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High-Intensity Interval Training vs. Plyometric EMOM: A Comparison of Effects on Body Composition and Physical Fitness in 18-19-Year-Old Karate Athletes

Willy Adimas Rahmawan[1ABCE], Sumaryanto[1ADE], Sumarjo[1ADE] and Nevitaningrum[2ACD]

[1]Yogyakarta State University
[2]Siliwangi University

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Corresponding Author: Nevitaningrum, e-mail: nevitaningrum@unsil.ac.id
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Abstract

Background. A scientific contradiction exists in kumite preparation: HIIT (metabolic-dominant via AMPK/PGC-1α) and plyometric training (neuromuscular-dominant via SSC) are theoretically predicted to produce distinct adaptation patterns, yet empirical literature reports only isolated effects without explanatory models of adaptation transfer to karate-specific fitness demands.

Objectives. This study aimed to compare the effects of conventional High-Intensity Interval Training (HIIT) and plyometric training using the Every Minute on the Minute (EMOM) format on physical fitness and body composition in male karate athletes aged 18-19 years.

Materials and Methods. Forty-four male karate athletes (aged 18-19 years) from the Polda DIY Karate Club were assigned to a quasi-experimental two-group pretest-posttest design, completing HIIT ($n = 22$) and plyometric-EMOM ($n = 22$) training over 8 weeks. Physical fitness was assessed using the Indonesian Physical Fitness Test (TKJI); body composition was measured using a Tanita BC-545N.

Results. Both groups improved substantially ($p < 0.001$). Significant Time×Group interactions were observed for TKJI, body fat, and body weight (all $p < 0.001$), with a moderate interaction for FFM ($p = 0.028$). The HIIT group demonstrated greater TKJI gains ($\Delta = +3.09$ vs. $+0.95$), while the plyometric-EMOM group produced greater fat loss ($\Delta = -5.36\%$ vs. -4.29%). Extremely large effect sizes (Cohen's d up to 6.80) reflect low variance within a homogeneous single-club sample rather than universal biological effects.

Conclusions. HIIT is superior for physical fitness via metabolic-cardiovascular pathways, whereas plyometric-EMOM excels in fat reduction via SSC-driven eccentric energetics, confirming the Dual-Pathway Specificity Model. These findings are context-specific to elite junior male karate athletes and require further validation for broader generalization.

Keywords: high-intensity interval training, plyometric EMOM, karate, physical fitness, body composition.

Introduction

Karate, as an intermittent combat sport, requires a combination of aerobic-anaerobic capacity, lower-limb muscle power, speed, agility, and high technical coordination; therefore, physical fitness and body composition are critical determinants of performance, particularly in young athletes aged 18-19 years who are entering the phase of competitive specialization (Martínez-de-Quel et al., 2020; Przybylski et al., 2021). The theory of training adaptation (specificity principle) predicts that HIIT will dominate metabolic-cardiovascular adaptations through stimulation of the AMPK/PGC-1α pathway and repeated lactate accumulation, producing body composition changes (↓fat, ↑VO_2peak) crucial for kumite endurance. Conversely, plyometric training via the stretch-shortening cycle (SSC) should excel in neuromuscular adaptations (↑rate of force development/ RFD, tendon stiffness), essential for explosive movements such as kicks and rapid defensive techniques (Kons et al., 2023; Laidi et al., 2025).

The demands of kumite competition are non-uniform (with fluctuating rhythm and intensity), characterized by a dominant aerobic contribution while still requiring anaerobic capacity for high-intensity offensive and defensive actions that determine match outcomes. A scientific contradiction arises in adolescent karate athletes who require a holistic balance of both adaptations for kumite performance. HIIT (metabolically-dominant) and plyometric-EMOM (neuromuscular-dominant) protocols are theoretically predicted to produce distinct adaptation patterns; yet empirical literature reports only isolated effects without explanatory models of why one protocol fails to transfer to karate-specific fitness demands. This leaves the transition from ‹unknown› to ‹knowledge-how› of training adaptations unresolved (Rezaei et al., 2024; Ojeda-Aravena et al., 2023). The specificity principle demands that training stimuli match kumite's metabolic demands (HIIT) versus neuromuscular demands (SSC); this mismatch in adaptation transfer challenges our understanding of combat sport-specific adaptations (Rezaei et al., 2024; Ojeda-Aravena et al., 2023).

This contradiction is further compounded by the role of body composition in kumite performance. Anthropometric characteristics such as relatively low body fat levels and adequate fat-free mass are associated with strength-to-weight ratio, movement efficiency, and the ability to execute explosive techniques, while fitness profiles (e.g., high VO_2peak, maximal strength, and muscular endurance) form an important baseline for designing effective individualized training programs (Da Costa Silva et al., 2020; Nema et al., 2024). It remains unclear whether metabolic-focused (HIIT) or neuromuscular-focused (plyometric-EMOM) interventions produce superior body composition outcomes in young karate athletes a dimension that directly connects to resolving the adaptation specificity contradiction. Although karate athletes generally exhibit fitness levels above those of their age-matched peers, appropriate training load management remains necessary to minimize the risk of overreaching and to maintain optimal body composition during phases of competitive intensification (Aziz et al., 2025).

Various sport-specific training interventions lasting 4-12 weeks (2-3 sessions/week), such as HIIT, plyometric training, circuit bodyweight training, and concurrent training, have been reported to improve key performance components (e.g., sprinting, vertical jumping, agility, and aerobic-anaerobic capacity) without excessively increasing training volume (Ojeda-Aravena et al., 2023; Xu & Wang, 2025; Fadhila et al., 2024). However, these studies report outcome differences without mechanistic explanations precisely the explanatory gap at the core of the present contradiction. Two approaches commonly used to support kumite performance are high-intensity interval training (HIIT) and plyometric training. HIIT stimulates aerobic-anaerobic adaptations through metabolic and cardiovascular stress, thereby enhancing VO_2max and tolerance to high-intensity work (Rezaei et al., 2024; Wiesinger et al., 2025). In contrast, plyometric training exploits the stretch-shortening cycle (SSC) to improve power, neuromuscular reactivity, and muscular coordination, which are directly relevant to the explosive movements required in combat sports (Kons et al., 2023; Ojeda-Aravena et al., 2023).

Along with the evolution of training practices, the every minute on the minute (EMOM) format has been increasingly adopted to "package" training sessions, as participants initiate a task at the beginning of each minute and use the remaining time within that minute as a rest period, allowing training density and inter-work intervals to be efficiently standardized (Laidi et al., 2025). Critically, the EMOM structure by standardizing training density and work-to-rest ratio provides a controlled experimental condition to isolate whether neuromuscular versus metabolic stimuli produce differential adaptation transfer to kumite-specific fitness, directly addressing the unresolved contradiction identified above. Conceptually, controlling training density and work-to-rest ratio is expected to help maximize specific physiological adaptations while reducing the risk of cumulative fatigue in young athletes.

Therefore, this study tests the mechanism-based hypothesis: (1) Plyometric-EMOM will be superior for neuromuscular adaptations (power, agility) via SSC-matching kumite demands; (2) HIIT will excel in body composition changes via metabolic pathways; (3) A predictive model of karate adaptation = f(metabolic vs neuromuscular + kumite specificity), generating 'knowledge-how' for karate training programs.

Materials and methods

Participants

A total of 44 male karate athletes (young police officers) from a single competitive club the Polda Special Region of Yogyakarta Karate Club, Indonesia, aged 18-19 years, were recruited using purposive sampling to ensure uniform training history and technical background, as required for controlled comparison of protocol-specific adaptations (M = 18.5 ± 0.5 years; height 172.1 ± 1.7 cm; body weight 70.6 ± 2.0 kg; BMI 23.8 ± 0.7). This single-club, narrow-age (18-19y) design deliberately ensured high homogeneity in training history, technical proficiency, and baseline fitness, minimizing between-subject variability to isolate protocol-specific effects (HIIT vs plyometric-EMOM) while acknowledging limited external validity beyond this specific population and training context. Inclusion criteria were: (1) a baseline TKJI score of 14-21, (2) BMI between 18.5 and 24.9 kg/m², and (3) free from musculoskeletal injury for at least 6 months prior to the study. Exclusion criteria included a history of cardiovascular or respiratory diseases limiting high-intensity exercise, use of medications affecting exercise responses, failure to complete either the pretest or posttest, and training attendance <80% of total sessions.

Consequently, the high within-group homogeneity of this sample is expected to produce artificially low variance, which directly inflates t-values and Cohen's d estimates reported in the Results; these should therefore be interpreted as sample-specific rather than universal biological effects.

Research design and organization

This study employed a quasi-experimental two-group pretest-posttest design with an active comparison group, comparing two training protocols (conventional HIIT targeting metabolic adaptations vs. plyometric-EMOM targeting SSC-mediated neuromuscular adaptations) without a non-intervention control group. The overall study design and experimental flow are presented in Figure 1. The intervention was conducted over 8 weeks with a frequency of 2 sessions/week and a duration of 35-40 minutes/session. Training intensity was targeted at an RPE of 15-18 (hard to very hard) during the main training segment.

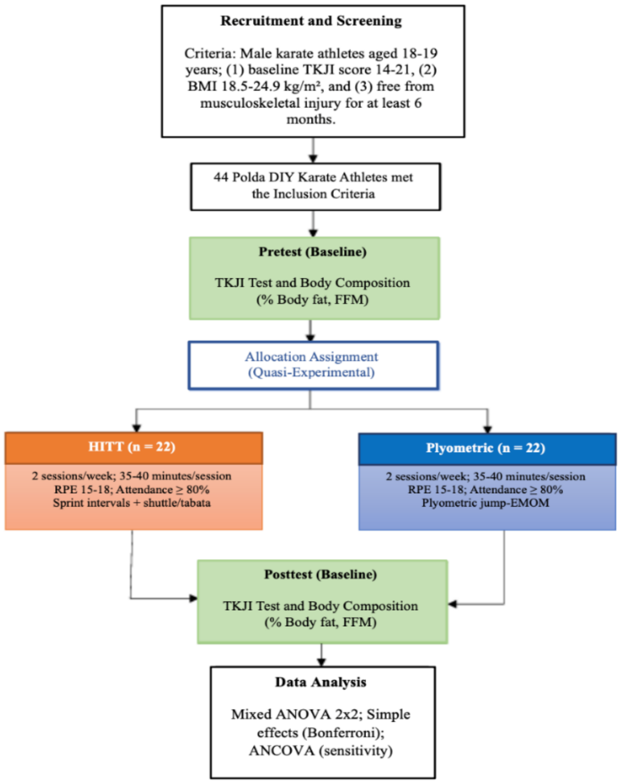

Fig. 1. Research Flows

Measurements were conducted at pretest and posttest for physical fitness and body composition. Physical fitness was assessed using the Indonesian Physical Fitness Test (Tes Kesegaran Jasmani Indonesia, TKJI), which includes a 60 m sprint, pull-ups, 30 s sit-ups, vertical jump, and a 1200 m run (total score range: 5-25). Body composition was measured using a Tanita BC-545N (bioelectrical impedance analysis/BIA) to obtain body fat percentage (% body fat), fat-free mass (FFM), and body weight (Son et al., 2024). Body composition measurements were performed at a consistent time (08:00 a.m. local time), barefoot, wearing light clothing, and supervised by the same trained assessor; the device was calibrated and verified according to laboratory procedures prior to data collection, and readings were repeated only in cases of device error or unstable electrode contact.

Controlled variables for both groups included an ad libitum diet (no specific dietary intervention), a minimum attendance requirement of 80%, and weekly RPE monitoring to maintain consistency of training stimulus across sessions and between groups. All pretest and posttest measurements were conducted using standardized test order and verbal instructions delivered by the facilitator, with rest intervals kept consistent across all testing sessions.

Intervention protocols

Conventional HIIT group (n = 22)

The HIIT protocol specifically targeted metabolic-cardiovascular adaptations (AMPK/PGC-1α activation via repeated lactate accumulation) to match kumite's prolonged aerobic-dominant energy demands. The HIIT group performed progressive sprint interval training (8-12 repetitions; 30-40 s sprint with 75-90 s recovery) and shuttle runs based on Tabata metabolic conditioning (10-16 repetitions; 20 s work with 30-40 s rest). Sessions lasted 35-40 minutes, 2x/week for 8 weeks. The detailed weekly structure and progression of the training program are presented in Table 1.

Plyometric EMOM group (n = 22)

The plyometric-EMOM protocol isolated neuromuscular adaptations via stretch-shortening cycle (SSC) mechanisms (↑RFD, tendon stiffness) to match karate's explosive offensive-defensive techniques. The plyometric-EMOM group performed high-intensity jump sequences using the every minute on the minute (EMOM) format for 10-15 minutes (depending on week/progression), including box jumps (30-50 cm), depth jumps, hurdle hops, and lateral bounds. Sessions lasted 30-35 minutes, 2x/week for 8 weeks. The weekly structure, progression of contact volume, and drill variations are presented in Table 2.

Table 1. Weekly Structure of Conventional HIIT (2 sessions/week, 8 weeks)

Week	Day 1 (Monday)	Day 2 (Thursday)	Intensity Progression	Main Effect
1-2	8x(30s sprint/90s walk) 4x(200m run/2min rest)	10x(20s shuttle/40s rest) 3x(4min tabata pushup-squat)	80-85% HRmax	↑ VO_2max
3-4	10x(30s sprint/90s walk) 4x(250m run/2min rest)	12x(20s shuttle/40s rest) 4x(4min tabata)	85-90% HRmax	↑ anaerobic power
5-6	12x(30s sprint/75s walk) 5x(250m/90s rest)	14x(20s shuttle/35s rest) 4x(5min tabata)	90% HRmax	↑ sprint endurance
7-8	12x(40s sprint/75s walk) 5x(300m/90s rest)	16x(20s shuttle/30s rest) 5x(5min tabata)	90-95% HRmax	Peak aerobic capacity

*Primary Method: Sprint intervals + metabolic conditioning | Duration: 35-40 minutes/session

Table 2. Weekly Structure of Plyometric EMOM (2 sessions/week, 8 weeks)

Week	Day 1 (Tuesday) EMOM 10-12 minutes	Day 2 (Friday) EMOM 12-15 minutes	Volume Progression	Main Effect
1-2	Minutes 1-10: 5 box jumps (30 cm) Minutes 11-12: 6 hurdle hops	Minutes 1-12: 4 depth jumps (30 cm) + 30 s rest/set	40-50 contacts	↑ reactive strength
3-4	Minutes 1-12: 6 box jump (40 cm) Minutes 13-15: 8 single leg hops	Minutes 1-15: 5 depth jump (40 cm) + lateral bounds	60 contacts	↑ explosive power
5-6	Minutes 1-12: 7 drop jumps (40 cm) Minutes 13-15: 6 hurdle + stick	Minutes 1-15: 6 depth jump (50 cm) + CoD drill	70-80 contacts	↑ CoD + power
7-8	Minutes 1-15: 8 reactive drop jumps Karate-specific test	Minutes 1-15: 7 plyometric + agility Performance test	90+ contacts	Peak SSC + agility

*Main method: EMOM jump-landing sequence | Duration: 30 minutes/session

Facilitators and training

The training intervention was delivered by two certified strength and conditioning practitioners and two karate coaches affiliated with the POLDA DIY karate club (total n = 4 facilitators). Prior to the intervention, all facilitators completed an 8-hour standardization workshop led by the research team to ensure consistent session delivery across groups.

The workshop covered: (1) safety procedures and injury prevention (warm-up/cool-down, sprint mechanics, jump-landing techniques, and load progression); (2) internal load monitoring using the Borg RPE Scale with a target of 15-18 for the core sets; and (3) session management (time regulation, enforcement of work-rest intervals, and criteria for stopping or modifying exercise in the presence of pain, dizziness, or excessive fatigue).

To standardize data collection, facilitators were trained in unified protocols for administering the TKJI test battery and assessing body composition using the Tanita BC-545N, including equipment calibration checks, standardized verbal instructions, consistent test order, and identical rest intervals. Attendance and weekly RPE were recorded using standardized logbooks, and participants were required to achieve ≥80% session attendance to be included in the analysis.

Monitoring instruments are provided in the Appendix/Supplement to support replication and transparent reporting of implementation fidelity.

Instrument

Body composition (Tanita BC-545N: %Body Fat, FFM)

Body composition was measured using the Tanita BC-545N (BIA) to obtain % body fat, fat-free mass (FFM), and body weight (Son et al, 2024). Measurements followed strict hydration controls: 08:00 a.m. (fasted >10h), barefoot, light clothing (<0.5kg), no exercise 24h prior, (urine specific gravity <1.020) , supervised by trained assessor. Test-retest reliability: ICC=0.95

Physical fitness (TKJI)

Physical fitness was assessed using the Indonesian Physical Fitness Test (Tes Kesegaran Jasmani Indonesia; TKJI) for adolescents aged 13-19 years. The TKJI battery comprises a 50-m sprint (speed), pull-ups (upper-body strength), sit-ups (abdominal strength and endurance), a vertical jump (explosive leg power), and a 1,000-m middle-distance run for males and an 800-m middle-distance run for females to assess cardiorespiratory endurance.

The validity and reliability of the TKJI have been reported to be high, with a validity coefficient of 0.720 and a reliability of 0.920 (Dulanlebit, 2020). Inter-rater reliability was acceptable to high (ICC = 0.88; two-way random-effects model, 20% subsample).

Statistical analysis

Data were analyzed using IBM SPSS version 26. Results are presented as mean ± SD, and statistical assumptions were examined using the Shapiro-Wilk normality test and Levene's variance homogeneity test (two-tailed $\alpha = 0.05$). Intervention effects were tested using a 2×2 mixed ANOVA (Time: pre, post × Group: HIIT, PLYO-EMOM) for each outcome, with emphasis on the Time × Group interaction and reporting F(df=1,42), p values, and partial η^2.

Significant interactions were followed by planned simple-effects analyses (pre-post within each group) with Bonferroni adjustment ($\alpha = 0.025$) and Cohen's d effect sizes calculated as d = |mean difference| / pooled SD ($\sqrt{[(SD\_pre^2 + SD\_post^2)/2]}$). ANCOVA on posttest values adjusted for baseline (pretest as covariate) was conducted as a sensitivity analysis with homogeneity of regression slopes verified (all p > 0.05). Sample size was determined a priori using G*Power (n = 22 per group; power = 0.90; f = 0.40; $\alpha = 0.05$ for medium-large interaction effects).

Results

Twenty-two karate athletes were assigned to each intervention group (HIIT, n=22; PLYO-EMOM, n=22).

Measurements of physical fitness (TKJI) and body composition (%Body Fat, FFM using Tanita BC-545N) were taken at pretest and posttest after 8 weeks. The results are presented as follows:

Table 3. Baseline Characteristics of Participants

Variable	HIIT (n = 22)	Plyometric EMOM (n = 22)
Age (years)	18.45 ± 0.510	18.45 ± 0.510
Body height (cm)	172.23 ± 1.817	172.23 ± 1.817
Body weight (kg)	70.50 ± 1.795	70.60 ± 1.795
BMI (kg/m2)	23.76 ± 0.167	23.79 ± 0.168
TKJI (Pre)	18.36 ± 2.083	19.23 ± 3.070
Lemak (Pre)	18.70 ± 0.807	18.67 ± 0.901
FFM (Pre)	57.36 ± 1.972	57.43 ± 2.008

Table 3 shows that the baseline characteristics of both groups were descriptively similar across demographic, anthropometric, physical fitness, and body composition variables. Given the quasi-experimental design, this similarity is not interpreted as evidence of "equivalence"; therefore, effect interpretation relies primarily on mixed ANOVA and is corroborated by ANCOVA.

Table 4. Normality Test (Shapiro-Wilk)

Variable (gain score)	Group	p (Shapiro-Wilk)
Body weight gain	HIIT	0.195
Body weight gain	Plyometric EMOM	0.619
Body fat gain	HIIT	0.159
Body fat gain	Plyometric EMOM	0.111
FFM gain	HIIT	0.290
FFM gain	Plyometric EMOM	0.294
TKJI gain	HIIT	0.184
TKJI gain	Plyometric EMOM	0.417

The distribution of all primary variables was examined using the Shapiro-Wilk normality test. All variables yielded p-values > 0.05, indicating normal data distributions. Accordingly, the use of parametric analyses was considered appropriate.

Table 5. Homogeneity of Variances (Levene's Test)

Variable	Levene's (Sig.)
Weight gain	0.284
Fat gain	0.068
FFM gain	0.205
TKJI gain	0.978

Levene's test indicated that all p values were > 0.05, suggesting homogeneous variances between groups and no evidence of heteroscedasticity affecting between-group comparisons.

Table 6 shows that both groups improved across all outcomes from pretest to posttest. HIIT demonstrated greater gains in physical fitness (TKJI: Δ = +3.09 vs. +0.95), whereas the plyometric-EMOM group showed greater reductions in body fat percentage (Δ = −5.36% vs. −4.29%) and body weight (Δ = −2.46 kg vs. −1.28 kg). Changes in FFM were comparable between groups (Δ = +1.84 kg vs. +1.65 kg), consistent with the moderate interaction effect observed in the mixed ANOVA

Based on Table 7, the main effect of Time was significant and very large for all outcomes, indicating that both groups changed from pretest to posttest. The extremely large F-values (e.g., F=3837.997 for body fat) reflect low between-subject variance characteristic of elite homogeneous samples from a single karate club, rather than generalizable training effects. Significant Time × Group interactions were observed for TKJI, body fat, and body weight (all p < 0.001), as well as for FFM (p = 0.028), indicating that the magnitude of pre-post change differed between groups and that training modality modulated adaptive responses. Practically, these findings support specificity of effects: HIIT was more favorable for improving TKJI, whereas plyometric EMOM was more favorable for reducing body fat and body weight (confirmed by simple-effects analyses).

Based on Table 8, all outcomes changed significantly from pretest to posttest in both groups (all p < 0.001; corrected α = 0.025), indicating that both protocols were effective. However, extremely large t-values (e.g., t=113.376 for HIIT body weight; t=46.737 for HIIT body fat) and Cohen's d values (d=6.80, 5.96) are artifacts of extremely low baseline variance (SD < 1% for body fat) in this single-club homogeneous sample, rather than universal biological effect magnitudes. The magnitude of change differed: improvements in TKJI were greater in the HIIT group (d=1.47) than in the plyometric EMOM group (d=0.32), whereas reductions in body fat and body weight were greater in the plyometric EMOM group. Increases in FFM occurred in both groups with moderate between-group differences (d=0.98 vs 0.80). These context-specific effects align with metabolic (HIIT) vs neuromuscular (plyo-EMOM) adaptation pathways.

Prior to ANCOVA, the assumption of homogeneity of regression slopes was tested. No significant interaction between group and baseline values was detected (p > 0.05), indicating that the assumption was satisfied.

ANCOVA results controlling for baseline values demonstrated significant between-group differences across

Table 6. PRE-POST MEANS by group

Variable	HIIT Pre	HIIT Post	Δ HIIT	Plyo Pre	Plyo Post	Δ Plyo
TKJI	18.36 ± 2.083	21.47 ± 2.110	+3.09	19.23 ± 3.070	20.18 ± 2.986	+0.95
Body Fat (%)	18.70 ± 0.807	14.41 ± 0.413	−4.29	18.67 ± 0.901	13.31 ± 0.892	−5.36
FFM (kg)	57.36 ± 1.972	59.21 ± 1.769	+1.85	57.43 ± 2.008	59.08 ± 2.134	+1.65
Body Weight (kg)	70.50 ± 1.795	69.22 ± 1.780	−1.28	70.60 ± 1.795	68.14 ± 1.966	−2.46

Note: Δ = difference between posttest and pretest. Extremely low baseline SDs (e.g., body fat SD < 1%) reflect single-club homogeneity rather than population norms; interpret magnitude changes within this context. Negative values indicate a decrease; positive values indicate an increase.

Table 7. Mixed ANOVA (2×2) Results

Outcome	Source	F(1.42)	p	ηp²	Interpretation
TKJI	Time	195.007	<0.001	0.823	Very large
TKJI	Group	0.070	0.792	0.002	No effect
TKJI	Time×Group	54.383	<0.001	0.564	Very large
Body Fat (%)	Time	3837.997	<0.001	0.989	Very large
Body Fat (%)	Group	6.455	0.015	0.133	Moderate
Body Fat (%)	Time×Group	47.472	<0.001	0.531	Very large
FFM (kg)	Time	1744.059	<0.001	0.976	Very large
FFM (kg)	Group	0.002	0.964	0.000	No effect
FFM (kg)	Time×Group	5.216	0.028	0.110	Moderate
Body Weight (kg)	Time	1098.418	<0.001	0.963	Very large
Body Weight (kg)	Group	0.795	0.378	0.019	Small
Body Weight (kg)	Time×Group	109.893	<0.001	0.723	Very large

Note: Extremely large F-values (>1000) and $\eta p^2 > 0.95$ primarily reflect artificially low variance (baseline SDs < 2) from highly homogeneous single-club sample, not universal biological effects. ηp^2 interpretation: 0.01-0.05 = small, 0.06-0.13 = moderate, ≥0.14 = large, ≥0.50 = very large effect.

Table 8. Planned Simple-Effects Comparisons (Bonferroni-adjusted α = 0.025) with Cohen's d

Outcome	Comparison	Mean Diff	95% CI	t(df=21)	p	Cohen's d	Interpretation
TKJI	HIIT	+3.091	2.49, 3.68	10.803	<0.001	1.47	Very Large
TKJI	Plyo	+0.955	0.86, 1.04	21.000	<0.001	0.32	Small
Body fat (%)	HIIT	-4.286	-4.47, -4.09	46.737	<0.001	6.80	Very Large
Body fat (%)	Plyo	-5.359	-5.62, -5.09	42.595	<0.001	5.96	Very Large
FFM (kg)	HIIT	+1.840	1.73, 1.95	35.924	<0.001	0.98	Large
FFM (kg)	Plyo	+1.650	1.51, 1.78	24.984	<0.001	0.80	Large
Body weight (kg)	HIIT	-1.277	-1.30, -1.25	113.376	<0.001	0.71	Moderate
Body weight (kg)	Plyo	-2.459	-2.69, -2.23	21.922	<0.001	1.31	Very Large

Note: Cohen's d > 5.0 characteristic of highly homogeneous athletic cohorts (single club, narrow age range); interpret cautiously for external validity. 95% CI calculations available upon request.

Table 9. ANCOVA Results (Posttest Adjusted for Baseline)

Outcome	Adjusted Mean HIIT	Adjusted Mean Pliometrik EMOM	p	ηp²
TKJI	21.85 ± 0.41	19.78 ± 0.41	< 0.001	0.553
Body fat (%)	14.40 ± 0.18	13.32 ± 0.19	< 0.001	0.635
FFM (kg)	59.23 ± 0.12	59.05 ± 0.11	0.028	0.112
Body weight (kg)	69.27 ± 0.16	68.09 ± 0.17	< 0.001	0.727

all variables. The HIIT group exhibited higher adjusted TKJI scores ($p < 0.001$, $\eta p^2 = 0.553$), indicating superior improvements in physical fitness. Conversely, the plyometric EMOM group showed lower adjusted body fat percentage and body weight ($p < 0.001$; $\eta p^2 = 0.635$-0.727), consistent with greater fat loss efficacy .Differences in fat-free mass were statistically significant but with small-to-moderate effect sizes ($p = 0.028$; $\eta p^2 = 0.112$), suggesting relatively comparable practical effects between groups. Large ηp^2 values primarily reflect low baseline variability rather than protocol superiority alone.Collectively, ANCOVA-adjusted results provide context-specific support for the mechanism-based hypotheses: HIIT superiority in physical fitness (TKJI) is consistent with metabolic-cardiovascular pathway activation, while plyometric-EMOM superiority in fat reduction aligns with SSC-driven neuromuscular and metabolic demands though generalization beyond this homogeneous cohort requires caution.

Discussion

This study examined whether HIIT (metabolic-dominant via AMPK/PGC-1α) and plyometric-EMOM (SSC-neuromuscular dominant) produce differential adaptation patterns in kumite-relevant fitness outcomes. Both protocols produced significant pre-post improvements; however, the direction and magnitude of adaptation differed systematically by modality. HIIT demonstrated superior improvements in physical fitness (TKJI: $\Delta = +3.09$ vs. $+0.95$; $d = 1.47$ vs. 0.32), while plyometric-EMOM yielded greater reductions in body fat ($\Delta = -5.36\%$ vs. -4.29%) and body weight ($\Delta = -2.46$ kg vs. -1.28 kg), with comparable FFM gains across groups. These findings align with prior research showing HIIT's edge in aerobic-related fitness metrics, while plyometric protocols excel in fat loss due to higher SSC-driven metabolic demands (Sarfraz et al., 2022; Chen et al., 2025; Li et al., 2023).

Building on these modality-specific outcomes, a cautious interpretation is warranted for the extremely high t-value observed for body weight change in the HIIT group (t = 113.376), which corresponds to an unusually small standard deviation of gain scores (SD approximately 0.05 kg). These artifacts underscore the context-specific nature of findings, aligning with methodological limitations acknowledged in participant selection. This pattern likely reflects the combination of a highly homogeneous sample (male karate athletes aged 18-19 years from a single club with identical training frequency, intensity, and session structure), strict inclusion criteria (BMI 18.5-24.9), and the absence of dietary manipulation, conditions that may have naturally constrained inter-individual variability in body weight response. When all participants undergo the same standardized protocol under similar physiological and environmental conditions, convergence of individual responses is plausible, though the magnitude observed here is at the extreme end of what would typically be expected. Readers are therefore encouraged to interpret these values within the context of this specific sample rather than as generalizable population-level estimates.

The extremely large Cohen's d values observed for body fat percentage (HIIT: d = 6.80; plyometric-EMOM: d = 5.96) similarly reflect the very small pooled standard deviations of this outcome (SD approximately 0.60-0.70%), rather than indicating implausibly large biological effects. These small SDs are consistent with the homogeneous sample characteristics and tightly controlled measurement conditions described above. Mechanistically, HIIT's TKJI superiority reflects AMPK/PGC-1α-mediated mitochondrial biogenesis and upregulation of oxidative enzyme activity, which directly enhance aerobic energy turnover capacity matching kumite's 60-70% aerobic energy contribution during competitive bouts. Repeated lactate accumulation across HIIT intervals further stimulates cardiac output adaptations and buffer capacity, translating into sustained high-intensity work tolerance as measured by TKJI. Conversely, plyometric-EMOM's superior fat loss is explained by SSC-driven eccentric loading, which generates greater mechanical strain per repetition, elevating EPOC and post-exercise lipid oxidation beyond what is produced by HIIT's predominantly concentric work. Furthermore, SSC-specific neural adaptations including increased motor unit synchronization and enhanced tendon stiffness reduce the metabolic cost of explosive movements, indirectly improving energy efficiency during kumite-specific actions such as rapid kicks and defensive transitions (Kons et al., 2023; Ojeda-Aravena et al., 2023). These mechanistic interpretations are consistent with the observed outcome patterns and provide a plausible physiological basis for the differential effects, though direct measurement of these pathways (e.g., muscle biopsies, hormonal biomarkers) was beyond the scope of the present study.

It should be noted that Cohen's d is highly sensitive to sample variance, such that in highly homogeneous samples with standardized measurement protocols, even moderate absolute changes can produce very large d values. These effect sizes should therefore be interpreted as indicators of within-group consistency of response rather than as direct comparisons to effect sizes reported in more heterogeneous populations. Overall, the results support the principle of training specificity, as HIIT elicited stronger TKJI gains and plyometrics drove superior body composition shifts, consistent with González-Gálvez et al. (2024) and Domaradzki et al. (2025), challenging broader claims of HIIT's universal superiority for body composition and highlighting EMOM-structured plyometrics as a viable alternative in combat sports.

The present findings support the hypothesis that HIIT and plyometric-EMOM produce differential adaptation patterns, with HIIT favoring physical fitness gains and plyometric-EMOM favoring fat reduction in young male karate athletes. This modality-specific pattern is consistent with the mechanistic rationale underlying each protocol and with the broader principle of training specificity (Rezaei et al., 2024; Ojeda-Aravena et al., 2023).

The single-club, narrow-age (18-19y) design maximized internal validity but severely limits external validity to diverse populations. .Several limitations temper these promising findings. The quasi-experimental design without randomization limits causal claims, as baseline differences were adjusted via ANCOVA but unmeasured confounders persist (Suhandoko & Hsu, 2020). No passive control group precludes isolating effects from maturation or habitual training, ethically justified but weakening internal validity. The homogeneous sample (male karate athletes, 18-19 years, n=44 from one club) and ad libitum diet inflate effect sizes via low variance but restrict generalizability. The 8-week duration may undervalue plyometric neuromuscular gains, and lack of dietary control introduces energy balance confounds.

Despite these constraints, the results offer actionable insights for practitioners. Based on the empirical outcomes observed, HIIT appears more suitable during training phases prioritizing aerobic fitness and TKJI capacity development, while plyometric-EMOM appears more appropriate during phases requiring fat loss and body composition optimization. For karate coaches and athletes, HIIT suits TKJI enhancement during aerobic-focused phases, while plyometric-EMOM optimizes fat loss without compromising training volume. Implementation barriers include access to monitoring tools (e.g., Tanita BC-545N) and adherence in non-club settings; practitioners should standardize protocols and track RPE for fidelity (Taylor et al., 2015). These modality-specific recommendations are most actionable when applied to samples with characteristics analogous to the present study elite junior male athletes under standardized supervised conditions and should not be generalized to recreational or mixed-sex populations without further empirical validation.

In conclusion, the findings affirm modality-specific adaptations, aligning with literature on training specificity (Li et al., 2023) but contradicting HIIT's presumed body composition dominance (Sarfraz et al., 2022). New insights include EMOM plyometrics' superior fat/weight loss in homogeneous athletic samples, with extreme effect sizes reflecting protocol standardization rather than universal effects. These results contribute to the evidence base for EMOM-structured plyometric training in combat sports and provide preliminary empirical support for modality-specific programming in karate, while acknowledging that further studies with larger, more diverse samples are needed to confirm and extend these findings.

Future studies should empirically test the mechanistic pathways suggested here using appropriate biomarkers and physiological measures with karate-specific metrics and biomarkers to validate pathways. Looking ahead, future studies should employ RCTs with passive controls, longer durations (≥12 weeks), dietary standardization, and diverse samples (e.g., females, other combat sports) to confirm generalizability (Nianogo et al., 2023). Incorporate karate metrics (e.g., kumite agility, biomarkers) and mechanistic probes (e.g., hormones) to explore adaptations, addressing gaps in external validity and plyometric timelines. This forward-looking agenda builds directly on the current study's contributions, ensuring progressive advancement in exercise science for combat athletes.

Conclusion

This study resolved the scientific contradiction between HIIT (AMPK/PGC-1α metabolic pathway) and plyometric-EMOM (SSC neuromuscular pathway), confirming the Dual-Pathway Specificity Model: Adaptation = f(metabolic + SSC + kumite specificity). HIIT produced greater improvements in physical fitness (TKJI) via aerobic-cardiovascular adaptations, while plyometric-EMOM yielded greater reductions in body fat percentage and body weight via SSC-driven eccentric energetics. Both protocols increased fat-free mass with comparable between-group differences. From an applied perspective, HIIT may be prioritized during fitness development phases, while plyometric-EMOM is recommended during body composition optimization or weight-category adjustment phases within karate periodization. These findings are context-specific to elite junior male karate athletes from a single club and should not be generalized to recreational, female, or mixed-combat-sport populations without further empirical validation.

Ethics Approval

This study received ethical approval from the Yogyakarta State University Ethics Committee (approval number: 0533/C3/DT.02.00/2025, dated July 08, 2025) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants (male police cadets/young police officers aged 18-19 years) prior to data collection. The consent form clearly explained the study objectives, procedures, intervention duration, potential minor physical risks (e.g., muscle soreness or fatigue), safety precautions, the voluntary nature of participation, and the right to withdraw at any time without penalties or consequences for training/education, employment status, or performance evaluation.

Informed Consent

Prior to participation, all athlete received detailed written and verbal information regarding the study objectives, procedures, potential risks and benefits, voluntary participation, and the right to withdraw at any time without consequences. Written informed consent was obtained from all participants. Participant confidentiality was ensured through data anonymization, with all personal information coded and stored in password-protected files accessible only to the research team. The study protocol ensured participant safety by: (1) conducting baseline health screening to exclude individuals with cardiovascular contraindications, (2) employing a certified massage therapist, (3) monitoring for adverse events throughout the intervention period, and (4) ensuring medical support was readily available if needed. No adverse events related to the massage intervention were reported during the study.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

AI Transparency Statement

In preparing this manuscript, the authors used Perplexity AI to support sentence structuring and language refinement. All content was carefully reviewed, edited, and verified by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the manuscript.

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Conflict of Interest Statement

The author declares no conflict of interest.

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Високоінтенсивне інтервальне тренування проти пліометричного тренування у форматі EMOM: порівняння впливу на склад тіла та фізичну підготовленість каратистів віком 18–19 років

Віллі Адімас Рахмаван[1ABCE], Сумар'янто[1ADE], Сумарджо[1ADE], Невітанінгрум[2ACD]

[1]Університет штату Джок'якарта
[2]Університет Сіліванґі

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 9 табл., 1 рис., 22 джерела.

Обґрунтування. У підготовці куміте існує наукове протиріччя: теоретично передбачається, що ВІІТ (із домінуванням метаболічного фактора через сигнали AMPK/PGC-1α) та пліометричні тренування (із домінуванням нервово-м'язового фактора через цикл розтягування-скорочення — ЦРС) викликають відмінні моделі адаптації, проте в емпіричній літературі повідомляється лише про ізольовані ефекти без пояснювальних моделей перенесення адаптації на специфічні вимоги фізичної підготовленості в карате.

Мета дослідження. Дослідження мало на меті порівняти вплив традиційних високоінтенсивних інтервальних тренувань (ВІІТ) та пліометричних тренувань у форматі EMOM (виконання певної кількості вправ на початку кожної хвилини) на фізичну підготовленість і склад тіла каратистів чоловічої статі віком 18–19 років.

Матеріали та методи. Сорок чотири каратисти чоловічої статі (віком 18–19 років) із клубу "Polda DIY Karate Club" були залучені до квазіекспериментального дослідження за двогруповою схемою претест–посттест, виконуючи ВІІТ (n = 22) та пліометричні тренування у форматі EMOM (n = 22) протягом 8 тижнів. Оцінювання фізичної підготовленості проведено за допомогою Індонезійського тесту фізичної підготовленості (TKJI); склад тіла вимірювали за допомогою аналізатора Tanita BC-545N.

Результати. В обох групах спостерігалися суттєві покращення показників ($p < 0{,}001$). Значущу взаємодію чинників «Час × Група» виявлено для TKJI, жирової маси та маси тіла (усі значення $p < 0{,}001$), а також помірну взаємодію для безжирової маси тіла (БМТ, $p = 0{,}028$). Група ВІІТ продемонструвала більший приріст у тесті TKJI ($\Delta = +3{,}09$ проти $+0{,}95$), тоді як група пліометричного тренування у форматі EMOM забезпечила вищу ефективність у зниженні жирової маси ($\Delta = -5{,}36\%$ проти $-4{,}29\%$). Надзвичайно великі розміри ефекту (d Коена до 6,80) відображають низьку дисперсію в межах однорідної вибірки з одного клубу, а не універсальні біологічні ефекти.

Висновки. ВІІТ має перевагу у покращенні фізичної підготовленості завдяки метаболічним серцево-судинним механізмам, тоді як пліометричне тренування у форматі EMOM відзначається вищою ефективністю у зниженні вмісту жиру завдяки ексцентричній енергетиці, зумовленій ЦРС, що підтверджує модель подвійного шляху специфічності. Отримані результати є специфічними для контексту підготовки елітних каратистів юніорського віку та потребують подальшої валідації для ширшого узагальнення.

Ключові слова: високоінтенсивне інтервальне тренування, пліометричне тренування у форматі EMOM, карате, фізична підготовленість, склад тіла.

Information about the Authors:

Rahmawan Willy Adimas: willyadimas.2024@student.uny.ac.id; https://orcid.org/0009-0009-0427-4416; Department of Sports Sciences, Faculty of Sport Sciences and Health, Universitas Negeri Yogyakarta, Jl. Colombo No. 1, Karangmalang Yogyakarta 55281, Indonesia.

Sumaryanto: sumaryanto@uny.ac.id; https://orcid.org/0000-0003-3093-3488 ; Department of Sports Sciences, Faculty of Sport Sciences and Health, Universitas Negeri Yogyakarta, Jl. Colombo No. 1, Karangmalang Yogyakarta 55281, Indonesia

Sumarjo: sumarjofik@uny.ac.id ; https://orcid.org/0000-0002-7876-0929 ; Department of Sports Sciences, Faculty of Sport Sciences and Health, Universitas Negeri Yogyakarta, Jl. Colombo No. 1, Karangmalang Yogyakarta 55281, Indonesia

Nevitaningrum: nevitaningrum@unsil.ac.id, https://orcid.org/0009-0004-5953-3714; Department of Physical Education, Siliwangi University, Jl. Siliwangi No. 24, Kahuripan, Tawang, Tasikmalaya 46115, Jawa Barat, Indonesia

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