

Cortisol–testosterone dynamics, state anger, and anxiety in national-level male boxers across a competitive bout

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Research Article

Keywords: Anger, competitive boxing, saliva, psychophysiological stress, state anxiety

Posted Date: June 4th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9774020/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background

While cortisol and testosterone track rapid physiological adaptations to competition, psychological states like anxiety and anger are driven by cognitive appraisal and context. This study examined concurrent neuroendocrine and emotional responses in boxing to determine if hormonal shifts mirror athletes' subjective stress.

Methods

Twenty national-level male boxers (age: 19.5 ± 2.4 years, range: 18–21 years) provided salivary cortisol and testosterone (sCor and sTes) samples at three time points (pre-, mid-, and post-competition). Competitive anxiety and state anger were assessed before and after the bout.

Results

sTes increased significantly during mid-competition, whereas sCor peaked post-competition ($p < .001$). Cognitive and somatic anxiety increased from pre- to post-competition ($p < .001$), while self-confidence and state anger remained unchanged ($p > .05$). No significant associations were found between hormonal reactivity and changes in anxiety or anger ($p > .05$).

Conclusion

Hormonal and emotional responses to competition followed distinct temporal patterns, with no evidence that acute endocrine changes reflect athletes' subjective emotional state. These findings highlight the limitations of using isolated hormonal measures to assess competitive stress and support the use of combined physiological and psychological monitoring approaches in applied sport settings.

1. Introduction

Competition represents a fundamental driving force that stimulates individuals' intrinsic motivation to outperform their opponents and achieve success [1]. In sporting settings, competition is a multidimensional process that challenges not only physical performance but also psychological resilience [2]. Exposure to competitive stressors elicits a range of physiological and psychological responses in athletes [3]. Real competition environments, in particular, provide ecologically valid conditions for examining the neuroendocrine and emotional reactions elicited by these stressors [4].

Combat sports place substantial psychophysiological demands on athletes due to their high physical intensity, pronounced competitive pressure, and strong performance expectations [5]. Among these

sports, boxing requires athletes to deliver controlled punches while simultaneously defending against incoming strikes [6]. Official boxing bouts consist of a predetermined number of rounds (typically 3–12), each characterized by short bursts of high-intensity, intermittent efforts [7]. Consequently, the repeated anaerobic demands and competitive pressure inherent to boxing contribute to significant accumulations of physiological and psychological stress [8].

Studies investigating hormonal responses to combat sport competitions indicate that both real and simulated bouts act as potent stressors on the endocrine system [8–10]. Within this context, cortisol and testosterone are frequently examined as key markers of neuroendocrine responses to competitive situations [11, 12]. Cortisol is a steroid hormone synthesized in the adrenal cortex that increases in response to physical and psychological stressors and is widely used as an objective indicator of stress [13]. Testosterone, on the other hand, is a steroid hormone that has been linked to competitive contexts and dominance-related behaviors, although its influence on behavior is complex, context-dependent, and not directly deterministic [14]. Evidence suggests a reciprocal regulatory relationship between cortisol and testosterone, whereby elevated cortisol may dampen the influence of testosterone on competitive behaviors, while increases in testosterone may correspond with competitive intensity and bout outcomes [15, 16]. However, it is important to note that circulating concentrations of cortisol and testosterone do not directly translate into immediate behavioral outputs. Their effects on behavior are mediated through binding to glucocorticoid and androgen receptors in the central nervous system, particularly in regions such as the amygdala, hippocampus, and prefrontal cortex, which are involved in emotional regulation and threat processing [17].

Psychological processes, including stress and anxiety, are closely linked to hormonal activity through the activation of the hypothalamic–pituitary–adrenal (HPA) axis and the sympatho-adrenal system [18]. Testosterone secretion is primarily regulated by the hypothalamic–pituitary–gonadal (HPG) axis [19]. While these endocrine systems respond rapidly to competitive stressors, their acute fluctuations may reflect physiological mobilization rather than immediate modulation of higher-order cognitive or emotional states. Accordingly, saliva-based hormone analyses have become a widely accepted method in sports science for evaluating training load, competition stress, recovery status, and overall physiological readiness [20]. Nevertheless, such measures should be interpreted cautiously when linked to behavioral constructs, as they represent peripheral indices rather than direct measures of central neuroendocrine activity. Exercise-induced reductions in plasma volume can transiently elevate measured hormone concentrations, which may overestimate endocrine activation if not carefully contextualized [21]. This consideration is particularly relevant in high-intensity, intermittent sports such as boxing.

Emotional factors, particularly anxiety and anger, represent additional components that significantly influence athletes' responses during competition [22]. Athletes' cognitive and emotional reactions are shaped by dynamic interactions between personal characteristics and situational demands, through which behavior emerges from person–environment interplay [23]. Within this framework, increases in anxiety before and during competition are expected and may alter both performance outcomes and accompanying hormonal patterns [24]. In high-intensity, contact sports such as boxing, the convergence

of competitive pressure, perceived threat, and anticipatory arousal often increases psychological load, thereby contributing to heightened stress and emotional reactivity [25]. Importantly, hormonal stress reactivity and subjective emotional responses may not follow parallel trajectories. While cortisol and testosterone responses reflect rapid physiological adaptations to competitive demands, psychological states such as anxiety and anger are shaped by cognitive appraisal, prior experience, and contextual interpretation [26]. Therefore, any association between acute hormonal changes and behavioral or emotional outcomes should be considered indirect and potentially non-linear.

Therefore, this study aims to investigate competition-induced psychophysiological stress and changes in state anger and anxiety levels in national-level male boxers. To achieve this, variations in salivary cortisol (sCor) and testosterone (sTes) concentrations, along with psychological responses (anger and anxiety), were assessed before, during, and after an actual competitive bout. Rather than assuming a direct causal relationship, this study explores whether concurrent changes in hormonal and psychological variables co-occur within an ecologically valid competitive context. We hypothesized that (i) sCor and sTes levels during competition would be significantly higher than pre-competition levels, (ii) post-competition state anger scores would be elevated compared to pre-competition state anger scores, and (iii) peak hormonal reactivity would not be correlated with pre-to-post changes in state anger or competitive anxiety.

2. Methods

2.1. Study design

The present study employed a field-based, naturalistic, and repeated-measures design in which athletes' psychophysiological stress responses were monitored during actual competitive bouts. Data collection was conducted during an elimination tournament used to select national team members. Potential candidates from the national pool were invited to this tournament, where they competed in single bouts determined by a randomized fixture. This procedure ensured an objective and ethically sound competition environment and provided an ecologically valid setting for examining neuroendocrine responses during real, high-stakes matches organized by a responsible manager affiliated with the national federation.

To this end, neuroendocrine responses were assessed by collecting salivary samples to determine cortisol and testosterone concentrations. State anger was measured using the State-Trait Anger Expression Inventory (STAXI) [27], while competitive anxiety was evaluated using the Competitive State Anxiety Inventory-2 (CSAI-2) [28].

2.2. Participants

A minimum required sample size of 20 participants was calculated through an a priori power analysis conducted with G*Power 3.1 software, assuming an alpha level of 0.05 and a statistical power of 0.80 [29]. Accordingly, twenty national-level male boxing athletes (age: 19.5 ± 2.4 years, range: 18–21 years;

height: 1.76 ± 0.1 m; body mass: 65.9 ± 12.4 kg; body mass index: 21.3 ± 3.4 kg/m²; sports experience: $8.5.1 \pm 1.8$ years) were voluntarily recruited for the study. All athletes were actively competing in national championships organized by the National Boxing Federation and also participated in international tournaments. The sample represented six senior weight classes (55, 60, 65, 70, 75, and 80 kg).

None of the participants reported any acute or chronic injuries, neurological disorders, or other health conditions that could adversely affect their performance during the study. At enrollment, all subjects were medically cleared and injury-free, as formally verified by their respective club managers. The use of performance-enhancing substances or medications and irregular training attendance were considered exclusion criteria.

Subjects were fully informed about the study procedures, potential risks, and benefits, and each provided both verbal and written informed consent prior to participation. The study protocol adhered to the principles of the Declaration of Helsinki and received ethical approval from the Social and Humanities Research Ethics Board of Karamanoğlu Mehmetbey University (approval ID: 09-2024/226).

2.3. Procedures and competition setting

All bouts in the elimination tournament were conducted in accordance with international boxing regulations and were overseen by an official referee. The tournament followed a single-elimination (knockout) format, whereby athletes were eliminated after a loss ("lose and exit"), and therefore competed in one bout within the scope of this study. Each match consisted of three 3-minute rounds with 1-minute rest intervals. The structure was intentionally designed to promote maximal competitive effort and to minimize tactical pacing strategies that could prolong the bout. None of the matches ended in a knockout. Because all bouts resulted in a clear win/lose outcome, the competitive context substantially increased the perceived difficulty, importance, and overall stress imposed on the athletes.

Each competition was conducted individually, athletes did not observe other matches, nor were they provided with information about opponents or match outcomes. All bouts were completed within the same competitive session on the same day. Each athlete contributed data from a single bout only (i.e., their first and only bout within the study context); therefore, no selection or randomization of bouts was required. To evaluate neuroendocrine changes (sCor and sTes) during the competition, saliva samples were collected at three time points: (i) pre-competition (immediately prior to warm-up, ~ 30 min before), (ii) mid-competition (after the second round), and (iii) post-competition (immediately after the bout (~ 5 min after the bout). In addition, athletes completed the STAXI (state anger) and CSAI-2 (competitive anxiety) questionnaires at time points synchronized with saliva collection immediately before and after the competition. In this context, sCor and sTes were used as physiological indicators of stress, whereas state anger and competitive anxiety were assessed as psychological responses to competitive demands, allowing for the examination of both physiological and subjective components of stress.

Although match outcomes (win/loss) were recorded, they were not included in the primary analyses. This decision was based on the study's aim to examine general psychophysiological responses to

competitive stress rather than performance determinants. Additionally, the relatively small sample size and potential inter-individual variability in opponent characteristics and bout dynamics limited the statistical power and interpretability of outcome-based comparisons.

Given the sensitivity and logistical challenges of collecting physiological and psychological data during a real competition, the first author (BB) was solely responsible for data acquisition. He coordinated with all athletes prior to the tournament and managed the entire procedure, including collecting saliva samples (pre-, mid-, and post-match) and administering questionnaires. Figure 1 illustrates the detailed experimental design.

2.4. Saliva collection

The saliva collection protocol was verbally explained to all athletes beforehand to prevent procedural errors and minimise potential bias. The sampling procedures followed the protocol described by Aydemir et al. [11]. Saliva samples were obtained by the passive drool method. Athletes first allowed saliva to accumulate in their mouths, with their chins tilted slightly downward. They then gently expelled the pooled saliva into 15-mL Falcon polypropylene tubes. Athletes were instructed to abstain from eating and drinking (except water) for at least 60 minutes prior to each sampling point. Tooth brushing was not permitted to avoid blood contamination. Each sample tube was pre-labelled with the athlete's study ID and sampling time point (pre-, mid-, and post-competition) and distributed to each athlete before the data-collection began.

To standardise circadian influences, athletes were instructed to wake between 8:00 and 9:00 a.m., consistent with their habitual schedule and to consume their routine match-day breakfast. All saliva samples were collected and transported to the laboratory located in the same city on the day of the tournament. Upon arrival, samples were immediately stored at -80°C in a laboratory deep-freezer until biochemical analysis [30].

2.5. Assessment of state anger and competition anxiety

Trait anger was assessed using the national adaptation of Spielberger et al.'s STAXI [27]. This scale measures an individual's general tendency to experience angry feelings. The national adaptation's 4-point response format was used, ranging from "not at all or almost never" to "very much so or almost always," with higher scores indicating greater levels of trait anger. Scores were calculated by summing all item responses, yielding a total score between 10 and 40. The internal consistency of the scale in the present study was high (Cronbach's $\alpha = 0.85$).

Athletes also completed the national adaptation of the CSAI-2 to assess competitive anxiety [28]. The CSAI-2 consists of 27 items across three subscales, cognitive anxiety, somatic anxiety, and self-confidence, with nine items per subscale. Items were rated on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much so). Subscale scores ranged from 9 to 36, with higher scores reflecting greater cognitive anxiety, greater somatic anxiety, or greater self-confidence. The internal consistency values for

the current study were as follows: cognitive anxiety ($\alpha = 0.84$), somatic anxiety ($\alpha = 0.88$), and self-confidence ($\alpha = 0.89$).

2.6. Biochemical analysis

All biochemical analyses were conducted in a certified biochemistry laboratory. Frozen saliva samples were thawed at room temperature and centrifuged at 3000 rpm for 15 minutes to remove cellular debris; only the clear supernatant was used for hormonal analysis.

sCor and sTes concentrations were measured using commercially available enzyme-linked immunosorbent assay (ELISA) kits (Bioassay Technology Laboratory Company, Shanghai, China). All samples were analysed in duplicate, and the mean value was used for statistical analysis. Concentrations were calculated according to the standard curve constructed using standard values and were expressed as $\mu\text{g/dL}$ for sCor and ng/dL for sTes.

The intra-assay and inter-assay coefficients of variation (CV) were within the acceptable limits specified by the manufacturer. The analytical sensitivity and measuring range of the assays were also consistent with the manufacturer's specifications.

2.7. Statistical analysis

Descriptive statistics are presented as mean ($\bar{X}$) and standard deviation (SD). Normality testing with the Shapiro–Wilk procedure showed that all dependent variables were normally distributed. A repeated-measures ANOVA was performed to evaluate differences in sCor and sTes across the three time points (pre-, mid-, and post-competition). When a significant main effect was observed, Bonferroni-adjusted post hoc comparisons were conducted to identify pairwise differences. Additionally, paired-samples t-tests were used to compare state anger scores and competitive anxiety levels between pre-competition and post-competition measurements. Effect sizes (Cohen's d_z) were calculated using the formula $d_z = t / \sqrt{n}$, which is recommended for within-subject (paired) designs, and were interpreted according to conventional thresholds, with values around 0.20 considered small, around 0.50 medium, and 0.80 and above considered large. To further examine the psychophysiological coupling between hormonal reactivity and emotional responses, delta (Δ) scores were as mid- minus pre-competition values for hormonal markers (ΔCort and ΔTest) and as post- minus pre-competition values for anxiety outcomes ($\Delta\text{Cognitive Anxiety}$ and $\Delta\text{Somatic Anxiety}$). Pearson correlation analyses were then conducted to assess the associations between peak hormonal reactivity (Δ from pre- to mid-competition) and subsequent changes in state anger and competitive anxiety (Δ from pre- to post-competition). Statistical significance was set at an alpha level of .05. All analyses were conducted using SPSS (Version 27; IBM Corp., Armonk, NY, USA).

3. Results

Table 1 presents the temporal changes in hormonal markers during the competitive bout, demonstrating significant effects of time on the levels of both sCor and sTes.

Table 1
Repeated-measures ANOVA results for pre-, mid-, and post-competition sCor and sTes levels.

Cortisol (µg/dL)	Pre-competition	Mid-competition	Post-competition	F	p-value	η²
	X (SS)	X (SS)	X (SS)			
	0.54 (0.03)	0.91 (0.08)	0.98 (0.03)	432.37	< 0.001	0.96
Testosterone (ng/dL)	38.83 (10.92)	91.67 (17.69)	48.42 (12.64)	509.23	< 0.001	0.96

A repeated-measures ANOVA revealed a significant main effect of time on cortisol levels, $F(2, 18) = 432.37, p < .001, \eta^2 = 0.96$. Pairwise comparisons indicated that post-competition cortisol levels were significantly higher than both mid-competition ($p < .001, +7.7\%$) and pre-competition values ($p < .001, +81.5\%$). Mid-competition cortisol levels were also significantly higher than pre-competition ($p < .001; +68.5\%$).

Similarly, testosterone levels showed a significant main effect of time, $F(2, 18) = 509.23, p < .001, \eta^2 = 0.96$. Mid-competition testosterone levels were significantly higher than both pre-competition levels ($p < .001; +136.1\%$) and post-competition levels ($p < .001, -47.2\%$). Post-competition testosterone levels also remained significantly higher than pre-competition levels ($p < .001, +24.7\%$; Figure 2).

Table 2 presents the paired-samples t-test results examining changes in competitive anxiety (CSAI-2) and state anger (STAXI) from pre- to post-competition.

Table 2
Paired-samples t-test results for pre- and post-competition anxiety (CSAI-2) and state anger (STAXI)

Variables	Pre-competition	Post-competition	t	p-value	Effect Size
	X (SS)	X (SS)			
Cognitive Anxiety (score)	21.30 (0.84)	44.75 (1.68)	-15.820	< .001	Large
Somatic Anxiety (score)	18.00 (0.86)	20.70 (0.61)	-4.801	< .001	Large
Self-Confidence (score)	27.75 (1.33)	28.30 (1.00)	-.873	.394	Small
State Anger (score)	17.40 (1.56)	18.30 (0.78)	-.903	.378	Small

A significant increase was found in cognitive anxiety from pre-competition to post-competition ($p < .001$), corresponding to an increase of a 110.1% increase and a large effect size ($dz = 3.54$). Somatic anxiety also increased significantly during the bout ($p < .001$), showing a more moderate rise of 15.0%, while still demonstrating a large effect size ($dz = 1.07$). In contrast, self-confidence did not change significantly from pre- to post-competition ($p > .05$), reflecting a small effect size ($dz = 0.20$). Similarly, state anger did not differ significantly between pre- and post-competition measurements ($p > .05$), corresponding to a small effect size ($dz = 0.20$).

Table 3 presents the correlations between peak sCor and sTes reactivity (and changes in competitive anxiety (Δ from pre- to post-competition).

Table 3 Correlations between peak hormonal reactivity and changes in competitive anxiety (Δ) from pre- to post-competition			
Variable 1 (Δ)	Variable 2 (Δ)	r	p-value
Δ Cortisol (pre→post)	Δ Cognitive Anxiety	0.28	.235
Δ Cortisol (pre→post)	Δ Somatic Anxiety	-0.10	.680
Δ Testosterone (pre→mid)	Δ Cognitive Anxiety	0.07	.771
Δ Testosterone (pre→mid)	Δ Somatic Anxiety	0.14	.568

Note Mean Δ Cortisol = 0.37; Mean Δ Testosterone = 52.84.

Changes in sCor from pre- to post-competition were not significantly associated with changes in either cognitive anxiety ($r = 0.28, p = .235$) or somatic anxiety ($r = -0.10, p = .680$). Likewise, sTes reactivity (Δ pre→mid) showed no significant relationships with changes in somatic or cognitive anxiety (somatic: $r = 0.14, p = .568$; cognitive: $r = 0.07, p = .771$).

4. Discussion

The present study aimed to investigate competition-induced neuroendocrine responses and emotional changes in national-level athletes during an actual boxing competition. Our findings demonstrate robust elevations in both sCor and sTes across competitive phases, with the most pronounced increase in sTes during mid-competition and sCor peaking post-competition. These endocrine shifts were accompanied by significant increases in cognitive and somatic anxiety from pre- to post-competition, however, peak hormonal reactivity did not correlate with changes in state anger or competitive anxiety, suggesting that neuroendocrine activation and subjective emotional states may be regulated by partially distinct mechanisms during real competitive encounters. Collectively, these results provide valuable insights into the hormonal and emotional responses of national-level boxers to genuine competitive stress.

The presence of a competitive environment serves as a potent stressor for athletes, eliciting physiological adjustments that prepare the organism to cope with imminent physical and psychological demands [4]. Our hormonal analyses revealed distinct temporal patterns for sCor and sTes across the competitive bout. sCor exhibited a progressive rise from pre-competition, peaking post-competition, consistent with cortisol's well-established role as an acute marker of metabolic and psychological load during high-intensity combat sports [8, 31]. However, this increase should be interpreted with caution. In addition to activation of the HPA axis, acute elevations in circulating hormone concentrations during and after high-intensity exercise may partially reflect exercise-induced reductions in plasma volume (i.e., hemoconcentration), rather than solely increased secretion. Therefore, the observed post-competition increase in sCor likely represents a combined effect of physiological stress, metabolic demand, and fluid shifts occurring during the bout. Accordingly, post-competition elevations in cortisol may reflect the integrated influence of psychological arousal, perceived threat, accumulated fatigue, and cognitive demands, although the relative contribution of these factors cannot be determined within the present study design. This pattern is broadly consistent with previous literature demonstrating increases in cortisol following intense athletic engagement [32, 33].

Similarly, studies conducted across different sporting disciplines have consistently shown significant increases in cortisol levels immediately before or during competition [11, 34, 35]. In tournament-style combat settings, post-bout cortisol responses have been reported to surpass pre-bout levels, suggesting that the cumulative physiological stress and unpredictability of competitive exchanges magnify HPA axis activation [36]. Notably, the high-impact, full-contact nature of combat sports, leads to particularly pronounced cortisol secretion, with levels often remaining elevated for an extended period after exertion has ceased. This delayed recovery underscores that competitive stress is not merely phasic but can exert extended physiological consequences. However, it is important to acknowledge that the physiological stress elicited by competition does not always translate into measurable changes in cortisol secretion [37]. In this regard, factors such as sport-specific characteristics, bout duration and continuity, contact intensity, and individual adaptive capacity may play a decisive role in shaping cortisol responses.

While sCor displayed its maximum response post-competition, sTes followed a distinct temporal trajectory, peaking during mid-competition. This divergence highlights the fundamentally different biological functions of the two hormones. Cortisol primarily reflects acute stress reactivity and metabolic mobilization, functioning as a key component of the HPA axis response to physical and psychological challenges [13]. In contrast, testosterone responses observed during competition should be interpreted as context-dependent physiological changes influenced by exercise intensity, metabolic demand, and competitive exposure, rather than direct indicators of behavioral processes such as dominance or aggression [38]. Accordingly, the mid-competition surge observed in sTes may be interpreted not only as a response to physical exertion but also as a response to psychological factors such as the experience of striving for success and the anticipation of victory. The relatively low testosterone levels recorded pre-competition may reflect the absence of physical engagement and the inhibitory influence of elevated cortisol levels. Supporting this interpretation, Casto and Edwards [39]

reported increases in sTes during competition among football players, followed by a decline within 30 minutes post-match. Similarly, Edwards and Kurlander [38] observed linear increases in sTes during warm-up and throughout competition in volleyball players and tennis players. However, variation in testosterone secretion suggests that competition-related changes should not be interpreted solely through the lens of competitive intensity; rather, they may reflect individual differences in psychological and physiological adaptation to competitive stress [40].

Additionally, given the well-established association between elevated testosterone and dominance-oriented or status-maintaining behaviors [41], one might expect corresponding changes in anger expression during competition. However, contrary to this theoretical expectation and to our hypotheses, state anger did not change significantly in this study, indicating a possible dissociation between neuroendocrine reactivity and observable emotional responses during real-world boxing performance. It is also worth noting that physical exercise itself is one of the most effective strategies for managing anger, because it promotes neurotransmitter synthesis, particularly of serotonin, which plays a key inhibitory role in anger and aggression [42]. Moreover, the relationship between competition and anger remains inconsistent across studies [43], which is likely attributable to differences in type of sport, competitive structure, and contextual demands [44]. Aggressive tendencies in sports have also been linked to broader sociocultural patterns of violence within specific disciplines, suggesting that anger expression may depend on factors beyond immediate physiological arousal [19]. Given this complexity in anger regulation, examining other emotional domains provides valuable insight into how athletes psychologically respond to competitive stress. In this regard, changes in emotional states paralleled, but did not directly mirror, the neuroendocrine patterns [35]. Both cognitive and somatic components of competitive anxiety increased significantly from pre- to post-competition, highlighting the anticipatory and reactive psychological burden experienced by athletes in real combat situations. This pattern aligns with previous research showing that competitive environments, particularly in high-intensity or contact sports, reliably elevate athletes' anxiety levels as they navigate performance demands, uncertainty, and outcome expectations [45–47]. However, as mentioned above, state anger did not change significantly, suggesting that anger may be less sensitive to acute competitive demands or more effectively regulated by experienced athletes. This dissociation implies that different emotional subsystems may be activated during boxing competitions, with anxiety particularly susceptible to competitive appraisal and outcome uncertainty.

Consistent with the study hypotheses, no significant associations were observed between hormonal reactivity and changes in anxiety or anger, despite clear hormonal and psychological changes across the competition. Neither sCor reactivity ($\Delta_{\text{pre} \rightarrow \text{post}}$) nor sTes reactivity ($\Delta_{\text{pre} \rightarrow \text{mid}}$) was correlated with changes in cognitive or somatic anxiety. This lack of association suggests that circulating hormone concentrations may not directly reflect subjective emotional states during acute competition. Rather, emotional responses may be influenced by cognitive appraisal, prior experience, and situational context, which may operate independently of acute peripheral endocrine fluctuations. This dissociation is consistent with previous evidence indicating that physiological and subjective stress responses do not always covary in competitive settings [37]. Taken together, these findings indicate that concurrent

changes in hormonal and emotional variables may follow distinct trajectories during competition, although causal relationships cannot be inferred from the present design. Rather than indicating a direct hormone–emotion coupling, emotional responses in athletes may be more strongly associated with contextual and cognitive factors than with acute hormonal fluctuations [48].

5. Limitations

This study has certain limitations that should be considered when interpreting the findings. First, sCor and sTes were collected at fixed time points, which may not fully capture rapid, dynamic fluctuations in endocrine responses occurring throughout competitive bouts. Second, although competition outcomes (i.e., winning versus losing) were recorded, they were not included in the primary analyses. This decision was made to maintain the focus on general psychophysiological responses to competitive stress rather than performance-related differences. In addition, the relatively small sample size and potential variability in opponent characteristics and bout dynamics limited the statistical power and interpretability of outcome-based comparisons. Third, including only male athletes limits the generalizability of the results to female boxers, among whom psychophysiological stress responses may differ due to sex-related hormonal and psychosocial factors. Finally, the relatively homogeneous, national-level competitive status of the sample may restrict the applicability of the findings to sub-elite or recreational athletes, who may exhibit distinct neuroendocrine and emotional responses to competitive stress.

6. Conclusion

This study demonstrates a temporal dissociation between neuroendocrine and emotional responses during real boxing competition in national-level athletes. While sCor and sTes exhibited clear phase-dependent reactivity, competitive anxiety increased independently of hormonal changes. These findings suggest that endocrine responses and subjective emotional states may operate through partially independent mechanisms under competitive stress. From a practical perspective, the present results do not support the use of isolated hormonal measurements to infer athletes' psychological state during competition. Instead, they reinforce the importance of integrating physiological and psychological assessments when monitoring competitive stress. Future research should examine these relationships using larger samples, more frequent measurements, and consideration of contextual factors such as competition outcome and athlete level to better understand their relevance for performance and applied practice.

Declarations

Ethics approval and consent to participate:

This study was approved by the Social and Humanities Research Ethics Committee of Karamanoğlu Mehmetbey University (Approval No: 09-2024/226). All participants provided written informed consent

prior to participation. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

Funding:

This study was supported by the Scientific Research Projects (BAP) Unit of Karamanoğlu Mehmetbey University (Grant No: 06-YL-24).

Author Contribution

BB: Conceptualization, Methodology, Data curation, Resources, Writing – review & editing, Visualization.
MM: Conceptualization, Methodology, Writing – review & editing, Supervision, Visualization. YM:
Conceptualization, Data curation, Formal analysis, Writing – original draft

Acknowledgement

The authors thank all athletes, coaches, and managers for their valuable cooperation and participation. This work was derived from the MSc dissertation of the first author, which was approved by the Department of Physical Education and Sports at the Institute of Health Sciences, Karamanoğlu Mehmetbey University.

Data Availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

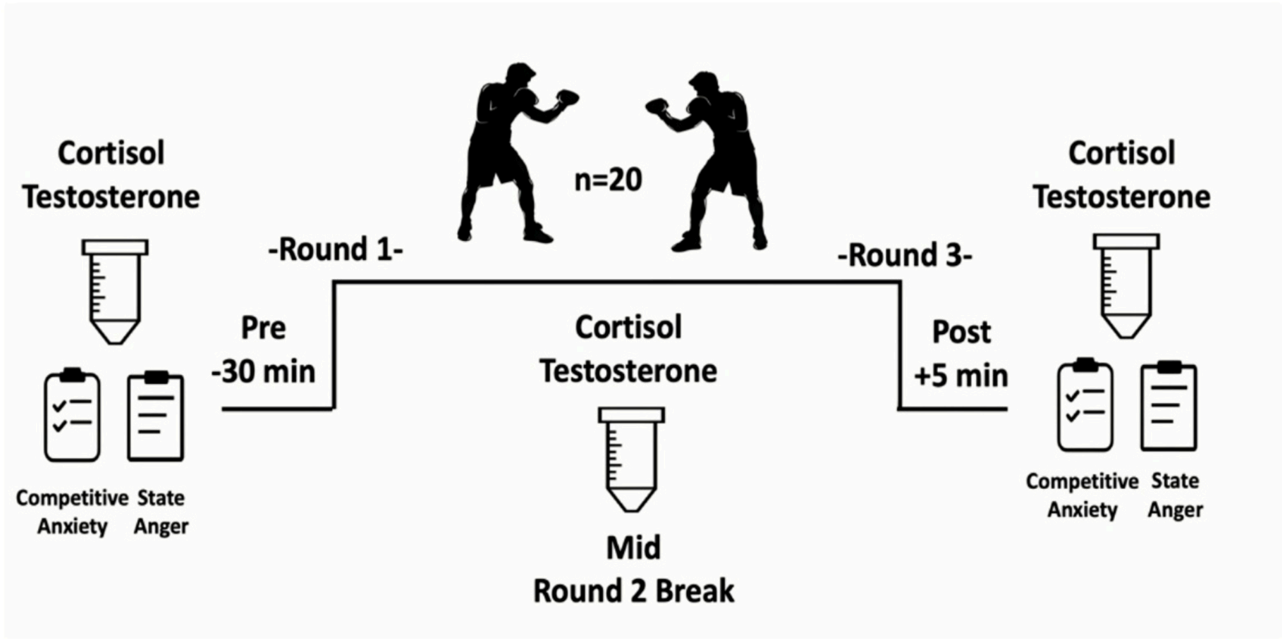


Figure 1

Experimental Design Overview

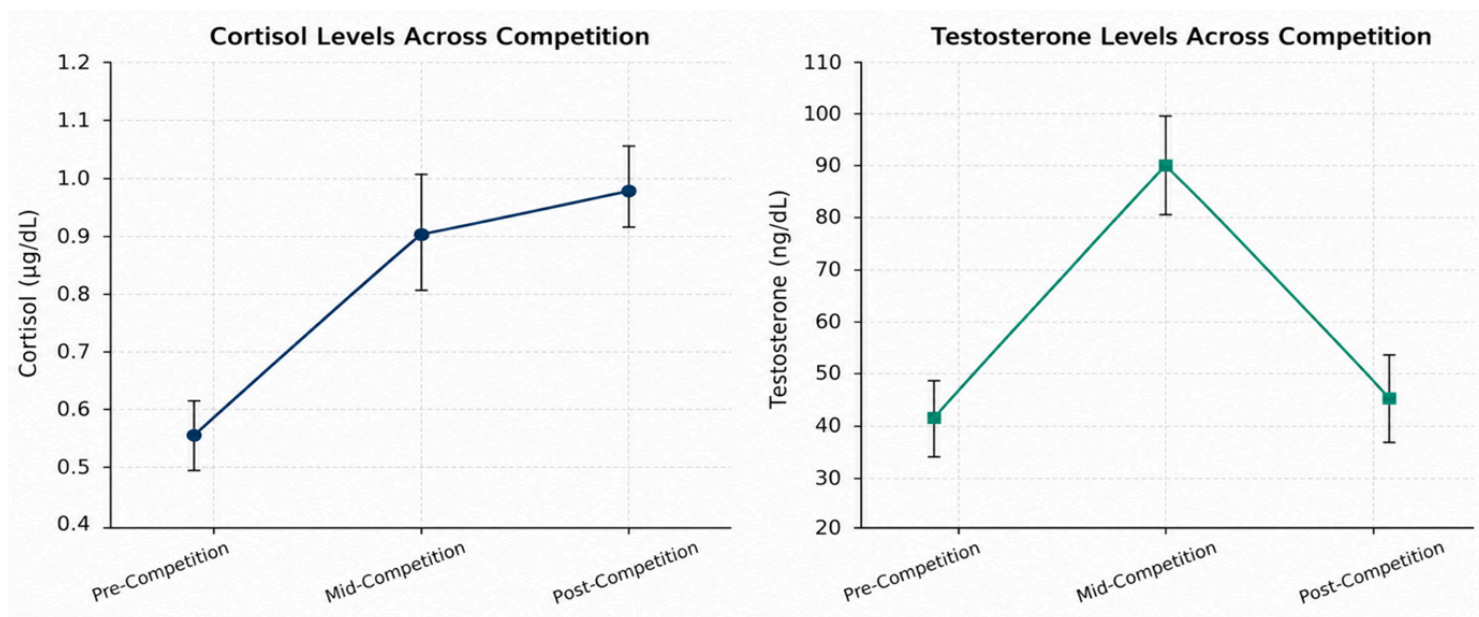


Figure 2

Mean sCor and sTes concentrations measured at three competition time points. Error bars indicate ± 1 SD. Both hormonal markers demonstrated a pronounced peak at mid-competition, reflecting acute psychophysiological activation during the bout.