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Subjective stress in female elite athletes and non-athletes: Evidence from cortisol analyses

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Abstract
Stress response can be considered a consequence of psychological or physiological threats to the human organism. Elevated cortisol secretion represents a biological indicator of subjective stress. The extent of subjectively experienced stress depends on individual coping strategies or self-regulation skills. Because of their experience with competitive pressure, athletes might show less pronounced biological stress responses during stressful events compared to non-athletes. In the present study, the short version of the Berlin Intelligence Structure Test, a paper-pencil intelligence test, was used as an experimental stressor. Cortisol responses of 26 female Swiss elite athletes and 26 female non-athlete controls were compared. Salivary free cortisol responses were measured 15 minutes prior to, as well as immediately before and after psychometric testing. In both groups, a significant effect of time was found: High cortisol levels prior to testing decreased significantly during the testing session. Furthermore, athletes exhibited reliably lower cortisol levels than non-athlete controls. No significant interaction effects could be observed. The overall pattern of results supports the idea that elite athletes show a less pronounced cortisol-related stress response due to more efficient coping strategies.

Keywords: Cortisol, athletes, intelligence test, sport

Introduction

Elite athletes are often confronted with highly stressful events during contests. Not only because the participation in important competitions can lead to nervousness, but also due to critical situations during a contest. Such critical situations leading to acute stress could be a tie-break situation in a tennis game, a referee's wrong decision, experiencing pain or being reprimanded by the coach. It has been demonstrated that coping abilities have a crucial impact on the performance and personal satisfaction of athletes (Anshel, 1990). The inability to cope with acute stressors during contests can have a negative effect on psychological processes such as concentration, attentional focus, and arousal. Lower concentration or attention can lead to lower sport performance. In case that the athlete is able to cope with the stressful demands, the crucial processes and the performance stay unaffected (Anshel, 1990; Smith, 1986).

It is well-known that stress reactions depend on three components: the characteristics of the stressor, the person's appraisal of the situation, and individual coping strategies (Lazarus & Folkman, 1984). Adequate coping strategies lead to less subjectively experienced stress. Consequently, a successful athlete might experience events during the contest generally as less stressful compared to a less successful athlete. The successful athlete might categorize an event as a challenge rather than a threat and is more likely to adopt an adequate and effective coping strategy. Proceeding from these considerations, elite athletes, compared to non-athletes, may also experience lower subjective stress in performance-related everyday-life situations.

From a biological view, there is a functional relationship between stress reaction and activity of two physiological systems, namely the sympatho-adreno-medullary (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis. Experienced stress activates the SAM system and involves increased blood pressure, heart rate and the secretion of epinephrine and norepinephrine. The activation of the HPA axis represents a mainly endocrine response to stress. During stressful situations, especially during experienced feelings of helplessness as well as perceived uncontrollability and inability to cope, the pituitary gland releases adrenocorticotropic hormone (ACTH) into the bloodstream which in turn leads to a release of corticosteroids, including cortisol, in the adrenal cortex. Cortisol responses reach their peak approximately 20-30 minutes after exposure to stress. Thus, elevated cortisol secretion represents a biological indicator of subjectively experienced stress. Therefore it is reasonable to assume that athletes show lower cortisol levels during threatening or challenging situations compared to non-athletes (Weiner, 1992).

It is necessary to distinguish between physical and psychological stressors. A large number of studies showed, that the HPA-axis can be stimulated by physical activity. For example, healthy participants showed elevated cortisol levels during sporting activity on bicycle ergometers (Davis, Gass, & Bassett, 1981; Mason, et al., 1973), treadmills (Luger, et al., 1987), and long-distance runs (Dessypris, et al., 1980). On the other hand, there is also evidence for psychological or cognitive stimuli affecting the cortisol levels. Mason (1968) postulated the following basic components of a psychologically provoked cortisol response: novelty or unpredictability of a situation, coping with stressful and uncontrollable situations, anticipation of future challenging events. For instance, elevated cortisol levels were found during anticipatory periods prior to exhausting muscle work (Mason, et al., 1973), academic or scholar exams (Hellhammer, Heib, Hubert, & Rolf, 1985) or public speeches (Lehnert, et al., 1989). Hence, expecting an upcoming threatening or challenging event can lead to a stress reaction represented by an increased cortisol secretion.

Studies comparing endocrine responses in athletes and non-athletes during psychologically stressful situations are extremely scant. In a recent study, Rimmele et al. (2007) compared cortisol responses of physically trained and untrained males to psychosocial stress induced by means of the Trier Social Stress Test (TSST - Kirschbaum, Pirke, & Hellhammer, 1993). The trained group consisted of members of Swiss national or Olympic teams recruited from endurance sports. The TSST consists of an anticipation period and a test period which includes a free speech and a mental arithmetic task in front of an audience. The trained group showed significantly lower heart rate and cortisol responses to the stressor compared to the untrained group. In a later study, Rimmele et al. (2009) found support for their previous findings. A group consisting of amateur sportsmen was added to the experimental design. Amateur sportsmen and untrained man showed the same cortisol levels and only elite sportsmen exhibited reliably lower cortisol levels after exposure to the TSST.

In a previous study, Sinyor, Schwartz, Peronnet, Brisson, and Seraganian (1983) compared self-reported arousal and anxiety, heart rate, and biochemical measures, such as cortisol and prolactin in trained and untrained subjects prior, during, and after exposure to three different cognitive tasks. The three tasks consisted of a mental arithmetic task during exposure to white noise, 23 quiz questions of varying difficulty, and a Stroop task. With this latter task, color-words were displayed on a screen and participants were required to report the color in which the word was printed. The font color was always different from the color-word. Trained subjects showed faster heart rate recovery. The trained group had marginally higher cortisol values than the untrained group but this effect failed to reach statistical significance.

With regard to cortisol measures, the findings of the mentioned studies are quite inconsistent. There might be several reasons for the discrepancy. A possible reason for these ambiguous results may represent differences in the operationalizations of athleticism. Synior et al. (1983) defined the trained group as subjects who participated heavily in “aerobic activities”. Rimmele et al. (2007) recruited only sportsmen who were members of national teams in endurance-trained sports. Additionally Rimmele et al. (2009) were able to show that the level of physical activity affects cortisol levels during stressful situations. Thus, athlete samples may have differed in the absolute level of physical fitness as much as in the efficiency of cognitive strategies for coping with stressful situations. Another possible reason that could account for divergent results in the studies by Rimmele et al. (2007, 2009) and Synior et al. (1983) may be the fact, that different psychological stressors were applied in the two studies. For example, on the one hand, the HPA axis has been shown not to be particularly sensitive to mental arithmetic tasks (Biondi & Picardi, 1999). On the other hand, it has been argued that stressors containing a socio-evaluative and uncontrollable element much more effectively produce an endocrine response compared to other stressors (Dickerson & Kemeny, 2004). This seems to be a crucial point since the TSST, as used by Rimmele et al. (2007, 2009), is characterized by a strong socio-evaluative component (Kirschbaum, et al., 1993).

A social-evaluative threat can be defined as a situation in which important aspects of self-identity are judged by others (Dickerson & Kemeny, 2004). While certain aspects of self-identity may be individually important in special situations or among certain groups of people – for instance athletic ability among athletes – intelligence is considered a core aspect of self-identity, sensitive to social judgment across diverse situations and domains (Crocker & Wolfe, 2001). Consequently, psychometric assessment of intelligence should cause a stress response accompanied by increased cortisol secretion. Furthermore, athletes might exhibit lower cortisol levels during performing on an intelligence test than non-athletes.

Although several studies analyzed endocrine effects while performing different cognitive tasks (Dickerson & Kemeny, 2004), to our knowledge, the effect of standardized psychometric intelligence tests on cortisol levels in athletes compared to non-athletes has not been investigated yet. In the present study, therefore, the short version of the Berlin Intelligence Structure Test (Jäger, Süss, & Beauducel, 1997), a paper-pencil intelligence test, was used as an experimental stressor. Cortisol measures prior and after the test have been taken as a physiological indicator of the subjective level of experienced stress.

We expected that the social-evaluative threat evoked by the intelligence test would elevate the cortisol levels significantly in both groups. Furthermore we predicted, in accordance with the explanations above, that the athletic sample would experience generally less subjective stress, hence show lower cortisol levels compared to the non-athletic sample.

Kirschbaum, Wüst, and Hellhammer (1992) investigated sex differences in cortisol responses to psychological stress in four independent studies. Men showed higher cortisol responses to stress and the anticipation of upcoming psychological stress compared to women. The authors suggested that sex differences in cognitive and/or emotional reactions to stress exposure may have led to the higher cortisol levels in men compared to women. To avoid any possible gender effects on subjectively experienced stress our sample includes solely female participants. A female sample may be of particular interest because previous studies on endocrine responses in athletes and non-athletes during psychologically stressful situations primarily investigated men.

Method

Participants

Participants were 26 female athletes ranging in age from 18 to 29 years (mean age ± SD = 21.0 ± 2.9 years) and 26 female non-athletes ranging in age from 18 to 31 years (mean age ± SD = 21.2 ± 2.7 years). The athletes group consisted of 11 members of the Swiss national foot orienteering team, six members of the Swiss national judo team, and nine members of top Swiss floorball teams. All participating athletes had accomplished secondary education and had acquired a general qualification for university entrance. As a matter of fact, 24 of the 26 athletes were enrolled in University or advanced technical college classes. Non-athlete controls were undergraduate psychology students from the University of Bern who neither were members of a sports club nor reported work out on a regular basis. All participants were offered individual intelligence profiles. In order to avoid interference with assessment of individual cortisol levels, participants were instructed to refrain from physical activity, drinking soft drinks with low pH, eating meals, and smoking at least one hour prior to testing. Informed consent was obtained from each participant before the experiment began.

Procedure

Berlin Intelligence Structure (BIS) Test

For the measurement of psychometric intelligence, the short version of the Berlin Intelligence Structure (BIS) test (Jäger, et al., 1997) was administered. This test is based on Jäger's (1984) BIS model of intelligence. The BIS model classifies cognitive abilities with respect to the required mental operations and, concurrently, with respect to the contents of the processed tasks. Four operations (Reasoning, Speed, Memory, and Creativity) and three contents (verbal, numerical, and figural) are differentiated. The short version of the BIS comprises 15 subtests. Reasoning is assessed by six subtests (two verbal, two numerical, and two figural subtests), while Speed, Memory, and Creativity are measured with one verbal, one numerical and one figural subtest, respectively. Scores on each of the 15 subtest were z standardized. The four operations were quantified by averaging the individual z standardized scores on the six or three subtests for each operation. A more detailed description of the BIS model and an evaluation of the BIS test are provided by Bucik and Neubauer (1996) and by Süß, Oberauer, Wittmann, Wilhelm, and Schulze (2002).

Assessment of cortisol levels

Cortisol concentration was assessed by collecting saliva samples using Salivette (Sarstedt, Sevelen, Switzerland) collection devices. Saliva contains free cortisol which is a reliable measure for cortisol concentration in blood plasma (Kirschbaum, 1991). Assessment took place at three different time points. Participants collected saliva samples themselves by chewing on the cotton swab for one minute. All saliva samples were kept frozen at -20 degrees Celsius until biochemical analysis. The samples were analyzed as described by Westermann, Demir & Herbst (2004). After preparing the samples by centrifuging at 3000 rounds per minute for five minutes to get a supernatant of low viscosity, a commercially available immunoassay with chemiluminescence detection was used (CLIA; IBL-Hamburg, Hamburg, Germany). In this study all cortisol measures are reported in nmol/l.

Time course of the study

All test sessions started in the afternoon and took 65 minutes. After arrival, participants were briefly informed about the study protocol and instructed how to collect the first saliva specimen (T1). The second sample (T2) was obtained 15 minutes later immediately before psychometric assessment of intelligence. During the 15 minutes prior to the second saliva sampling, participants filled in a questionnaire on personal details, such as demographic information and sportive activities, and were given general instructions on the subsequent psychometric assessment of intelligence. After collection of the second saliva specimen, participants worked on the short form of the BIS intelligence test for 50 minutes. The final sample (T3) was collected after completion of the intelligence test.

Results

Descriptive statistics for cortisol levels (three time points) and the operation-related abilities as measured with the BIS test (Reasoning, Speed, Memory, and Creativity) are presented in Table 1.

	Athletes		Non-athletes	
	Mean	SEM	Mean	SEM
Cortisol				
T1	6.19	.66	7.86	.66
T2	5.44	.61	8.82	.69
T3	3.93	.41	6.14	.53
Intelligence				
Speed	.09	.13	-.09	.14
Memory	-.20	.12	.20	.12
Creativity	-.02	.12	.02	.15
Reasoning	-.19	.15	.19	.12

Table 1: Mean and standard error of the mean for the cortisol concentration at the three different time points of assessment (15 minutes before, immediately before and immediately after intelligence testing) in nmol/l, and mean z-scores and standard error of the mean (SEM) for each operation of the Berlin Intelligence Structure Test in athletes (N = 26) and non-athletes (N = 26).

A two-way analysis of variance was conducted with athletes and non-athletes being two levels of a group factor and the three measures of cortisol secretion [15 minutes prior to the assessment (T1), immediately before the assessment (T2) and immediately after the assessment (T3)] being three levels of a repeated-measurement factor. This analysis was computed to investigate a possible differential temporal course of cortisol secretion from 15 minutes prior to the psychometric assessment of intelligence until the end of the assessment. The main effect of the temporal course yielded statistical significance [$F(2,100) = 22.20$; $p < .001$; $\eta^2 = .31$]. After high cortisol measures prior to the intelligence test, cortisol levels decreased during the testing session in both groups. Post-hoc Scheffé-tests revealed that cortisol secretion was significantly lower at T3 compared to T2 but did not vary significantly from T1 to Also the group effect was statistically significant [$F(1,50) = 10.50$; $p < .01$; $\eta^2 = .17$]. Athletes showed reliably lower absolute cortisol levels (5.19 ± .53 nmol/l) compared to non-athletes (7.61 ± .53 nmol/l). Although the interaction effect just failed to reach statistical significance [$F(2,100) = 3.06$; $p = .052$; $\eta^2 = .06$], there was a slight increase in cortisol secretion from T1 to T2 in the non-athletic group, while the athletic group showed a slight decrease of cortisol secretion from T1 to T2.

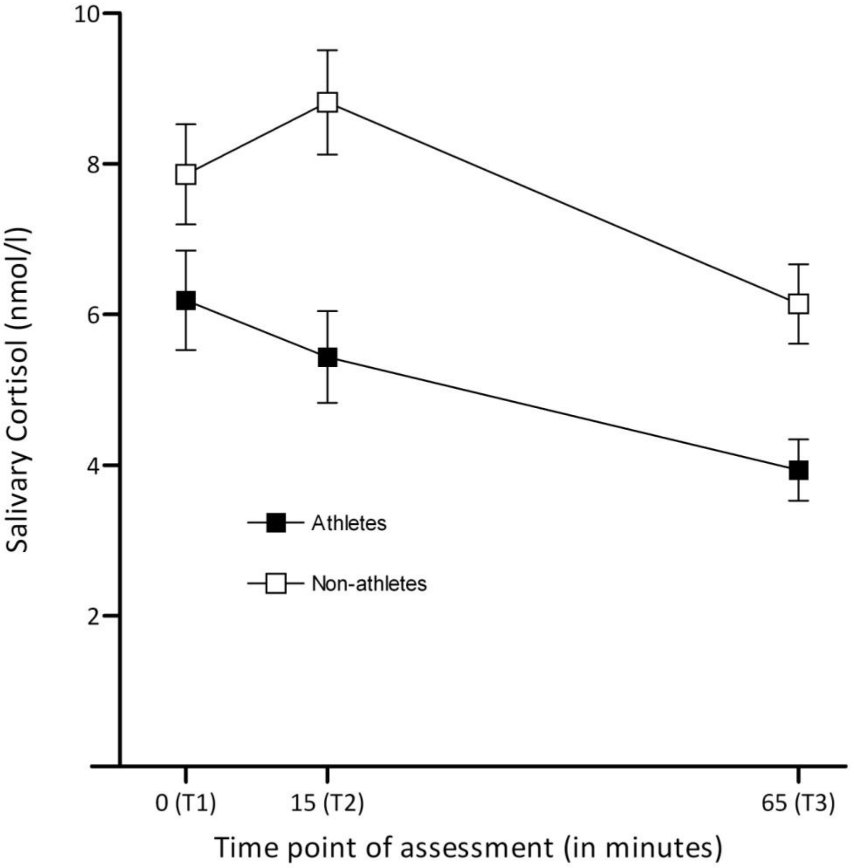

Figure 1. Mean cortisol levels and standard error of mean for each assessment time point (T1: Cortisol sampling on arrival 15 minutes before intelligence testing; T2: immediately before intelligence testing which was 15 minutes after arrival; T3: immediately after intelligence testing which was 65 minutes after arrival).

Discussion and conclusion

In the present study, salivary cortisol levels prior to and immediately after completion of an intelligence test were investigated with emphasis on differences between athletes and non-athletes. The analyses showed differences in salivary cortisol levels over time. After high cortisol measures prior to the intelligence test, cortisol levels decreased significantly during the testing session in both groups. Furthermore differences in cortisol levels between athletes and non-athletes were found. Throughout the three time points of cortisol measurement the athletes showed lower cortisol levels compared to non-athletes. All participants refrained from physical activity, eating meals, smoking, and drinking soft drinks with low pH at least one hour prior to the experiment. All participants were female and of similar age. Controlling these variables, the constant difference over time in cortisol levels between athletes and non-athletes supports the idea that highly trained and professional athletes use better or more efficient coping strategies compared to untrained people (Anshel, 1990).

To answer the question of whether intelligence tests produce an increased cortisol response, it is necessary to distinguish between base and reaction levels in our data. Base cortisol levels represent endocrine activity without responding to a stressor. Only reaction measures would be indicators for subjectively experienced stress. The analyses revealed reliably lower salivary cortisol levels in athletes compared to non-athletes at all three time points of cortisol measurement. If our data consisted only of basal measures in situations where stressors are absent, highly trained athletes should have lower cortisol levels compared to untrained individuals. According to Luger et al. (1987), repetitive high physical activity leads to alterations in baseline as well as in reaction cortisol levels. Highly trained runners showed elevated basal cortisol concentrations compared to sedentary participants and moderately trained runners. In the same study, highly trained runners showed lower cortisol reactions during physical activity compared to untrained controls. Based on these findings, our cortisol data do not represent basal cortisol measures because athletes show lower cortisol levels compared to non-athletes. Both groups did not engage in physical activity at least one hour prior to the experiment. This leads to the assumption that the higher salivary cortisol secretion in athletes compared to non-athletes in the present study was due to the anticipation of the psychometric assessment of intelligence. Further support for this assumption provides the decrease of salivary cortisol during the test session. Previous studies on the circadian activity revealed a moderate decrease of salivary cortisol during the afternoon. The decrease of salivary cortisol observed from T2 to T3 in the present study is larger than the decrease which could have been expected due to normal circadian activity (Kirschbaum, 1991). A third argument for the assumption that the cortisol levels in our data represent stress reactions are the absolute values for each assessment time. Considering the daytime of assessment our cortisol measures for athletes and non-athletes of 7.02 ± 3.45 (T1), 7.13 ± 3.71 (T2), and 5.04 ± 2.63 nmol/l (T3) were higher than baseline salivary cortisol levels as measured by Kirschbaum (1991) where mean salivary cortisol levels were of 4.50 ± 3.5 nmol/l (n = 708) between 3 pm and 5 pm.

The first cortisol measure (T1) might represent an anticipatory response prior to the assessment of intelligence. During the first measure of cortisol secretion 15 minutes prior to the assessment of intelligence, participants knew that they were supposed to undergo psychometric assessment of intelligence. A reason for a stress reaction prior to the intelligence test might be the uncertainty about the form and content of the upcoming cognitive tasks and, of course, the social-evaluative element of such a test. Intelligence builds a fundamental aspect of self-identity (Crocker & Wolfe, 2001) and was going to be measured by a test. Consistent with earlier studies (Hellhammer, et al., 1985; Lehnert, et al., 1989; Mason, et al., 1973), the anticipation of future threatening or challenging events elevated cortisol levels. Both groups, athletes and non-athletes, showed a stress reaction. The fact that athletes showed lower cortisol secretion compared to non-athletes at T1 indicates that athletes used better coping strategies prior to the actual stressor.

The next cortisol specimen (T2) was taken immediately prior to the assessment of intelligence. Again athletes showed significantly lower stress reactions compared to non-athletes. Although the measures at T2 did not differ significantly from T1 within the groups, there was a tendency for a slight decrease in the athletes group and an increase in the non-athletic group. This differential pattern of results suggests that athletes not only use better coping strategies but also engage them earlier.

Cortisol secretion decreased significantly in both groups from immediately before to immediately after the assessment of intelligence. This decrease of cortisol secretion indicates that subjectively experienced stress decreased during the assessment of intelligence. A possible reason for the decreasing stress could be that participants became familiar with the nature of the tasks and had the chance to judge or estimate their performance. Such an adaptation to the situation should decrease the social-evaluative threat by the assessment of intelligence. Without any physical or psychological stressors the sole working on cognitive or arithmetical tasks does not lead to higher cortisol activity (Biondi & Picardi, 1999). Because we would not expect athletes to have lower cortisol levels compared to non-athletes in situations without any stressors, the significant difference between athletes and non-athletes in T3 might indicate that base levels might not have been reached yet immediately after intelligence testing since it takes cortisol measures around 20 minutes to reach their maximum levels after exposure to a stressor and about 40 minutes on average to return to basal levels again (Dickerson & Kemeny, 2004; Kirschbaum, 1991).

Mental performance data is shown in Table 1. Possible differences in intelligence between athletes and non-athletes are not part of this study and are therefore discussed very briefly. Non-athletes showed a better performance in Reasoning and Memory compared to athletes. One possible explanation could be that athletes took the test session less seriously which might have an impact on the subjective social-evaluative threat of such an intelligence test. Consequently this idea would also explain the lower cortisol levels. The missing differences in the other operations and the fact, that the athletes and their coaches received intelligence profiles as feedback do not support this idea. Another explanation could be that the non-athletes group used better memory strategies. Some of the Psychology students might have acquired useful strategies in study courses and it is possible that they also have more experience in intelligence testing, especially concerning tasks measuring reasoning skills. Also relations between cortisol secretion and memory performance should be mentioned here briefly. A large amount of literature documents effects of stress on memory. However, the direction of this effect does not seem to be consistent. While some studies found a negative effect of cortisol on memory, others showed that stress can enhance memory performance (Buchanan, Tranel, & Adolphs, 2010). It could be that in our non-athletes sample the higher cortisol levels had a positive effect on memory performance, but the fact that enhancing effects were mainly found in emotionally arousing memory tasks does not support this assumption (Buchanan & Lovallo, 2001; Cahill, Gorski, & Le, 2010). The examination of differences in intelligence scores between athletes and non-athletes and the question in what extent cortisol levels affect psychometric intelligence demand further research.

To avoid any clues which could lead to an additional threat of self-esteem and, therefore, to higher stress reactions, no self-evaluation of the subjectively experienced stress has been conducted. In future studies information about subjectively experienced stress might help interpret and assure the meaning of cortisol data. Another limitation of the present study can be seen in the fact that no clear baseline measure was obtained. As mentioned above, cortisol levels reach their peak around 20 minutes after exposure to a stressor. It should be noted, however, that several samplings during the period after the completion of the intelligence test would have been helpful to better understand the differences between athletes and non-athletes.

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