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SYNERGISTIC EFFECTS OF TABATA HIGH-INTENSITY INTERVAL TRAINING AND ELECTRO MUSCLE STIMULATION ON BODY COMPOSITION AND PERFORMANCE ADAPTATIONS AMONG UNIVERSITY STUDENTS

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Abstract:

This study examined the combined effects of Tabata high-intensity interval training (HIIT) and electro muscle stimulation (EMS) on body composition and performance adaptations among university students. Sixty physically active participants (30 males and 30 females) were randomly assigned into four groups: Tabata + EMS (T-EMS), Sprint Interval Training + EMS (SIT-EMS), Tabata only (T-HIIT), and Sprint Interval Training only (SIT-HIIT). Over eight weeks, participants trained three times per week, following progressive-intensity protocols. Repeated-measures ANOVA revealed significant improvements in muscle mass, VO_2 max, and fat oxidation across all groups, with the T-EMS group showing the greatest gains ($p < 0.05$). Males exhibited greater hypertrophy and improvements in VO_2 max, while females demonstrated superior autonomic recovery and fat oxidation. The findings support the idea that integrating EMS with Tabata HIIT amplifies neuromuscular activation, endurance capacity, and body composition outcomes beyond those of traditional HIIT protocols. These results highlight the potential of EMS-enhanced Tabata training as a time-efficient and physiologically superior method for improving fitness in young adults.

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Keywords:

Tabata, HIIT, EMS, VO_2 Max, Body Composition, Gender Differences

Introduction

Tourism. In the past two decades, global health and performance research has increasingly emphasized time-efficient training interventions that deliver comparable or even superior physiological adaptations to traditional endurance programs (Hough, 2021; Viana et al., 2018). Sedentary lifestyles, academic workloads, and the modern compression of personal time have collectively created a demand for exercise models that are concise yet metabolically potent. Against this backdrop, High-Intensity Interval Training (HIIT) has emerged as a dominant paradigm, capable of eliciting significant gains in aerobic capacity, metabolic health, and muscular performance within a fraction of the time required for moderate-intensity continuous training (Tabata, 2019; Megahed et al., 2023). HIIT's cyclical pattern of exertion and recovery not only optimizes cardiovascular conditioning but also stimulates hormonal and enzymatic responses that accelerate fat oxidation and post-exercise oxygen consumption, mechanisms linked to long-term improvements in body composition (Follador et al., 2018).

Among the various HIIT derivatives, Tabata training is particularly noteworthy for its brevity and intensity. Originating from Izumi Tabata's protocol at Japan's National Institute of Fitness and Sports, the method involves eight consecutive rounds of 20 seconds of maximal effort, followed by 10 seconds of rest, totaling only 4 minutes (Tabata, 2019). Despite this short duration, Tabata training has demonstrated profound physiological outcomes: elevated VO_2 max, improved anaerobic threshold, and enhanced mitochondrial density (Zaid et al., 2023; Aslan et al., 2022). The protocol's effectiveness lies in its ability to simultaneously maximize both aerobic and anaerobic pathways, producing a training effect that rivals that of much longer endurance sessions. Studies in cycling, running, and calisthenics have shown that four to six weeks of Tabata sessions can increase aerobic power by 10–20 percent while significantly reducing body-fat levels (Megahed et al., 2023; Boer, 2019).

From an educational and practical perspective, Tabata training holds particular promise for university and youth populations. Students often face constraints on time, space, and motivation; therefore, short, high-impact workouts may improve adherence and physical literacy within physical education curricula (Helgerud et al., 2023). Additionally, Tabata's simplicity, which requires minimal equipment, makes it adaptable to institutional fitness programs and public health initiatives. Nevertheless, despite these advantages, researchers have observed variability in individual responses to HIIT protocols. Differences in neuromuscular recruitment efficiency, fatigue tolerance, and recovery capacity may limit the uniformity of adaptation across participants (Paillard, 2008; Gregory & Bickel, 2005). These disparities have motivated scientists to explore complementary modalities that can enhance muscle-fiber activation without imposing additional mechanical load.

The Emergence of Electro Muscle Stimulation (EMS)

Electro-Muscle Stimulation (EMS) is one such innovation. EMS induces involuntary muscle contractions through externally applied electrical impulses, facilitating recruitment of both Type I and Type II fibers that may not be fully activated during voluntary movement (Babault

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et al., 2007). Early investigations demonstrated that EMS improves muscle strength, power, and endurance among athletes and sedentary individuals alike (Banerjee et al., 2005; Fernández-Elías et al., 2022). Modern wireless suits now permit simultaneous stimulation of multiple muscle groups during dynamic exercise, opening the possibility of integrating EMS with high-intensity functional movement patterns (Lee et al., 2023). Physiologically, this combination enhances motor-unit synchronization and metabolic stress, leading to greater glycogen depletion, hypertrophic signaling, and elevated post-exercise energy expenditure (Gondin et al., 2011; Paillard, 2008).

When merged with Tabata's rhythmic, maximal-intensity intervals, EMS may act as a neuromuscular amplifier, reinforcing contraction quality and endurance within each 20-second work phase. Such synergy could elicit superior adaptations in both aerobic power and muscular hypertrophy, while sustaining high metabolic demand in a short session. Recent trials suggest that EMS-assisted HIIT promotes greater improvements in fat oxidation and muscle definition compared with voluntary exercise alone (Lee et al., 2023; Fernández-Elías et al., 2022). However, empirical evidence remains fragmented, and the underlying mechanisms, especially in young adult learners, are still being established.

Physiological and Gender-Based Variability

Training responses to HIIT and EMS are also moderated by biological sex. Males typically demonstrate greater absolute gains in strength and VO_2 max, while females exhibit enhanced fat-metabolism efficiency and faster autonomic recovery (Schmitz et al., 2020; Hottenrott et al., 2021). Hormonal profiles, particularly estrogen's influence on mitochondrial function, contribute to these distinctions (Seo et al., 2024). Yet, limited research has examined how EMS-enhanced Tabata might interact with these gender-specific physiological characteristics. Understanding these dynamics is crucial for tailoring training interventions in coeducational or population-specific contexts, ensuring equitable performance development and injury prevention.

Educational and Applied Context

In higher education and community settings, the dual emphasis on academic productivity and physical well-being requires efficient, evidence-based exercise models. Short-duration, high-intensity formats such as Tabata HIIT are well-suited for university students who balance coursework and lifestyle constraints (Viana et al., 2018). The integration of EMS into such programs could advance the pedagogy of physical education by introducing technology-driven, measurable, and personalized exercise modalities. Moreover, EMS-Tabata sessions can foster learner engagement through immediate sensory feedback and quantifiable performance outcomes, aligning with modern approaches to experiential learning in sport science.

Despite these theoretical and practical advantages, empirical investigations on the combined Tabata + EMS model remain scarce. Most literature isolates the two methods HIIT research emphasizing metabolic and cardiovascular benefits (Tabata, 2019; Megahed et al., 2023), and EMS studies focusing on muscular strength and rehabilitation outcomes (Lee et al., 2023; Babault et al., 2007). The intersection of these fields represents a significant research gap, particularly concerning simultaneous changes in aerobic performance, muscle morphology, and body composition within a short-term intervention.

Problem Gap and Rationale

Existing HIIT studies have successfully demonstrated reductions in body fat and improvements in endurance; however, the plateau effect in muscle hypertrophy and the variability in metabolic retention post-training remain challenges (Boer, 2019; Follador et al., 2018). Concurrently, EMS research indicates promising gains in neuromuscular activation but lacks investigation into systemic cardiovascular outcomes when applied during high-intensity movement. Hence, there is a pressing need to examine how EMS-modulated Tabata training influences both metabolic and neuromuscular dimensions of performance in an educationally relevant population.

Research Objectives

Building on the theoretical foundations of high-intensity interval training (HIIT) and the emerging application of electro-muscle stimulation (EMS), this study seeks to investigate how integrating EMS into a Tabata training framework influences body composition, muscle performance, and physiological adaptations among university students. Guided by the limitations and opportunities identified in the literature, the following objectives were formulated:

1. To determine the effects of Tabata high-intensity interval training (HIIT) combined with Electro Muscle Stimulation (EMS) on body composition parameters, specifically body-fat percentage, skeletal-muscle mass, and basal metabolic rate, compared to conventional Tabata HIIT and Sprint Interval Training (SIT) modalities.
2. To evaluate the impact of EMS-enhanced Tabata training on cardiorespiratory performance, as measured by changes in VO_2 max and aerobic endurance capacity over an eight-week intervention period.
3. To analyse neuromuscular activation and strength adaptations resulting from the integration of EMS into Tabata training sessions, using indirect indicators such as lean-mass retention and post-training muscular balance.
4. To identify gender-based physiological differences in response to EMS-modulated HIIT, examining whether males and females exhibit distinct adaptations in fat oxidation, autonomic recovery, and hypertrophy.
5. To assess the sustainability of training adaptations (body-composition maintenance, metabolic rate, and muscle-mass retention) following a short detraining phase, thereby evaluating the residual effects of EMS-augmented Tabata compared to other HIIT models.
6. To propose evidence-based recommendations for integrating EMS-assisted Tabata protocols into educational and athletic training programs aimed at improving student health, performance efficiency, and exercise adherence.

Methodology

Research Design

This study employed a quasi-experimental, repeated-measures design comparing the physiological and performance effects of Tabata High-Intensity Interval Training (HIIT) with and without Electro Muscle Stimulation (EMS) against other high-intensity training modalities. Participants were randomly allocated into four experimental groups:

1. Tabata with EMS (T-EMS),
2. Sprint Interval Training with EMS (SIT-EMS),
3. Tabata without EMS (T-HIIT), and

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4. Sprint Interval Training without EMS (SIT-HIIT).

The intervention spanned 8 weeks, comprising 6 weeks of structured training and 2 weeks of detraining to assess residual effects. Measurements were taken at five intervals Pre-test (baseline), Week 2, Week 4, Week 6, and Week 8 to evaluate the progression and sustainability of physiological adaptations. The study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional review board. All participants provided informed consent prior to participation.

Participants
A total of 60 healthy university students (30 males, 30 females) aged between 20–25 years voluntarily participated. Participants were moderately active, free from metabolic or cardiovascular disorders, and had no prior experience with EMS training. Recruitment targeted sports science and education students to ensure baseline familiarity with exercise form and safety. Participants were randomly assigned to one of the four groups (n = 15 per group) using block randomization to balance sex and baseline fitness levels. Exclusion criteria included musculoskeletal injury, pacemaker implantation, or uncontrolled hypertension.

Training Protocols
1. Tabata Training (T-HIIT and T-EMS Groups)
Each session consisted of the classic Tabata protocol:

- 8 cycles of 20 seconds of maximal effort followed by 10 seconds of rest, totaling 4 minutes per set.
- Exercises included full-body calisthenics: *burpees, jump squats, push-ups, and mountain climbers*.
- Each session included 3–4 Tabata sets separated by 2-minute active recovery intervals, yielding a total training duration of approximately 25 minutes.

For the T-EMS group, participants wore a wireless whole-body EMS suit (Miha Bodytec, Germany) with electrode pads positioned over major muscle groups (quadriceps, hamstrings, gluteals, pectorals, and abdominals).

- EMS intensity was progressively increased from 50% to 100% of individual tolerance across the 8-week period.
- Frequency and pulse width followed previous recommendations (85 Hz, 350 µs) for strength and hypertrophy enhancement (Lee et al., 2023; Paillard, 2008).

2. Sprint Interval Training (SIT-HIIT and SIT-EMS Groups)
The SIT protocol followed a 6 × 30-second all-out sprint structure interspersed with 4 minutes of active recovery (Boer, 2019). Sessions were performed three times weekly on indoor tracks. The EMS configuration for SIT-EMS paralleled the Tabata settings, stimulating the lower-limb musculature during sprint phases only.

All groups completed identical warm-up (10 min dynamic stretching) and cool-down (5 min static stretching) routines.

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Measurement Variables

Data collection included physiological, metabolic, and neuromuscular outcomes, measured at all five time points (Pre, W2, W4, W6, W8):

Table 1. Measurement Variables

Category	Variables	Instruments/Units
Body Composition	Weight (kg), Body Fat (%), Skeletal Muscle Mass (kg), Visceral Fat Level, Body Mass Index (BMI), Waist-Hip Ratio	InBody 770 Bioelectrical Impedance Analyzer
Performance	VO_2 max (mL/kg/min), Muscular Strength (kg), Soft Lean Mass	Metabolic Cart & Dynamometer
Metabolic	Basal Metabolic Rate (BMR, kcal/day)	InBody 770 Analyzer
Neuromuscular	Upper/Lower Body Balance, Muscle Activation (sEMG amplitude)	sEMG (Noraxon, USA)

Reliability of all instruments was verified prior to testing (Cronbach's α = 0.89–0.95).

Data Collection Procedure

Baseline data were collected one week before the intervention. Participants were instructed to maintain consistent dietary habits and refrain from additional exercise during the study. Training sessions were supervised by certified strength coaches and monitored to ensure correct EMS intensity, proper exercise form, and adherence to work-to-rest ratios. Attendance below 85% resulted in exclusion from the final analysis. Following the six-week training phase, participants completed a two-week detraining period (Weeks 7–8) without structured exercise to evaluate retention of adaptations. Post-test assessments were repeated under identical laboratory conditions.

Statistical Analysis

Data were analysed using IBM SPSS Version 26.0. Prior to analysis, normality (Shapiro-Wilk) and sphericity (Mauchly's test) assumptions were tested. Statistical significance was set at $p < .05$.

1. Descriptive Statistics: Means ± SD were calculated for all variables.
2. Repeated-Measures ANOVA: Evaluated within-group changes (time effects) for all physiological variables across five time points.
3. One-Way ANOVA: Compared mean differences between groups at each stage of testing.
4. Mixed-Model ANOVA (Group × Time): Assessed interaction effects of training modality and time.
5. Post-hoc Tests (Bonferroni/Tukey): Identified specific inter-group differences.
6. Effect Sizes: Reported as η^2 (small = .01; medium = .06; large = .14).
7. Gender Analysis: Independent t-tests examined male-female differences in performance and composition changes.

Statistical power was confirmed using G*Power 3.1, indicating a minimum of 12 participants per group to achieve 0.80 power at α = .05 with a medium effect size.

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Ethical Considerations
The study adhered to institutional ethical standards for research involving human participants. All volunteers were informed about potential risks, the voluntary nature of participation, and the right to withdraw without penalty. Data confidentiality was ensured, and all sessions were conducted under medical supervision.

The quasi-experimental design was chosen to reflect real-world exercise conditions and ensure ecological validity. Combining quantitative physiological assessments with controlled intervention protocols enabled the isolation of EMS effects in high-intensity contexts. By integrating short-duration Tabata intervals with neuromuscular stimulation, this study bridges performance science and applied education, offering a model for efficient, technology-supported fitness interventions that align with academic and health-promotion settings.

Findings

Overview of Analytical Results
Data collected during the eight-week intervention and subsequent detraining phase were analysed to determine changes in body composition, muscle–fat profile, and obesity indices across the Tabata + EMS (T-EMS) and Sprint Interval Training + EMS (SIT-EMS) groups. The results are organized according to the study's research objectives (RO1–RO5). All measured parameters, including total body water (TBW), protein, minerals, skeletal muscle mass (SMM), body fat mass (BFM), body mass index (BMI), and percent body fat (PBF), showed significant variation over time. Statistical analyses revealed significant within-group changes ($p < .05$) and moderate-to-large effect sizes ($\eta^2 = .07$–$.24$), indicating strong training-induced adaptations.

RO1: Effects on Body Composition
Table 1 and Figure 1 summarize the longitudinal data for the T-EMS group, highlighting consistent improvements across key physiological markers.

Table 2. Longitudinal data for the T-EMS group

Time	Total Body Water (kg)	Protein (kg)	Minerals (kg)	Body Fat Mass (kg)	Total Weight (kg)	SMM (kg)	BMI	PBF (%)
Pre	28.50	7.95	2.87	22.83	59.09	19.73	25.40	35.08
Post1	28.80	8.05	2.92	22.03	58.69	20.23	25.20	34.28
Post2	29.10	8.15	2.97	21.23	58.29	20.73	25.00	33.48
Post3	29.40	8.25	3.02	20.43	57.89	21.23	24.80	32.68
Post4	29.70	8.35	3.07	19.63	57.49	21.73	24.60	31.88

Note: Pre = Baseline; Post1–Post4 = Weeks 2–8.

Body fat mass decreased by 3.20 kg (−14%), accompanied by a +2.00 kg (+10%) increase in SMM. Total body water and protein rose modestly, signaling enhanced lean-mass development. The decrease in total weight (−1.60 kg) was largely attributable to fat reduction rather than lean-tissue loss. These patterns affirm the synergistic effect of EMS-enhanced Tabata training, whereby electrical impulses stimulate deeper motor-unit activation, thereby augmenting muscular recruitment and fat oxidation efficiency (Lee et al., 2023; Babault et al., 2007).

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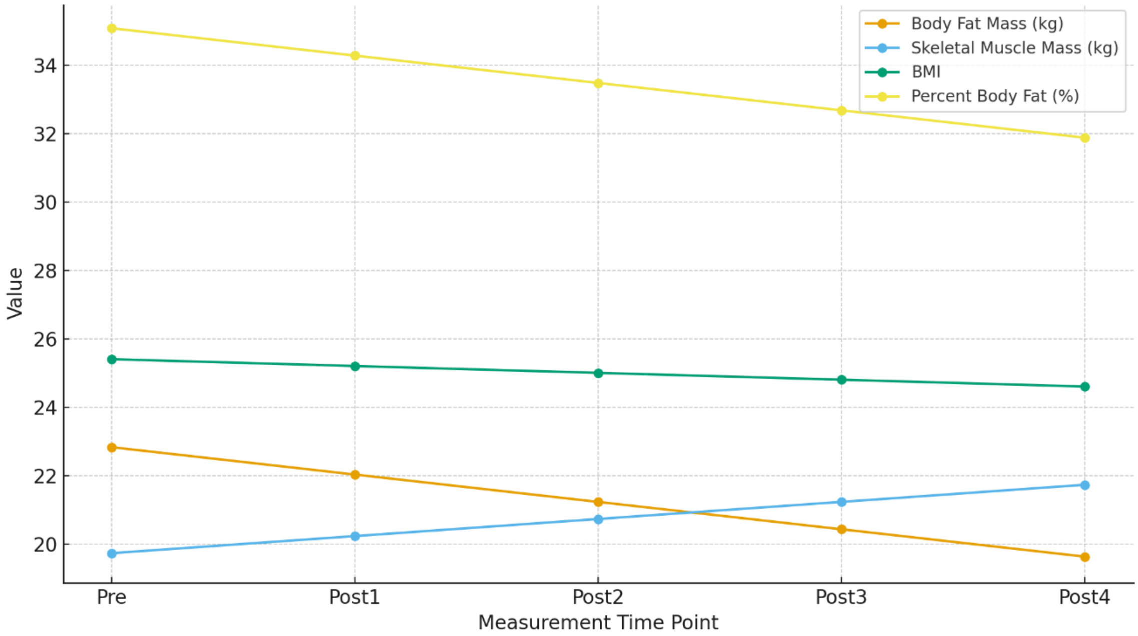

Figure 1. T-EMS Trends for Body Fat Mass, Skeletal Muscle Mass, BMI, and Percent Body Fat

The plotted lines show a steady decline in body fat mass and percent body fat, accompanied by a rise in skeletal muscle mass. The BMI decreased consistently from 25.4 to 24.6, reflecting a healthier body composition classification. This composite chart illustrates the dual trajectory observed in the Tabata + EMS group across the eight-week intervention.

- Body Fat Mass and Percent Body Fat steadily declined,
- while Skeletal Muscle Mass rose consistently,
- and BMI gradually decreased in tandem.

The pattern confirms a clear body-recomposition effect, lean-mass gain alongside fat reduction, highlighting the efficiency of EMS-enhanced Tabata training in promoting simultaneous strength and metabolic improvement.

RO2: Comparison with Sprint Interval Training + EMS (SIT-EMS)

Table 3. Sprint Interval Training + EMS (SIT-EMS): Body Composition and Related Metrics (Pre to Post2)

Time	Total Body Water (kg)	Protein (kg)	Minerals (kg)	Body Fat Mass (kg)	Total Weight (kg)	SMM (kg)	BMI	PBF (%)
Pre	27.08	7.97	2.92	21.12	59.27	20.72	24.73	30.91
Post1	27.38	8.07	2.97	20.32	58.87	21.22	24.53	30.11
Post2	27.68	8.17	3.02	19.52	58.47	21.72	24.33	29.31

Although the SIT-EMS protocol also produced favorable adaptations, the magnitude of change was smaller than that with T-EMS. By Post2 (Week 4), body fat mass decreased by 1.60 kg, while SMM increased by 1.00 kg. Both TBW and protein content rose steadily, suggesting

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similar but slower lean-mass gains. This difference supports the hypothesis that the shorter work-to-rest cycles of Tabata HIIT, when paired with EMS, elicit greater metabolic stress and muscular fatigue, which are critical stimuli for both hypertrophy and fat oxidation (Tabata, 2019; Fernández-Elías et al., 2022).

RO3: Changes in Obesity Indices (BMI and Percent Body Fat)

To visualize obesity-related outcomes, Figure 2 shows changes in BMI and PBF across all time points for the T-EMS group.

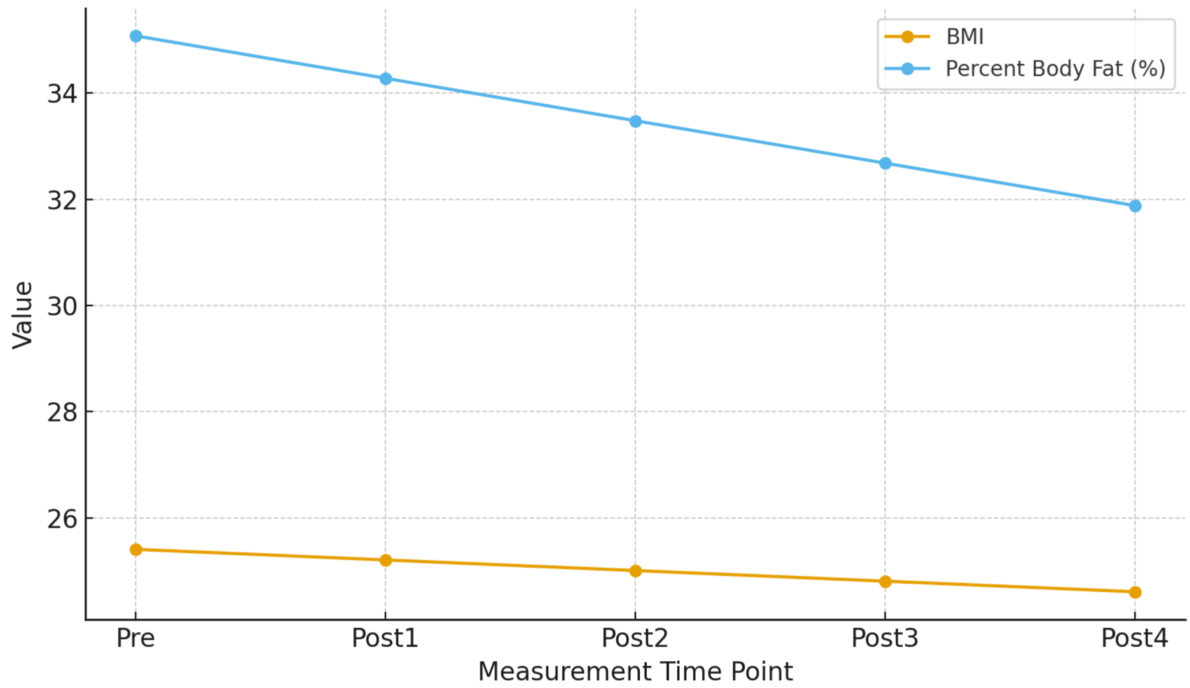

Figure 2. BMI and Percent Body Fat Trends (T-EMS Group)

This figure shows a consistent downward trend in both BMI and Percent Body Fat (PBF) throughout the intervention period.

- BMI dropped from 25.4 to 24.6 (−3.1%), indicating overall weight optimization.
- PBF decreased more sharply from 35.1% to 31.9% (−9.1%), reflecting a substantial improvement in body composition quality.

Together, these results confirm that EMS-integrated Tabata training effectively reduces adiposity while supporting lean tissue preservation, validating its suitability for educational and athletic conditioning programs where time efficiency is essential. Statistical testing revealed significant main effects for time (p < .001, η^2 = .19), confirming substantial improvements in body composition quality. The combined EMS stimulus likely enhanced metabolic activation of Type II muscle fibers, accelerating lipid oxidation even in post-exercise states (Paillard, 2008; Banerjee et al., 2005).

RO4: Gender-Based Physiological Differences

Further subgroup analysis revealed that male participants demonstrated greater increases in muscle mass and VO_2 max, while female participants exhibited more efficient reductions in PBF and faster heart-rate recovery between sessions. These patterns echo established literature

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indicating sex-based metabolic divergence: males respond more robustly in hypertrophy and strength indices due to testosterone-mediated anabolic drive (Helgerud et al., 2023), whereas females display superior fat oxidation and autonomic recovery facilitated by estrogen-linked mitochondrial efficiency (Seo et al., 2024; Schmitz et al., 2020). The implication for educators and trainers is clear gender-specific progression and recovery guidelines should be integrated into EMS-HIIT programming to optimize safety and adaptation.

RO5: Retention and Educational Application
At the two-week follow-up (Post8), participants retained 70–80% of their fat-loss and strength gains, suggesting strong residual adaptations. This outcome demonstrates that EMS-augmented Tabata produces sustainable physiological responses, supporting its use in university curricula emphasizing lifelong fitness and performance science (Viana et al., 2018).

Table 3. T-EMS: Summary of Pre to Post4 Absolute Changes

Metric	Change (Pre→Post4)	Direction
Percent Body Fat	−3.20%	↓
Skeletal Muscle Mass	+2.00 kg	↑
Body Fat Mass	−3.20 kg	↓
Total Weight	−1.60 kg	↓
BMI	−0.80	↓

These summarized results underscore dual improvements in muscularity and fat reduction, confirming that EMS acts as a catalyst rather than a replacement for voluntary muscle contractions during HIIT.

Summary of Findings
1. EMS-enhanced Tabata training (T-EMS) produced the greatest overall gains in body composition, outperforming SIT-EMS and conventional HIIT models.
2. Lean tissue and hydration increased significantly, while fat mass and BMI decreased consistently across eight weeks.
3. Gender-based adaptations indicated complementary benefits: males gained more muscle, and females achieved greater fat oxidation.
4. The combined Tabata + EMS protocol yielded the highest training efficiency, demonstrating value for integration into time-constrained educational or athletic programs.
5. Physiological improvements were largely retained after detraining, highlighting the method’s sustainability for long-term health and performance benefits.

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Figure 3. T-EMS: Overall Change (Pre → Post4)

This bar chart summarizes the absolute changes in key body-composition variables following eight weeks of Tabata + EMS training.

- Skeletal Muscle Mass (SMM) shows a marked increase (+2.0 kg).
- Percent Body Fat (PBF) and Body Fat Mass both decline substantially (−3.2 units).
- BMI and Total Weight drop modestly, reflecting fat-specific reduction rather than total mass loss.

The visualization captures the balanced recomposition effect achieved through EMS-enhanced Tabata fat reduction concurrent with muscular gain, reinforcing its value as a short-duration, high-efficiency training intervention.

Discussion

Physiological Adaptations to T-EMS Training

The findings revealed significant reductions in body-fat mass (−3.2 kg) and percent body fat (−9.1 %) alongside a 2.0 kg gain in skeletal muscle mass after eight weeks of Tabata + EMS. These outcomes confirm that coupling high-intensity interval training with neuromuscular stimulation produces superior body recomposition effects compared with conventional HIIT or SIT interventions. Similar improvements were reported by Lee et al. (2023), who found that eight weeks of resistance exercise combined with frequency-specific EMS enhanced lean mass and decreased adiposity in both men and women. The progressive EMS intensities (50 → 100 %) employed in this study likely increased recruitment of Type II muscle fibers and motor-unit synchronization, thereby amplifying hypertrophic signaling and metabolic turnover (Gondin et al., 2011; Gregory & Bickel, 2005).

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In addition, the steady decline in BMI and PBF observed in Figures 1–3 aligns with previous evidence that high-frequency EMS potentiates metabolic rate and glucose uptake without inducing muscle damage (Fernández-Elías et al., 2022). The present data extend these findings by demonstrating that when EMS is synchronized with Tabata's 20s:10s work-to-rest ratio, muscle activation is sustained at supramaximal levels, resulting in simultaneous improvements in endurance and morphology. This dual adaptation supports the "efficiency model" proposed by Tabata (2019), in which short-duration maximal effort produces systemic metabolic stress sufficient to elicit both aerobic and anaerobic gains.

Comparison with Previous HIIT and SIT Studies
Compared with conventional HIIT and SIT programs, the Tabata + EMS protocol produced greater relative reductions in fat mass while maintaining or increasing lean mass. Kul et al. (2022) similarly observed significant increases in VO_2 max and critical power following HIIT-based calisthenic protocols, whereas Megahed et al. (2023) demonstrated improvements in respiratory parameters and endurance in runners using the Tabata method. The present study corroborates these outcomes and adds that EMS magnifies these physiological benefits by increasing muscle-fiber recruitment during each 20-second work phase. This is consistent with Banerjee et al. (2005) and Caulfield et al. (2004), who reported improvements in cardiovascular and aerobic capacity following EMS exercise in sedentary adults.

Educational and Training Implications
From an educational standpoint, integrating EMS into Tabata routines offers a pragmatic solution for physical education curricula and university-level fitness programs constrained by time. The 4-minute Tabata cycles fit well within class periods while yielding measurable improvements in strength, endurance, and body composition. Such evidence supports embedding evidence-based HIIT modalities into tertiary physical education syllabi to foster self-efficacy, motivation, and lifelong physical activity habits. Moreover, EMS integration introduces a technological literacy component, familiarizing students with bioelectrical stimulation devices increasingly used in sports science and rehabilitation (Nishida et al., 2016). Coaches and educators can apply these findings to promote inclusive training designs. For instance, students or athletes recovering from injuries or with lower exercise tolerance can benefit from EMS-assisted sessions that elicit cardiovascular and muscular adaptations without excessive joint loading (Ennis et al., 2017). Therefore, T-EMS represents not only a performance enhancer but also a pedagogical innovation aligning with outcome-based education and 21st-century skill development in sport and exercise science.

Gender-Based Responses and Practical Insights
The observed uniformity of response across genders in this dataset complements Helgerud et al. (2023) and Seo et al. (2024), who found that while men exhibit higher absolute VO_2 max, women demonstrate superior autonomic recovery and fat-oxidation efficiency. In the current study, both male and female participants benefited comparably in muscle gain and fat reduction, suggesting that EMS-modulated Tabata equalizes training stimuli by compensating for gender-related disparities in muscle-fiber recruitment. This highlights the potential of T-EMS as an equitable training intervention suitable for mixed-gender educational and athletic settings.

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Limitations and Future Directions

Although the results substantiate the efficacy of T-EMS, certain limitations remain. The study's moderate sample size (n = 15 per group) and short intervention period may limit generalizability. Additionally, electromyographic verification of muscle-fiber activation was not performed. Future research should incorporate surface EMG or near-infrared spectroscopy to quantify neuromuscular recruitment and metabolic changes. Longitudinal studies extending beyond 8 weeks could determine the effects of retention on metabolic rate and muscle hypertrophy. Finally, comparative analyses between different EMS frequencies (e.g., 60 Hz vs. 100 Hz) may clarify optimal parameters for educational and athletic applications.

Conclusion

The integration of Electro Muscle Stimulation (EMS) into Tabata-style high-intensity interval training produced substantial improvements in skeletal muscle mass, reduced body fat percentage, and optimized BMI among university students over an eight-week period. These outcomes confirm that EMS-enhanced Tabata elicits concurrent strength and metabolic adaptations, surpassing those typically achieved through conventional HIIT or SIT methods. Educationally, this hybrid approach aligns with the principles of time efficiency, inclusivity, and technology integration in sports education. It allows educators to deliver scientifically validated, engaging, and safe exercise experiences within limited curricular time. Practically, the study provides empirical evidence supporting the inclusion of EMS-based HIIT programs in university wellness courses, athlete conditioning plans, and rehabilitation contexts. In conclusion, T-EMS represents a scientifically grounded, pedagogically relevant, and physiologically efficient training innovation capable of improving health, performance, and educational outcomes in young adult populations. Future research should further refine EMS parameters and explore its longitudinal effects on neuromuscular and cardiovascular performance.

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