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Article

Competitive Stress Elicits Distinct Psychophysiological and Immunological Responses in Elite Water Polo Players

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Abstract

Objectives: This study investigated the interplay between pre- and post-match physiological responses and subsequent emotional changes in elite male water polo players, focusing on differences between official championship (competitive) and non-competitive (training) settings. **Methods:** Sixteen male Italian Serie C water polo players participated. Salivary biomarkers (cortisol, immunoglobulin A (IgA), and uric acid) were measured, alongside psychological assessments of cognitive anxiety, somatic anxiety, and self-confidence. Measurements were taken before and after both training and competition matches. **Results:** A significant anticipatory rise in salivary cortisol was observed before competition matches compared to training, highlighting the psychological stress associated with competitive events. Post-match, cortisol levels remained elevated to a greater extent after competition. Salivary IgA levels decreased significantly following both training and competition, with a more pronounced reduction after official matches, and exhibited a negative correlation with cortisol. Salivary uric acid, a marker of oxidative stress, increased post-exercise and was significantly higher after competition. Players reported higher somatic and cognitive anxiety and lower self-confidence before competition compared to training, and pre-competition cortisol levels were positively correlated with both anxiety measures and negatively correlated with self-confidence. **Conclusions:** These findings highlight the distinct physiological and psychological responses elicited by competitive versus non-competitive settings in water polo, emphasizing the importance of considering the emotional context when monitoring athletes' stress and recovery. The social meaning of competitive contexts may be embodied, impacting stress and immune responses.

Keywords: competition stress; salivary biomarkers; cortisol reactivity; mucosal immunity (IgA); psychophysiological responses

1. Introduction

Water polo represents a high-intensity team sport characterized by significant metabolic, neuromuscular, and psychological demands [1]. The rigors of training and competition can lead to a spectrum of physiological states, ranging from acute fatigue to overreaching and, in severe cases, overtraining syndrome. While strategic overreaching can enhance performance, overtraining is associated with prolonged performance decrements [2]. Therefore, meticulous monitoring of individual athletes is essential to evaluate training-induced effects on well-being and performance,

facilitating the development of personalized recovery protocols. Individual biochemical parameters serve as valuable metrics for tailoring recovery strategies. Physical and psychological stressors engage multiple physiological systems, including the hypothalamic-pituitary-adrenal axis, the sympathetic nervous system, and the immune system. Corticotropin-releasing hormone (CRH) plays a central role in mediating these responses: activating the sympathetic nervous system, leading to an increased release of adrenaline, and enhancing cortisol production by stimulating the secretion of adrenocorticotrophic hormone (ACTH) from the pituitary gland [3]. Exercise-induced stress elicits biological responses that vary according to intensity, duration, and the athlete's training status. Extended or intense physical activity elevates serum cortisol, increases adrenaline and cytokine release, and decreases immunoglobulin A (IgA) at both salivary and serum levels [4–7]. Traditional biochemical assessments typically involve invasive blood sampling, often met with athlete reluctance. However, research demonstrates a strong correlation between plasma and salivary biomarker concentrations, indicating that salivary analytes reflect systemic physiological changes. Consequently, salivary analysis offers a non-invasive alternative for monitoring hormonal, immunological, and oxidative stress markers. This approach enhances athlete compliance and facilitates longitudinal monitoring, thus optimizing training and recovery interventions [4,8].

The relationship between endocrine activity and both mental and physical strain in athletes has been extensively studied, particularly when comparing individual and team sports [9]. In addition, cortisol levels are pivotal in the modulation of both systemic and neuroendocrine stress responses. Salivary cortisol quantification has been validated as a reliable proxy for assessing physiological and psychological stress induced by physical exercise [4,6,8–10]. Cortisol induces catabolic processes within skeletal muscle, impacting protein metabolism. This catabolic action facilitates the mobilization of free amino acids, which serve as supplementary substrates for oxidative phosphorylation during and post-exercise. This physiological response is crucial for homeostatic adaptation to stressors, such as those encountered during physical exertion [4,11].

Furthermore, salivary immunoglobulin A (IgA), a key component of mucosal immunity against exogenous pathogens within the upper respiratory tract, has been reported to exhibit a substantial reduction in football players following a competitive international match [12,13]. Notably, even a single training match can reduce salivary IgA, with considerable inter-individual variability [14,15].

Psychological adaptations, such as mood and emotional state, are shaped by the symbolic and socio-cultural context of competition. The concept of embodiment—rooted in phenomenology and expanded in anthropology and psychology—posits that cognitive and emotional processes are deeply rooted in lived bodily experience and shaped by social context [16]. This perspective allows for the examination of physiological and psychological responses as interdependent phenomena, with the body serving as the site where social-symbolic perceptions, expectations, and self-confidence are manifested. Morgan [17] introduced the Profile of Mood States scale (POMS) in sports, demonstrating that elite athletes typically exhibit high vigor and lower anger, tension, fatigue, depression, and confusion scores compared to population norms. However, athletes undergoing intense and strenuous training can shift POMS profile characterized by reduced vigor and increased tension, depression, anger, fatigue, and confusion [18].

The present study aimed to examine how emotions experienced in anticipation of a championship match influence neuroendocrine, oxidative, and immune changes in elite water polo players. These changes were compared with those observed before and after a standard training session (i.e., a friendly match), similar in intensity and duration. To achieve this, salivary cortisol, IgA, and uric acid levels before and after the various match sessions were measured. Finally, mood was assessed in the same context.

2. Materials and Methods

2.1. Saliva Sample Collection and Analysis

All analytical tests in this study were performed on saliva rather than blood, due to the noninvasive nature of saliva collection and the autonomy it provides participants. Saliva can be collected directly by the athlete, without the need for medical personnel, and in environments such as swimming pools.

Saliva samples were collected before (PRE; 15–20 minutes prior) and after (POST; 15–20 minutes following) two training match sessions (SESSIONS 1 and 3) and two official league matches (SESSIONS 2 and 4). All sessions were scheduled between 7:00 PM and 9:00 PM to minimize circadian variability in biomarker levels.

Participants were male water polo players competing in the Italian Serie C league. Sixteen players were selected: goalkeepers: $n = 2$, field players: $n = 10$, and center forwards: $n = 4$.

Saliva samples were obtained using cotton swabs and saliva collecting tubes (SARSTEDT S.r.l., Trezzano sul Naviglio, Milano, Italy). The athletes were instructed to place the cotton swab into their mouths, under the tongue, for 2 minutes. The absence of blood contamination was checked with a salivary blood contamination kit (Salimetrics LLC, Cambridge, UK). The saliva collecting tubes were centrifuged at 3000 rev/min for 10 minutes at 4 °C. After collection, the swabs were placed in special tubes, stored in a refrigerated bag at 4 °C for a maximum of 2 hours, and then were stored at -80 °C until they were assayed. To exclude inter-assay variance, all samples were thawed once and analysed in triplicate in the same assay run. As stated above, participants refrained from consuming any food, drinking hot fluids, or brushing their teeth for two hours before their arrival. Upon their arrival, before starting the training session, participants were asked to remain seated for 15 min before providing their resting sample (PRE), and subsequently, they completed the training/match sessions. At the end of the training/match session, they were asked to remain in a relaxed position (e.g., seated or standing) for 15 min until the collection time point (POST). Concentrations of cortisol were assessed by Enzyme immunoassay (EIA test, Pantex, Santa Monica, USA), IgA and uric acid (EMELCA Bioscience, The Netherlands) were assessed via enzyme-linked immunosorbent assays (ELISA), following manufacturers' instructions. For cortisol, the assay range was 0.1 ng/mL – 30 ng/mL, and the sensitivity 0.0392 ng/mL. For IgA, the range was 0.24-1,000 ng/mL, and the sensitivity was <0.24 ng/mL. Finally, for uric acid the range was 617.3-50,000 pg/dL with a sensitivity of 243.1 pg/dL. All samples were tested in duplicate. Intra-assay deviation was 6.3% for the EIA test and <10% for all ELISA kits.

2.2. Cognitive and Somatic Anxiety, and Self-Confidence Assessment

The Competitive State Anxiety Inventory-2 (CSAI-2) was utilized [19] to assess athletes' cognitive and somatic anxiety, as well as their self-confidence. Cognitive anxiety is understood as negative self-assessments and doubts regarding an athlete's performance capabilities. Somatic anxiety pertains to the athlete's awareness of physiological symptoms of anxiety, such as muscle tension and elevated heart rate [20]. The CSAI-2 comprises 27 items, divided into three subscales: cognitive anxiety, somatic anxiety, and self-confidence, each containing 9 items. Responses are recorded on a 4-point Likert scale, yielding subscale scores ranging from 9 to 36. Higher scores on the cognitive and somatic anxiety subscales indicate greater anxiety levels, while higher scores on the self-confidence subscale reflect increased self-confidence. Sample items include statements such as "I am concerned about this competition" (cognitive anxiety), "My body feels tense" (somatic anxiety), and "I am feeling self-confident" (self-confidence). Previous studies reported Cronbach's alpha coefficients of 0.89 for cognitive anxiety and 0.92 for both somatic anxiety and self-confidence [21]. All participants were familiarized with the questionnaire, which was integrated into the team's monitoring system by the coaching staff. Questionnaires were completed 15–20 minutes before and after each session. The factorial validity of the CSAI-2R was previously established by Cox et al. (2003) [22].

2.3. Statistical Analyses

Dependent variables were assessed for normality using the Shapiro-Wilk test. Statistical analyses were conducted in two phases. Changes in variables were analyzed PRE and POST for the first and last training sessions in both groups. Cortisol and uric acid were analyzed using repeated-measures ANOVA (RM-ANOVA) with SESSION (training vs. competition) and TIME (PRE vs. POST) as within-subjects factors.

To compare changes between PRE and POST values across sessions, the fold change (POST/PRE) was calculated for each parameter. The resulting Δ Cortisol, Δ IgA, and Δ Uric Acid values were compared using ANOVA with session (training vs. competition) as the factor. Significant interactions were further examined using Bonferroni post hoc tests. Statistical analyses were performed using Prism10 (GraphPad Software, Boston, USA). Data are presented as means \pm standard error. Statistical significance was set at $p < 0.05$.

Spearman correlation coefficients were calculated to examine relationships between anxiety components and hormonal parameters. All analyses used an alpha level of 0.05.

3. Results

3.1. Salivary Cortisol Levels

Salivary cortisol levels ($\mu\text{g/mL}$) were analyzed using two-way repeated measures ANOVA, revealing significant effects of session type (training vs. competition) [$F(1,49) = 2.021$; $p < 0.001$], time (PRE vs. POST) [$F(1,49) = 57.713$; $p < 0.001$], and their interaction [$F(1,49) = 61.661$; $p < 0.001$].

Bonferroni post hoc tests indicated a significant increase in salivary cortisol from PRE to POST in all sessions: PRE 1: $0.382 \pm 0.063 \mu\text{g/mL}$, POST 1: $0.603 \pm 0.100 \mu\text{g/mL}$ ($p = 0.048$); PRE 2: $0.570 \pm 0.109 \mu\text{g/mL}$, POST 2: $1.163 \pm 0.273 \mu\text{g/mL}$ ($p = 0.011$); PRE 3: $0.317 \pm 0.085 \mu\text{g/mL}$, POST 3: $0.854 \pm 0.343 \mu\text{g/mL}$ ($p = 0.030$); PRE 4: $0.801 \pm 0.214 \mu\text{g/mL}$, POST 4: $3.057 \pm 0.807 \mu\text{g/mL}$ ($p < 0.001$) (Figure 1A).

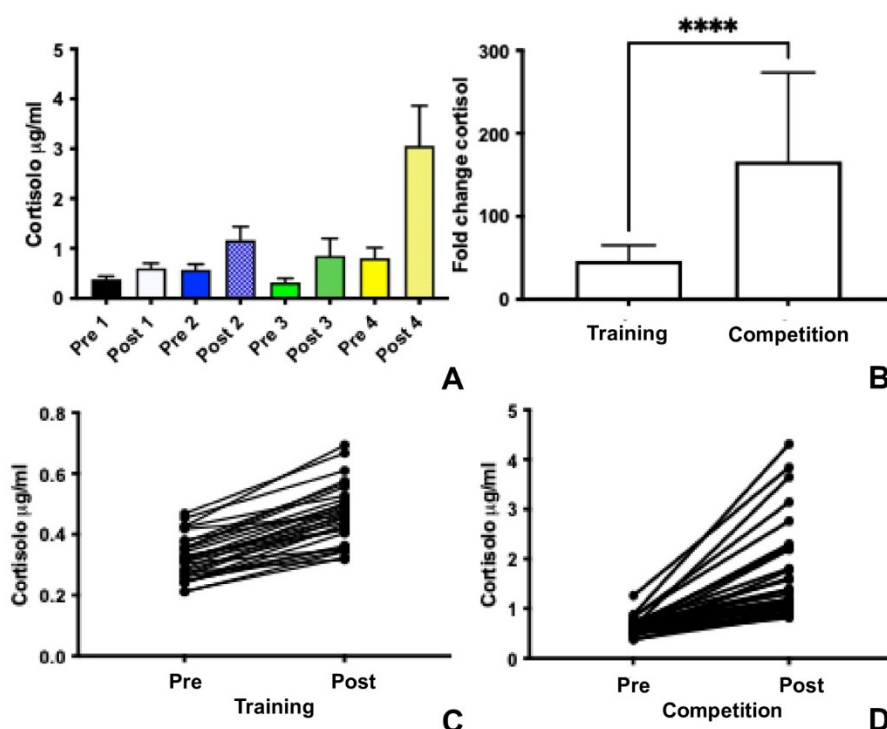


Figure 1. Cortisol values and $\Delta\%$ cortisol. Panel A. Cortisol values before (PRE) and after (POST) training sessions (PRE 1 and 3, POST 1 and 3) and competition sessions (PRE 2 and 4, POST 2 and 4). Panel B. $\Delta\%$ Cortisol of training (left) and competition sessions (right). Panels C and E. Pre and post cortisol values, respectively for training and competitive sessions. Data are presented as means \pm standard error.

Overall, competition matches elicited a greater increase in salivary cortisol than training sessions: PRE-training: $0.349 \pm 0.080 \mu\text{g/mL}$, POST-training: $0.728 \pm 0.276 \mu\text{g/mL}$ ($p < 0.001$); PRE-competition: $0.686 \pm 0.203 \mu\text{g/mL}$, POST-competition: $2.110 \pm 1.138 \mu\text{g/mL}$ ($p = 0.001$) (Figure 1C,D).

The percentage change in cortisol ($\Delta\%$ cortisol) was significantly higher during competition ($201.2 \pm 125.7\%$) compared to training ($131.0 \pm 138.3\%$; $p = 0.013$) (Figure 1B).

3.2. Salivary IgA Levels

Salivary IgA concentrations ($\mu\text{g/mL}$) were analyzed using two-way repeated measures ANOVA, revealing significant effects of session type [$F(1,49) = 3.199$; $p = 0.007$], time [$F(1,49) = 58.710$; $p < 0.001$], and their interaction [$F(1,49) = 124.241$; $p < 0.001$]. The large SESSION \times TIME interaction reflects the consistency of IgA suppression across repeated competitive sessions rather than an overestimation driven by outliers, as evidenced by comparable variance and directionality of responses across all sessions.

Bonferroni post hoc tests showed that IgA levels decreased significantly from PRE to POST in both training and competition sessions: PRE 1: $249.40 \pm 43.02 \mu\text{g/mL}$, POST 1: $170.81 \pm 27.82 \mu\text{g/mL}$ ($p = 0.001$); PRE 2: $271.33 \pm 26.88 \mu\text{g/mL}$, POST 2: $176.30 \pm 25.53 \mu\text{g/mL}$ ($p < 0.001$); PRE 3: $375.82 \pm 19.92 \mu\text{g/mL}$, POST 3: $155.83 \pm 18.92 \mu\text{g/mL}$ ($p < 0.001$); PRE 4: $380.44 \pm 64.01 \mu\text{g/mL}$, POST 4: $186.00 \pm 27.82 \mu\text{g/mL}$ ($p < 0.001$) (Figure 2A).

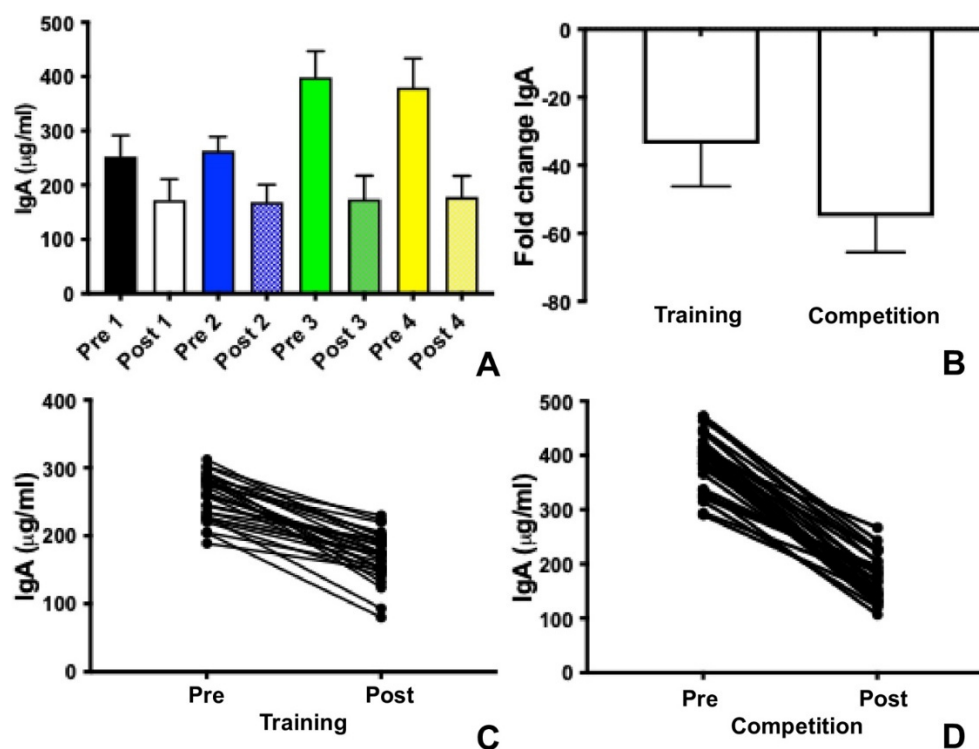


Figure 2. IgA values and $\Delta\%$ cortisol. Panel A. IgA values before (PRE) and after (POST) training sessions (PRE 1 and 3, POST 1 and 3) and competition sessions (PRE 2 and 4, POST 2 and 4). Panel B. $\Delta\%$ IgA of training (left) and competition sessions (right). Panels C and E. Pre and post IgA values, respectively for training and competitive sessions. Data are presented as means \pm standard error.

When pooling all training and all competition sessions, IgA levels were consistently lower after activity: Training: $260.30 \pm 36.45 \mu\text{g/mL}$ (PRE) vs. $173.50 \pm 25.95 \mu\text{g/mL}$ (POST), $p < 0.001$; Competition: $378.10 \pm 54.47 \mu\text{g/mL}$ (PRE) vs. $165.90 \pm 29.17 \mu\text{g/mL}$ (POST), $p < 0.001$ (Figure 3C,D).

The percentage change in IgA (ΔIgA) was significantly greater during competition ($-55.36 \pm 9.70\%$) than during training ($-32.60 \pm 10.36\%$; $p < 0.001$) (Figure 2B).

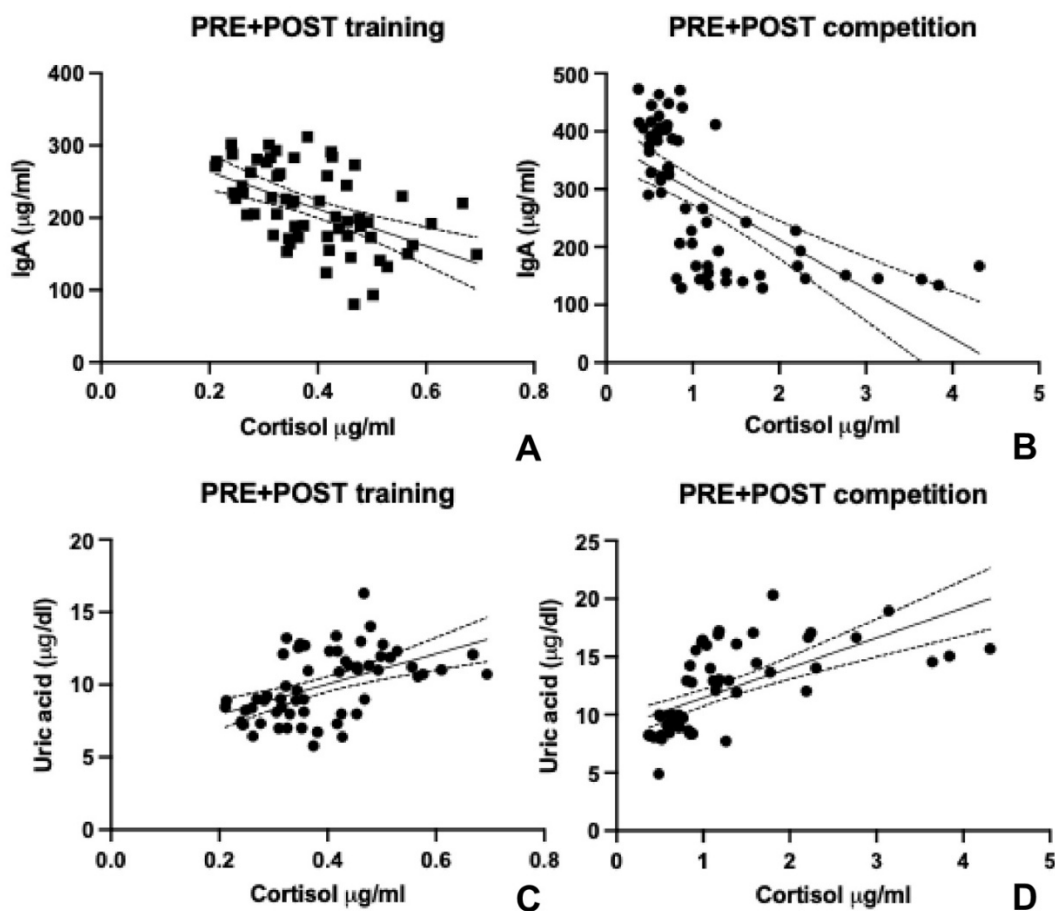


Figure 4. Relationship among Cortisol, IgA, and uric acid values after training and competition matches. A significant negative relationship appeared between cortisol and IgA values during PRE- and POST-training matches (panels A and B, respectively). On the contrary, a positive relationship between cortisol and uric acid in the same experimental conditions (panels C and D).

3.4. Relationships Among Cortisol, IgA, and Uric Acid

A significant negative relationship between cortisol and IgA values during PRE- and POST-training matches was evident: the higher the PRE- or POST cortisol values, the lower the PRE- or POST IgA values ($r = -0.454$, $p = 0.009$). Similar results were obtained comparing cortisol and IgA values PRE or POST competition matches ($r = -0.541$, $p = 0.001$) (Figure 4A,B).

Conversely, a positive relationship between cortisol and uric acid was observed (Figure 4C,D), both comparing values during the training matches ($r = 0.534$, $p = 0.009$) than during the competition matches ($r = 0.515$, $p < 0.001$).

3.5. Psychological Measures

CSAI-2 questionnaire results are summarized in Table 1. Significant differences were observed between training and competition matches for both pre- and post-session somatic and cognitive anxiety, with higher values during competition.

Somatic anxiety differed significantly between pre- and post-session for both training ($p < 0.001$) and competition ($p = 0.002$). Cognitive anxiety also differed significantly between pre- and post-session for training ($p = 0.003$) and competition ($p = 0.005$).

Self-confidence scores were significantly lower before than after both training and competition ($p < 0.001$ for both). Furthermore, self-confidence was significantly lower during competition sessions compared to training ($p < 0.001$).

Table 1. Somatic, cognitive, and self-confidence score values obtained during training and competitive situations. Data presented as mean \pm Standard deviation.

Condition	Somatic anxiety		Cognitive anxiety		Self-confident	
	Pre	Post	Pre	Post	Pre	Post
Training	11.63 \pm 3.22	16.00 \pm 3.63	11.06 \pm 1.57	13.19 \pm 2.76	25.13 \pm 3.14	20.13 \pm 3.13
Competition	12.38 \pm 3.46	16.50 \pm 3.06	11.88 \pm 1.41	13.56 \pm 1.54	22.19 \pm 3.23	19.13 \pm 3.12

3.6. Correlations Among Psychological Parameters and Cortisol

Correlation analyses were conducted to examine the relationship between CSAI-2 components and salivary cortisol concentrations measured before and after different sessions, both in training and competitive matches (Figure 5). Cortisol concentrations were significantly positively correlated with CSAI-2 somatic anxiety in both training and competitive sessions ($r = 0.548$, $p < 0.001$, and $r = 0.572$, $p < 0.001$). Similarly, cortisol was positively correlated with CSAI-2 cognitive anxiety in both training ($r = 0.548$, $p < 0.001$) and competition ($r = 0.524$, $p < 0.001$) sessions.

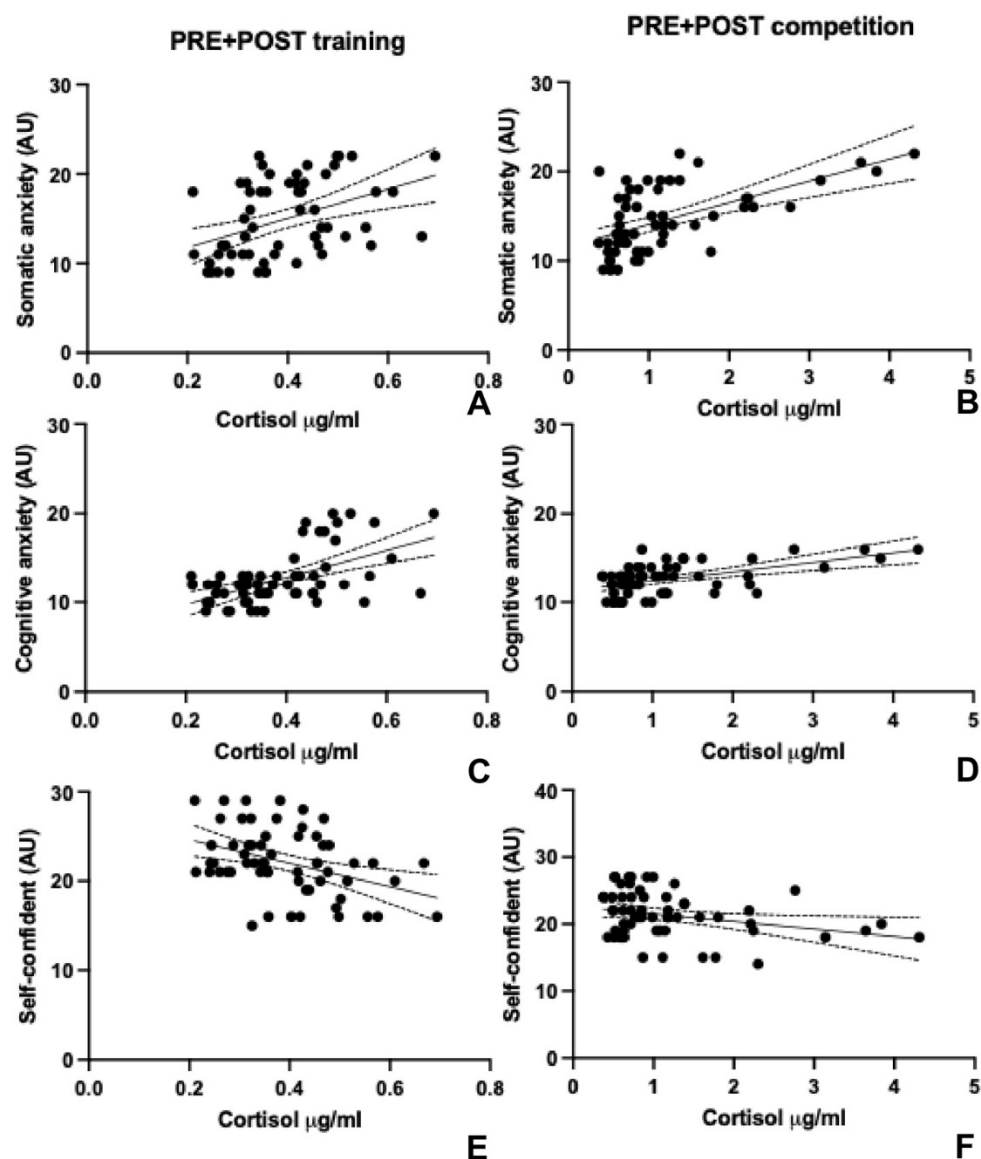


Figure 5. Correlations among psychological parameters and cortisol. Positive correlations between salivary cortisol concentrations and (A, B) somatic anxiety, (C, D) cognitive anxiety, and an inverse correlation between cortisol levels and self-confidence in elite water polo players, measured before and after training and competition matches. AU = Arbitrary Units.

Cortisol levels were negatively correlated with CSAI-2 self-confidence during training sessions ($r = -0.473$, $p = 0.005$). During competition, this negative correlation was present but did not reach statistical significance ($r = -0.288$, $p = 0.026$).

4. Discussion

It is widely established that challenges encountered during one's working life (i.e., unemployment, low salary, particularly demanding work activities) can be associated with an increased risk of developing health issues [23,24]. Similarly, prolonged and intense physical activity, such as that induced by official sports competitions, elicits stress levels and influences the immune responses of athletes differently compared to non-competitive activities [23–27]. This confirms the relationship between hormonal and immunological alterations and aggressive and offensive behaviours expressed during the game [25–27].

The present research investigates the influence of emotional processes that characterize the anticipation phase of training/competition (“friendly/official”) matches on specific hormonal, immunological, and oxidative stress responses that manifest during a match in a team of professional water polo players. The objective was therefore to evaluate the stress response in elite water polo athletes during a training and a competitive session. Furthermore, under the same conditions, the effect on the mucosal immune response was evaluated by measuring salivary IgA levels and the state of oxidative stress by assessing uric acid levels.

Before the competition match, salivary cortisol levels increased more than those observed before the training session. These results are consistent with various studies indicating that anticipatory psychological stress associated with competition triggers cortisol secretion [4,6,8–10,13,14]. In both cases, an increase in cortisol levels is evident; however, in the case of a formal competition, the rise is significantly higher. Elevating cortisol concentrations in the pre-competitive phase plays a salient role in activating competitive motivation and mobilizing physiological resources necessary to prepare the athlete for the impending event. Thus, the anticipatory increase of salivary cortisol occurs before sports competition, characteristic of athletes under psychosocial and physical stress conditions. Cortisol levels were also elevated after the competition compared to the training session. This substantial increase in cortisol and, consequently, the decrease in IgA, can be interpreted through the lens of embodiment. This response is not merely an objective physiological measurement but a manifestation of symbolic perception and social relations: the body reflects the different meanings and social dynamics between a friendly match and a formal competition in the form of physiological changes following the event. Furthermore, an increase in cortisol levels was observed at the end of training, albeit of lesser magnitude, during the resting period (pre-training match). In summary, a significant variation in cortisol levels was also reported before and after training and on the day of competition. These data are consistent with previously reported findings [28,29], highlighting cortisol elevation's positive role in cognitive processes.

Several scientific studies show that hormone levels in athletes (like testosterone and cortisol) can change depending on how skilled they are in their sport, whether they are male or female, their role on the team, and how well they play. Often, top-level athletes have more testosterone (a hormone that helps build muscles) and less cortisol (a hormone linked to stress), while less experienced athletes might have the opposite reaction [11,30]. In water polo, each player's time in the water can vary greatly. So, how long they play, what their job is on the team, and how much their body works can all affect their stress response in different ways [31]. Changes in hormones after exercise can indicate if an athlete is training too hard (a phase called “overreaching” or “overtraining”). The ability to measure these things in the saliva of high-level athletes, because it's similar to what is found in the blood, makes these kinds of studies much easier. Often in elite water polo players, these levels change after matches, but luckily, they don't reach dangerous levels. It's interesting to note that cortisol levels were higher in the later stages of training or competitive matches compared to the first, perhaps because their bodies were preparing for the upcoming competitions. Finally, there is also a link between stress hormones, like what has been seen in soccer players [10,13,30,31].

It is well-established that intense physical activity also induces alterations in the body's defence mechanisms against illness. Of particular significance is mucosal immunity, primarily mediated by the production of IgA: the initial barrier against pathogens that can enter our body and lead to respiratory tract infections [32]. Several studies have indicated that in the saliva of athletes participating in team sports, IgA levels fluctuate depending on the season, the significance of a match, and the intensity or type of physical exertion [32–36]. Furthermore, the mucosal immune response may differ between competitive athletes and non-athletes, likely associated with the varying levels of physiological stress experienced [37]. These differences in immune responses can also be interpreted through the lens of embodiment, as the psychological perception of stress, particularly about the symbolic meaning of competition, may shape physiological reactions in distinct ways between competitive and non-competitive individuals. In the present study, IgA levels decreased following both training and competition, but the magnitude of reduction was significantly greater after official matches. This finding suggests that competitive stress exacerbates exercise-induced mucosal immunosuppression. Notably, IgA concentrations were inversely correlated with cortisol levels in both training and competitive contexts. This relationship supports the hypothesis that stress-related glucocorticoid activation contributes to transient immune suppression, although previous studies have reported heterogeneous results. The robustness of the IgA response is further supported by the consistent direction and magnitude of suppression observed across all competitive sessions. The results we obtained are very similar to previous reports [37–39]. However, this correlation is not always straightforward. Some studies highlight that a clear link between salivary IgA and cortisol is not always evident [34–39]. Therefore, the relationship between IgA and cortisol may depend on various factors, such as the intensity of stress, the duration of exercise, the type of sport, and individual differences. Further research is needed to better understand the relationship between IgA and salivary cortisol.

While regular/moderate physical exercise or recreational sports activity significantly improve redox parameters and confer numerous health benefits, intense exercise/competitive sport can generate an excess of oxidative stress, potentially leading to damage to the organism [4–7,40]. We evaluated oxidative stress using salivary uric acid as a biomarker, given that the oxidation of salivary proteins represents the first line of defence against free radicals in oral tissues [4]. Our observations indicated that salivary uric acid levels increased post-exercise and were significantly higher in pre-/post-competition sessions compared to pre-/post-training matches. Uric acid levels were positively correlated with salivary cortisol concentrations. It is known that cortisol increases concurrently with elevated oxidative stress following acute exercise [4,40].

Regarding the anxiety components, we found significant differences when comparing training and competitive sessions. Specifically, players exhibited greater somatic and cognitive state anxiety and lower self-confidence in the pre-competitive phase compared to the training phase. These results are consistent with other studies that have demonstrated significant game effects on cognitive and somatic state anxiety, as well as self-confidence in various sports [41–43]. Somatic state anxiety is related to the perception of physiological responses to psychological stress [28,44]. Additionally, cognitive anxiety, which is associated with fear about the consequences of failure [45,46], was reported to be higher in competitive sessions compared to training sessions. These findings are consistent with recent research in other sports, suggesting the anxiogenic nature of sports competitions [28,40–47]. Moreover, the high-anxiety state observed was concurrent with the anticipatory response of salivary cortisol, confirming the previously described relationship between cortisol and competition-related negative mood [28,40–47]. Therefore, cortisol concentrations before competitive sessions were significantly and positively correlated with cognitive and somatic anxiety scores. Finally, for the self-confidence parameter, and consistent with other studies [28,40–47], players showed higher values in the pre-training compared to the competitive sessions, further confirming the psychological disturbances induced by competitive situations, which were detected early through the reported physiological anticipatory responses. Finally, elevated pre-competition anxiety levels and associated cortisol increases, contrasted with lower self-confidence, suggest a potential

psychological state that could negatively impact decision-making processes during critical championship water polo matches compared to training scenarios. In addition, the elevated levels of pre-competition anxiety and the associated increase in cortisol, coupled with lower self-esteem, suggest a potential psychological state that may negatively affect decision-making processes during crucial water polo matches, as opposed to training scenarios. The importance of considering the concept of embodiment in psychological experiences and how these are expressed through the body, has been illustrated in this study by highlighting the strong relationship between anxiety, cortisol levels, and decision-making. This relationship becomes visible using various biomarkers. Altogether, these findings contribute to a deeper understanding of the human condition, showing how objective data and subjective experiences are deeply interconnected and, when examined together, can offer a more comprehensive perspective in behavioral and physiological research.

The relationship between cortisol, anxiety, and decision making in sports is complex and multifactorial. During sports competitions, cortisol levels increase in response to anticipatory stress, preparing the athlete for the psychological and physiological demands of the competition. Somatic anxiety is related to the perception of physiological responses to psychological stress, such as increased heart rate and muscle tension [27,28]. Cognitive anxiety, on the other hand, is associated with fear of the consequences of failure. Moderate levels of cortisol can have a positive effect on sports performance, improving cognitive processes, and attention control [28]. However, excessively high or low levels of cortisol can have debilitating effects, reducing the inhibition of irrelevant stimuli for the task, and compromising performance [28]. On the other hand, elevated cortisol levels can lead to a decrease in muscle mass, compromised recovery, and reduced energy levels, negatively affecting sports performance [28].

Anxiety can negatively influence decision making in sports, as it can reduce the ability to concentrate and increase the tendency to make impulsive decisions [47]. Cognitive anxiety can lead to greater concern about the consequences of failure, negatively affecting the ability to make quick and accurate decisions [47]. Managing anxiety through relaxation techniques and psychological interventions can improve decision making, helping athletes maintain calm and concentration during competitions [47].

5. Conclusions

This study on elite water polo players highlights the significant physiological and psychological impact of competitive matches compared to training sessions. The anticipation and execution of a championship game elicited a more pronounced stress response, evidenced by greater increases in salivary cortisol and uric acid, coupled with a more substantial decrease in salivary IgA. These biochemical alterations were intertwined with the athletes' psychological states, as heightened cognitive and somatic anxiety and diminished self-confidence were observed before competition. The positive correlations between cortisol and both cognitive and somatic anxiety underscore the close interplay between the neuroendocrine and psychological responses to competitive stress. Furthermore, the inverse relationship between cortisol and IgA suggests a potential link between stress and mucosal immunity in this athletic population. Thus, competitive experiences seem to be socially constructed and embodied, as athletes' perceptions of the game context are translated into measurable physiological responses. These findings emphasize the importance of considering both physiological and psychological markers when monitoring the well-being and performance of water polo players, particularly in the context of high-stakes competitions. Future research could explore personalized interventions targeting these stress responses to optimize athlete preparation and recovery. The anticipation and execution of a championship game elicited a more pronounced stress response, evidenced by greater increases in salivary cortisol and uric acid, coupled with a more substantial decrease in salivary IgA. These biochemical alterations were intertwined with the athletes' psychological states, as heightened cognitive and somatic anxiety and diminished self-confidence were observed before competition. The positive correlations between cortisol and both cognitive and somatic anxiety underscore the close interplay between the neuroendocrine and

psychological responses to competitive stress. Furthermore, the inverse relationship between cortisol and IgA suggests a potential link between stress and mucosal immunity in this athletic population. These findings emphasize the importance of considering both physiological and psychological markers when monitoring the well-being and performance of water polo players, particularly in the context of high-stakes competitions. Once more, these findings suggest that competitive experiences are socially constructed and embodied, with athletes' perceptions of the game context being translated into measurable physiological responses. Future research could explore personalized interventions targeting these stress responses to optimize athlete preparation and recovery.

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