The Cortisol Awakening Response and Resilience in Elite Swimmers

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Abstract

The sports environment is stress-eliciting in that it encapsulates perceived uncontrollability, unpredictability and requires ego-involvement. The HPA axis has been shown (indicated by cortisol release) to respond to anticipated sports competition up to a week prior to the event. Research also alludes to the importance of individual differences, such as optimism and trait perfectionism, in moderating the impact of cortisol upon performance. In total, 41 (male n=27) national (n=38) and international (n=3) swimmers were recruited from northeast England and Australia. Swimmers completed a measure of resilience and also provided buccal saliva swabs, from which total cortisol release prior to and during the event was calculated. Findings revealed that resilience significantly predicted performance and the influence of AUC (cortisol release) upon performance was moderated by resilience. These findings suggest that resilience can influence athletic performance either directly or indirectly, through appraisal (i.e., interpretation of the stressor to be facilitative and non-threatening).

Introduction

The stress response involves a complex signaling pathway among neurons and somatic cells. The hypothalamic-pituitary-adrenal (HPA) axis is one of the physiological systems involved in this response, and its activation results in the secretion of several hormones, including cortisol [13]. Cortisol is a primary glucocorticoid hormone and is essential for maintaining homeostatic metabolism and glucose regulation [29]. However, consistently elevated cortisol levels are characteristic of an ongoing perceived threat and can have several negative outcomes, such as immunosuppression and inability to respond appropriately to stressors [11]. Cortisol secretion typically follows a relatively stable diurnal circadian rhythm, in that levels of the hormone reach a peak level around 1 h after awakening, and then decrease throughout the day, with virtually undetectable levels at midnight [10].

The Cortisol Awakening Response (CAR), i.e., the measurement of the morning cortisol release (cortisol peaks in the morning in order to prepare the body for the coming day), can be used as an indicator of the acute reactivity of the HPA axis [40]. On a physiological level, CAR reflects the perceived, anticipated demands of the respective day and also perceptions of emotional experiences from the previous day [1]. Specifically, higher anticipated demands and perceptions of negative emotions such as sadness and threat from the previous day typically lead to a more pronounced CAR. A latent state-trait model suggests that along with its trait characteristic (it is relatively stable over time), the CAR also incorporates occasion specificity and therefore can be utilized as a measure of situation-specific perceived stress [23]. The CAR also allows for better control of confounds; within the first 30 min after awakening, the diurnal cycle of cortisol release has a sharp increase of up to 75% compared to awakening levels [42]. Therefore, the CAR has been utilized as a biomarker in research for situation-specific stress.

Sports is a competitive and stress-eliciting activity [34] in that it encapsulates perceived uncontrollability (competitors, external factors), unpredictability and requires ego-involvement, i.e., the desire to win [4]. The stressors experienced by athletes are intermittent, varied and can be categorized as competitive (e.g., performance preparation), organizational (e.g., securing future funding) and personal (e.g., the death of a close family member) [17,38]. Specifically, competition stress can be intermittent or consistent and incorporates a range of physiological (pushing one's body to the limit), psychological (maintaining behavioral and emotional control when the stakes are high) and social factors (maintaining government funding/family expectations). As a result, the athletic arena is a unique, natural context in which researchers can examine behavior in high-pressure environments.

When considering specifically competition demands, the anticipation of a sports event can bring about an elevation in cortisol levels as much as a week prior to the event [5,15,16]. Although an anticipatory rise in cortisol (and perceived anxiety) is common among all athletes [15], individual differences (such as appraisals of challenging situations) and social support are thought to be important in moderating the effects of perceived anxiety upon physiological responses to stress [20]. Research that examines these differences in stress appraisal (via assessing important individual differences) is necessary to better understand performance on a psychophysiological level. With few exceptions [32], relatively little research has attempted to explain individual differences in hormonal changes in anticipation of sports competition from the measurement of psychological variables.

Selected individual difference variables have been shown to play an important role in determining the physiological response to stress. One study, by [41] found maladaptive trait perfectionism to be associated with more pronounced cortisol responses to the Trier Social Stress Test among a sample of 50 men. Moreover, positive psychological traits such as a tendency to expect life outcomes and future events to be positive (i.e., optimism) have been found to moderate the potential negative impact of stress (heightened cortisol levels) upon autoimmune functioning [9]. And also, research has noted a significant, inverse relationship between self-efficacy and cortisol response to a physical exercise task in both trained and untrained males [35]. These studies further support the notion that individual differences do play an important role in moderating the impact of perceived stress/adversity (indicated via cortisol increases) upon indicators of sports performance (directly via influencing physiological functioning and indirectly via influencing perceptions).

One psychological variable that holds theoretical importance within the context of stress is resilience [18]. Recently research has developed a grounded theory model of resilience in sports that incorporates protective factors (such as optimism or social support), adversity (of varying degrees from high-level competition stress to a prolonged period of injury or death of a loved one) and adaptive development (performance maintenance or improvement) [19]. From this perspective, resilience can be defined as "the role of mental processes and behavior in promoting personal assets and protecting an individual from the potential negative effect of stressors" (2012, p 675; 2013, p. 16) [18,19]. The model is also consistent with theoretical perspectives of resilience outside of sports [7,27,37]. In summary, resilience is demonstrated when, a) some degree of adversity and pressure is experienced and b) the individual is still able to experience positive outcomes, such as successful performance [17–19]. In the current study, we focused on resilience protective factors (e.g., motivation, confidence) that are proposed to buffer the effects of stressors on competition performance. This approach is consistent with methodological recommendations regarding the study of resilience in sports [17,18].

This study therefore assessed resilience by a) assessing a response to stress/adversity, namely the high level of athletic competition with perceived high importance, by including a physiological marker of perceived stress (increase in cortisol from baseline to competition), a measure of resilience protective factors and a measure of performance as an indicator of adaptation (i.e., positive functioning) following stress by assessing performance in a high-level competitive swimming meet. In doing so, it is hoped that this study will provide quantitative support for the qualitative propositions that form the recent sports-specific model of resilience [17,18].

In summary, research has shown that resilience appears to manifest at a physiological, cognitive, affective and behavioral level. However, the physiological correlates of resilience, particularly an important biomarker, i.e., cortisol (CAR), have yet to be included in empirical tests of this phenomenon in sports contexts. As a result, the purpose of this study was to investigate the relationship between the CAR and resilience in a group of highly trained, elite swimmers. In line with research evidence [15], it was expected that participation in competition would lead to a significant increase in acute salivary cortisol concentrations (from baseline), but that total competition cortisol release at competition would be higher for the poorest performers and those with lower self-reported scores of resilience. It was also expected that psychological resilience (protective factors) would moderate the potential detrimental influence of high cortisol levels (perceived adversity) upon performance (adaptation).

Method
▼

Participants

Participants were recruited from swimming clubs in northeastern England and Australia. 41 competitive (male n = 27) swimmers (M_{age} = 15.2 years) ranging from national (n = 38) to international (n = 3) standard took part in the study. The amount (M_{hours} = 32.4, S.D. = 1.34) and intensity (Borg scale rating Mean = 3.5) of training leading up to the competition was similar for each participant, as these variables can influence cortisol levels (Bonifazi et al., 2000). Prior to taking part in the study, all participants were informed of their right to withdraw, provided informed consent, and ethical clearance was awarded by the University Ethics Committee; in addition, the study meets the ethical standards of IJSM [22]. Participants were free of any medication, were non-smokers and had no history of endocrine disorders.

Measurements

Resilience

Owing to the unavailability of a sports-specific tool to measure resilience among athletes [17], the Academic Resilience Scale [27] was adapted to suit the sports context. Participants were required to respond to 6 items, such as "*I don't let a bad swim/performance effect my confidence*" anchored by a 7-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. Support for the factorial validity of the measurement method has been demonstrated [27]. The scale has also been shown to have adequate levels of internal consistency and test-retest reliability (Time 1 Cronbach's $\alpha = 0.80$; Time 2 Cronbach's $\alpha = 0.82$; test-retest $r = 0.67$) and to have predictive validity in that it significantly predicts educational and psychological outcomes such as enjoyment of school, class participation, and general self-esteem [27].

Training amount and intensity

Participants rated the intensity of each swimming training session (for the week leading up to the competition) using Borg's RPE (rate of perceived exertion) scale [6]. Respondents were asked to rate the intensity of the swimming session on a scale, anchored from 1 = *very low intensity* to 10 – *very high intensity*. An average intensity index for each swimmer was calculated.

Cortisol

Saliva testing protocol: CAR was assessed by collecting saliva swab samples from swimmers at 8:00 a.m., 8:15 a.m. and 8:30 a.m. (both on the competitive day and before a low intensity, tapered training session one week prior to the event). The swim event occurred between 10 a.m. and 11 a.m. for each swimmer. The testing procedure was conducted in this way to lessen the effect of the circadian diurnal rhythm upon cortisol levels [33].

Collection: To represent the unbound serum levels of cortisol, saliva samples (salivary cortisol level is a non-invasive and reliable marker of HPA activity) [7] were collected (producing a volume of 1–3 ml for each sample). Saliva sampling is an accurate measure of serum levels (the biologically active fraction) [28, 30] and correlations between the 2 values are highly significant, r (47) = 0.91, $p < 0.0001$ [14]. Participants received instructions on salivation before each sampling stage (chew on the Salivette swab for 60 s and place it into the plastic tube), and they were requested to refrain from consuming any drinks or food other than water up to 1 h prior to testing. Participant-administered tests are a reliable method of sampling when clear, concise instructions are provided and the individual has had prior practice [14].

Assaying: Samples were stored at around −30° Celsius and were subsequently thawed and centrifuged to separate the mucins prior to analysis. Salivary cortisol levels were produced in duplicate (nanograms per milliliter) by using commercial enzyme-linked immunosorbent assay (ELISA) kits (Salivary Cortisol ELISA, SLV-2930, DRG Instruments GmbH, Germany) with a sensitivity of 0.537 ng/ml, intra-assay variation of 1.80% (M = 12.79 ng/ml) and inter-assay variation of 7.16% (M = 23.29 ng/ml). All samples were assayed in the same session to avoid the confounding influence of different testing procedures and environment.

Cortisol calculations: The Cortisol Awakening Response was indexed by calculating the Area Under the Curve (AUC), utilizing the trapezoid formulas [31]. The baseline AUC score (the first 4 saliva samples) was then subtracted from the competition AUC index (4 competition samples), in order to represent the difference in total cortisol release on the day of competition, compared to the individual's own resting state (baseline measurement).

Performance

Participants performed a 100 m sprint event at a national-level competition in their respective countries. Performance was calculated by subtracting personal best time from the time swum in the measured competitive event, in order to provide a relative performance index.

Procedures

Participants refrained from consuming food or caffeine 1 h prior to testing [26]. The saliva sampling protocol took place on 2 occasions: one week prior to the event and on the day of the actual event (see saliva testing protocol). Half an hour prior to the swim event, participants also completed the survey package containing self-reporting questionnaires. Participants also provided responses (on a Likert scale from 1–9) to measures of perceived importance and satisfaction following the competitive swim [25]. These state variables have been shown to influence cortisol release (all participants reported that they were either mostly or completely satisfied with their performance and perceived it to be a very important event). Moreover, female participants were asked to report their stage of the menstrual cycle (this was found to not significantly correlate with cortisol production: $r = 0.12$, $p > 0.05$ and therefore the female and male samples were dealt with as a combined sample in subsequent analyses).

Data analyses

Bivariate correlations were utilized to identify any significant associations between CAR, resilience and performance. Benchmarks were employed for the interpretation of interpreting effect sizes for difference tests (small: 0.10; medium: 0.30; large: 0.50) [8]. A one-way repeated measures ANOVA was performed to determine the change in cortisol level from basal to pre-competitive measurements. Multiple regression analysis was employed to examine the primary research question, with performance included as the dependent variable, and resilience, AUC and its interaction serving as the independent variables. Perceived satisfaction and importance were entered as control variables in order to account for their influence on performance. The control variables were entered during Step 1. Resilience and competition AUC were entered in Step 2 (and zero-centered to test interactions on subsequence steps [2]. In Step 3, the 2-way interaction term was added (resilience × AUC).

Results

The descriptive data demonstrated adequate skewness and kurtosis values and therefore normality was assumed. The swimmers' baseline cortisol levels were in the normal range ($M_{score} = 0.231\,\mu g/dl$) [12]. There was a significant difference in cortisol levels between participants' resting baseline concentration and their pre-competitive levels ($F(1,40) = 84.29$, $p < 0.001$, $\eta^2 = 0.334$, CI: 0.323–0.625). It was therefore assumed that the competitive event was perceived with sufficient stress intensity in order to create a significant anticipatory rise in cortisol. Bivariate correlations revealed a significant positive correlation ($r = 0.544$, $p < 0.01$) between competition AUC and baseline AUC (i.e., those who had high levels of cortisol at resting also had higher levels during competition). There was also a significant negative correlation between resilience and baseline AUC ($r = -0.357$, $p < 0.01$) and between resilience and competition level AUC ($r = -0.326$, $p < 0.01$).

Moderated hierarchical regression analysis

The results of the multiple regression are presented in **Table 1**. Variables were mean-centered prior to analysis. Perceived importance and satisfaction were not significant predictors of performance ($\beta = 0.021$; $p > 0.05$). In step 2, cortisol (competi-

Table 1 Linear regression model (stepwise selection) for predicting performance using CAR and resilience scores.

Predictor	DV = Performance			
	B	β	95 % CI for B	
			Lower	Upper
(Constant)			23.338	29.933
Control variables	− 0.012	− 0.023	− 0.234	0.256
CAR	− 0.321 *	− 0.291	0.324	0.561
Resilience	0.402 *	0.432	0.149	0.387
CAR, Resilience	0.244 *	− 0.403	0.223	0.653
R^2	0.321			
F	65.192 *			

* $p < 0.05$ (2-tailed); CI = confidence interval

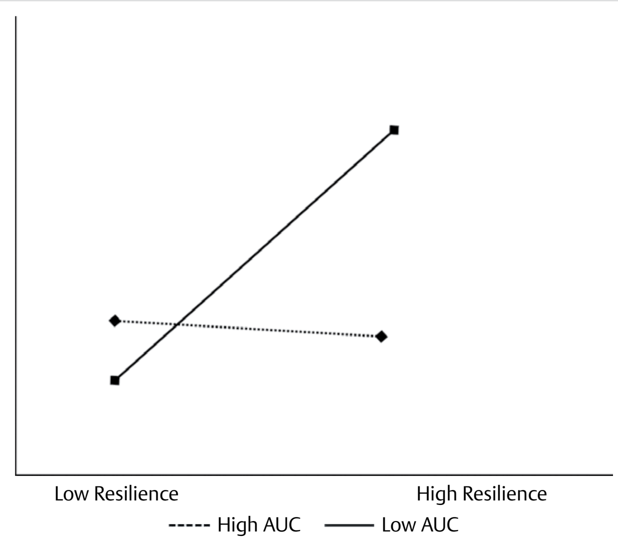

Fig. 1 Resilience X AUC interaction.

tion-baseline level) or the anticipatory rise in cortisol (β = −0.291; p = 0.04) and resilience (β = 0.432; P = 0.003) added a significant portion of variance (21 %) to the model. The cortisol (competition level – baseline level) × resilience interaction term explained an additional 12 % of the variance in performance (β = −0.403; P = 0.009). In order to further explore this interaction effect, performance was computed when CAR remained constant and resilience was 1 SD above and 1 SD below the mean [2]. As shown in **Fig. 1**, the best performers were most resilient and had the lowest levels of cortisol.

Discussion

The present study investigated the association between CAR (neuroendocrine stress response), self-reported trait resilience scores (specifically protective factors) and swimming performance (adaptation to stress). As expected, the competition event generated significant cortisol increases for the swimmers, and therefore the sports event was characterized as stressful [15]. As expected, the data also demonstrated significantly that resilience was positively associated with performance, i. e., those reporting greater resilience performed best in the competitive swim event. This finding supports the qualitative findings of research into resilience conceptualization in sports contexts [18].

Further analysis revealed a significant interaction between resilience and cortisol secretion (AUC). This interaction effect suggested that the influence of AUC upon performance was moderated by resilience. Specifically, the most successful performers (those who demonstrated the most successful adaptation following perceived stress) self-reported high levels of resilience (protective factors) and had a reduced cortisol response to competition (lower perceived stress). This finding provides quantitative support for the conceptualization of resilience that incorporates an initial perception of stress/adversity (with varying intensity) alongside protective factors (resilience scale) that can buffer an individual from the potential negative impact of perceived stress upon adaptation/performance [18, 19]. The findings also suggest that resilience can influence performance directly (positive correlation between resilience and performance) and indirectly via appraisal (initial appraisal of the stressor and the influence of stable protective factors such as confidence/self-control).

In this study, those swimmers who had relatively lower levels of resilience and a reduced response to competition performed the poorest. A blunted cortisol response (an ability to respond sufficiently to stress) is thought to indicate an inability to rebound from failures and manage competition stress. Perhaps more surprisingly, in those swimmers with a pronounced physiological response to the competitive event, higher levels of resilience were associated with poorer performance than those with lower levels of resilience. One possible explanation for this interaction is that the influence of psychological resilience (specifically protective factors) becomes less prominent in times of extreme physiological stress/adversity (indicated by cortisol level). So in those who respond moderately to stress (those in the low cortisol category), being psychologically resilient (the perception that one can rebound from failure) is adaptive for performance. In a sense, this finding concurs with catastrophe theories [21] in that an individual can manage physiological stress/adversity up to an optimum or 'critical' point (their maximum stress threshold) and up to this point, psychological variables and strategies will mitigate any negative impact upon performance. However, beyond this point, the individual is overwhelmed by the 'adversity' and is unable to manage the perceived demand. Future research may wish to examine inter-individual differences in cortisol response, resilience and performance across several competitions, in order to further explore this proposition.

Another possible explanation for this finding is that there are mediating variables that link to performance (that has not been assessed in the current study, e. g., emotions). For instance, if an individual perceives an event to be a threat, they will experience negative emotions, but if they are resilient, they are more likely to be able to experience a more positive outcome in times of adversity (one characterized by negative emotions). Future research that examines the interaction between resilience, emotions and physiological response represents an interesting avenue. Alternatively, it may be that resilience plays a different role in terms of 'protecting' from performance slumps in times of high stress/adversity when different stressors are involved, i. e., competitive, organizational, personal [17, 38]. Research has also highlighted the potential mediating impact of interpretation of emotions (i. e., either as facilitative for performance or debilitative). Future research may wish to empirically examine these proposed interpretations and examine their impact upon performance. Also, the possibility that negative emotions can serve as an adaptive source of motivation for athletes to apply and direct greater effort/attention towards achieving their goals should be considered [39].

It should be noted that the present study assessed one psychological aspect of resilience, i.e., protective factors [17]. Moreover, the academic resilience measure was adapted to better suit sports participants. However, these adaptations have not been fully supported in the athletic context and therefore findings should be interpreted with this limitation in mind. The academic measure is thought to be transferable to an athletic context, in that education and sports encapsulate similar contextual, organizational and personal stressors (e.g., normative comparisons, outcome achievements, tiered systems of organization, i.e., international and national levels in sports and grade A, B classes in education). Also, the protective factors examined in this measure are likely to be important in both sports and educational contexts. That is, self-belief, control, composure and persistence are highly relevant psychological attributes in both domains. Despite this limitation, this study does provide initial quantitative support for a sports-specific model of resilience [18,38]. Future research may wish to build on the findings of previous research on resilience in sports [18,19,38] and the findings of this study, in order to develop a sports-specific tool for measuring resilience [36].

Other limitations of the current study should also be acknowledged; the inclusion of a heterogeneous sample of swimmers means that generalizations cannot be made beyond this population. This approach was chosen as concentrations of hormones can be effected by many confounds including the amount and type of physical exertion required, a number of environmental variables (e.g., presence of competitors, competition type) and the standard and importance of competition. Having said this, the current study is the first to consider resilience and its relationship with cortisol patterning and swimming performance. Also, resilience or psychological recovery from failures is particularly important in a sport such as swimming, as competitors typically swim more than one race in a single competition session.

It should also be noted that we assessed one indicator of physiological arousal in this study (i.e., cortisol), and indeed a number of other indices can capture physiological arousal, including blood pressure and heart rate variability and startle effects [3]. In the case of this study, these measurements proved impractical, given the nature of a swimming competition meet. To this end, a more comprehensive assessment of different hormones is thought to be a more valid indication of physiological arousal, as hormones rarely operate in isolation. Indeed, there are agonist and antagonist hormones, e.g., dehydroepiandrosterone and allopregnanolone (both neuroactive steroids) that dampen the effect of cortisol post-stress [3]. Perhaps future research could consider more comprehensive profiles of hormonal levels as markers of psychological functioning [24]. It is important to understand the nature of such relationships in order to strengthen theoretical understanding of resilience and develop more objective markers for the construct.

A sports-specific model of resilience suggests that athletes commonly reported meta-cognitions as central to resilience, i.e., an awareness of one's own cognitions and an ability to appraise them in a way that is facilitative for future behavior (e.g., an athlete has a poor performance, initially appraises this negatively but later uses the experience to motivate him/herself to train harder) [18,38]. Perhaps future research may wish to examine the nature of these meta-cognitions, along with measures of pre-competitive anticipation (emotions) and post-event attributions (the cognitive appraisal of event outcomes) and their relationship with cortisol secretion and performance. In conclusion, the present research builds on the qualitative findings of previous research into resilience in sports [18,38] and provides quantitative support for the notion that resilience is an important construct in buffering an individual from the potential negative effects of stress, even enabling individuals to experience positive outcomes/adaptation following perceived stress.

Conflict of interest: The authors have no conflict of interest to declare.

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