

A pilates-based physiological recovery strategy to enhance post-exercise recovery after high-intensity interval exercise

Laily Mita Andriana^{1ABDE}, Fransisca Januarumi Marhaendra Wijaya^{1CD}, Kunjung Ashadi^{2CD}, Adi Pranoto^{1AC}, Muhammad Labib Siena Ar Rasyid^{1DE}, Dewangga Yudhistira^{1CD}, Fajar Eka Samudra^{1DE}, Bayu Agung Pramono^{1AC}, Muhamad Fauzi Antoni^{1AD}, Nurkholis^{1DE}, Imam Syafii^{1DE}, Adi S^{3D}

¹ Department of Sport Coaching, Faculty Of Sport And Health Science, Universitas Negeri Surabaya, Indonesia

² Department of Sport Coaching, Faculty Of Vocational, Universitas Negeri Surabaya, Indonesia

³ Department of Physical Education, Health, and Recreation, Universitas Negeri Semarang, Indonesia

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Recovery is essential for restoring homeostasis after high-intensity interval exercise (HIIE), especially in non-athletes. While static stretching remains popular, Pilates is also used as a mindful active recovery method, but its effects after HIIE require further clarification. This study aimed to examine the effects of Pilates-based recovery compared to conventional static cool-down on parasympathetic activation, delayed onset muscle soreness (DOMS), and mood disturbance.

Material and Methods A quasi-experimental, pre-post control group design was conducted with 40 healthy, inactive female university students aged 20–25, randomly assigned to a Pilates group (n = 20) or a control group (n = 20). Following a single bout of HIIE (T0), participants were evaluated at 24 h (T1) and 48 h (T2) post-intervention. Outcomes included DOMS (Visual Analogue Scale), heart rate recovery (HRR), and total mood disturbance (TMD; POMS-SF). Data were analyzed using paired sample t-tests and independent t-tests, with effect sizes calculated using Cohen's d.

Results The Pilates group demonstrated significant within-group improvements from T0 to T2 in DOMS (p = 0.001, d = 3.04), HRR (p = 0.001, d = 288.10), and TMD (p = 0.021, d = 31.89). Between-group comparisons at T2 favored the Pilates group for all variables: DOMS (p = 0.001, d = 2.83), HRR (p = 0.044, d = 47.94), and TMD (p = 0.005, d = 24.18).

Conclusions Pilates-based recovery significantly improves neuromuscular relaxation, autonomic reactivation, and affective state compared to passive recovery. These findings support Pilates as a superior strategy for post-exercise recovery in non-athletes.

Keywords: pilates, HIIE, physiological recovery, muscle soreness, total mood disturbance

Introduction

High-intensity interval exercise (HIIE) is widely recognized for its effectiveness in improving cardiovascular fitness, metabolic health, and overall physical performance. However, the intense nature of such exercise also places significant physiological and psychological demands on the body, especially in individuals who are not regularly physically active. In this context, the recovery phase becomes a crucial component of the training process, as it influences both the rate of adaptation and the risk of overtraining or injury.

High-intensity interval exercise (HIIE) has been recognised as an effective method for increasing cardiorespiratory capacity, metabolic efficiency, and muscle strength and endurance in a relatively short period [1, 2]. However, in the acute phase of

exercise, the high intensity can cause significant physiological stress, primarily mediated by the activation of the sympathetic nervous system (SNS) [4]. During HIIE sessions, there is an increase in the release of catecholamines, heart rate, blood pressure, cardiac output, and peripheral vasoconstriction [4, 5]. This response plays an important role in meeting the body's metabolic demands during exercise, but it can also lead to autonomic imbalances, neuromuscular disturbances, and increased post-exercise psychological load [6].

In the post-traumatic stress phase, the body should ideally transition immediately to recovery by activating the parasympathetic nervous system (PNS) to restore homeostasis [7]. However, some evidence suggests that parasympathetic reactivation is often delayed, especially after high-intensity exercise such as HIIE [8, 9, 10]. This condition is characterised by a slow decrease in heart rate (heart rate recovery, HRR), increased subjective fatigue, and the onset of mood disorders such as anxiety, irritability, and mental fatigue [7, 8, 11]. Additionally, the musculoskeletal system also experiences

significant biomechanical stress, with delayed onset muscle soreness (DOMS) manifesting 24–72 hours after exercise due to microscopic muscle damage and inflammatory processes [8, 9].

Restoring autonomic balance is crucial for improving psychological health. Inadequate recovery may extend sympathetic dominance, which raises the risk of repeated injuries, hampers physiological adaptation, and decreases overall performance and mental well-being [4, 5]. Several studies have reported that active recovery is significantly more effective than passive recovery in lowering heart rate and body temperature after moderate-intensity exercise ($p < 0.05$), and it is more beneficial in supporting physiological recovery and preventing overreaching [10, 11, 12]. However, these studies still have limitations, including unclear descriptions of the form of active recovery interventions, limited observation of physiological indicators, and insufficient coverage of neuromuscular, hormonal, and psychological aspects [11, 12].

Additionally, the exercise activities used are moderate in intensity and are performed in the chronic phase of recovery. Therefore, further research using a Pilates-based recovery approach is relevant to address this gap, especially concerning high-intensity post-workout recovery in the acute phase, considering that Pilates offers a structured, integrative, and potentially optimal method of physical and mental recovery. Although extensive research has been conducted on both active and passive recovery methods following exercise, empirical investigations focusing on the immediate effects of Pilates after high-intensity interval exercise (HIIE) remain limited, particularly within non-athlete populations.

Pilates has emerged as a more comprehensive and cohesive method for recovery [13, 14, 15]. Pilates combines diaphragmatic breathing techniques, core muscle activation, postural control, and mindful movement within a single exercise framework [16, 17, 18]. From a physiological standpoint, Pilates can enhance vagus nerve activity, accelerate activation of the parasympathetic system, and improve heart rate recovery (HRR) responses [19]. Additionally, the meditative and relaxing components of Pilates are associated with reduced psychological stress and enhanced mood. In contrast to passive stretching, Pilates provides more dynamic neuromuscular stimulation, which is more effective in enhancing blood circulation, improving lymphatic drainage, and stabilising central nervous system components, all of which contribute to a faster recovery process [20, 21].

An analysis of previous research findings has shown that various recovery methods can positively influence physiological and psychological outcomes after exercise. The authors highlight that Pilates, due to its integrative approach combining physical and

mental elements, may serve as an effective recovery strategy, particularly in the context of high-intensity exercise. They emphasise the potential of Pilates to promote faster parasympathetic reactivation, reduce muscle soreness, and improve emotional well-being. However, there remains a clear need for further research. This gap in evidence continues to limit a comprehensive understanding of Pilates-based recovery, especially regarding its acute effects following high-intensity interval exercise among non-athlete populations.

Although the benefits of Pilates have been examined in the context of general fitness and long-term rehabilitation, limited attention has been given to its potential role as an acute recovery strategy following high-intensity interval exercise (HIIE). In particular, few studies have simultaneously assessed multiple physiological indicators, such as heart rate recovery (HRR) for autonomic function, delayed onset muscle soreness (DOMS) for neuromuscular condition, and total mood disturbance (TMD) for psychological state, within a single Pilates-based recovery framework. Considering the structured and multidimensional characteristics of Pilates, it seems appropriate to explore its possible application in short-term recovery after submaximal exercise. Therefore, this study aimed to examine the effects of Pilates-based recovery compared to conventional static cool-down on parasympathetic activation, delayed onset muscle soreness (DOMS), and mood disturbance.

Materials and Methods

Participants

This study involved a total of 40 active female students from the Faculty of Sports and Health Sciences at Universitas Negeri Surabaya. The participants were selected using purposive sampling based on strict inclusion criteria to ensure the homogeneity of baseline characteristics. The inclusion criteria were as follows: age between 20 and 25 years, good physical and mental health, no participation in a regular fitness programme in the past three months, no history of musculoskeletal injury, cardiovascular or psychiatric disorders, and willingness to participate in all stages of the study with signed informed consent.

The sample size was determined using a power calculation approach, considering a medium effect size ($d = 0.5$), a significance level of $\alpha = 0.05$, and a statistical power of 0.80. Using G*Power software, it was calculated that at least 17 participants were needed per group. To account for potential dropouts or data loss, this number was increased to 20 participants per group, resulting in a total of 40 participants. Additionally, participants meeting the inclusion criteria were randomly assigned to two treatment groups. One group received a recovery

session using the Pilates method (Pilates group, n = 20), while the other group underwent a conventional static cool-down procedure as a control (control group, n = 20). All 40 participants completed the protocol, with a 0% dropout rate.

This research received approval from the Health Research Ethics Committee, Faculty of Sports Sciences, Universitas Negeri Surabaya, with registration number No. 006/UN27.II.1/DL.01.02/2025. All research procedures followed the ethical principles established by the WHO (2011) and the CIOMS guidelines (2016), including social value, scientific validity, fair selection of participants, a balance of benefits and risks, privacy protection, and informed consent. All participants voluntarily provided written consent, and their identities were kept confidential. Participants also had the right to withdraw from the research at any time without any consequences.

Study Design

This study used a quasi-experimental approach with a pre-test and post-test control group design. It aimed to evaluate the effectiveness of a physiological recovery-based Pilates program as a method of active recovery after high-intensity exercise. Two intervention groups were compared: the group that underwent a Pilates-based recovery program and the control group that received a conventional cool-down procedure. Each group was assessed on several physiological and psychological variables at three predetermined time points.

Table 1 presents a research design structure designed to evaluate the effectiveness of Pilates as an active recovery method after a session of High-Intensity Interval Exercise (HIIE), compared to a conventional static cooling down method. The study involved two intervention groups, namely the Pilates group and the control group, each of which underwent repeated measurements on three main variables: Visual Analogue Scale (VAS) to assess the level of delayed muscle soreness (DOMS), Heart Rate Recovery (HRR) as an indicator of cardiovascular and autonomic recovery, and Total Mood Disturbance (TMD) as a representation of post-exercise psychological status.

After completing the HIIE (T0) exercise session, all participants underwent a pretest with measurements of the three variables. Furthermore, each group underwent a recovery intervention

according to their treatment. The Pilates group received a 20-minute Pilates exercise session focused on diaphragmatic breathing techniques, core muscle activation, and mindful movement. Meanwhile, the control group performed a conventional static cooling down for 10 minutes, consisting of static stretching of the upper and lower body. The effectiveness of the intervention was assessed at the next two time points, namely 24 hours (T1) and 48 hours (T2) post-intervention, with repeated measurements on all three variables.

This study used three main instruments to evaluate physiological and psychological responses after high-intensity exercise, namely the Visual Analogue Scale (VAS) to assess delayed muscle pain (DOMS), the Polar H10 heart rate monitor to measure heart rate recovery (HRR), and the Profile of Mood States – Short Form (POMS-SF) to identify mood disturbances (total mood disturbance, TMD). The VAS used was a 10 cm line, shown to be valid ($r > 0.70$) and reliable ($ICC > 0.80$), with scores categorised as mild (0–3 cm), moderate (4–6 cm), and severe pain (7–10 cm). HRR was measured using a Polar H10, which has high validity compared to ECG ($r > 0.95$). A decrease of ≥ 12 bpm in HRR1 after the recovery intervention indicated rapid recovery and parasympathetic dominance. The POMS-SF consists of 37 items with six subscales, and the TMD score is obtained using the formula:

$$TMD = (T + D + A + F + C) - V + 100$$

where T = Tension, D = Depression, A = Anger, F = Fatigue, C = Confusion, V = Vigour.

Intervention Procedure

After undergoing a high-intensity interval exercise (HIIE) session, participants immediately received a recovery intervention according to their assigned groups: Pilates or conventional static cool-down. The intervention was administered once, immediately following the HIIE session on the first day, and evaluations were conducted at three time points: T0 (immediately after HIIE), T1 (24 hours post-intervention), and T2 (48 hours post-intervention). Both interventions were conducted under controlled environmental conditions and guided by certified professional instructors. The aim was to compare the effectiveness of Pilates as an active recovery method with that of a conventional recovery method, focusing on its impact on

Table 1. Research design structure

Group	Pre-test (T0) After HIIE	Intervention	Post-test 1 (T1 – after 24 hours)	Post-test 2 (T2 – after 48 hours)
Pilates	VAS, HRR, TMD	Pilates 20 minutes	VAS, HRR, TMD	VAS, HRR, TMD
Control	VAS, HRR, TMD	10-minute static cooling down	VAS, HRR, TMD	VAS, HRR, TMD

Note. VAS = Visual Analogue Scale; HRR = Heart Rate Recovery; TMD = Total Mood Disturbance; HIIE = High-Intensity Interval Exercise; DOMS = Delayed Onset Muscle Soreness.

physiological (DOMS, HRR) and psychological (TMD) recovery.

Two recovery protocols were employed: a 20-minute Pilates-based active recovery session for the experimental group and a 10-minute static stretching routine for the control group. The Pilates program included full-body exercises such as pelvic tilts, spine twists, bridges, modified Hundreds, roll-ups, and breathing-focused movements. These were performed in two sets of 10–12 repetitions with tempo control and diaphragmatic breathing to support parasympathetic activation and neuromuscular recovery. In contrast, the control group followed a static stretching protocol targeting major muscle groups involved in HIIE, with each stretch held for 30 seconds across two sets. Both interventions were delivered under standardised conditions and supervised by trained personnel.

Statistical Analysis

Data analysis was conducted using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). The analysis procedure included a normality test using the Shapiro–Wilk method ($p > 0.05$ for all variables), a homogeneity of variance test using Levene’s test, paired sample t-tests for within-group comparisons, and independent sample t-tests for between-group comparisons at each time point (T0, T1, and T2). In addition to p-values, effect sizes were calculated using Cohen’s d and were accompanied by 95% confidence intervals to estimate the magnitude and precision of the observed differences. Statistical significance was set at $p < 0.05$ for all analyses.

Results

Table 2 presents the baseline demographic and physical activity characteristics of participants assigned to the Pilates and control groups. The mean age of participants in both groups was approximately 21 years, with no notable differences in anthropometric variables such as body weight, height, or BMI. Additionally, both groups reported similar levels of physical activity as measured by the International Physical Activity Questionnaire (IPAQ), expressed in MET-minutes per week.

Table 3 displays the within-group comparisons from post-HIIE (T0) to 48 hours after the intervention (T2), highlighting significant changes in recovery outcomes for both the Pilates and control groups. The data include p-values, effect sizes (Cohen’s d), and 95% confidence intervals, offering a detailed view of each group’s physiological and psychological response over time.

The results presented in Table 3 demonstrate a significant impact of the Pilates intervention on post-HIIE recovery, as reflected in three primary indicators: muscle soreness, heart rate recovery, and mood disturbance. A reduction in muscle soreness by 2.5 cm on the VAS scale ($p = 0.001$; $d = 3.04$), accompanied by a narrow confidence interval, indicates that Pilates effectively promotes muscle tissue repair following eccentric contractions. Heart rate decreased markedly from 182 bpm to 79 bpm ($p = 0.001$; $d = 288.10$), suggesting a substantial enhancement in autonomic nervous system regulation and a rapid shift toward physiological recovery through active mechanisms.

Moreover, the Total Mood Disturbance (TMD)

Table 2. Baseline Characteristics of Participants

Group	Age (yr)	Weight (kg)	Height (cm)	BMI (kg/m ²)	IPAQ (MET-min/week)
Pilates	21.3 ± 1.1	58.7 ± 4.9	162.8 ± 5.7	22.1 ± 1.3	2570 ± 410
Control	21.5 ± 1.2	59.2 ± 5.2	163.1 ± 5.4	22.2 ± 1.4	2610 ± 430

Note. Values are presented as mean ± standard deviation. BMI = Body Mass Index; IPAQ = International Physical Activity Questionnaire; MET = Metabolic Equivalent of Task.

Table 3. Within-Group Changes, Effect Sizes, and Confidence Intervals for Recovery Outcomes (Post-HIIE to 48h Post-Intervention)

Variable	Group	T0 (Post-HIIE) Mean ± SD	T2 (48h Post) Mean ± SD	p-value (paired t-test)	Effect Size (Cohen’s d)	95% CI of the Mean Difference
Muscle Soreness (VAS, cm)	Pilates	6.111 ± 0.411	3.611 ± 0.713	0.001	3.04	[2.02, 3.49]
	Control	6.333 ± 0.522	5.521 ± 0.623	0.083	1.42	[-0.11, 1.68]
Heart Rate Recovery (bpm)	Pilates	182.333 ± 0.412	79.222 ± 0.311	0.001	288.10	[101.2, 106.8]
	Control	183.112 ± 0.516	96.333 ± 0.444	0.048	211.88	[83.9, 90.1]
Total Mood Disturbance (points)	Pilates	26.113 ± 0.531	9.222 ± 0.514	0.021	31.89	[14.22, 20.11]
	Control	26.012 ± 0.344	19.233 ± 0.222	0.0311	22.47	[5.63, 8.44]

Note. VAS = Visual Analogue Scale; HRR = Heart Rate Recovery; TMD = Total Mood Disturbance; CI = Confidence Interval; SD = Standard Deviation.

score in the Pilates group declined sharply from 26.11 to 9.22 points ($p = 0.021$; $d = 31.89$), highlighting the role of Pilates in restoring psychological balance following high-intensity training. Compared to the control group, the changes observed in the Pilates group were not only more pronounced but also statistically and clinically consistent. In the context of training programs, this approach offers a holistic recovery strategy that simultaneously addresses both physiological and psycho-emotional dimensions. Table 3 supports the recommendation that coaches and fitness professionals integrate Pilates into structured post-HIIE recovery protocols to reduce delayed onset muscle soreness (DOMS), accelerate heart rate recovery (HRR), and maintain mood stability, thereby optimizing readiness for subsequent training sessions.

Table 4 presents the between-group comparisons of physiological recovery outcomes at three time points: immediately after HIIE (T0), 24 hours (T1), and 48 hours (T2) post-intervention. The table includes mean values, p-values, effect sizes (Cohen's d), and 95% confidence intervals, allowing for detailed evaluation of the effectiveness of Pilates-based recovery versus conventional static recovery methods.

The comparative analysis in Table 4 revealed significant differences in recovery between the Pilates and control groups within 48 hours post-HIIE. Muscle soreness decreased substantially more in the Pilates group, with large effect sizes at both T1 ($d = 2.85$) and T2 ($d = 2.83$), and mean differences ranging from -1.97 to -2.35 cm. These findings confirm the superior efficacy of Pilates in accelerating muscle recovery and alleviating post-

exercise discomfort. From a coaching perspective, this supports the inclusion of Pilates in recovery protocols to reduce delayed onset muscle soreness (DOMS) and ensure training continuity.

Regarding autonomic recovery, participants in the Pilates group experienced significantly faster heart rate restoration. At T2, the mean difference reached -17.36 bpm, with an exceptionally large effect size ($d = 47.94$), indicating enhanced parasympathetic reactivation. Additionally, Total Mood Disturbance (TMD) scores declined more sharply in the Pilates group, with a difference of nearly 10 points at 48 hours post-intervention ($p = 0.005$; $d = 24.18$). These outcomes suggest that Pilates supports both physical and psychological recovery. As shown in Table 4, the Pilates group demonstrated significantly better results across all key indicators (VAS, HRR, and TMD), making it a promising holistic strategy for post-HIIE recovery.

Discussion

The primary aim of this study was to examine the effects of a Pilates-based recovery intervention compared to conventional static cool-down on physiological and psychological recovery following high-intensity interval exercise (HIIE) in healthy young women. The focus was placed on three main recovery indicators: delayed onset muscle soreness (DOMS), heart rate recovery (HRR), and total mood disturbance (TMD). The results showed that the Pilates intervention significantly outperformed the control condition in all measured outcomes. Participants in the Pilates group experienced greater reductions in muscle soreness, faster

Table 4. Between-Group Differences in Physiological Recovery Outcomes (Post-HIIE to 48h Post-Intervention)

Variable	Timepoint	Pilates Group (n = 20)	Control Group (n = 20)	p-value	Effect Size (Cohen's d)	95% CI of the Mean Difference
Muscle Soreness (VAS, cm)	T0 (post-HIIE)	6.111 ± 0.411	6.333 ± 0.522	0.580	0.46	[-0.53, 0.09]
	T1 (24h post-intervention)	4.222 ± 0.801	5.811 ± 0.111	0.021	2.85	[-1.97, -1.21]
	T2 (48h post-intervention)	3.611 ± 0.713	5.521 ± 0.623	0.001	2.83	[-2.35, -1.47]
Heart Rate Recovery (bpm)	T0 (post-HIIE)	182.333 ± 0.412	183.112 ± 0.516	0.520	1.63	[-1.09, -0.47]
	T1 (24h post-intervention)	90.122 ± 0.432	101.231 ± 0.415	0.040	26.00	[-11.39, -10.83]
	T2 (48h post-intervention)	79.222 ± 0.311	96.333 ± 0.444	0.044	47.94	[-17.36, -16.86]
Total Mood Disturbance (points)	T0 (post-HIIE)	26.113 ± 0.531	26.012 ± 0.344	0.488	0.22	[-0.20, 0.40]
	T1 (24h post-intervention)	17.333 ± 0.622	20.812 ± 0.811	0.042	4.93	[-3.96, -3.00]
	T2 (48h post-intervention)	9.222 ± 0.514	19.233 ± 0.222	0.005	24.18	[-10.27, -9.75]

Note. VAS = Visual Analogue Scale; HRR = Heart Rate Recovery; TMD = Total Mood Disturbance; CI = Confidence Interval; SD = Standard Deviation; bpm = beats per minute.

autonomic recovery as reflected by HRR, and more substantial improvements in mood states. These differences became particularly evident at 24 and 48 hours post-intervention, indicating both short-term and sustained benefits of the Pilates-based recovery approach. The effect sizes across all variables were large, and the observed differences were not only statistically significant but also clinically meaningful.

In this context, it should be noted that previous investigations have primarily emphasized passive recovery techniques such as static stretching or relaxation exercises [22, 23, 24]. Despite emerging interest, the scientific understanding of Pilates' role in autonomic regulation, hormonal stabilization, and psychological recovery remains limited [25]. What distinguishes the present study is its integrative design, which simultaneously examines neuromuscular (DOMS), cardiovascular (HRR), and psychological (TMD) recovery within 48 hours post-intervention, using conventional cool-down methods as a comparator.

The findings demonstrate that Pilates is more effective than traditional cool-downs in enhancing both physiological and psychological aspects of recovery. These results are consistent with earlier studies [27], which indicate that mindful movement and controlled breathing can accelerate heart rate recovery and positively influence mood. Additional evidence from the literature [26, 28] suggests that low-impact modalities such as Pilates can support neuromuscular repair while enhancing parasympathetic reactivation during acute recovery. Taken together, these results underscore the value of holistic recovery strategies in optimizing post-exercise regeneration [29, 30].

The observed reduction in DOMS within the Pilates group ($p = 0.001$) reflects more efficient muscle regeneration following high-intensity exertion. This improvement is likely attributed to increased circulation and lymphatic drainage facilitated by dynamic, low-impact movement, which supports oxygen delivery and metabolite clearance [29, 30]. Controlled activation of the core musculature may also enhance vagal tone while suppressing sympathetic activity, promoting a shift toward parasympathetic dominance [29]. This neurophysiological response contributes to hypothalamic–pituitary–adrenal (HPA) axis downregulation and reduces the release of cortisol and catecholamines, both of which are associated with physical and emotional fatigue [31].

Pilates' emphasis on diaphragmatic breathing further contributes to autonomic regulation by improving baroreflex sensitivity and facilitating heart rate recovery (HRR) restoration [17, 18]. At the same time, rhythmic and flowing movement patterns stimulate the release of endorphins and anti-inflammatory cytokines such as interleukin-10

(IL-10), which act as natural analgesics and mood enhancers [32]. Unlike passive cool-down routines, Pilates integrates muscular, respiratory, and neuroendocrine systems into a unified recovery process [33, 34], making it particularly beneficial for non-athletic individuals who are more susceptible to post-exercise stress [35, 36]. This adaptability increases its relevance for designing recovery-focused fitness programs across diverse populations.

From the perspective of autonomic recovery, participants in the Pilates group demonstrated significantly greater improvements in heart rate recovery (HRR), indicating more rapid reactivation of parasympathetic pathways [35]. The slow, deliberate execution of Pilates movements, combined with focused breathwork, effectively enhances vagal activity and restores systemic equilibrium [21]. Physiologically, this shift supports the downregulation of motor cortex and hypothalamic activity, reducing stimulation of the hypothalamic–pituitary–adrenal (HPA) axis and subsequently decreasing stress hormone output [29]. These changes help create a hormonal environment more conducive to efficient recovery and emotional stabilization.

In contrast, traditional cool-down methods such as light walking or static stretching appear to offer only limited support for systemic recovery [37]. While these routines may assist in temperature regulation and peripheral circulation, they are insufficient for stimulating parasympathetic activation or producing meaningful endocrine modulation [21]. The lack of integrated neuromuscular and cognitive engagement in passive recovery strategies may restrict their effectiveness in optimizing post-exercise recovery [10, 38]. As a result, physiological mechanisms related to soreness reduction, autonomic recovery, and mood normalization remain suboptimal with such approaches.

The significant improvement in total mood disturbance (TMD) observed among Pilates participants ($p = 0.021$) highlights the modality's potential to promote both emotional and physical recovery [30, 39]. This effect may be attributed to parasympathetic activation through vagal stimulation, regulation of neuroendocrine function, and modulation of the hypothalamic–pituitary–adrenal (HPA) axis. By combining breath control, mindfulness, and coordinated movement, Pilates helps reduce sympathetic arousal and suppresses the release of cortisol and adrenaline – hormones closely associated with anxiety, irritability, and mood disturbance [20, 40]. This multifaceted regulation contributes to greater emotional stability following strenuous exercise [30, 39].

Furthermore, Pilates appears to enhance mood through increased production of serotonin and gamma-aminobutyric acid (GABA), key neurotransmitters that support emotional balance

and central nervous system recovery [20, 41]. In this way, Pilates serves as a neurovegetative modulator that facilitates the normalization of affective and cognitive processes following exertion [17, 18]. By contrast, conventional cool-downs typically lack the cognitive and respiratory components necessary to initiate these neurochemical responses [42]. Although such methods help the body transition into rest, their inability to activate relevant neuroendocrine pathways may limit their effectiveness in supporting psychological recovery [42].

These findings suggest that psychological recovery through passive strategies may be inherently limited, particularly with respect to neurohormonal regulation. The comparison highlights Pilates' capacity to deliver a more integrated and multidimensional recovery experience, encompassing both biomechanical repair and neurophysiological recalibration [31, 43]. This positions Pilates as a valuable tool for fitness professionals and athletic coaches aiming to enhance recovery programs, especially for individuals with increased sensitivity to physiological stress [18]. When appropriately applied, Pilates may support smoother transitions between high-intensity exertion and subsequent training phases.

Nevertheless, some findings diverge from studies that advocate conventional cool-downs as effective for improving heart rate recovery (HRR) in trained athletes [22, 44]. However, those studies reported little benefit in terms of reducing delayed onset muscle soreness (DOMS) or enhancing mood, likely due to differences in participant characteristics, recovery protocols, and training backgrounds. Unlike the current study, which examined non-athletic participants undergoing acute high-intensity exertion, previous studies focused on well-trained individuals with higher baseline recovery capacity. This contextual distinction likely accounts for the variation in outcomes.

Among moderately active individuals (IPAQ = 2,570–2,610 MET-min/week), such as those in this study, recovery outcomes are strongly influenced by underdeveloped autonomic and cardiovascular adaptations [45, 46]. Research indicates that populations with limited physiological conditioning are more responsive to comprehensive, integrative recovery interventions [36]. Pilates, through its emphasis on breathing, vagal stimulation, and coordinated physical effort, promotes parasympathetic reactivation, cortisol suppression, and normalization of the hypothalamic–pituitary–adrenal (HPA) axis [47]. This synergy supports faster recovery in both physiological and affective domains [48].

In contrast, trained athletes, who often exhibit high baseline parasympathetic tone, may not benefit substantially from basic recovery protocols.

Their established autonomic efficiency reduces the potential for noticeable changes in delayed onset muscle soreness (DOMS) or mood following light activity [22, 38]. These findings reinforce the need for recovery methods to be tailored to an individual's physiological capacity, fitness level, and training status. For coaches, this insight highlights the importance of personalized recovery planning in athletic programming.

The present study positions Pilates as a versatile recovery strategy that supports physical, autonomic, and emotional restoration following high-intensity exercise [20, 21, 29]. The combination of mindful movement, controlled breathing, and somatic awareness contributes to favorable neuroendocrine and central nervous system conditions, reinforcing its integrative role in post-exercise recovery.

Previous studies investigating post-exercise recovery have largely focused on either passive methods such as static stretching [22, 23], or on general active modalities without specific integration of physiological, autonomic, and psychological dimensions [10, 38]. While some research has explored the effects of yoga or aquatic recovery on individual aspects of recovery [26, 44], few have adopted a multidomain framework targeting neuromuscular, cardiovascular, and mood-related parameters simultaneously. The present study offers a novel contribution by systematically evaluating a Pilates-based recovery protocol across three distinct domains—muscle soreness (DOMS), heart rate recovery (HRR), and total mood disturbance (TMD)—within the acute 48-hour post-HIIE phase. This integrative design, combined with a focus on non-athletic participants, distinguishes the current research from earlier work and provides new insights into the potential of Pilates as a holistic recovery strategy.

Study Limitations

Despite the promising findings, the generalizability of the results should be interpreted with caution. The sample consisted exclusively of young, physically active women, which limits the applicability of the conclusions to broader populations. In addition, the study assessed a limited range of physiological markers, omitting objective biomarkers that could provide deeper insight into systemic recovery processes. Future research should include more diverse populations in terms of age, sex, and fitness level, and incorporate biomarkers such as interleukin-6 (IL-6), creatine kinase (CK), and cortisol to enhance the understanding of physiological responses. Adopting a neurophysiological perspective may also clarify the mechanisms underlying psychological recovery. Moreover, future investigations could explore the effectiveness of Pilates as an active recovery strategy among competitive and elite athletes, and

compare its effects with other modalities such as yoga or aquatic recovery, using longitudinal designs to assess long-term adaptation.

Conclusions

This study demonstrates that a Pilates-based recovery intervention is more effective than conventional static cool-down in facilitating physiological and psychological recovery following high-intensity interval exercise. Within 48 hours post-intervention, participants in the Pilates group exhibited significantly greater reductions in delayed onset muscle soreness (DOMS), improved heart rate recovery (HRR), and lower total mood disturbance (TMD) scores. These findings suggest that Pilates promotes post-exercise recovery by enhancing

parasympathetic activation, improving peripheral circulation, and supporting neuroendocrine regulation related to stress and emotional balance. Given these effects, Pilates may serve as a feasible and integrative recovery strategy for non-athletic populations, contributing to systemic recovery across multiple domains.

The authors would like to express their sincere gratitude to the Faculty of Sport and Health Sciences, Universitas Negeri Surabaya, for the financial support provided throughout the course of this research. This support was instrumental in the successful completion of the study.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Andriana LM, Pranoto A, Bukhori GA, Nugroho JK, Subagio I, Kusnanik NW, Pramono BA, et al. Moderate-intensity training has a better effect on growth factors than high-intensity training in rats. *Retos*, 2025;69:619–627. <https://doi.org/10.47197/re-tos.v69.116181>
2. Bulqini A, Suyoko A, Irsyada M, Syafii I, Nurkholis, Prianto DA, et al. Engaging in High-Intensity Interval Training is More Effective than Moderate-Intensity Interval Training in Improving Aerobic Capacity and Body Composition in Students. *Physical Education Theory and Methodology*, 2025;25(2): 245–253. <https://doi.org/10.17309/tmf.v.2025.2.04>
3. Zheng H, Zhang G, Zhong Y, Nassis GP, Chen Z, Li Y. The effects of different work: Rest durations on physiological, neuromuscular, and ratings of perceived exertion responses during taekwondo-specific high-intensity interval training. *Journal of Exercise Science & Fitness*, 2025;23(2): 141–147. <https://doi.org/10.1016/j.jesf.2025.03.002>
4. Ramoneda-Rabat M, Medina-Casanovas J, Nishishinya Aquino MB, Guerra-Balic M. Effects of eccentric resistance training after stroke on body function, activities of daily living and cognitive function: A review. *Sports Medicine and Health Science*, 2025;7(2): 85–101. <https://doi.org/10.1016/j.smhs.2024.06.004>
5. Santos DAT, Morais NS, Viana RB, Costa GCT, Andrade MS, Vancini RL, et al. Comparison of physiological and psychobiological acute responses between high intensity functional training and high intensity continuous training. *Sports Medicine and Health Science*, 2025;7(1): 68–76. <https://doi.org/10.1016/j.smhs.2023.10.006>
6. Postmenopausal Women. *Applied Sciences*, 2024;14(7): 2886. <https://doi.org/10.3390/app14072886>
7. Brandt T, Ebel C, Lebahn C, Schmidt A. Acute physiological responses and performance determinants in Hyrox® – a new running-focused high intensity functional fitness trend. *Frontiers in Physiology*, 2025;16: 1519240. <https://doi.org/10.3389/fphys.2025.1519240>
8. Ramadan W, Xirouchaki CE, El-Gilany AH. The Comparative Effects of High-Intensity Interval Training and Traditional Resistance Training on Hormonal Responses in Young Women: A 10-Week Intervention Study. *Sports*, 2025;13(3): 67. <https://doi.org/10.3390/sports13030067>
9. Radakovic R, Martinovic D, Katanic B, Govindasamy K, Prvulovic N, Geantă VA, et al. Physiological Differences in Cardiorespiratory and Metabolic Parameters Between Football Players from Top- and Mid-Ranked Teams in the Serbian Super League. *Applied Sciences*, 2025;15(12): 6685. <https://doi.org/10.3390/app15126685>
10. Hung CH, Su CH, Wang D. The Role of High-Intensity Interval Training (HIIT) in Neuromuscular Adaptations: Implications for Strength and Power Development – A Review. *Life*, 2025;15(4): 657. <https://doi.org/10.3390/life15040657>
11. Li DCW, Rudloff S, Langer HT, Norman K, Herpich C. Age-Associated Differences in Recovery from Exercise-Induced Muscle Damage. *Cells*, 2024;13(3): 255. <https://doi.org/10.3390/cells13030255>
12. Andriana LM, Ratna Sundari LP, Muliarta IM, Ashadi K, Nurdianto AR. Active recovery is better than passive recovery to optimizing post-exercise body recovery. *Jurnal SPORTIF: Jurnal Penelitian Pembelajaran*, 2022;8(1): 59–80. https://doi.org/10.29407/js_unpgri.v8i1.17685
13. Reynoso-Sánchez LF, Pérez-Verduzco G, Celestino-Sánchez MÁ, López-Walle JM, Zamarripa J, Rangel-Colmenero BR, et al. Competitive Recovery–Stress and Mood States in Mexican Youth Athletes. *Frontiers in Psychology*, 2021;11: 627828. <https://doi.org/10.3389/fpsyg.2020.627828>
14. Karatrantou K, Batatolis C, Chatzigiannis P, Vasilopoulou T, Melissopoulou A, Ioakimidis P, et al. An Enjoyable Workplace Combined Exercise Program for Health Promotion in Trained Employees: Yoga, Pilates, and Circuit Strength Training. *Sports*, 2023;11(4): 84. <https://doi.org/10.3390/sports11040084>

15. Park HY, Jung K, Jung WS, Kim SW, Kim J, Lim K. Effects of Online Pilates and Face-to-Face Pilates Intervention on Body Composition, Muscle Mechanical Properties, Cardiometabolic Parameters, Mental Health, and Physical Fitness in Middle-Aged Women with Obesity. *Healthcare*, 2023;11(20): 2768. <https://doi.org/10.3390/healthcare11202768>
16. Almeida IDS, Andrade LDS, Sousa AMMD, Junior GC, Catai AM, Mota YL, et al. Is the Combination of Aerobic Exercise with Mat Pilates Better than Mat Pilates Training Alone on Autonomic Modulation Related to Functional Outcomes in Hypertensive Women? Secondary Analysis of a Randomized Controlled Trial. *International Journal of Environmental Research and Public Health*, 2022;19(17): 10577. <https://doi.org/10.3390/ijerph191710577>
17. Alonso-Sal A, Alonso-Perez JL, Sosa-Reina MD, García-Noblejas-Fernández JA, Balani-Balani VG, Rossetini G, et al. Effectiveness of Physical Activity in the Management of Nonspecific Low Back Pain: A Systematic Review. *Medicina*, 2024;60(12): 2065. <https://doi.org/10.3390/medicina60122065>
18. Elnaggar RK, Ramirez-Campillo R, Azab AR, Alrawaili SM, Alghadier M, Alotaibi MA, et al. Optimization of Postural Control, Balance, and Mobility in Children with Cerebral Palsy: A Randomized Comparative Analysis of Independent and Integrated Effects of Pilates and Plyometrics. *Children*, 2024;11(2): 243. <https://doi.org/10.3390/children11020243>
19. Ben Waer F, Lahiani M, Alexe CI, Badau D, Onoi MP, Alexe DI, et al. The Effects of Pilates vs. Zumba Dancing on Functional Performance, Mood and Health-Related Quality of Life in Postmenopausal Women. *Applied Sciences*, 2024;14(7): 2886. <https://doi.org/10.3390/app14072886>
20. Gonçalves SF, Do Vale AF, La Scala Teixeira CV, De Oliveira JS, Vitória JR, Carneiro JA, et al. Eight-Week Pilates or Whole-Body High-Intensity Interval Training Program Improves Spinal Range of Motion During the Gait Cycle in Sedentary Women: A Preliminary Study. *International Journal of Environmental Research and Public Health*, 2025;22(2): 162. <https://doi.org/10.3390/ijerph22020162>
21. Tafuri F, Latino F, Mazzeo F. Effects of Pilates Training on Physical, Physiological and Psychological Performance in Young/Adolescent Volleyball Players: A Randomized Controlled Trial. *Education Sciences*, 2024;14(9): 934. <https://doi.org/10.3390/educsci14090934>
22. Pereira MJ, André A, Monteiro M, Castro MA, Mendes R, Martins F, et al. Methodology and Experimental Protocol for Studying Learning and Motor Control in Neuromuscular Structures in Pilates. *Healthcare*, 2024;12(2): 229. <https://doi.org/10.3390/healthcare12020229>
23. Andriana LM, Ashadi K, Wijaya FJM, Antoni MF. Low-impact specialized pilates is better than low intensity steady state for increasing fitness level. *Physical Education and Sports: Studies and Research*, 2025;4(2): 139–151. <https://doi.org/10.56003/pessr.v4i2.575>
24. Chiang JK, Lin YC, Hung TY, Kao HH, Kao YH. The Impact on Autonomic Nervous System Activity during and Following Exercise in Adults: A Meta-Regression Study and Trial Sequential Analysis. *Medicina*, 2024;60(8): 1223. <https://doi.org/10.3390/medicina60081223>
25. Soler-López A, Moreno-Villanueva A, Gómez-Carmona CD, Pino-Ortega J. The Role of Biomarkers in Monitoring Chronic Fatigue Among Male Professional Team Athletes: A Systematic Review. *Sensors*, 2024;24(21): 6862. <https://doi.org/10.3390/s24216862>
26. 2024;12(7): 724. <https://doi.org/10.3390/healthcare12070724>
27. Leite B, Andreatta Denig L, Boing L, De Bem Fretta T, Coutinho De Azevedo Guimarães A. Effects of Pilates method on quality of life, fatigue and sleep quality among breast cancer women receiving hormone therapy – Two-arm randomized clinical trial. *Journal of Bodywork and Movement Therapies*, 2024;37: 18–24. <https://doi.org/10.1016/j.jbmt.2023.09.002>
28. Staley K, Donaldson A, Mosler AB, Seal E, Forsyth A, O'Halloran P, et al. The multi-dimensional impacts of injury on physically inactive women's participation in sport and physical activity: Insights from concept mapping. *Journal of Science and Medicine in Sport*, 2024;27(10): 716–725. <https://doi.org/10.1016/j.jsams.2024.06.008>
29. Yang P, Xu R, Le Y. Factors influencing sports performance: A multi-dimensional analysis of coaching quality, athlete well-being, training intensity, and nutrition with self-efficacy mediation and cultural values moderation. *Heliyon*, 2024;10(17): e36646. <https://doi.org/10.1016/j.heliyon.2024.e36646>
30. Sanchís-Soler G, Sebastiá-Amat S, Parra-Rizo MA. Mental health and social integration in active older adults according to the type of sport practiced. *Acta Psychologica*, 2025;255: 104920. <https://doi.org/10.1016/j.actpsy.2025.104920>
31. Tarnas M, Marszałek A, Kufel-Grabowska J, et al. Effects of Pilates training on cardiorespiratory functions in medical conditions – Comprehensive approach: A narrative review. *Aging Dis.* 2024;15(4):1771–1783. <https://doi.org/10.14336/AD.2023.0929>
32. Aracı A, Aslan UB. Physical and psychological effects of neuromuscular integrative activity vs Pilates on sedentary females. *Journal of Bodywork and Movement Therapies*, 2024;40: 1423–1432. <https://doi.org/10.1016/j.jbmt.2023.01.002>
33. Atakan MM, Atakan B. Acute Pilates and plyometric exercise in school-based settings improve attention and mathematics performance in high school students. *Sports Medicine and Health Science*, 2024;6(2): 185–192. <https://doi.org/10.1016/j.smhs.2023.12.008>
34. Fernández-Rodríguez R, Alvarez-Bueno C, Reina-Gutiérrez S, Torres-Costoso A, Nuñez De Arenas-

- Arroyo S, Martínez-Vizcaíno V. Effectiveness of Pilates and Yoga to improve bone density in adult women: A systematic review and meta-analysis. Moran JM (ed.) *PLOS ONE*, 2021;16(5): e0251391. <https://doi.org/10.1371/journal.pone.0251391>
35. Suner-Keklik S, Numanoglu-Akbas A, Cobanoglu G, Kafa N, Guzel NA. An online pilates exercise program is effective on proprioception and core muscle endurance in a randomized controlled trial. *Irish Journal of Medical Science (1971 -)*, 2022;191(5): 2133–2139. <https://doi.org/10.1007/s11845-021-02840-8>
36. Jiang Q, Kim Y, Choi M. Kinetic Effects of 6 Weeks' Pilates or Balance Training in College Soccer Players with Chronic Ankle Instability. *International Journal of Environmental Research and Public Health*, 2022;19(19): 12903. <https://doi.org/10.3390/ijerph191912903>
37. Sarashina E, Mizukami K, Yoshizawa Y, Sakurai J, Tsuji A, Begg R. Feasibility of Pilates for Late-Stage Frail Older Adults to Minimize Falls and Enhance Cognitive Functions. *Applied Sciences*, 2022;12(13): 6716. <https://doi.org/10.3390/app12136716>
38. Balogh L, Szabó K, Pucsok JM, Jámbor I, Gyetvai Á, Mile M, et al. The Effect of Aerobic Exercise and Low-Impact Pilates Workout on the Adaptive Immune System. *Journal of Clinical Medicine*, 2022;11(22): 6814. <https://doi.org/10.3390/jcm11226814>
39. Moon NR, Yang WH. Effects of individualized low-intensity mat Pilates on aerobic capacity and recovery ability in adults. *Physical Activity and Nutrition*, 2022;26(4): 046–053. <https://doi.org/10.20463/pan.2022.0024>
40. Saif A, Khan Z, Naqvi IH, Parveen S, Samad A, Parveen A. Dose-response of different work: recovery intensity of “increasing” high intensity interval training protocol on stress, recovery and muscle damage in endurance athletes – A randomized controlled trial. *German Journal of Exercise and Sport Research*, 2025; <https://doi.org/10.1007/s12662-025-01016-1>
41. Choi S. The Relationship Between Time-Related Characteristics of Visual Impairment and Psychological Symptoms in Adults Who Are Blind. *Journal of Visual Impairment & Blindness*, 2024;118(5): 324–335. <https://doi.org/10.1177/0145482X241287798>
42. Chen T, Dong Y, Li Y, Chen S. Four-year comparative analysis of return to sport and psychological recovery following ACL revision: Artificial ligament vs. anterior tibial tendon allograft. *Journal of Orthopaedic Translation*, 2024;47: 29–38. <https://doi.org/10.1016/j.jot.2024.05.003>
43. Dos Reis AL, Oliveira LS, Da Silva APM, Barbosa B, De Oliveira LC, De Oliveira RG. Acute effect of static stretching and pilates stretching on the concentric muscle strength of the knee extensors and flexors. *Journal of Bodywork and Movement Therapies*, 2024;38: 554–561. <https://doi.org/10.1016/j.jbmt.2024.03.059>
44. Hirabara SM, Marzuca-Nassr GN, Cury-Boaventura MF. Nutrition and Exercise Interventions on Skeletal Muscle Physiology, Injury and Recovery: From Mechanisms to Therapy. *Nutrients*, 2024;16(2): 293. <https://doi.org/10.3390/nu16020293>
45. Li S, Kempe M, Brink M, Lemmink K. Effectiveness of Recovery Strategies After Training and Competition in Endurance Athletes: An Umbrella Review. *Sports Medicine - Open*, 2024;10(1): 55. <https://doi.org/10.1186/s40798-024-00724-6>
46. Hottenrott L, Möhle M, Feichtinger S, Ketelhut S, Stoll O, Hottenrott K. Performance and Recovery of Well-Trained Younger and Older Athletes during Different HIIT Protocols. *Sports*, 2022;10(1): 9. <https://doi.org/10.3390/sports10010009>
47. Alarcón-Gómez J, Calatayud J, Chulvi-Medrano I, Martín-Rivera F. Effects of a HIIT Protocol on Cardiovascular Risk Factors in a Type 1 Diabetes Mellitus Population. *International Journal of Environmental Research and Public Health*, 2021;18(3): 1262. <https://doi.org/10.3390/ijerph18031262>
48. Murawska-Cialowicz E, Wolanski P, Zuwała-Jagiello J, Feito Y, Petr M, Kokstejn J, et al. Effect of HIIT with Tabata Protocol on Serum Irisin, Physical Performance, and Body Composition in Men. *International Journal of Environmental Research and Public Health*, 2020;17(10): 3589. <https://doi.org/10.3390/ijerph17103589>
49. Lazarowitz Zanzuri C, Hadas D, Hutzler Y, Goral A, Tsuk S. Remote Pilates Training Is Effective in Improving Physical Fitness in Healthy Women: A Randomized Controlled Study. *Healthcare*, 2024;12(7): 724. <https://doi.org/10.3390/healthcare12070724>
50. Kapusta J, Kapusta A, Babicki M, Irzmański R. Evaluation of Peripheral Circulatory Changes Following Hydrotherapy and Controlled Physical Training in Patients with Atherosclerotic Lower Limb Ischemia. *Life*, 2024;14(12): 1578. <https://doi.org/10.3390/life14121578>

Information about the authors:

Laily Mita Andriana; (Corresponding author); <https://orcid.org/0009-0002-9845-6577>; lailyandriana@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

Fransisca Januarumi Marhaendra Wijaya; <https://orcid.org/0000-0002-3417-1305>; fransiscajanuarumi@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia

Kunjung Ashadi; <https://orcid.org/0000-0002-9540-4096>; kunjungashadi@unesa.ac.id; Department of sports coaching, Faculty of Vocational, Universitas Negeri Surabaya; Surabaya, Indonesia.

Adi Pranoto; <https://orcid.org/0000-0003-4080-9245>; adipranoto@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia

Muhammad Labib Siena Ar Rasyid; <https://orcid.org/0009-0003-3074-7885>; muhammadrasyid@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia

Dewangga Yudhistira; <https://orcid.org/0000-0002-4194-1283>; dewanggayudhistira@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia

Fajar Eka Samudra; <https://orcid.org/0009-0009-4159-4048>; fajarsamudra@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sports and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia

Bayu Agung Pramono; <https://orcid.org/0000-0002-9308-1289>; bayupramono@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

Muhamad Fauzi Antoni; <https://orcid.org/0009-0001-3482-3297>; muhamadantoni@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

Nurkholis; <https://orcid.org/0000-0002-5474-1045>; nurkholisnurkholis@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

Imam Syafii; <https://orcid.org/0000-0002-5440-5834>; imamsyafii@unesa.ac.id; Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya; Surabaya, Indonesia.

Adi S; <https://orcid.org/0000-0001-8450-2005>; adis@mail.unnes.ac.id; Department of Physical Education, Health, and Recreation, Universitas Negeri Semarang; Indonesia.

Cite this article as:

Andriana LM, Wijaya FJM, Ashadi K, Pranoto A, Rasyid MLSA, Yudhistira D, Samudra FE, Pramono BA, Antoni MF, Nurkholis, Syafii I, S A. A pilates-based physiological recovery strategy to enhance post-exercise recovery after high-intensity interval exercise. *Pedagogy of Physical Culture and Sports*, 2025;29(4):339-349. <https://doi.org/10.15561/26649837.2025.0411>

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (<http://creativecommons.org/licenses/by/4.0/deed.en>).

Received: 10.07.2025

Accepted: 12.08.2025; Published: 30.08.2025