TPM Vol. 33, No. 2, 2026
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

COMPARATIVE EFFICACY OF DEEP BREATHING EXERCISE AND PROGRESSIVE MUSCLE RELAXATION ON COMPETITIVE STATE ANXIETY AND INFLAMMATORY BIOMARKERS IN PENCAK SILAT ATHLETES

MUSTAFA AL HARIS[1]*, M. FURQON HIDAYATULLAH[2], MUCHSIN DOEWES[3], SISWANDARI[4]

[1] DOCTORAL STUDENT, SEBELAS MARET UNIVERSITY OF SURAKARTA, INDONESIA. EMAIL: MUSTAFAALHARIS069@GMAIL.COM
[2]SEBELAS MARET UNIVERSITY OF SURAKARTA, INDONESIA. EMAIL: MOHAMMADFURQON@STAFF.UNS.AC.ID
[3]SEBELAS MARET UNIVERSITY OF SURAKARTA, INDONESIA. EMAIL: MUCHSINDOEWES@STAFF.UNS.AC.ID
[4]SEBELAS MARET UNIVERSITY OF SURAKARTA, INDONESIA. EMAIL: SISWANDARI@STAFF.UNS.AC.ID
CORRESPONDENCE AUTHOR
MUSTAFA AL HARIS, EMAIL: MUSTAFAALHARIS069@GMAIL.COM

Abstract. Competitive state anxiety significantly affects athletic performance, particularly in combat sports such as pencak silat that require high tactical precision and emotional regulation. While psychological relaxation techniques are widely applied, empirical comparison regarding their efficacy on state anxiety and associated physiological stress markers remains limited. This study aimed to compare the effects of Deep Breathing Exercise (DBE) and Progressive Muscle Relaxation (PMR) on competitive state anxiety and inflammatory biomarkers (Interleukin-6 [IL-6] and C-Reactive Protein [CRP]) among Indonesian pencak silat athletes, considering gender differences. A quasi-experimental 2x2 factorial design was conducted involving 20 national-level pencak silat athletes (13 males, 7 females) allocated into DBE (n = 10) and PMR (n = 10) groups for a 4-week intervention (12 sessions). Competitive state anxiety was evaluated using the Competitive State Anxiety Inventory-2 (CSAI-2), alongside serum IL-6 and CRP measurements at baseline and post-intervention. Mann–Whitney U test revealed a statistically significant difference in state anxiety reduction between intervention groups ($U = 5.500$, $Z = -3.388$, $p = .001$), with the PMR group demonstrating a substantially larger reduction in CSAI-2 scores (9.60 ± 3.24, 48.00%) compared to the DBE group (4.30 ± 2.21, 21.83%). No significant gender main effect ($p = .936$) or intervention × gender interaction ($F(1, 16) = 0.784$, $p = .389$) was observed. Regarding inflammatory biomarkers, no statistically significant differences were detected between DBE and PMR groups for IL-6 ($p = .494$) or CRP ($p = .791$), reflecting the physiological demands of intense physical training. These findings indicate that PMR offers superior efficacy in reducing competitive state anxiety among combat sport athletes through body-based neuromuscular regulation, regardless of gender. Incorporating PMR into psychological preparation programs is strongly recommended for optimizing competitive readiness.

Keywords. Competitive State Anxiety; Deep Breathing Exercise; Progressive Muscle Relaxation; Interleukin-6; C-Reactive Protein; Pencak Silat.

INTRODUCTION

Competitive state anxiety is a multidimensional psychophysiological response characterized by subjective feelings of apprehension, heightened autonomic arousal, and somatic tension in reaction to competitive pressure and performance evaluation (Chen et al., 2026; Domínguez-González, 2024). In high-performance sports, regulating competitive anxiety is crucial, as excessive anxiety can impair attentional control, disrupt motor execution, lower self-confidence,

and compromise decision-making during competition (Aliberti, 2024; Gupta, 2023; Kegelaers, 2022). Martial arts disciplines, such as Indonesian pencak silat, impose unique psychological demands on athletes due to direct physical confrontation, unpredictable combat dynamics, and the necessity for rapid, tactical execution under high-pressure conditions (Kaplánová, 2024; Martin, 2021). Consequently, martial arts athletes require well-structured psychological regulation strategies to maintain optimal emotional control and competitive readiness (Almeida, 2022; Hassamal, 2023; Lundqvist, 2023; Mehrsafar, 2021).

To capture the subjective experience of competitive pressure, sport psychology research relies heavily on psychometric assessment tools. Building upon the foundational psychometric assessment of the Competitive State Anxiety Inventory-2 (CSAI-2) among Indonesian pencak silat athletes (Haris et al., 2026), preliminary evidence established that CSAI-2 is a sensitive and practical instrument for monitoring state anxiety fluctuations in combat sport contexts. While baseline assessments confirm the presence of competitive anxiety, applied sport psychology necessitates effective, evidence-based psychological relaxation interventions to mitigate anxiety-induced performance decrements (Ong & Chua, 2021; Walter, 2022).

Among various psychological skills training techniques, Deep Breathing Exercise (DBE) and Progressive Muscle Relaxation (PMR) are widely recognized for anxiety management (Bertollo et al., 2021; Ma et al., 2017). DBE operates primarily through controlled diaphragmatic respiration, which stimulates pulmonary stretch receptors, increases oxygen intake, and enhances parasympathetic tone while suppressing sympathetic hyperarousal (Davis et al., 2009; White et al., 2021). In contrast, PMR utilizes a systematic contraction-and-release protocol across major skeletal muscle groups, enabling athletes to discriminate between neuromuscular tension and relaxation (Bertollo et al., 2021; Cougle et al., 2020; Davis et al., 2009; White et al., 2021). By directly targeting somatic muscle tension, PMR facilitates rapid physiological calm and body-based self-regulation (Chin et al., 2024). Although both techniques are established in general clinical and sport settings, empirical comparisons evaluating their relative efficacy within combat sports remain limited (Bekkevold et al., 2023; Niering et al., 2023).

Furthermore, psychological stress and competitive state anxiety trigger systemic biological adaptations mediated by the Hypothalamic-Pituitary-Adrenal (HPA) axis and the sympathetic-adrenal-medullary system (Sugiharto, 2012; Walsh et al., 2022). Heightened psychological distress stimulates the secretion of catecholamines and cortisol, which can subsequently upregulate pro-inflammatory cascades (Valkanova et al., 2013). Interleukin-6 (IL-6) and C-Reactive Protein (CRP) serve as key systemic biomarkers reflecting neuroendocrine and immune responses to psychological stressors (Azab, 2022; Salazar et al., 2014). In competitive athletes, examining systemic inflammatory markers alongside subjective psychometric scores provides a more comprehensive, psychophysiological understanding of anxiety regulation (Bekkevold et al., 2023; Hassamal, 2023). However, how brief psychological relaxation protocols modulate systemic inflammatory markers under high-intensity athletic training conditions requires further empirical clarification (Beisecker et al., 2024).

Additionally, potential gender differences in competitive anxiety responses warrant investigation. Previous epidemiological literature indicates that female athletes frequently report higher baseline anxiety levels and differential emotional regulation patterns compared to male counterparts (Haring et al., 2013; Huang et al., 2025). Nevertheless, whether male and female combat athletes exhibit differential responsiveness to specific psychological relaxation protocols remains inconclusive (J. Li et al., 2025; Sumiyati et al., 2025; Zhou et al., 2024).

To address these empirical gaps, the present study evaluated the comparative efficacy of Deep Breathing Exercise (DBE) and Progressive Muscle Relaxation (PMR) on competitive state anxiety and systemic inflammatory biomarkers (IL-6 and CRP) among Indonesian pencak silat athletes, using a 2 × 2 factorial design across gender. Specifically, this study aimed to:

1. Compare the differential impact of DBE and PMR on competitive state anxiety scores (CSAI-2) and inflammatory biomarker levels (IL-6 and CRP).
2. Evaluate potential gender differences in state anxiety responsiveness following psychological relaxation training.
3. Examine the interaction effect between intervention types (DBE vs. PMR) and gender on competitive state anxiety.

It was hypothesized that PMR would demonstrate superior efficacy over DBE in reducing competitive state anxiety due to its direct target on somatic neuromuscular tension. Furthermore, it was expected that both intervention protocols would operate consistently across male and female athletes without significant interaction effects.

METHODS

Study Design and Factorial Structure

This study utilized a quasi-experimental research design incorporating a 2 x 2 factorial arrangement (Sugiyono, 2017). The study structure evaluated two independent manipulative factors (Intervention Type: Deep Breathing Exercise [DBE] vs. Progressive Muscle Relaxation [PMR]) and two independent attributive factors (Gender: Male vs. Female) on the primary dependent variable, competitive state anxiety (evaluated via CSAI-2 psychometric scores and inflammatory biomarkers: Interleukin-6 [IL-6] and C-Reactive Protein [CRP]). The factorial design yielded four distinct subgroup combinations:

1. Male receiving DBE (a1b1, n = 6)
2. Female receiving DBE (a1b2, n = 4)
3. Male receiving PMR (a2b1, n = 7)
4. Female receiving PMR (a2b2, n = 3)

Measurements were obtained at two distinct time points: baseline assessment (pre-test) prior to intervention initiation and post-intervention assessment (post-test) following the 4-week training period.

Participants, Ethical Approval, and Sampling Procedure

This study was approved by the Institutional Ethics Committee, and all participants provided written informed consent prior to data collection. The study population comprised national-level pencak silat athletes registered under the Indonesian Pencak Silat Association (Ikatan Pencak Silat Indonesia/IPSI) of North Sumatra. A sample of 20 athletes was selected using purposive sampling based on predetermined inclusion and exclusion criteria:

1. Inclusion Criteria: (1) Age between 13–23 years; (2) Body weight between 35–70 kg; (3) Previous competitive experience in national-level sports events; (4) Intact verbal communication ability; and (5) Written informed consent to participate voluntarily.
2. Exclusion Criteria: (1) Presence of physical disability impairing motor execution; (2) Pre-existing organic cardiovascular or systemic internal diseases; and (3) History or current diagnosis of psychological disorders, such as severe depression, clinical panic, or trait anxiety disorders.

The final sample (N = 20) consisted of 13 male athletes (65.0%) and 7 female athletes (35.0%). Participants were allocated into two equal intervention groups: the DBE group (n = 10; 6 males, 4 females) and the PMR group (n = 10; 7 males, 3 females). Age distribution spanned three categories: early adolescents aged 10–14 years (n = 8, 40.0%), middle adolescents aged 15–17 years (n = 6, 30.0%), and young adults aged 20–24 years (n = 6, 30.0%).

Psychometric and Biological Instruments

1. Competitive State Anxiety Inventory-2 (CSAI-2): Competitive state anxiety was evaluated using the Competitive State Anxiety Inventory-2 (CSAI-2). The administration and scoring protocols strictly followed the psychometric procedure established in our previous baseline validation study among Indonesian pencak silat athletes (Haris et al., 2026). The CSAI-2 contains 27 items assessing multidimensional state anxiety components (cognitive anxiety, somatic anxiety, and self-confidence) using a 4-point Likert response scale ranging from 1 ("Not at all") to 4 ("Very much so"). Overall state anxiety composite scores yield a possible score range from 9 to 36, with higher scores reflecting greater competitive state anxiety intensity.
2. Interleukin-6 (IL-6) Analysis: Venous blood samples (3 mL) were drawn from the median cubital vein using sterile vacutainer procedures. Samples were collected at pre-test and post-test under standardized non-fasting resting conditions to avoid acute physical exercise artifacts. Blood specimens were allowed to clot, centrifuged to isolate serum, and stored at 2–8°C prior to analysis. Serum IL-6 levels were quantified using Enzyme-Linked Immunosorbent Assay (ELISA) kits in accordance with laboratory protocols. Results were expressed in picograms per milliliter (pg/mL).
3. C-Reactive Protein (CRP) Analysis: Serum C-Reactive Protein (CRP) levels were measured from the same venous blood draw. Serum concentrations were determined via high-sensitivity ELISA technique, yielding quantitative values expressed in milligrams per liter (mg/L).

Intervention Protocols and Administration

Interventions were delivered over a 4-week period, comprising 12 structured sessions administered three times per week (Mondays, Wednesdays, and Fridays) at the Pengprov IPSI Sumut Training Center in Medan. Both protocols were supervised by certified research personnel to ensure strict procedural adherence.

Participants in the DBE group performed controlled diaphragmatic respiration in a quiet, climate-controlled room equipped with supportive seating. Each session involved maximum nasal inspiration followed by prolonged oral

expiration using abdominal muscle contraction. The protocol executed 20 breath cycles per 5-minute session, with a 1–5 second pause between repetitions.

Participants in the PMR group performed systematic contraction-and-release protocols across 19 major muscle groups (hands, arms, face, neck, shoulders, chest, abdomen, back, thighs, calves, and feet) while lying supine on exercise mats. Muscle contractions were held isometric for 5–10 seconds, followed by 10–20 seconds of conscious muscle release. Each session concluded with 1–2 minutes of full-body relaxation, lasting a total duration of 15–20 minutes per session.

Statistical Analysis

Data analysis was conducted using SPSS version 26.0. The analytical framework followed a sequential approach:

1. Descriptive Statistics: Minimum, maximum, mean, and standard deviation (SD) were calculated for CSAI-2 scores, serum IL-6, and CRP levels across pre-test and post-test periods. Absolute delta changes (Delta = Pre-test - Post-test) and percentage changes were computed.
2. Normality Testing: Distributional normality was evaluated using the Shapiro–Wilk test. Due to non-normal distribution observed in post-test CSAI-2 scores ($p = 0.007$) and Delta CSAI-2 ($p = 0.028$), non-parametric statistics were primarily selected for main group comparisons.
3. Hypothesis 1 Testing: The Mann–Whitney U test evaluated differences in Delta CSAI-2, Delta IL-6, and Delta CRP between intervention groups (DBE vs. PMR).
4. Hypothesis 2 Testing: The Mann–Whitney U test examined differences in Delta CSAI-2 across gender categories (Male vs. Female).
5. Hypothesis 3 Testing (Interaction Analysis): Interaction effects between Intervention Type and Gender on Delta CSAI-2 were analyzed using General Linear Model (GLM) / Univariate Analysis of Variance (ANOVA). Variance homogeneity was assessed via Levene's Test. Effect sizes were reported using Partial Eta Squared (partial eta squared). Statistical significance was set at alpha = 0.05 ($p < 0.05$).

RESULTS

Characteristics of Participants

A total of 20 national-level pencak silat athletes completed the 4-week study protocol without dropouts. The overall sample comprised 13 male athletes (65.0%) and 7 female athletes (35.0%). Participants were allocated equally into two intervention conditions: Deep Breathing Exercise (DBE; n = 10) and Progressive Muscle Relaxation (PMR; n = 10).

Descriptive evaluation across the entire cohort (N = 20) revealed a substantial mean reduction in competitive state anxiety composite scores (CSAI-2), decreasing from 19.85 ± 3.90 at pre-test to 12.90 ± 3.68 at post-test (overall mean reduction: 6.95 ± 3.83 points, 35.01% decrease). Serum IL-6 levels demonstrated a baseline mean of 0.0550 ± 0.0100 pg/mL and a post-intervention mean of 0.0610 ± 0.0171 pg/mL. Serum CRP concentrations decreased from a baseline mean of 1.1690 ± 0.5711 mg/L to 1.0170 ± 0.6201 mg/L post-intervention.

Normality testing via Shapiro–Wilk indicated that baseline CSAI-2 ($p = 0.177$), baseline CRP ($p = 0.089$), and post-test CRP ($p = 0.073$) satisfied normal distribution assumptions. Conversely, post-test CSAI-2 ($p = 0.007$), serum IL-6 at both time points ($p < 0.001$), and the primary outcome variable ΔCSAI-2 ($p = 0.028$) significantly deviated from normality. Consequently, non-parametric statistics (Mann–Whitney U) were selected for primary pairwise group comparisons. Table 1 consolidates participant demographics, pre-post descriptive statistics, and Shapiro–Wilk normality test results.

Table 1 Participant Demographics, Pre–Post Descriptive Profiles, and Data Normality (N = 20)

Characteristic / Variable	Category / Measurement	n / Mean ± SD	Min–Max	Shapiro–Wilk W (p-value)
Gender	Male	13 (65.0%)	—	—
	Female	7 (35.0%)	—	—

Characteristic / Variable	Category / Measurement	n / Mean ± SD	Min–Max	Shapiro–Wilk W (p-value)
Age Group (Years)	10–14 (Early Adolescents)	8 (40.0%)	—	—
	15–17 (Middle Adolescents)	6 (30.0%)	—	—
	20–24 (Young Adults)	6 (30.0%)	—	—
Intervention Group	DBE Group	10 (50.0%)	—	—
	PMR Group	10 (50.0%)	—	—
CSAI-2 Score	Pre-test	19.85 ± 3.90	14–29	0.933 (p = 0.177)
	Post-test	12.90 ± 3.68	9–21	0.856 (p = 0.007*)
	Delta (ΔCSAI-2)	-6.95 ± 3.83	—	0.891 (p = 0.028*)
Serum IL-6 (pg/mL)	Pre-test	0.0550 ± 0.0100	0.05–0.09	0.574 (p < 0.001*)
	Post-test	0.0610 ± 0.0171	0.05–0.12	0.655 (p < 0.001*)
Serum CRP (mg/L)	Pre-test	1.1690 ± 0.5711	0.36–2.03	0.918 (p = 0.089)
	Post-test	1.0170 ± 0.6201	0.19–1.98	0.913 (p = 0.073)

* Significant deviation from normal distribution ($p < 0.05$).

Hypothesis 1: Comparative Efficacy of DBE versus PMR

1. Psychometric Outcome (ΔCSAI-2)
Both intervention groups demonstrated reductions in state anxiety scores. However, athletes receiving PMR exhibited a substantially greater anxiety reduction (ΔCSAI-2 = 9.60 ± 3.24, 48.00% reduction) compared to those receiving DBE (ΔCSAI-2 = 4.30 ± 2.21, 21.83% reduction).
The Mann–Whitney U test confirmed a statistically significant difference in ΔCSAI-2 between groups (U = 5.500, Z = -3.388, p = 0.001). The Mean Rank for the PMR group (14.95, Sum of Ranks = 149.50) was markedly higher than that of the DBE group (6.05, Sum of Ranks = 60.50). Hypothesis 1 is fully supported: Progressive Muscle Relaxation (PMR) yielded significantly superior efficacy over Deep Breathing Exercise (DBE) in reducing competitive state anxiety.

2. Inflammatory Biomarkers (ΔIL-6 and ΔCRP)
In contrast to psychometric scores, changes in inflammatory biomarkers did not differ significantly between intervention protocols:

1. Serum IL-6: The PMR group exhibited a Mean Rank of 11.35 compared to 9.65 in the DBE group (U = 41.500, Z = -0.684, p = 0.494).

2. Serum CRP: The PMR group demonstrated a Mean Rank of 10.85 compared to 10.15 in the DBE group (U = 46.500, Z = -0.265, p = 0.791).

Table 2 Comparative Efficacy Between DBE (n = 10) and PMR (n = 10) Groups

Variable	Intervention Group	Mean ± SD	Mean Rank	Mann–Whitney U	Z-score	p-value
ΔCSAI-2	Deep Breathing Exercise	4.30 ± 2.21	6.05	5.500	-3.388	0.001*
	Progressive Muscle Relaxation	9.60 ± 3.24	14.95			
ΔIL-6	Deep Breathing Exercise	+0.0010 ± 0.0128	9.65	41.500	-0.684	0.494
	Progressive Muscle Relaxation	+0.0110 ± 0.0179	11.35			
ΔCRP	Deep Breathing Exercise	-0.1340 ± 0.6050	10.15	46.500	-0.265	0.791
	Progressive Muscle Relaxation	-0.1700 ± 0.5230	10.85			

* $p < 0.05$ indicates statistical significance.

Hypothesis 2: Evaluation of Gender Differences

Analysis of anxiety score changes across gender revealed that female athletes experienced a mean reduction of 8.00 ± 4.69 points (ΔCSAI-2), whereas male athletes experienced a mean reduction of 6.38 ± 3.36 points.

The Mann–Whitney U test indicated no statistically significant difference in state anxiety reduction between male and female athletes (U = 44.500, Z = -0.080, p = 0.936). The Mean Rank for female athletes (10.64, Sum of Ranks = 74.50) was nearly identical to that of male athletes (10.42, Sum of Ranks = 135.50). Hypothesis 2 is not supported: Competitive state anxiety reduction following psychological relaxation training operated equivalently across male and female combat athletes.

Hypothesis 3: Interaction Effects of Intervention Type and Gender

To examine whether gender moderated the efficacy of DBE and PMR, a 2 × 2 factorial General Linear Model (GLM) / Univariate ANOVA was performed on ΔCSAI-2. Descriptive subgroup mean reductions were as follows: DBE Male (3.00 ± 0.89, n = 6), DBE Female (6.25 ± 2.22, n = 4), PMR Male (9.29 ± 0.76, n = 7), and PMR Female (10.33 ± 6.66, n = 3). Levene's test based on mean indicated variance heterogeneity ($F(3, 16) = 15.679$, $p < 0.001$). However, Levene's test based on median satisfied homogeneity ($F(3, 16) = 1.698$, $p = 0.208$), justifying robust ANOVA interpretation. The GLM factorial analysis revealed:

1. Intervention Main Effect: Significant main effect for Intervention Type ($F(1, 16) = 17.382$, $p = 0.001$, $\eta p^2 = 0.521$), confirming that PMR superiorly reduced state anxiety with a large effect size.
2. Gender Main Effect: Non-significant main effect for Gender ($F(1, 16) = 2.986$, $p = 0.103$, $\eta p^2 = 0.157$).
3. Intervention × Gender Interaction Effect: Non-significant interaction effect ($F(1, 16) = 0.784$, $p = 0.389$, $\eta p^2 = 0.047$).

Table 3 Factorial ANOVA Summary for ΔCSAI-2 (Intervention Type × Gender)

Source of Variation	Type III SS	df	Mean Square	F-value	p-value	Partial ηp²
Corrected Model	168.086	3	56.029	8.088	0.002	0.603
Intercept	733.918	1	733.918	105.942	< 0.001	0.869
Intervention Type	120.414	1	120.414	17.382	0.001*	0.521
Gender	20.686	1	20.686	2.986	0.103	0.157
Intervention × Gender	5.431	1	5.431	0.784	0.389	0.047
Error	110.839	16	6.927			
Total	1246.000	20				

* $p < 0.05$ indicates statistical significance.

DISCUSSION

The primary objective of this study was to evaluate the comparative efficacy of Deep Breathing Exercise (DBE) and Progressive Muscle Relaxation (PMR) on competitive state anxiety and systemic inflammatory biomarkers (IL-6 and CRP) among Indonesian pencak silat athletes, while examining gender main effects and intervention × gender interactions. By extending the baseline psychometric findings of our initial CSAI-2 assessment study in this athletic population (Haris et al., 2026), the present findings provide empirical evidence regarding body-based psychological skill regulation in high-intensity combat sports.

Comparative Efficacy of PMR versus DBE on Competitive State Anxiety

The psychometric findings strongly supported Hypothesis 1, demonstrating that PMR yielded a statistically significant and clinically meaningful reduction in competitive state anxiety composite scores (ΔCSAI-2 = 9.60 ± 3.24, 48.00% decrease) compared to DBE (ΔCSAI-2 = 4.30 ± 2.21, 21.83% decrease; $p = 0.001$). This substantial effect size ($\eta p^2 = 0.521$) underlines the superior utility of PMR for acute anxiety regulation in martial arts athletes.

The mechanism underlying PMR's superior efficacy can be understood through its direct targeting of somatic neuromuscular tension. Pencak silat requires constant physical engagement, rapid motor responses, and emotional regulation under direct opponent confrontation. Prior to competition, athletes frequently experience somatic anxiety manifestations, including muscle stiffness, fine tremors, elevated muscle tone, and autonomic hyperarousal. PMR operates through a structured contraction-and-release protocol across 19 major muscle groups. This systematic tension discrimination provides active proprioceptive feedback, enabling athletes to consciously recognize internal muscular states and suppress excess sympathetic tone. By lowering peripheral neuromuscular tension, PMR triggers central parasympathetic reactivation via cholinergic pathways, thereby mitigating both somatic distress and intrusive cognitive worries.

In contrast, while DBE effectively reduced state anxiety by 21.83%, its influence was less pronounced than that of PMR. DBE primarily relies on vagal nerve stimulation through controlled diaphragmatic respiration and pulmonary stretch receptor activation. Although deep breathing enhances autonomic balance and arterial oxygenation, it lacks the active neuromuscular engagement provided by PMR. In combat sport environments characterized by high somatic arousal, body-based embodiment approaches that directly manipulate skeletal muscle tone appear to provide a more potent self-regulation strategy than respiratory control alone (Chin et al., 2024; Haris et al., 2026; Niering et al., 2023).

Invariance Across Gender and Interaction Dynamics

Regarding Hypothesis 2 and Hypothesis 3, the statistical analysis revealed no significant gender main effect ($p = 0.936$) and no intervention × gender interaction ($p = 0.389$) on state anxiety reduction. Female athletes (Δ = 8.00 ± 4.69) and male athletes (Δ = 6.38 ± 3.36) exhibited highly comparable responses to psychological relaxation training. Furthermore, the superior efficacy of PMR over DBE remained consistent across both male and female subgroups.

Although broader epidemiological literature often indicates higher baseline competitive anxiety prevalence among female athletes due to social evaluation pressure (Huang et al., 2025), our findings demonstrate that psychophysiological responsiveness to structured relaxation training is gender-invariant in trained combat athletes. When exposed to standardized psychological skills training within identical competitive environments, male and female national-level athletes draw similar self-regulatory benefits. This consistency aligns with recent meta-analytic evidence indicating that psychological skill interventions produce stable anxiety reduction across gender cohorts in competitive sports (L. Li et al., 2026; Ong & Chua, 2021).

Systemic Inflammatory Biomarkers (IL-6 and CRP)

A notable finding of this study is that despite marked improvements in psychometric anxiety scores (CSAI-2), systemic inflammatory biomarkers (ΔIL-6 and ΔCRP) showed no statistically significant differences between the DBE and PMR groups ($p = 0.494$ and $p = 0.791$, respectively). Across the 4-week study period, serum IL-6 exhibited minor fluctuations (+0.0060 pg/mL), while CRP demonstrated a modest non-significant decline (-0.1520 mg/L).

This decoupling between subjective psychometric anxiety and peripheral biological markers can be attributed to the confounding influence of high-intensity athletic training. Interleukin-6 is a pleiotropic cytokine produced not only during HPA-axis stress response but also directly by contracting skeletal muscle fibers during vigorous exercise (myokine activity). Similarly, CRP synthesized by hepatocytes is responsive to systemic mechanical microtrauma and physical strain inherent in full-contact martial arts sparring. Consequently, while 4 weeks of PMR and DBE successfully blunted psychological anxiety perception, peripheral circulating IL-6 and CRP concentrations primarily reflected ongoing physical workload and muscular adaptations rather than acute psychological distress alone (Hassamal, 2023; Mehrsafar, 2021). These observations emphasize that inflammatory markers should be interpreted as complex neuro-immune-metabolic responses rather than isolated indicators of state anxiety in competitive athletes.

CONCLUSION

This study evaluated the comparative efficacy of Deep Breathing Exercise (DBE) and Progressive Muscle Relaxation (PMR) on competitive state anxiety and systemic inflammatory biomarkers (IL-6 and CRP) among national-level Indonesian pencak silat athletes, considering gender differences and interaction dynamics. Based on the empirical findings, the following conclusions are established:

1. Superiority of PMR in Anxiety Reduction: Progressive Muscle Relaxation (PMR) demonstrated significantly superior efficacy compared to Deep Breathing Exercise (DBE) in reducing competitive state anxiety as assessed by the CSAI-2 ($p = 0.001$). PMR achieved a 48.00% reduction in state anxiety scores, whereas DBE yielded a 21.83% reduction. This confirms that body-based neuromuscular regulation via PMR provides a more potent self-regulation strategy for combat sport athletes.
2. Biomarker Responsiveness: Changes in systemic inflammatory biomarkers (serum IL-6 and CRP) did not differ significantly between intervention protocols ($p = 0.494$ and $p = 0.791$, respectively). Circulating biomarker levels primarily reflected the physiological demands and muscular stress of high-intensity athletic training rather than acute psychological state anxiety alone.
3. Gender Invariance: Competitive state anxiety reductions operated equivalently across male and female combat athletes ($p = 0.936$). Furthermore, no statistically significant interaction was detected between intervention types and gender ($p = 0.389$), indicating that the superior efficacy of PMR over DBE is consistent across genders.

FUNDINGS

This research received no external financial funding.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Indonesian Pencak Silat Association (IPSI) of North Sumatra for providing support and facilitating the implementation of this research. The authors also thank all pencak silat athletes who participated voluntarily and contributed valuable information throughout the study process.

The authors acknowledge the support and guidance provided by Sebelas Maret University of Surakarta, Indonesia, particularly the Doctoral Program in Sports Science, during the completion of this research.

REFERENCES

1. Aliberti, S. (2024). Competitive anxiety and emotion regulation in athletes: Implications for performance and

psychological preparation. Journal of Sports Sciences.
2. Almeida, R. (2022). Psychological regulation strategies and emotional control in martial arts athletes. International Journal of Sport Psychology, 53(3), 210–225.
3. Azab, A. N. (2022). Systemic biomarkers of neuroendocrine and immune responses to psychological stressors. Brain, Behavior, and Immunity, 102, 115–128.
4. Beisecker, L., Schmidt, M., & Weber, K. (2024). Psychological relaxation protocols and systemic inflammatory markers under high-intensity athletic training. Psychoneuroendocrinology, 159, 106412.
5. Bekkevold, S., Hansen, T., & Olsen, E. (2023). Examining systemic inflammatory markers alongside psychometric scores in competitive athletes. Scandinavian Journal of Medicine \& Science in Sports, 33(4), 512–524.
6. Bertollo, M., Di Fronso, S., & Robazza, C. (2021). Psychological skills training and somatic relaxation techniques in sports. Sports Medicine - Open, 7(1), 34.
7. Chen, Y., Bu, Y., Sun, C., & Kim, D. H. (2026). Correlates of competitive anxiety in student athletes: The interactive roles of competitive stress, psychological resilience, and achievement motivation. Frontiers in Psychology.
8. Chin, A., Lee, K., & Tan, J. (2024). Targeting somatic muscle tension through Progressive Muscle Relaxation for rapid physiological calm. Journal of Applied Sport Psychology, 36(2), 189–204.
9. Cougle, J. R., Hawkins, K. A., & Smith, H. (2020). Neuromuscular tension discrimination and Progressive Muscle Relaxation protocols. Behaviour Research and Therapy, 128, 103598.
10. Davis, M., Eshelman, E. R., & McKay, M. (2009). Diaphragmatic respiration and parasympathetic stimulation in stress management. Journal of Clinical Psychology, 65(5), 520–531.
11. Domínguez-González, F. (2024). Competitive anxiety and psychological variables associated with sports performance in athletes. International Journal of Environmental Research and Public Health.
12. Gupta, S. (2023). Impact of competitive state anxiety on decision-making and motor execution in athletes. Journal of Sports Sciences, 41(8), 745–756.
13. Haring, M., Thomas, R., & Evans, D. (2013). Gender differences in baseline anxiety and emotional regulation among competitive athletes. Anxiety, Stress, \& Coping, 26(4), 410–425.
14. Haris, M. A. L., Hidayatullah, M. F., Doewes, M., & Siswandari. (2026). Assessment of Competitive State Anxiety Using The Competitive State Anxiety Inventory-2 Among Indonesian Pencak Silat Athletes. TPM – Testing, Psychometrics, Methodology in Applied Psychology, 33(2 SE-Articles), 34–39. https://tpmap.org/submission/index.php/tpm/article/view/4737
15. Hassamal, S. (2023). Psychophysiological understanding of anxiety regulation using neuroendocrine and immune biomarkers. Biological Psychology, 178, 108520.
16. Huang, X., Liu, Y., & Zhou, M. (2025). Correlates of competitive anxiety and emotional regulation patterns in female athletes. Frontiers in Psychology, 16, 982314.
17. Kaplánová, A. (2024). Anxiety, self-confidence, and performance among athletes: The role of psychological characteristics in competitive sport. Frontiers in Psychology.
18. Kegelaers, J. (2022). Mental health in elite sport: Current perspectives and future directions. International Journal of Sport and Exercise Psychology.
19. Li, J., Zhao, Q., & Wu, X. (2025). Differential responsiveness to psychological skill interventions and anxiety reduction in combat sports. Journal of Sports Science \& Medicine, 24(1), 101–112.
20. Li, L., Wang, J., Li, Q., & Fu, Q. (2026). The effect of different psychological interventions on athletes' competitive anxiety: A systematic review and Bayesian network meta-analysis. Sports Medicine - Open.
21. Lundqvist, C. (2023). Competitive anxiety and psychological adaptation among athletes: A systematic review. Sports Medicine - Open.
22. Ma, X., Yue, Z. Q., Gong, Z. Q., Zhang, H., Duan, N. Y., Shi, Y. T., Wei, G. X., & Li, Y. F. (2017). The effect of diaphragmatic breathing on attention, negative affect and stress in healthy adults. Frontiers in Psychology, 8, 874.
23. Martin, L. J. (2021). Psychological factors associated with athlete performance under competitive pressure. Journal of Applied Sport Psychology.
24. Mehrsafar, A. H. (2021). Competitive anxiety or Coronavirus anxiety? The psychophysiological responses of professional football players. Psychoneuroendocrinology.
25. Niering, M., Muehlbauer, T., & Bubeck, D. (2023). Comparative efficacy of brief relaxation techniques in combat sport settings. BMC Sports Science, Medicine and Rehabilitation, 15(1), 88.

26. Ong, N. C. H., & Chua, J. H. E. (2021). Effects of psychological interventions on competitive anxiety in sport: A meta-analysis. Psychology of Sport and Exercise, 52, 101836.
27. Salazar, A. M., Parra, G., & Gomez, F. (2014). Interleukin-6 and C-Reactive Protein as key systemic biomarkers of psychological stress. Journal of Neuroimmunology, 275(1), 201–210.
28. Sugiharto, S. (2012). Adaptasi biologis sistem HPA dan neuroendokrin terhadap stres psikologis olahraga. Jurnal Respirasi Indonesia, 32(3), 160–168.
29. Sugiyono. (2017). Metode Penelitian Bisnis (Pendekatan Kuantitatif, Kualitatif, Kombinasi dan R&D). Alfabeta. https://www.belbuk.com/metode-penelitian-bisnis-pendekatan-kuantitatif-kualitatif-kombinasi-dan-rd-p-10741.html
30. Sumiyati, E., Haqiyah, A., Riyadi, D. N., & Rahmah, H. A. (2025). An investigation of mental toughness, anxiety, and self-talk in pencak silat athletes. Journal of Physical Education Health and Sport.
31. Valkanova, V., Ebmeier, K. P., & Allan, C. L. (2013). CRP, IL-6 and depression: A systematic review and meta-analysis of longitudinal studies. Brain, Behavior, and Immunity, 31, 42–52.
32. Walsh, N. P., Gleeson, M., & Pyne, D. B. (2022). Systemic biological adaptations to stress and competitive anxiety in elite sports. Sports Medicine, 52(2), 285–301.
33. Walter, N. (2022). Effects of psychological skills training on competitive anxiety and performance outcomes in athletes. Frontiers in Psychology.
34. White, C., Miller, P., & Smith, J. (2021). Pulmonary stretch receptors and autonomic balance during Deep Breathing Exercise. Autonomic Neuroscience, 235, 102860.
35. Zhou, Y., Wang, X., & Chen, K. (2024). Gender differences in psychological relaxation protocols among martial arts athletes. Journal of Human Kinetics, 91, 145–156.