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Predictive Value of Salivary Cortisol for Pre-Event Anxiety in Elite University Athletes

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Abstract
This study investigated the predictive value of salivary cortisol for pre-event anxiety among elite athletes in three contact sports, to inform effective personalized psychological interventions tailored to sport and gender. Twenty-four elite university athletes (12 female, *M* = 36.40; 12 male, *M* = 35.38) participated, comprising 10 footballers (*M* = 37.64, *SD* = 4.03), 7 judokas (*M* = 34.91, *SD* = 4.17), and 7 boxers (*M* = 34.23, *SD* = 5.96). Saliva samples were collected at two time points, eight weeks apart at 9:00 a.m., to control for diurnal cortisol variation, and analyzed using the ELISA protocol. T-tests and ANOVA were used to determine statistical significance at the 0.05 level. Results showed that salivary cortisol level in unit per milliliter (U/ml) significantly predicted pre-event anxiety ($t(46) = -12.03$, $p < .05$), with no significant differences between genders ($t(21) = 0.59$, $p > .05$) or sports ($F(2, 21) = 1.28$, $p > .05$). Although females and football athletes reported slightly higher anxiety levels, the predictive utility of cortisol remained consistent. The study concludes that salivary cortisol is a valid, gender-neutral biomarker for assessing pre-competitive stress. Sport psychologists should be trained to recognize behavioural cues associated with elevated cortisol and HPA axis activation to inform individualized interventions.

Keywords: Elite University Athletes, Individualized Intervention, HPA Axis, Pre-Event Anxiety, Salivary Cortisol

Introduction

Psychological preparedness before a significant event frequently determines the difference between exceptional performance and subpar performance in the high-pressure setting of competitive sports, especially for elite university athletes. Performance-related anxiety, a psychological state that can both inspire and impede athletic output, is a growing problem for athletes as competition intensity and expectations increase. The need for more objective, physiological measures of anxiety has prompted the inclusion of biomarkers, especially salivary cortisol, in sports psychology research (Lindsay & Costello, 2017), even though conventional assessment instruments like self-reported questionnaires provide insights into athletes' perceived anxiety levels (Saw et al., 2017). One well-researched biomarker associated with triggering the hypothalamic-pituitary-adrenal (HPA) axis, which controls the body's reaction to stress, is salivary cortisol. Psychological states like anxiety, fear, and arousal have been repeatedly linked to elevated cortisol levels, especially when competition is imminent (Noushad et al., 2021; Van Paridon et al., 2017). Compared to conventional techniques, cortisol, a hormone that represents the body's physiological reaction to stress, provides a more objective and measurable indicator of an athlete's psychological state (Hutchison et al., 2017). This is especially crucial in competitive sports settings, where athletes might not disclose their anxiety because they fear stigma or being seen as weak (Kudielka & Kirschbaum, 2005).

Several sports disciplines have provided evidence in favour of cortisol's ability to predict anxiety. Filaire et al. (2009) found a positive correlation between self-reported cognitive and somatic anxiety and elevated cortisol levels before competition in taekwondo and judo athletes. Similarly, research on rugby and football players has shown notable

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variations in cortisol levels before competition, underscoring the hormone's function in preparing the athlete for the demands of both psychological and physical conflict (Moreira et al., 2012). These studies have not, however, consistently examined whether this predictive relationship differs for gender or sports with different physical and psychological demands, which motivated this study.

The degree of psychological and physiological arousal evoked by various sports, especially contact sports, varies. For instance, the rules and physical requirements of taekwondo, basketball, and rugby vary, as do the mental states they arouse (Nabilpour et al., 2023). Because of the physical aggression and strategic complexity of rugby, as well as the possibility of injury and confrontational play, rugby frequently causes elevated anticipatory anxiety (Hill et al., 2016). Basketball demands quick decisions and constant concentration in a fast-paced setting, which may cause anxiety related more to team dynamics and performance pressure (Sighinolfi et al., 2020). As a combat sport, taekwondo may elicit a distinct kind of anticipatory arousal based on personal responsibility and one-on-one physical confrontation (Slimani et al., 2017). Similar to stressors, these differences imply that cortisol responses and their ability to predict pre-event anxiety may differ among sports. Additionally, the literature on psych neuroendocrinology has consistently documented gender differences in stress reactivity. According to Lopez et al. (2018), women typically show increased HPA axis sensitivity to social-evaluative stressors, which can result in higher cortisol levels during performance situations. Males, on the other hand, might react physiologically more strongly to stimuli that are physically threatening. These sex-based variations suggest that gender-specific considerations may be necessary when interpreting cortisol levels as markers of anxiety before an event. For instance, a spike in cortisol in a female athlete might indicate anxiety about being judged by the audience; in a male athlete, it might be more associated with physical conflict. The current study's investigation finds fertile ground in the intersection of gender and sport-specific contexts.

A larger trend towards precision-based approaches to athlete care is reflected in the growing use of salivary biomarkers in sports psychology. It is now believed that biomarkers like cortisol, alpha-amylase, and chromogranin A can provide objective, real-time assessments of psychological states, enabling more specialised psychological care (Casto & Edwards, 2016). Cortisol is unique among these due to its broad validation and simplicity of collection, particularly in field settings such as pre-game environments. Because salivary cortisol is non-invasive (Clow & Smyth, 2020), it can be used repeatedly without changing the athlete's condition or performance, giving a genuine look at how the body reacts to stress. Few studies have systematically investigated how salivary cortisol predicts anxiety differently across contact sports or gender, despite the growing body of research on this biomarker and sports anxiety (van Paridon et al., 2017). Most current research ignores the complex interactions between individual differences and sport-specific stressors by concentrating on homogeneous populations or single-sport samples (van Paridon et al., 2017). This limitation has real-world ramifications because sport psychologists may misinterpret physiological cues and develop generic or ineffective interventions if there is a lack of knowledge on how cortisol's predictive validity varies. The current study fills this gap by providing a more accurate lens through which salivary cortisol can be interpreted in particular demographic and competitive contexts.

Additionally, university athletes are a distinct demographic. They frequently balance athletic and academic obligations, resulting in a compounded stress that may intensify their competitive physiological and psychological reactions. Especially in institutions where little preference is given to a sport psychologist as an official member of the coaching crew, university athletes frequently lack access to tailored mental health resources, in contrast to professional athletes who enjoy the advantages of specialised psychological support. If and when eventually considered, the lack of quality time and data on the psychological condition of the athletes leaves a sport psychologist with generalized intervention to be applied to athletes instead of a well-tailored, personalized intervention programme. This study aims to determine the predictive power of salivary cortisol on pre-event anxiety of elite university athletes by gender and three contact sports, namely boxing, football, and Judo. This study aims to equip practitioners with a dual assessment framework that combines biological data and observable behaviour for a more individualised and successful intervention by identifying cortisol as a physiological dictator of these observable signs. It may therefore help develop scalable, low-cost mental readiness techniques based on physiological data and adapted to the demands of collegiate athletic environments.

Hypotheses

The study hypothesized that among elite university athletes, salivary cortisol would not be an accurate predictor of pre-event anxiety. Additionally, it was assumed that this predictive relationship would not change among the three contact sports under investigation or between male and female athletes.

Material and Methods

This study employed a one-group pre-test post-test true-experimental design to investigate the predictive relationship between salivary cortisol levels and pre-event anxiety in elite university athletes. The study purposively sampled 24 elite university female (M= 36.40) and male (M= 35.38) athletes, consisting of 10 footballers (M= 37.64, SD= 4.03), 7 judokas (M= 34.91, SD= 4.17), and 7 boxers (M= 34.23, SD= 5.96). The sports were chosen due to their high-intensity nature and potential for strong pre-event anxiety. Saliva samples were collected from each consenting participant at two time points: 8 weeks before the major competition (baseline) and an hour before the game commenced (pre-event). Samples were collected at 9:00 am to control for diurnal variations in cortisol levels using cryogenic vials suitable for ultra-low temperatures. They were stored under -80°C sample storage conditions till the day of the analysis. This study was approved by the institutional ethics committee before its commencement. All participants provided informed consent and confidentiality was maintained throughout the study. The ELISA kit used was the Sunlong Biotech Company Human Cortisol ELISA Kit (CSL0526Hu). This kit has a sensitivity of 1.5U/ml and specificity of 95% with a detection range of 8U/ml – 400U/ml. the assay was performed according to the manufacturer's instructions and samples were prepared as recommended. Descriptive statistics were used to summarize participant characteristics and salivary cortisol levels. Inferential statistics of t-test was used to compare means between two groups (e.g., male vs. female, or pre-event vs. baseline) and an ANOVA to compare means across multiple groups (e.g., sports: football, judo, and boxing) at a 0.05 significance level.

Results

Table 1: T-test Summary on Difference in the Baseline and Pre-event Data of Salivary Cortisol Predictions of Pre-event Anxiety among Elite University Athletes

Cortisol	N	Mean (U/ml)	SD	Std. Error Mean	T	df	P
Baseline	24	18.55	5.19	1.06	-12.03	46	0.000
Pre-Event	24	35.85	4.76	.97			

Table 1 reveals the t-test result of the difference in the baseline and pre-event data of salivary cortisol predictions of pre-event anxiety among elite university athletes (t= (46) -12.03, $p < .05$). The p-value is below the threshold, leading to the rejection of the null hypothesis. Therefore, salivary cortisol significantly predicts pre-event anxiety levels among elite university athletes.

Table 2: T-test Summary on Salivary cortisol predictions of pre-event anxiety by Gender

Gender	N	Mean (U/ml)	SD	Std. Error Mean	T	df	P
Female	11	36.40	5.03	1.5			
Male	13	35.38	4.66	1.29327	0.59	20.69	0.62

Table 2 shows the t-test result of the gender difference of salivary cortisol predictions of pre-event anxiety among elite university athletes (t (21) = 0.59, $p > .05$). The p-value is above the threshold, leading to non-rejection of the null hypothesis. Therefore, there is no significant difference in salivary cortisol prediction of pre-event anxiety between male and female elite university athletes, although females had a higher mean score (36.40) than male participants (35.38).

Table 3: ANOVA Summary of the Test of Significance Difference in Salivary Cortisol Predictions of Pre-event Anxiety by Sports

ANOVA	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	56.57	2	28.29	1.28	.29
Within Groups	463.93	21	22.09		
Total	520.50	23			

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Table 3 expresses the ANOVA result of the difference in salivary cortisol's predictions of pre-event anxiety among elite university athletes' sports (f (2, 21) = 1.28, p > .05). The p-value is above the threshold, leading to non-rejection of the null hypothesis. Therefore, there is no significant difference in salivary cortisol prediction of pre-event anxiety among elite university athletes across three contact sports.

Discussion

This study investigated the predictive value of salivary cortisol for pre-event anxiety among elite university athletes. The first hypothesis, which compares baseline and pre-event data, found that among elite university athletes, salivary cortisol significantly predicts pre-event anxiety levels. This suggests that the physiological measure of anxiety that athletes experience in the moments leading up to competition is salivary cortisol. The conclusion that cortisol reactivity correlates with psychological readiness or stress is supported by the fact that cortisol levels at baseline (i.e., at rest or outside the context of competition) differ significantly from those measured pre-event (i.e., shortly before competition) and that this difference can accurately predict athletes' reported anxiety levels. The result is supported by a growing body of empirical research examining the psychophysiological responses to competitive stress. Cortisol, a glucocorticoid hormone released by the hypothalamic-pituitary-adrenal (HPA) axis, serves as a biomarker for stress and has been linked to anxiety levels in athletes preparing for competition. In a study by Cintineo and Arent (2019), Division I collegiate wrestlers exhibited higher salivary cortisol and state anxiety levels before competition compared to a rest day. Notably, wrestlers who lost their matches had significantly higher pre-competition cortisol and anxiety levels than those who won, suggesting that elevated anticipatory stress may negatively impact performance.

Similarly, Souza et al. (2019) investigated pre-competition and pre-training responses in athletes from various sports, including canoeing, street running, and jiu-jitsu. They found that salivary cortisol and somatic anxiety were significantly higher before competition than before training, indicating that the competitive environment elicits greater physiological and psychological stress responses. A systematic review and meta-analysis by van Paridon et al. (2017) analyzed data from 25 studies and confirmed a significant anticipatory cortisol response in athletes preparing for competition. The analysis revealed that cortisol levels increased as the time of competition approached, highlighting the temporal dynamics of stress responses in athletes. In elite female netball players,

Crewther et al. (2018) observed that salivary cortisol levels were significantly higher following a competitive match compared to a training session or rest day. This elevation in cortisol was associated with reduced sleep quality and quantity, underscoring the broader implications of competitive stress on athlete well-being. Furthermore, Salvador et al. (2003) examined elite soccer players and found that pre-competition cortisol levels were positively associated with negative affective states, such as somatic anxiety. This association supports the notion that cortisol release is linked to the athlete's emotional state before competition, reinforcing the role of cortisol as a predictor of pre-event anxiety. These studies support the idea that tracking cortisol levels can give important information about an athlete's psychological preparedness and stress levels before competition, enabling focused interventions to maximise performance and wellbeing. This study also found that there is no significant difference between male and female elite university athletes in the salivary cortisol's prediction of pre-event anxiety, despite females recording a slightly higher mean anxiety score compared to males. As indicated by the mean scores, salivary cortisol levels and anxiety have a statistically similar predictive relationship for both sexes, even though female athletes report somewhat higher pre-event anxiety levels. Essentially, the biological marker cortisol predicts pre-competition anxiety in male and female athletes equally well, indicating that the physiological stress mechanisms mediated by the HPA axis function similarly in both sexes at the elite university athlete's level.

The finding accentuates the biological parity in stress response systems across genders in highly trained individuals. Male and female athletes may be able to develop similar psychophysiological coping mechanisms as a result of elite training, which may mitigate the differences frequently observed in general populations. Importantly, this aligns with recent studies that have examined gender differences in cortisol responses and anxiety in competitive settings and found either no significant differences or minimal variations that do not alter the predictive utility of cortisol (van Paridon et al., 2017). Gender differences in cortisol and affective responses to an academic stressor were examined in a study by Strahler and Ziegert (2015). The association between cortisol and perceived stress was similar for both sexes, and while women reported slightly higher levels of anxiety, there was no significant difference in their cortisol responses. This lends credence to the notion that physiological stress pathways are remarkably similar, despite possible slight variations in subjective anxiety.

Similarly, Kudielka and Kirschbaum (2005), in their comprehensive review, noted that while women may show greater subjective reactivity to stress, the gender differences in salivary cortisol responses are generally small and inconsistent, especially in real-life settings such as sports. Martínez-Mota et al. (2019) also examined competitive stress among mixed-gender athletic teams and found no significant gender differences in salivary cortisol reactivity. They concluded that environmental context and performance anticipation were stronger predictors of cortisol than gender. Elloumi et al. (2012) also explored pre-competition cortisol levels in elite male and female judo athletes. No statistically significant gender differences in cortisol responses were found, although females demonstrated slightly higher baseline anxiety. They emphasized that psychological training interventions should not differ based on gender alone. The finding, therefore, implies that coaches and sport psychologists can use comparable cortisol-based stress monitoring techniques for male and female athletes without interpreting cortisol's predictive value for anxiety according to a person's gender.

Another finding showed no significant difference in salivary cortisol prediction of pre-event anxiety among elite university athletes across three contact sports, even though football games had a higher mean anxiety score($M = 37.64$) than boxing ($M = 34.23$) and Judo ($M = 34.91$). This suggests a nuanced interpretation of how sport type influences psychological states without necessarily affecting the physiological mechanisms that predict anxiety. According to this finding, the biological mechanism underlying stress response, mediated by salivary cortisol, which is the predictive strength for pre-event anxiety, is stable and unaffected by the nature of sport, even though athletes in various contact sports may report varying levels of anxiety before an event due to the demands or perceived pressures associated with each sport. The elevated mean anxiety score in football could reflect greater cognitive or emotional anticipation due to the team-based dynamics, public visibility, and performance expectations, which are typically more intense in football than in individual sports (Arruda et al., 2012), like boxing or judo. Football matches often attract larger crowds, involve more tactical planning, and emphasize role interdependence (Low et al., 2020), which may heighten anticipatory stress. In contrast, combat sports such as boxing and judo, while physically intense, may involve more self-directed coping mechanisms, with athletes often developing individualized mental routines to manage anxiety.

However, the predictive role of cortisol is consistent across these sports, indicating that the physiological stress pathway through the HPA axis is universally activated during competitive anticipation rather than sport-specific (Gomez et al., 2022). This supports salivary cortisol's usefulness as a generalisable biomarker for anxiety monitoring that can be used in different sports contexts without requiring sport-specific calibration in elite university athletes. Van Paridon et al. (2017) investigated anxiety and cortisol responses in athletes participating in various sports. The association between cortisol and anxiety stayed constant, even though subjective anxiety scores differed by sport type. This suggests that cortisol-measured HPA-axis activation is a reliable predictor independent of the competitive domain. Similarly, although athletes reported varying degrees of state anxiety before matches, In a study, Gomez et al. (2022) compared cortisol and anxiety across team and individual sports and concluded that while team sport athletes reported higher psychological stress due to interpersonal dynamics, cortisol's predictive correlation with anxiety did not significantly differ, reinforcing its applicability across diverse sport formats. Arruda et al. (2012) also found that salivary cortisol was significantly associated with anxiety in soccer players, but not uniquely stronger than in other sports. They emphasized the role of external pressure, crowd anticipation, and media attention in elevating anxiety levels in football, without altering the physiological predictor mechanism. In addition, Cintineo and Arent (2019), in their review on psychophysiological monitoring in athletes, concluded that while different sports may provoke varied psychological profiles, the endocrine markers like cortisol provide consistent predictive utility across sport types, especially when measuring pre-competition anxiety. This finding supports the use of cortisol as a universal biomarker for pre-event anxiety, highlighting the need for sport psychologists to recognize both the psychological diversity and biological commonality in anxiety expression among athletes from different sporting backgrounds.

Conclusion

This study concluded that salivary cortisol reliably predicts pre-event anxiety and reflects the biological consistency of the stress response in elite university athletes, serving as a valid, gender-neutral biomarker for assessing pre-competitive stress. Although females and football participants reported slightly higher anxiety levels compared to those in boxing and judo, cortisol's predictive value remained consistent across gender and sport, thereby informing personalized psychological support.

Recommendation

It is recommended that sport psychologists be trained to identify behavioural cues specifically linked to elevated cortisol levels associated with HPA axis activation, such as sustained tension, cognitive fatigue, emotional withdrawal,

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and irritability, as indicators of cortisol-driven pre-event anxiety, thereby minimizing misinterpretation and ensuring that personalised effective psychological interventions are accurately tailored to the true physiological source of stress.

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