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A laboratory study on attentional bias as an underlying mechanism affecting the link between cortisol and performance, leading to a discussion on the nature of the stressor (artificial vs. psychosocial)

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A B S T R A C T

Although cortisol is assumed to influence performance by affecting cognition during stressful and competitive situations, to date this assumption has not been tested empirically. Therefore, the aim of this study was to investigate whether the influence of cortisol on performance is mediated by attentional processing of emotional information. Forty-six male golfers were tested in a mixed design. The cold pressor task (CPT) was used to artificially increase cortisol levels in the experimental group relative to the control group, who had to put their forearm in warm water. Before and after water immersion the golfers performed one-armed 1.5-m puts and completed the Sport Emotional Stroop Task. Cortisol was significantly increased in the experimental group (CPT). Further, a significant decrease in attentional bias toward negative sport words was detected in the CPT group. However, no changes in putting performance due to an increase in cortisol were observed in the CPT group. Regarding the cortisol–performance relationship, the nature of the stressor (i.e., artificial vs. psychosocial) seems to play a role, as no connection was found in this study using an artificial stressor, whereas previous research using a psychosocial stressor (e.g., an actual competition) did find a connection. On the basis of these results I cautiously conclude that the subjective appraisal of a stressor, which is arguably higher for a psychosocial stressor, is more relevant for sport performance than just a change in cortisol level. However, as the stress response is psychophysiological in nature, future research should continue to investigate the role of cortisol.

1. Introduction

In recent years, researchers have sought to understand how psychological stress (e.g., nervousness, anxiety) impacts sport performance [39]. Yet, because stress is considered a psychophysiological reaction, the impact of physiological changes, for example, an increase in the stress hormone cortisol and its impact on performance, has also been of interest. Competitive sport settings have been used as a psychosocial stressor to observe changes in hormonal concentrations, such as cortisol or testosterone level (see review by Wood and Stanton [43]), before and after a competition in relation to the final outcome, that is, whether the athlete has won or lost (see review by Salvador and Costa [35]). Recently, the focus has moved from considering the cortisol–outcome relationship to investigating the cortisol–performance relationship, which has the advantage of better reflecting athletes' ability. In other words, final outcome (i.e., win vs. loss; rank) can depend on a vast number of factors, including luck and the abilities of the opponents and/or teammates, whereas performance as a process of reaching the final outcome is less influenced by factors outside of experimental control.

1.1. Cortisol and sport performance

In most cases, research has revealed a negative relationship between cortisol and performance. For instance, in dance, a negative correlation between peak cortisol levels and self-reported performance evaluation was found [34]. In rugby, lower salivary cortisol responses were associated with better coaches' evaluations and higher overall performance indicators [5]. In the same direction, cortisol assessed continuously during a golf competition was found to be negatively correlated with the 36-hole golf performance [9]. Also in tennis, a cortisol rise induced with a standardized stress induction (i.e., the second part of the Trier Social Stress Test, TSST; [17]) was negatively correlated with a standardized performance measurement (second serve in tennis; [21]). And finally, in a recent single case study comparing two competing male tennis players, several negative correlations between cortisol and

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performance parameters were found [22]. In contrast, there is less support for the opposite conclusion: A positive correlation between cortisol and performance was found in a weight-lifting study (in this case official weight-corrected performance; [25]), and no significant correlation between cortisol, assessed before several basketball games, and athletes' or coaches' technical evaluations was found [32]. Overall, there is more support for a negative than a positive relationship between cortisol and sport performance, but the effects that mediate the cortisol–performance relationship remain unclear.

To date, the mechanisms underlying the cortisol–performance relationship have either not been mentioned (i.e., [9,25]) or they have been explained by psychological concepts (cognitive appraisal based on [23,32]), social evaluation (i.e., [34]), social status (e.g., [22]), or physiological effects of cortisol (e.g., metabolic effects; [21]). The effects of cortisol on cognition have been acknowledged only recently as a way to explain the mechanisms of cortisol impacting performance ([20,21,32]). In detail, it has been pointed out that "biological responses, indeed, can influence physical functioning [i.e., sport performance] because of the related changes that may occur in the arousal level as well as in cognition" ([32], p. 515).

1.2. Attention as the underlying mechanism for the cortisol–performance relationship

Cognition as a proposed mechanism to explain the cortisol–performance relationship seems to be valid from a biological point of view, as cortisol is able to pass the blood–brain barrier and binds to glucocorticoid receptors that are particularly high in density in the prefrontal areas of the brain, where they impact prefrontal-limbic circuits of emotion regulation (see [24]). Cortisol has been shown to redirect attentional focus toward task-relevant information, thereby inhibiting attention to emotional task-irrelevant information [30]. The "cognitive-processing hypothesis" describes the impact of cortisol on the cognitive processing of emotional stress-related information (e.g., failure thoughts in a competition; [30]). In detail, in the cognitive system, elaborate and goal-directed behavior (i.e., a top-down activity) is superior to processing emotional information (i.e., a bottom-up process; also see attentional control theory by Derakshan and Eysenck [7]). During stressful situations the former gives way to a driven and reflex-like behavior. Due to higher cortisol concentration, attention will be redirected toward task-relevant information and away from salient stimuli.

The cognitive-processing hypothesis is largely supported by empirical evidence. For example, administration of 40 mg of hydrocortisone (i.e., artificial cortisol) was found to induce allocation of attention away from threat stimuli (i.e., angry faces) in healthy participants (i.e., low-anxiety group) in comparison to a placebo group, which saw no such reaction [29]. Similarly, 0.15 mg/kg of cortisol led to a decrease in reaction time to affective stimuli, in this case positive and negative words (i.e., Affective Go/No-Go Task; [2]). Similarly, 10 mg hydrocortisone increased inhibition for angry faces, whereas this effect was not found for 40 mg in the same study [38]. Yet importantly, not all empirical data support the cognitive-processing hypothesis. For example, one study revealed that high cortisol responders showed an attentional bias toward threatening stimuli (i.e., angry faces) after a psychosocial stressor (i.e., the TSST; [33]). In summary, a recent meta-analysis focusing on the effects of administered and, thus, artificially increased cortisol on core executive function concluded that "an acute increase in cortisol … enhances inhibition" ([36], p. 98). Overall, the suggested underlying mechanism for the cortisol–performance relationship—that cortisol enhances selective attention [36]—has not been investigated so far; doing so would represent an important theoretical advancement in the understanding of how hormones influence human behavior.

1.3. Present study

In the current study, I asked if selective attention mediates the cortisol–performance relationship in the sport context. I planned to increase cortisol in an experimental group with an artificial stressor, the cold pressor task (CPT), which reliably provokes a rise in cortisol level in a short amount of time (e.g., [4]). I then operationalized sport performance with a golf putting task, a standardized task not confounded by variables such as opponents or teammates. To operationalize selective attention, I administered an emotional Stroop task with sport-related stimuli (i.e., the Sport Emotional Stroop Task, SEST; [1]). I implemented a mixed design in which participants had to perform the SEST and the golf putt twice, in one of two experimental conditions (i.e., experimental group: cold water, CPT; control group: warm water).

To investigate the research question ("Does selective attention mediates the cortisol-performance relationship?"), several hypotheses within this study need to be supported. I expected that participants in the CPT group would experience higher levels of cortisol in comparison to the control group (Hypothesis 1; [4]). On the basis of empirical evidence, I expected participants in the CPT group to perform less well than the control group in the putting task, due to higher levels of cortisol in the CPT group (Hypothesis 2; [9,21]). Finally, I expected that attentional bias would be lower in the CPT group in comparison to the control group after water immersion (Hypothesis 3; [36]).

2. Method

2.1. Participants

Initially 66 male participants (plus 2 pilot participants) were tested. Several participants had to be excluded from data analyses for the following reasons: One did not comply with the experimental instructions; 10[1] had the yips, which is characterized by an involuntary movement of the wrist or the forearm shortly before impact (see [18]); one was using medication; and four were currently injured. An additional four were excluded from cortisol analyses as they were smokers. Overall, a total of 46 participants were analyzed.

The remaining 46 golfers (M_{age} = 25.5 years; *SD* = 4.1) participated in a mixed-design experiment. For detailed descriptive information about the groups see Table 1. All participants were nonsmokers, free of medication, and had no history of endocrine disorders.

The ethics committee of the local university approved the study, following requirements of the Declaration of Helsinki. Participants received 25 euros to take part in the experiment.

2.2. Procedure

The experiment lasted approximately 60 min. A full overview of the procedure is displayed in Fig. 1. Participants were welcomed in the laboratory and instructed about the tasks they were to perform via previously recorded audio files, for standardization purposes. They then signed the informed consent form. This was followed by the first cortisol sample and stress-level assessment (time T1), for which participants completed a visual analogue scale (VAS). I then obtained baseline measurements of the putting task and the SEST in a counterbalanced order. Cortisol and stress were assessed between tasks (T2) and again after the second task (T3). This was followed by the water immersion (CPT group [n = 23] vs. control group [n = 23]; see Table 1 for details on participants for each group). For this, participants were asked to put their nondominant forearm in water for 180 s. After participants dried their hands, they gave the fourth saliva sample and completed the VAS (T4) and were instructed to watch a neutral video

[1] This number is in line with a prevalence rate of 16.67% for yips among golfers (see [18]).