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A link between cortisol and performance: An exploratory case study of a tennis match

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ABSTRACT

So far, studies have focused mainly on changes in cortisol levels before and after competitions, and little is known about cortisol secretion within a competition. In this exploratory study we aimed to gather in-depth information about cortisol development during a tennis match and to relate cortisol levels to specific performance parameters of two competitive male players. Thereby, we were also able to compare winner and loser directly. A total of 20 samples per player were assessed before (4 samples), during (10 samples), and after (6 samples) a match and on a resting day (5 samples). Cortisol was higher on competition day in comparison to resting day in both players. Further, cortisol was higher in the loser before (17%), during (65%), and after (54%) the match. In addition, cortisol was negatively correlated with certain performance parameters (e.g., unforced errors and return performance) but uncorrelated with other performance parameters such as serving performance. Further research should look into within-competition cortisol variations, additionally assessing different hormones, and take into account the methodological concerns that were identified in this single case study.

1. Introduction

Competitive situations are particularly prevalent in sports, which explains the increasing body of research focusing on cortisol in relation to competition in this domain (for an overview, see Ehrlenspiel and Strahler, 2012). Cortisol is considered a primary physiological and thus objective marker of the activity of the hypothalamic pituitary adrenal (HPA) system, which responds to a wide range of psychological stressors, such as competitive situations (Gaab et al., 2005). The typical cortisol response pattern shows an anticipatory rise before competition (e.g., Filaire et al., 2001) and a second increase shortly after competition due to intense mental and athletic effort (e.g., Kraemer et al., 2001). The question of how cortisol behaves during a competition remains unanswered. Thus, this study examined cortisol development during an official competition of two competing male tennis players.

So far, research has focused mainly on the relationship between outcome (winning vs. losing a competition) and cortisol levels before and after competitions, and findings are rather contradictory (for a review and the model of neuroendocrine and mood responses to a competitive situation see Salvador and Costa, 2009). So far all three possible relationships between outcome and cortisol have been found: higher cortisol in losers before and after competition (e.g., in tennis; Filaire et al., 2009) including higher cortisol increase in losers after competition (e.g., badminton; Jiménez et al., 2012), higher cortisol in winners before a competition (e.g., in judo by Suay et al., 1999; in triathlon by Balthazar et al., 2012), and no detectable difference (e.g., soccer player by Oliveria, Gouveia, and Oliveira, 2009). These divergent findings might be explained by the studies being on different sports, with various physical requirements and various exercise intensities, as well as by inconsistent assessment times of cortisol samples (e.g., 30 min, 60 min, or right before and after competition).

As outcome (winning vs. losing) does not necessarily reflect performance but can depend, for example, on luck or on the opponent, closer attention has to be paid to performance. It has been argued that the reason cortisol influences performance is psychological (e.g., social evaluation; e.g., Rohleder et al., 2000) or physiological (e.g., Crewther et al., 2006) in nature. Recently it has also been suggested that the impact of cortisol on cognition (e.g., attention or decision making) might mediate the cortisol–performance relationship (e.g., Robazza et al., 2012; Lautenbach et al., 2014; see review and the cognitive processing hypothesis by Putman and Roelofs, 2011). Thus the possible reasons why cortisol might influence performance are as broad as the conflicting empirical data.

So far, less research has been done on the cortisol–performance relationship and findings are inconsistent. In basketball, no significant correlations were found between cortisol levels assessed immediately

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before several games and retrospective performance evaluations from athletes and coaches (Robazza et al., 2012). In contrast, a negative link between cortisol response to psychosocial stress induced before and sports performance (i.e., the second tennis serve) was found by Lautenbach, Laborde, Achtzehn and Raab (2014) in a controlled, non-competitive situation. Also, during a 36-hole golf competition negative relationship between cortisol during the day of competition and performance was detected, implying that higher cortisol levels are related to poorer golfing performance (Doan et al., 2007). A contradictory result was found in a weight-lifting study, showing that official weight-corrected (WC) performance was positively correlated with cortisol level after weighing (Passelergue et al., 1995).

Within the empirical data, results are conflicting and only a limited number of studies have focused on the cortisol–performance relationship. Thus, there is a need to look very closely at cortisol development, particularly during but also before and after a competition, and to connect it to objective performance parameters. Observing cortisol development and relating it to performance in a single case study with two opponents has limitations (see Discussion) but also advantages. First, it is possible to look at individual changes very closely, which is particularly important in cortisol development since interindividual differences in ranges of cortisol concentration have been identified, for example, with respect to circadian rhythm (Westermann et al., 2004). Second, additional research questions can be generated from findings derived from case studies that can be answered with a larger sample size.

To do this, we assessed the cortisol level of two competing male tennis players before, during, and after an official tennis match in a detailed fashion and related it to match outcome as well as to specific performance parameters (e.g., unforced errors, winners [i.e., hits that are a direct point in tennis], and serving performance), thereby overcoming the limitations of the aforementioned studies. First, instead of focusing on only one indicator of performance during an actual competition, as done by Doan et al. (2007), we derived specific performance parameters that are often used in tennis match analyses (Fernandez-Fernandez et al., 2008), and thus we captured performance in great detail. Further, we relied on more than one saliva sample before and after competitions, in contrast to the procedures of the majority of the aforementioned studies. We also, for the first time, compared direct opponents, that is, players who competed against each other, allowing us to see the effect of this interaction on the cortisol level, which is not possible when considering winners and losers of different games. Fourthly, we assessed cortisol development for a more common competition duration (in contrast to 10 h of competition in Doan et al., 2007), which is also more applicable to different sports (e.g., basketball, soccer, judo, and wrestling) and competitive settings (e.g., examination and job interview). Additionally, tennis is an individual sport and even though performance is influenced by the opponent, performance is certainly not influenced by other team members to the same extent as in team sports, such as basketball (Robazza et al., 2012). Finally, we connected cortisol level to objective performance data instead of to coaches' or players' evaluations (Robazza et al., 2012).

In summary, to address the gaps in the existing literature, in the current study we sought to gather in-depth information about cortisol development during a real competition and to connect it to performance parameters in an exploratory fashion, in hopes of better understanding of the cortisol–outcome and cortisol–performance relationships. We hypothesized (a) a higher level of cortisol in the loser before and after the match, in keeping with previous findings in tennis by Filaire et al. (2009). In addition, we expected this pattern to continue throughout the duration of the match. (b) In regard to findings of Jiménez et al. (2012), we predicted that the increase in cortisol from before to after the match would be higher in the loser. (c) Concerning the relationship between cortisol levels and objective tennis performance parameters, we predicted negative correlations (Doan et al., 2007; Lautenbach et al., 2014).

Table 1
Detailed participant information.

Characteristics	Player A Winner	Player B Loser
Age (in years)	39	28
Weight (in kg)	88	75
Height (in cm)	200	179
BMI (kg/m^2)	22	23.4
Occupation	Controller	Student
Tennis experience (in years)	25	18
Handedness	Right	Right
Physical activities (per week)	1 h tennis 1 h running 1.5 h swimming	1 h tennis 1 h running

2. Method

2.1. Studied case

Two healthy, nonsmoking male tennis players (see Table 1 for detailed information) competed against each other in an official tournament in the third highest league in Germany. Player A was not taking any drugs or medication, whereas Player B took terbinafine, a synthetic allylamine antifungal, in tablet form. No significant interaction between terbinafine and cortisol has been reported (Abdel-Rahman et al., 1999), so Player B was not excluded from the data analyses. Further, neither player had a history of endocrine disorders.

Prior to the match, the study was explained to the players and both gave their informed consent. They knew in advance that the match would be videotaped and that they would be asked to provide cortisol samples and complete questionnaires before, during, and after the match. The study was approved by the ethics committee of the local university and conducted in accordance with the Declaration of Helsinki.

2.2. Materials and measures

2.2.1. Questionnaires[1]

2.2.1.1. Competitive State Anxiety Inventory. The German version (Ehrlenspiel, Brand, and Graf, 2009) of the Competitive State Anxiety Inventory (CSAI-2; Martens et al., 1990) was used to assess the individual perceived anxiety level and its subjective functionality as well as frequency before and during the match. On a Likert scale ranging from 1 (not at all) to 4 (very much so) participants had to answer 12 questions measuring self-confidence, somatic anxiety, and cognitive anxiety. Reliability of the subscales measured by internal consistency was considered good for the subscales self-confidence (Cronbach's $\alpha = .82$) and somatic anxiety ($\alpha = .81$) and acceptable for the subscale cognitive anxiety (Cronbach's $\alpha = .79$).

2.2.1.2. Affect grid. The Affect Grid is a single-item scale (Russell et al., 1989) for measuring affect intensity and valence. The participant is asked to make a cross in a 9 × 9-unit square. The anchors for intensity are stress (on the left) and relaxation (on the right) and for valence strong arousal (at the top) and sleepiness (at the bottom).

2.2.1.3. Distraction items. To assess the subjective view of the extent to which data collection during the match affected the players' performance, we used three items asking participants how much their

[1] Even though we developed no hypotheses regarding these parameters, we aimed to give as much detail as possible on the psychological and physiological states of the players during the match. Thus we also assessed questionnaire data on subjective stress. We provide the descriptive statistics as well as correlation analyses and cortisol data in the Supplementary materials to enable researchers to build on this information in the future.