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Anticipatory cortisol, testosterone and psychological responses to judo competition in young men

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Abstract

This study compares the anticipatory hormonal and psychological responses of 17 male judo players to an official competition with the data obtained during eight resting sessions carried out at the same time of day, throughout an entire sports season. Testosterone (T) and cortisol (C) levels were determined 1 h and 30 min before competition, and mood, anxiety and expectancies were also evaluated. C levels and anxiety scores were concurrently higher before the contest than in resting conditions; however, non-significant correlations between them were found. The anticipatory T response was not significant for the whole group. However, one group of subjects did display T increases, higher C levels, and higher motivation to win scores than the other group. Furthermore, this group also obtained a better outcome. Thus, this hormonal pattern and its relationships with psychological variables suggest an adaptive psychobiological response to a competition. Results are discussed in the context that neuroendocrine response to competition is associated with cognitive appraisal.

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Keywords: Testosterone; Cortisol; Competition; Anticipatory responses; Anxiety; Mood; Attribution; Appraisal

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1. Introduction

Competition is a challenging situation which usually stimulates intense responses from participants, and sport contexts have been shown to be a useful setting for studying standardized competitiveness. Their value, especially in adolescent and young men, in attempting to find parallels with the social/competitive aggression displayed in other species, has been argued by several authors (Mazur and Booth, 1998; Salvador et al., 1999). A number of studies have tried to confirm in humans the differences in testosterone (T) and cortisol (C) response, depending on the outcome (victory or defeat), found in other species. However, these attempts have had contradictory results. In this context, complex psychological processes related to emotional and/or cognitive interpretation of the situation have been claimed to be more important for hormonal responses than the outcome itself. Thus, androgenic response has been associated with the involvement of the subject in the situation, with T showing positive correlations with motivation to win (Suay et al., 1999) and internal attribution (Serrano et al., 2000), but negative correlations with external attribution of the outcome (González-Bono et al., 1999, 2000). On the other hand, C has been related to the state-anxiety experienced during the contest (Harris et al., 1989; O'Connor et al., 1989; Serrano et al., 2000).

From an endocrinological point of view, the response to competitive situations is elicited even before the competitive activity starts. The organismic control of resources, including hormonal responses, in order to adjust to changing anticipated demands, has strongly been emphasized within the framework of the 'allostasis' (Schulkin et al., 1994). In fact, the existence of an anticipatory C response prior to stressful events of a physical nature has long been recognized (Mason et al., 1973; Sutton and Casey, 1975). More recently, it has been reported that this anticipatory response to competition includes elevations of C (Passelergue and Lac, 1999; Suay et al., 1999; Filaire et al., 2001a) and of T (Booth et al., 1989; Mazur et al., 1992; Suay et al., 1999). This response is different from that observed in anticipation to other psychologically stressful situations, in which C increases are accompanied by T decreases (Schulz et al., 1996). It has been suggested that this elevation of T has a preparatory purpose, which is specific to competitive settings (Booth et al., 1989). However, it has been pointed out that this anticipatory rise, while present in the aggregate, is not highly reliable across subjects (Mazur et al., 1997). In several studies, heightened T before competitive situations has not been found (González-Bono et al., 1999; Filaire et al., 2001b; Passelergue and Lac, 1999).

It has been stated that every anxiety-arousing situation is characterized by its being perceived as a threat, by its being only partially controlled and by uncertainty about the outcome and/or its consequences (Sapolsky, 1994). Sports competition meets these three characteristics, including both physiological and psychosocial stressors. Hence, it can be considered as an anxiety-arousing situation. The different expectations and mood states prior to the contest could also play an important role in the hormonal anticipatory response. In fact, some studies focusing on psychoendocrine responses to competition have shown that T is positively associated with motivation to win (Suay et al., 1999) and positive mood (Vigor) assessed before competitive

encounters (Salvador et al., 1991), although another study failed to find significant associations with anxiety (Filaire et al., 2001a,b). Furthermore, it has been reported that the subject's expectation determines the positive or negative effects of anxiety on performance (Carver and Scheier, 1988) and that self-confidence can moderate the effects of physiological arousal and cognitive anxiety on performance (Hardy, 1990). In a previous study, self-efficacy scores before the contest were related to C response depending on outcome (Suay et al., 1999). Hence, the association between anticipatory hormonal responses and psychological dimensions is not a clear, simple result, suggesting a fairly complex description of relationships.

It is worth noting that the hormonal response prior to competition has been established within a broad time range. Hormonal increases have been reported the day before the contest (Mazur et al., 1992), 1 h before (Eubank et al., 1997), during the 15 or 10 min prior to the competitive event (Booth et al., 1989; Suay et al., 1999) or immediately before (Sutton and Casey, 1975; Passelergue and Lac, 1999; Filaire et al., 2001a,b), and generally using just one sample. An ample period has the inconvenience of introducing other potentially confounding factors (for instance, hours of sleep or meals), whereas a very short interval involves including the effects of the 'warming-up' prior to the competition. On the other hand, the values obtained in the contest have been compared with resting basal values sampled on just one, perhaps non-representative day, on some occasions at different hours of the day.

Keeping all this in mind, this study focuses on hormonal and psychological anticipatory responses of judo players to a real contest (not organized ad hoc, for experimental purposes). Due to the high inter-individual hormonal variability, intra-subject designs are better for evaluating the hormonal responses. Therefore, in addition to hormone levels on the day of the contest, we also studied measures on non-competitive days at similar times of the day, so as to establish the subjects' basal levels more accurately. Our main goal was to verify the anticipatory hormonal and psychological responses to competition during the period immediately preceding the contest. For this purpose, we employed two samples in order to better characterize the response, but avoided the potential contaminating effects derived from warming-up. A second aim was to study the relationships between T and C levels and some relevant psychological variables assessed before the competition, such as expectations, anxiety and mood. In accordance with previous research, in which we found an anticipatory hormonal response to competition (Suay et al., 1999), we expected that C levels would be higher and subjects would feel more anxious before the contest than in the resting situations studied. Moreover, we expected that T would be positively related to the motivation to win and positive mood, whereas C would be positively correlated with anxiety and negative expectations to win. A non-directional hypothesis is formulated concerning T changes.

2. Methods

2.1. Sample

The sample composed of 17 young male judo fighters. All subjects reported being drug free, which presumably could affect hormonal levels at the time of the study.

They signed informed consent forms, approved by the local Medical Ethics Committee, in order to take part in the investigation. Subjects participated in laboratory tests to evaluate their maximum physical fitness. Their main general characteristics are shown in Table 1.

2.2. Procedure

At the beginning of the study, an ergometric cycling test was carried out in order to find out the fitness status of the subjects. Briefly, the ergometric protocol consisted of a maximal test in which work loads were increased by 30 W/min, until voluntary exhaustion was reached. Afterwards, eight resting sessions (RSs), one every fortnight, were held during the second part of the sports season (February–June), apart from the competitive sessions. There was no physical activity 24 h before and after each RS was carried out. In each RS, two saliva samples were taken at 10:00 and 10:30 h to determine T and C levels. Approximately in the middle of the period studied, judo fighters participated in a regional competition with a similar schedule to that of the RSs, where saliva samples were taken at 9:50 and 10:20 h, the latter approximately 30–40 min before each subject's first combat. Levels obtained from the first sample are named Comp-T₁ for T and Comp-C₁ for C, and levels from the second sample are named Comp-T₂ and Comp-C₂, respectively. Subjects were weighed between both salivary samples for selection of weight fighting category, and they warmed up after the second salivary sample was collected.

In RSs as well as in competition, subjects filled in the state anxiety inventory (STAI-S) and the profile of mood states (POMS) between salivary samples. On a specific scale, subjects rated their expectations about the contest.

2.3. Hormonal measurements

Subjects were instructed about salivary sample collection at the beginning of the study and were reminded in each session. Saliva was collected directly from mouth to tube (Unitek R). Samples were centrifuged and frozen at -20°C until determination. All the samples of every subject were run in duplicate in the same assay.

Table 1
Characteristics of the sample

	Mean	SEM
Age (years)	19.35	0.61
Judo practice (years)	10.41	0.12
Height (cm)	176.63	12.79
Weight (kg)	74.05	3.74
Body mass index (kg/m ²)	23.62	0.52
W _{max} (W)	301.54	9.46
VO _{2max} (l/min)	3.38	0.11
Anaerobic power _{max} (W)	666.46	33.41

Hormonal determinations were made by RIA in the Hormone Laboratory at hospital La Fe (València, Spain). The salivary T assay required a previous extraction phase. Afterwards, ^{125}I -testosterone tracer was added and decanted into a coated tube with a highly specific antibody provided by a commercial kit (ICN Biomedicals, Costa Mesa, CA). Samples were counted by gamma counter for 1 min.

T levels were expressed in picomoles per liter, and intra- and inter-assay variation coefficients were 5.7 and 6.2%, respectively. Sensitivity was below 6 pmol/l.

Salivary C was determined by a commercial kit adapted to salivary levels after dilution of the antibody in the buffer, as was recommended in the protocol (Orion Diagnostica, Espoo, Finland). Saliva (100 ml) was mixed with ^{125}I -cortisol tracer and highly specific antibody. Samples were decanted and counted for 1 min. C levels were expressed in nanomoles per liter. Good precision was obtained with intra- and inter-assay variation coefficients of 2.2 and 8.2%, respectively, with a sensitivity of 1 nmol/l.

2.4. *Psychological measures*

Anxiety and Mood states were assessed by means of the Spanish versions of STAI-S (Spielberger et al., 1982; TEA, Madrid) and the POMS, respectively. This latter questionnaire comprised six scales: Anxiety, Depression, Anger, Vigor, Fatigue, and Confusion (McNair et al., 1971; Balaguer et al., 1993). All the subscales except Vigor express negative mood. The Spanish version of the STAI permits scores between 0 and 60 because the items are scored from 0 to 3 instead of the original 1–4 scale. For this reason, both direct and percentile scores will be offered.

Before the contest, subjects answered two questions about their interest in winning and their possibilities of doing so, on a five-point Likert scale (0=not at all; 1=a little; 2=moderately; 3=quite a bit; 4=extremely).

3. **Statistics**

MANOVAs with two within-subject factors ('moment': first and second sample in each session; and 'session': eight levels corresponding to the eight RSs) were used to study hormonal stability in RSs. MANOVAs with two within-subject factors (moment: the two saliva samples; and session: competition vs. mean values of the RSs) were used to compare hormonal levels in competition and non-effort situations. When the results were significant, repeated measures ANOVAs with the appropriate within-subject factor were carried out. One-way ANOVAs were performed to examine the differences between subgroups established depending on the T response.

Spearman correlations were employed with hormonal and psychological variables, and Bonferroni adjustments were applied. Hormonal changes to compare different patterns in the hormonal anticipatory response were calculated by means of differences between the first and second sample. Descriptive data are expressed as mean \pm SEM. All analyses were run in the SPSS 8.0 package for Windows. A confi-

dence interval of 95% was considered significant in all analyses; two-tailed significance levels are reported.

4. Results

4.1. Reference values and stability of hormones in RSs

T levels measured in the RSs varied in a range of 128.56–311.20 pmol/l (202.88 ± 34.32 pmol/l). Values are similar to those measured in other studies (Dabbs et al., 1991). The MANOVAs did not show any significant effect of the factors moment or session on T levels in the RSs. C oscillated between 4.84 and 16.74 nmol/l (9.49 ± 1.24 nmol/l), which was within salivary C reference values (Aardal and Holm, 1995). When only the C levels measured in the RSs were considered, the MANOVA showed a significant effect of moment ($F_{1,8} = 8.82$; $p < 0.05$) but not of session. The lack of a significant effect of the factor session in RSs permitted the use of the means of the first (T₁ or C₁) and second samples (T₂ or C₂) for subsequent analyses. Table 2 shows descriptive hormonal data for each of the eight RSs and the calculated means.

4.2. Hormonal responses to competition

The MANOVA with session (competition vs. RSs) and moment (first and second samples) as within-subject factors revealed significant effects of moment ($F_{1,16} = 11.28$; $p < 0.005$) and session ($F_{1,16} = 8.27$; $p < 0.02$) on C levels (Fig. 1). Simple effects analyses (ANOVA) showed significantly higher levels in competition than in RSs in both moments measured ($F_{1,16} = 7.24$; $p < 0.02$; $F_{1,16} = 7.58$; $p < 0.02$ for Comp-C₁ and Comp-C₂, respectively).

For T, the equivalent MANOVA with session and moment did not present significant effects (for moment effect: $F_{1,16} = 0.65$, $p < 0.43$; for session effect: $F_{1,16} =$

Table 2
Mean (SEM) of T and C levels in each of the eight RSs and the mean values for both means

	T ₁	T ₂	C ₁	C ₂
RS 1	207.30 (29.88)	190.64 (17.03)	12.06 (1.16)	8.98 (0.82)
RS 2	221.97 (20.66)	161.07 (21.97)	10.44 (1.29)	7.34 (1.03)
RS 3	177.65 (23.09)	163.71 (24.33)	10.47 (0.81)	8.40 (0.59)
RS 4	171.03 (23.44)	176.60 (23.10)	8.18 (1.44)	6.54 (0.92)
RS 5	176.30 (23.85)	179.94 (22.78)	8.94 (1.96)	7.14 (1.29)
RS 6	210.93 (30.22)	201.45 (22.95)	13.51 (1.90)	8.23 (0.90)
RS 7	219.53 (19.01)	231.72 (19.19)	11.66 (1.97)	9.05 (1.14)
RS 8	264.51 (34.82)	219.85 (19.79)	11.66 (1.25)	9.05 (1.07)
Mean values	203.57 (15.37)	190.02 (13.39)	10.87 (1.02)	8.14 (0.59)
N	17	17	17	17

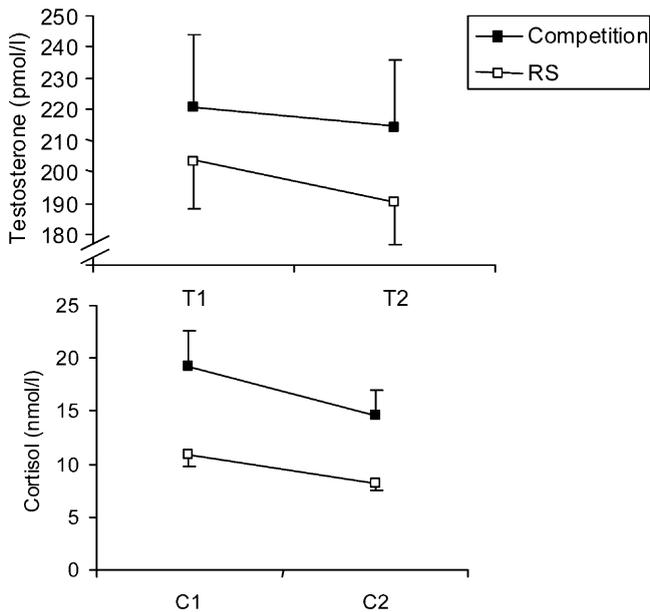


Fig. 1. Mean and SEM for testosterone (T1 and T2) and cortisol (C1 and C2) levels before competition and mean values of the RSs.

0.70, $p < 0.42$; and for moment vs. session interaction: $F_{1,16} = 0.16$, $p < 0.70$). A great variability was found in the data, which showed important individual differences among the T anticipatory response patterns displayed by subjects.

It has been proposed that an individual can be considered as a C-responder when his/her C levels rise more than 15% from the baseline (Kirschbaum and Hellhammer, 1989). To our knowledge, no similar criteria have been proposed to define a T response, which would permit the discrimination between responders and non-responders. Trying to advance in this line, if we select those subjects who experienced increases larger than 15% of baseline (a percent change which also implies an absolute value greater than 20 pmol/l), we found a small group of six subjects (T-responders). These subjects displayed higher Comp-C₂ levels ($F_{1,16} = 5.41$; $p < 0.03$) and showed marginally more interest in winning the contest ($F_{1,16} = 4.17$; $p < 0.06$) than the other 11 subjects.

4.3. Psychological responses to competition

Significant effects of session (competition vs. RSs) were found on the STAI-S ($F_{1,16} = 5.93$; $p < 0.03$), with mean scores being 17.59 (SEM = 1.82, percentile of the mean = 45, with individual percentile oscillating from 35 to 50) in competition and mean scores of 14.29 (SEM = 1.28, percentile of the mean = 25, with individual percentile oscillating from 23 to 35) in RSs. The factor Session was also significant on the Anxiety scale of POMS ($F_{1,16} = 6.66$; $p < 0.02$), with higher

scores before the competition (Competition: mean = 7.76, SEM = 1.22, T-scores from 35 to 39; and RSs: mean = 5.25, SEM = 0.70, T-scores from 34 to 36). This factor did not prove to be significant on the other POMS scales.

All subjects reported a high motivation to win and self-confidence with scores between 3 (quite a bit) and 4 (extremely). The descriptive data for both items are shown in Table 3.

4.4. Correlations between hormonal and psychological variables

Only the second hormonal values, that is, those closer to the competition, showed significant correlations with some psychological measures. T levels (Comp-T₂) were negatively correlated with *Fatigue* ($r = -0.67$; $p < 0.003$). Furthermore, Comp-C₂ was positively related to the *possibilities of winning* ($r = 0.64$; $p < 0.006$).

5. Discussion

The wide set of reference saliva samples, provided throughout 16 weeks at the same times at which the contest took place, allows us to appreciate that hormonal levels were quite stable in resting conditions (RSs), and that C levels were significantly higher in competition, thus confirming previous reports about the existence of an anticipatory C response to this type of situation. C levels in the second sample (Comp-C₂) were lower than in the first one, collected 30–40 min before (Comp-C₁). So, it seems that there is a rise in C quite a while before the start of the competition and then, a decline as it approaches. This decline was also observed in the RSs, suggesting that it may reflect the circadian variation of C, which has been shown to be capable of overlapping even the effect of other factors such as the physical effort made (Thuma et al., 1995). Considering that the subjects were ready to perform a

Table 3
Mean (SEM) Anxiety and POMS prior to the competition and prior to the eight RSs

	Competition	RSs
STAI-S		
Anxiety	17.59 (1.82)	14.29 (1.28)
POMS		
Tension-Anxiety	7.76 (1.22)	5.25 (0.70)
Anger	6.06 (1.08)	5.37 (0.81)
Fatigue	2.76 (0.76)	2.57 (0.70)
Depression	3.20 (1.12)	3.33 (1.13)
Confusion	3.88 (0.69)	3.49 (0.64)
Vigor	17.82 (1.46)	16.89 (0.93)
Total score	102.00 (4.07)	103.12 (4.07)
Interest in winning	3.76 (0.29)	–
Possibilities of winning	3.82 (0.21)	–

physical effort, the anticipatory C rise could be considered as physiologically advantageous, since it facilitated a greater energy availability during the start of the effort, which is considered to be a part of the physiological preparation for activity (Arthur, 1987). In fact, pre-effort C rises have been related to the intensity of the subsequent exercise, since significant correlations have been found between previous C levels and post-exercise lactate (Stupnicki et al., 1995).

In real sports competitions, the warming-up makes it very difficult to collect salivary samples closer to the start without overlapping pre-competition and hormonal variations due to the exercise. In our case, since warming-up was performed after the second salivary sample, the C response is clearly independent of the physical activity developed during these exercises. Nevertheless, between the first and second samples, subjects were weighed in order to determine the weight-category of each fight. It is possible that this fact could affect glucocorticoid levels, since at this moment subjects received more information about who the exact opponents were against whom they had to compete, and this, in turn, could affect their expectancies. This procedure could not be avoided without disturbing the usual schedule of real competitions. However, far from being an inconvenience, it suggests a new interesting aspect to take into account in real, face-to-face confrontations. The correlations of hormones with psychological dimensions only appeared in relation to the second sample.

Anxiety scores were also significantly higher in competition than in the RSs, thus confirming the anxiogenic nature of sports contests. The high anxiety state was concurrent with the C anticipatory response, suggesting that the previously described relationship between C and competition-related negative mood (O'Connor et al., 1989; Serrano et al., 2000) could be replicated here. However, no statistically significant relations between C and anxiety measures have been found. Instead, C was positively related to self-confidence (*possibilities of winning*). On the other hand, T was negatively related to the state of fatigue experienced before the contest, which is consistent with the positive association between T and Vigor reported in sports situations (Salvador et al., 1991; Tanaka et al., 1989), although it has not been replicated here.

The anticipatory T response described in previous studies (Booth et al., 1989; Mazur et al., 1992; Mazur et al., 1997; Suay et al., 1999) did not appear in the whole group of judo players. However, an individualized analysis of the hormonal responses showed different patterns in the pre-competitive T behavior. In spite of the fact that at the time of day at which the competition took place T levels were decreasing due to the circadian rhythm, some subjects displayed an anticipatory rise of T, while others did not. The T increase, larger than 15% of baseline values in all the T-responders, was accompanied by a greater motivation to win and higher C levels just before the competition.

Different neuroendocrine patterns of response have been associated with distinct coping styles (Henry, 1986) in animals (Koolhaas, 1994) as well as in humans (Salvador et al., unpublished data). Concretely, it has been suggested that the optimal response to a challenge would be characterized by a continuous increase in T, together with a low previous level and a moderate response of C (Dienstbier, 1989;

Eubank et al., 1997), an endocrine response which has been considered to be specific to the 'pure fight pattern of response' (Henry, 1986). A pre-competitive pattern of hormonal response characterized by T increases has been described in a subgroup of elite canoeists (Eubank et al., 1997), who also appraised their somatic anxiety as enhancing (and not worsening) their subsequent competitive performance. Currently, two different directions—*facilitating* vs. *debilitating*—in the experience of anxiety have been proposed (Jones and Swain, 1992, 1995). While the canoeists differed in the *directional dimension* (facilitating vs. debilitating), our T-responders did not differ from the others in the anxiety scores obtained (STAI-S). Since we did not have a directional measure of their feelings of anxiety, we cannot characterize our T-responders as *facilitators*. Nevertheless, considering that they were more motivated to win before the contest, and also that they actually won (five of the six subjects obtained a first place while the other classified second), we may speculate that their psychobiological response to the competition was adequate or facilitating.

A problem inherent to this type of studies, centered in real situations, is the low number of subjects. The impossibility of replicating the conditions of each situation prevents the aggregation of cases in order to obtain bigger samples. Thus, the number of subjects in most of the studies cited is nearly 15, oscillating between 6 (Booth et al., 1989) and 17 subjects (Filaire et al., 2001a). These studies have, on the other hand, strong advantages, such as the typical ego-involvement of real situations, and offer the possibility of making important hypotheses to be later studied in the laboratory. For example, one issue which could be modulated by the cognitive interpretation of the situation is the relationships between T response to competition and anxiety dimension.

In summary, in the present study we have confirmed the anticipatory C elevations to the competition. More importantly, all relationships found concerning C suggest that the high levels of this hormone could be facilitating an appropriate state to fight by enhancing energy availability, together with a psychological state characterized by high motivation to win and self-confidence, which would contribute to ensuring a maximum competitiveness and effort. Moreover, although we failed to find an anticipatory T response to competition, some individuals did display the expected T increases in addition to greater motivation to win. In our opinion, it would be interesting to go further in the study of the possible role of this specific anticipatory response (T and C increases) in facilitating successful coping.

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