and overall function.

2. Methods

2.1 Protocol and Registration

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

2.2 Eligibility Criteria

- Population: Adults (≥18 years), including healthy individuals, those with overweight/obesity, type 2 diabetes, metabolic syndrome, hypertension, or psychiatric comorbidities such as depression/anxiety.
- Interventions: Studies involving MICT, mHIT, or HIIT interventions.
- Comparators: Any other exercise modality (e.g., MICT vs HIIT) or no-exercise controls.
- Outcomes: Must report ≥1 relevant cardiometabolic outcome (lipids, insulin resistance, blood pressure, endothelial function, inflammatory markers, VO_2max), and/or psychological outcomes (depression, anxiety, quality of life), musculoskeletal adaptations (bone density, muscle strength, injury risk), or medication usage changes.
- Study Design: Randomized controlled trials (RCTs) and meta-analyses published between 2008 and 2023 in peer-reviewed journals.

2.3 Search Strategy

We conducted an electronic search in PubMed, Web of Science, and Scopus from January 2008 to December 2023. Key terms included:

- (“high-intensity interval training” OR HIIT)
- (“moderate-intensity interval training” OR mHIT)
- (“moderate-intensity continuous training” OR MICT)
- (lipids OR insulin OR blood pressure OR depression OR anxiety OR “mental health” OR musculoskeletal OR “bone density” OR medication OR “psychiatric” OR cardiometabolic)

Reference lists of relevant articles were screened manually for additional studies.

2.4 Study Selection and Data Extraction

Two reviewers (working independently) screened titles and abstracts. Full texts were retrieved if eligibility was unclear or if the study met inclusion criteria. Any discrepancies were resolved by consensus or a third reviewer. Extracted data included population characteristics, intervention protocols (duration, frequency, intensity), outcome measures, and main results focusing on cardiometabolic, mental health, musculoskeletal, and medication-related endpoints.

2.5 Quality Assessment

We applied the Cochrane Risk of Bias tool for RCTs and the AMSTAR 2 checklist for meta-analyses, including only moderate- to high-quality studies in the final synthesis [11].

2.6 Data Synthesis

Due to heterogeneity in interval protocols (work-rest ratios, intensities) and populations, we performed a narrative synthesis, highlighting major trends, effect sizes from meta-analyses, and relevant subgroup insights (e.g., patient type, exercise intensity, medication changes, musculoskeletal adaptations).

3. Results

3.1 Study Selection

Our database search yielded 1,358 records, plus 25 additional items from reference lists. After removing duplicates (n=158), 1,200 unique records remained. Of these, 1,022 were excluded at the title/abstract level for irrelevance or insufficient data. We reviewed 178 full-text articles, excluding 86 for various reasons (e.g., not RCT/meta-analysis, incomplete outcome data). Ultimately, 92 publications (78 RCTs, 14 meta-analyses) were included.

3.2 Study Characteristics

Included RCTs primarily lasted 8–16 weeks, with sample sizes from 20 to >200 participants. Interventions ranged from 2–5 sessions/week. Many meta-analyses pooled data from 15–30+ RCTs, offering robust quantitative estimates of intervention effects [1–3,12].

3.3 Summary of Key Findings

3.3.1 Lipid Profile and Insulin Sensitivity

- Lipid Profile: Both MICT and HIIT yield modest improvements in LDL, HDL, and triglycerides [2,4]. Some meta-analyses suggest slightly larger increases in HDL with HIIT, although differences vs. MICT are often small when overall energy expenditure is matched [5].
- Insulin Sensitivity: In populations with overweight, obesity, or prediabetes, HIIT can significantly reduce insulin resistance indices (e.g., HOMA-IR) [6]. Longer-term glycemic markers (HbA1c) may not differ substantially from MICT if total weekly workload is similar [13].

3.3.2 Blood Pressure and Endothelial Function

- Blood Pressure: Most trials show systolic BP reductions of ~3–5 mmHg and diastolic reductions of ~2–4 mmHg with consistent aerobic training [1,14]. HIIT and MICT produce comparable net BP effects in many analyses [15].
- Endothelial Function: HIIT and mHIT often elicit strong gains in flow-mediated dilation (FMD), presumably via higher shear stress [7,16]. MICT also improves FMD, but at a possibly slower rate in sedentary or cardiometabolically compromised adults.

3.3.3 Cardiorespiratory Fitness (VO_2max)

HIIT's hallmark advantage is its time efficiency for boosting VO_2max [17]. For example, 4×4-minute intervals at ~90% HR_max can match or exceed the cardiorespiratory gains from a longer moderate-intensity continuous session (45–60 minutes). However, MICT remains widely recommended due to accessibility and tolerability, especially for beginners or those preferring lower exertion [3].

3.3.4 Inflammatory Markers

Regular aerobic exercise—whether HIIT, mHIT, or MICT—tends to lower systemic inflammation (e.g., CRP, IL-6) over time, often associated with weight/fat loss, improved insulin action, and better immune regulation [18]. Evidence is inconclusive as to whether HIIT significantly outperforms MICT in terms of anti-inflammatory effects, but consistency in training appears paramount [4,18,19]. A few studies indicate that moderate-intensity interval approaches (mHIT) may optimize the balance between eliciting an inflammatory response post-exercise and facilitating adequate recovery [8,18].

3.3.5 Mental Health: Depression, Anxiety, and Medication Usage

- Depression & Anxiety: Multiple RCTs and meta-analyses confirm that aerobic exercise—regardless of intensity—can significantly reduce depressive and anxiety symptoms [9,14,20]. While some data imply slightly stronger acute mood elevation with vigorous intervals, sustained adherence appears more critical for long-term mental health improvements [1].
- Medication Tapering: In stable psychiatric patients, structured exercise programs (including intervals) have occasionally allowed for partial dosage reductions of antidepressants or anxiolytics under medical supervision [9,10,20]. Similar findings exist for hypertensive patients, where consistent engagement in aerobic exercise can lower blood pressure sufficiently to permit a careful reduction in antihypertensive medication [10,14]. Despite these promising developments, more robust, long-term trials are needed before general clinical recommendations can be made for routine medication tapering.

3.3.6 Musculoskeletal Responses

The musculoskeletal system is pivotal in determining exercise capacity, injury risk, and overall adherence [7]. Interval protocols, particularly mHIT, may reduce mechanical overloading compared to high-volume MICT, while still stimulating musculoskeletal adaptations such as increased muscle strength and favorable stress on bone (potentially aiding bone density) [8]. In populations prone to joint issues or osteopenia, intervals at moderate intensity might be safer than high-intensity intervals or prolonged continuous sessions [19]. On the other hand, short, intense HIIT bouts recruit fast-twitch muscle fibers, fostering gains in anaerobic capacity that could improve functional performance [16,17]. Further research is warranted to explore these adaptations and their implications for older or frail individuals.

3.3.7 Detailed Considerations for HIIT vs. mHIT Protocols

High-Intensity Interval Training (HIIT) and Moderate-Intensity Interval Training (mHIT) share the principle of alternating bouts of work with active recovery, but differ in how hard the work interval is performed and how long it lasts. These distinctions can influence the physiological adaptations, adherence, and safety profiles for different populations [5,8].

3.3.7.1 Protocol Characteristics

1. Work Interval Intensity:
   - HIIT: Commonly ≥80% of VO_2max or HR_max, reaching 85–95% in many protocols, driving rapid VO_2max improvements [5].
   - mHIT: Typically around 70–80% of VO_2max or HR_max [8]. Intervals may be longer (3–5 min) and less taxing, potentially safer for older or comorbid participants.
2. Recovery Periods:
   - HIIT: Passive or active recovery can last 1–4 min, depending on work duration (e.g., 4×4 min at ~90% HR_max, 3 min recovery at ~50–60% HR_max) [5].
   - mHIT: Recovery at light intensity (~50–60% HR_max). Because intervals are moderate rather than near-maximal, systemic stress is lower [8].
3. Session Duration:
   - HIIT: Often 15–25 min plus warm-up/cooldown.
   - mHIT: Might be 20–30 min total, shorter than standard 45–60 min MICT [7,8].

3.3.7.2 Physiological Rationale

1. Muscle Fiber Recruitment:
2. Higher intensities (HIIT) recruit more type II (fast-twitch) fibers, boosting anaerobic capacity and insulin sensitivity [6]. mHIT still engages type II fibers but with lower peak heart rates [8].
3. Mitochondrial Biogenesis and Enzyme Activity:
4. Interval training upregulates PGC-1α, driving mitochondrial biogenesis [7]. Studies indicate short-duration HIIT can induce oxidative enzyme increases (citrate synthase) akin to longer MICT [13]. mHIT similarly confers benefits with possibly less perceived exertion [8].
5. Cardiac Output and Stroke Volume:
6. Repeated near-maximal efforts in HIIT acutely raise stroke volume, accelerating VO_2max gains. mHIT fosters improved cardiac function at moderate intensities.

3.3.7.3 Evidence in Different Populations

1. Healthy Young Adults:
2. HIIT (e.g., 4×4 min @ 85–90% HR_max) can boost VO_2max within 2–3 weeks [5]. mHIT offers similar benefits with milder intensities.
3. Older Adults or Cardiac Patients:
4. Supervised HIIT in cardiac rehab can yield larger VO_2max and LV function gains vs. MICT [14]. mHIT is safer for individuals with advanced disease or low exercise tolerance [15].
5. Obesity and Type 2 Diabetes:
6. HIIT is linked to greater improvements in insulin resistance vs. continuous exercise [6], while mHIT can yield comparable glycemic control in a less strenuous format [8].
7. Psychiatric Populations:
8. Intervals may help reduce depressive symptoms. The novelty and variation in intensity can improve adherence for some, although high perceived exertion might deter others [9,20].
9. Performance-Oriented Athletes:
10. Many athletes integrate HIIT to raise lactate threshold and VO_2max. mHIT might be used on lighter days or for recovery intervals.

3.3.7.4 Practical Implications for Adherence

1. Perceived Exertion:
2. HIIT often yields high RPE scores, motivating some but deterring others [5]. mHIT provides interval benefits with reduced discomfort, which can foster better adherence [8].
3. Safety Considerations:
4. Comorbid conditions (cardiac disease, joint pathology) necessitate progressive introduction. Warm-up, cooldown, and individualized progression remain crucial.
5. Combining Intervals with MICT:
6. Some programs alternate intervals (HIIT or mHIT) weekly with moderate continuous sessions, balancing variety and manageability [3].

4. Discussion

The overall findings confirm that aerobic exercise—whether continuous moderate-intensity or interval-based—significantly enhances cardiometabolic health in adults at risk of chronic disease [1,2,4]. HIIT often matches or exceeds MICT in improving VO_2max, insulin sensitivity, and endothelial function over relatively short training durations, offering a time-efficient approach [5,6]. Meanwhile, mental health benefits—particularly reduced depressive and anxiety symptoms—are robust across intensities, highlighting exercise as a potent adjunct therapy for psychiatric conditions [9,20].

Musculoskeletal considerations also emerge, including the potential for improved bone density and muscle strength that might reduce injury risk and bolster long-term adherence [7,8]. The magnitude of these adaptations can differ by protocol; mHIT may favor moderate mechanical loading that enhances skeletal and muscular health without excessive strain [19]. Conversely, HIIT's higher intensities can expedite anaerobic and cardiovascular gains but may pose greater acute demands on joints [6,16].

4.1 Clinical Implications

1. Individualized Prescription:
2. Tailoring the program to a patient's baseline fitness, musculoskeletal status, mental health needs, and medication profile fosters better adherence and outcomes [2,9]. For instance, healthy young individuals may embrace HIIT for rapid improvements, whereas older or deconditioned patients could start with mHIT or MICT.
3. Safety and Progression:
4. Particularly for individuals with cardiac disease or joint limitations, short or moderate intervals under supervision might be safer initially, with progression to more intense protocols as tolerated [15]. Warm-ups, cooldowns, and progression steps reduce arrhythmia and musculoskeletal risks [7,19].
5. Medication Tapering in Psychiatric and Hypertensive Populations:
6. Emerging data show that consistent exercise can facilitate partial dosage reductions of certain psychotropics and antihypertensives in stable patients [9,10,14]. Nonetheless, such tapering must be closely managed by clinicians, emphasizing patient-specific factors and regular monitoring of symptoms.

4.2 Expanded Considerations

Musculoskeletal Gains: A notable subset of studies identified improved muscle strength markers (e.g., leg press, isokinetic knee extension) and potential benefits for bone health (e.g., increased bone mineral density in weight-bearing intervals) [7,8,19]. These adaptations may also enhance functional capacity in older adults, facilitating greater independence [16,19]. For instance, mHIT may better suit individuals at higher fracture risk who still desire the benefits of interval training.

Medication Use: Although the data remain preliminary, some small-scale RCTs reported that after 8–12 weeks of consistent interval exercise, psychiatrists and primary care physicians could reduce dosage of SSRIs (selective serotonin reuptake inhibitors) or anxiolytics in certain stable patients [9,20]. Hypertensive individuals performing regular HIIT or mHIT have similarly demonstrated sustained BP improvements, allowing careful medication tapering [10,14]. Large-scale, long-term investigations are needed to confirm these findings and identify which subgroups are most likely to benefit from dose reduction.

4.3 Limitations

1. Protocol Heterogeneity:
2. Interval durations, intensities, and total volumes vary widely, complicating direct comparisons across studies [3].
3. Long-Term Adherence and Clinical Outcomes:
4. Most trials last only 8–16 weeks, leaving questions about sustained adherence, major cardiovascular events, and stable medication reduction [10].
5. Mental Health Measures:
6. Different scales for depression, anxiety, and quality of life hamper cross-study comparison [9,20].
7. Musculoskeletal Assessments:
8. Many RCTs did not systematically measure bone density or muscle strength, limiting the ability to conclusively link interval protocols to skeletal health [7,19].

4.4 Future Directions

1. Comparative Cost-Effectiveness:
2. Resource use (equipment, supervision) and real-world outcomes could shape clinical guidelines [2].
3. Mechanistic Insights:
4. Investigating neurobiological pathways (BDNF, cortisol, catecholamines) may explain varied responses to intense intervals [9,18].
5. Medication Reduction Trials:
6. Larger, longer-term RCTs focusing on medication tapering (antihypertensives, antidepressants) are critical to formalize clinical recommendations [14,20].
7. Musculoskeletal-Specific Research:
8. Stratified analyses on bone density and muscle function under different interval protocols, especially in older or frail populations, would illuminate how best to optimize skeletal health [7,8].

4.5 Additional Perspectives: Implementation and Psychosocial Considerations

Beyond direct physiological outcomes, real-world implementation of interval training must address psychosocial and environmental factors [1,9]. Busy individuals might gravitate toward HIIT for time savings, but others might find near-maximal efforts too strenuous, risking attrition [5,8]. Community-based programs that incorporate mHIT could bolster social support and adherence, particularly if participants share similar fitness levels or health challenges [20].

Self-determination theory posits that intrinsic motivation improves when individuals experience autonomy, competence, and relatedness [21]. Exercise programs allowing participants to self-select interval intensity or modify work-rest ratios accordingly can enhance perceived autonomy and competence, leading to sustained participation [8,21]. This is especially relevant in psychiatric populations, where fostering a sense of control and gradual mastery can have therapeutic benefits [9,21].

Technology (e.g., wearable devices, online coaching) can further individualize interval prescriptions [22]. For older adults or low-tech settings, simplified heart rate monitors or supervised sessions remain viable. Additionally, public health strategies might integrate interval-based recommendations into guidelines, highlighting incremental progression for individuals with comorbidities [2,15]. Cost-effectiveness analyses could reveal whether investing in supervised HIIT/mHIT yields better population-level outcomes versus standard MICT [2,10].

5. Conclusions

Key Takeaways

1. Aerobic exercise—continuous or interval-based—consistently improves lipid profiles, insulin sensitivity, blood pressure, endothelial function, and mental health (depression, anxiety) [1–4,9,20].

2. HIIT is often time-efficient, matching or surpassing MICT in VO_2max gains and metabolic benefits, though it carries higher perceived exertion [5,6].

3. mHIT can deliver interval-related advantages with moderate intensities, possibly boosting musculoskeletal health and adherence among those who find HIIT overly strenuous [8,19].

4. Medication tapering under clinical supervision has been reported for some stable psychiatric and hypertensive patients engaged in interval training, though further trials are needed to confirm feasibility and safety [9,10,14,20].

5. Musculoskeletal adaptations (e.g., improved muscle function, potential bone health gains) may reinforce long-term compliance and overall physical resilience [7,8].

In summary, tailoring HIIT, mHIT, or MICT to individual preferences, health status, and psychological needs is paramount. More large-scale, long-term RCTs are necessary to validate medication reductions and to delineate the optimal interval protocols for musculoskeletal outcomes, ensuring maximal benefits with minimal risk.

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Author's Contribution

- Conceptualization: DW, MS
- Methodology: DK, WK, DW, MSt
- Formal Analysis: DL, KT, IK
- Investigation: WM, KM
- Writing—Draft Preparation: IK, WK
- Supervision: AM, MS

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