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Hormonal responses to competition

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Sports competitions have been employed to analyze the influence of social confrontations on hormonal levels. However, results have been inconsistent. Several variables such as outcome, physical exertion, mood and causal attribution have been considered as important mediators of this influence. Our aim was to examine their role in the testosterone and cortisol responses to a real confrontation. To this end, twelve judoists who participated in a competition between clubs were studied. Results showed non significant differences depending on outcome in hormones, physical exertion, mood and causal attribution; only satisfaction with the outcome being significant. Interestingly, testosterone response was positively associated with self-appraisal of performance and attribution of outcome to personal effort. Cortisol response showed a very consistent relationship with negative mood. These findings support a clear association of competition-induced hormonal responses with cognitive and emotional aspects rather than with objective (outcome or physical exertion) characteristics of the situation.

Respuesta hormonal a la competición. Las competiciones deportivas han sido utilizadas para analizar la influencia de enfrentamientos sociales sobre los niveles hormonales. Sin embargo, los resultados han sido inconsistentes. Diversas variables como el resultado, el esfuerzo físico, el estado de ánimo y la atribucin causal han sido consideradas como importantes mediadores de dicha influencia. Nuestro objetivo fue examinar su papel en la respuesta de la testosterona y del cortisol en un enfrentamiento real. Para ello, doce judokas que participaban en una competición real entre clubs, fueron estudiados. Los resultados no mostraron diferencias significativas en función del resultado en los niveles hormonales, esfuerzo físico, estado de ánimo ni en la atribución causal; únicamente la satisfacción con el resultado fue significativa. Interesantemente, la respuesta de la testosterona fue positivamente asociada con la autosatisfacción (self-appraisal) de la ejecución y la atribución del resultado al esfuerzo personal. El cortisol mostró una relación consistente con el estado de ánimo negativo. Estos resultados apoyan una clara asociación de las respuestas hormonales inducidas por la competición con aspectos cognitivos y emocionales más que con características objetivas de la situación (resultado o esfuerzo físico).

The study of the hormonal responses to competition has mainly been conducted to confirm in humans the influence of the outcome of social confrontations on hormonal levels found in other species. A number of studies have employed sports competitions as controlled and standardized situations to analyze this subject, however, the results have been inconsistent. A possible explanation is the different temporal intervals employed to study the endocrine response. A first study involving 8 tennis players reported that the testosterone (T) plasma levels were higher in winners than losers within two hours after the competition (Mazur and Lamb, 1980). In other studies, however, the differences have been found in shorter periods afterwards, for instance, significantly greater percent changes in T and higher cortisol (C) levels in winners than in losers were found comparing titers measured 10 min before and 10 min after wrestling bouts (Elias, 1981). Moreover, the greatest differences between 6 winners and losers of tennis matches were found in T levels obtained 15 min before the match compared to samples collected immediately afterwards (Booth, Shelley, Mazur, Tharp and Kittok, 1989). In two studies involving judo combats, non significant differences between winners and losers in serum T and C were found, when values measured 10 min before and 45 min after combat were compared (Salvador, Simón, Suay and Llorens, 1987; Salvador, Suay and Cantón, 1990). In a third study, significantly higher serum levels of C, although not of T, were found in winners than in losers 10 min before and 10 min after the combat (Suay et al., 1999).

On the whole, these studies show that the greatest effects of outcome on T and C appear in short periods after contests. However, in all these situations subjects made a physical effort which in itself could be a sufficient stimulus to produce important hormonal variations (Howlett, 1987; Sutton, Farrell, and Harber, 1990), which could affect the T and C response to competition, especially when hormonal measurements have been collected shortly after the competition, without a physical recovery period. Hence, the different levels of physical exertion could explain the inconsistencies found in the studies carried out and may even be an alternative explanation for the hormonal variations produced in competition.

Mazur and Lamb (1980) suggested that the mood experienced by subjects after the competition plays a main role in the T

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changes depending on the outcome. Several studies have emphasized this role (Booth et al., 1989; Gladue, Boechler and McCaul, 1989) although mood is not considered the only factor mediating hormonal response (McCaul, Gladue and Joppa, 1992). These latter authors using a luck-controlled task (coin tossing) concluded that winning or losing, regardless of actual performance or merit, differentially influenced T levels. This statement contrasts with previous results by Mazur and Lamb (1980) who reported a second study concerning lottery winners who obtained an economical prize equal to that of the tennis match winners; a lack of winning/losing effects was found in this situation, which was interpreted as due to the absence of personal effort in achieving the prize. Recently, we found that T response positively correlated to personal contribution to outcome (measured as scores divided by playing time) and negatively to the external attribution of the outcome (luck) in professional basketball players who won an important match (González-Bono, Salvador, Serrano and Ricarte, 1999). All these findings emphasize the influence of personal contribution to the outcome and/or causal attribution of outcome on the hormonal responses to competition.

Measuring salivary hormones facilitates the acquisition of a wider number of samples to explore the temporal interval as well as to study real competitive situations. It is important to take into account this point because the meaning of the competition for participants and the competitiveness involved could condition T response (Salvador et al., 1987; Mazur, Booth and Dabbs, 1992; Mazur and Booth, 1998; Suay et al., 1999).

This study aimed to examine the role of the mentioned variables (outcome, physical exertion, mood and causal attribution) on the T and C responses to a real judo competition. This type of confrontation provides an important personal involvement derived from the competitiveness and the interest in winning rival clubs. Both objective (lactate) and subjective (perceived exertion scale) measurements of physical exertion were employed. Lactate is considered a reliable indicator of effort, and perceived exertion scales have demonstrated high, positive correlations with it (Watt and Grove, 1993). Moreover, mood as well as perceived personal contribution, involving performance appraisal and causal attribution, was measured to study their role in the endocrine response. According to the previous findings, we expected the greatest differences in hormonal response between winners and losers to be soon after the end of the competition, subsequently vanishing with the passage of time, and these different changes would not be due to differences in the physical effort exerted, but rather to psychological aspects, including mood and feelings of competence. With regard to C, increases in both winners and losers were expected, especially in winners on the basis of the results found in the literature.

Methods

Sample

It was composed of twelve male judo fighters who participated in a real judo competition between various clubs of Valencia (Spain) in the first half of the sports season. All were informed about protocol and gave written consent approved by the local Committee of Medical Ethics. Sample characteristics are shown in Table 1.

Design and experimental protocol

This study is a part of a larger research project. At the beginning of the study, subjects were submitted to a medical examination in the Sports Medical Centre in Cheste (Valencia, Spain), which included a maximal cycloergometric test (Wasserman protocol) and other physiological measurements (see Table 1). Fourteen subjects of the research project belonged to clubs, which participated in the competition, together with other judoists (a total of 27). It was only possible to get a sufficient number of samples from twelve of them, all of whom were drug free. They fought two or three combats depending on the result of the previous encounter in the competition. At the end of the competition 5 judoists finished in first position in their category (gold medal) and were considered winners, whereas the rest were considered losers.

Five salivary samples for hormonal determinations were collected in the competition. The temporal period was established according to previous data (González-Bono, 1993), and the possibilities permitted by the referees and coaches. Two samples were taken before the competition: one before the weigh-in (9:20 a.m.) and the second approximately 30 min afterwards (9:50 a.m.). The inter-club competition took place from 10:15 to 11:25 a.m. although subjects confronted each other at different times according to their corresponding combats. Post-competition salivary samples were collected at 10, 30 and 45 min after the end of the last combat for each subject.

Simultaneously with the second pre-competition salivary sample, Profile of Mood States (POMS) inventory was completed by subjects. Furthermore, between the first and second post-competition salivary samples, subjects again filled out the POMS inventory and answered several questions on perceived exertion and on their appraisal of the outcome and performance.

Just before the first combat and immediately after the last combat of each subject, samples of capillary blood were taken from the ear lobe in order to measure basal and maximal level of lactate, respectively.

Hormonal measurements

Subjects were instructed about salivary sample collection at the beginning of the study, and reminded in each session. Saliva was stimulated by water with lemon juice and was directly collected from mouth to tube (Unitek R) five minutes later. Salivary samples were centrifuged and frozen at -20 C until determination. All the samples of every subject were run in duplicate in the same assay. Hormonal determinations were made by RIA in the Hormone Laboratory in Hospital La Fe (Valencia, Spain).

Table 1
Mean, SEM and range of the main characteristics of the sample

	MEAN	SEM	RANGE
Age (yrs)	20.25	0.61	17-23
Height (cm)	179.33	2.47	164-190
Weight (Kg)	77.16	3.06	62-92
Body Mass Index (BMI)	23.88	0.42	20.98-25.48
VO2max (ml/min)	3516	147.98	2863-4202
LAmax (mmol/l)	9.32	0.54	7.3-12.4
FCmax (beats/min)	182.77	2.83	163-190

The salivary T assay required a previous extraction phase, which was carried out by employing 3.5 ml of ether and separating supernatant by freezing. After evaporation, ^{125}I-Testosterone tracer was added and decanted into a coated tube with high specific antibody provided by commercial kit (ICN Biomedicals, Costa Mesa, CA). Bath incubation was performed at 37 ºC for 2 hours. After 10 minutes of temperature equilibration, samples were decanted and counted by gamma counter for 1 minute. Internal and external control tubes were routinely included in duplicate in every assay. Testosterone levels were expressed in pg/ml and intra and interassay variation coefficients were 5.7 and 6.2 %, respectively. Due to the adaptation of the commercial kit to salivary samples, sensitivity was recalculated as the detectable concentration equivalent to twice the standard deviation of the zero-binding value, which was below 6 pmol/l.

Salivary C was determined by a commercial kit adapted to salivary levels after dilution of the antibody in buffer as was recommended in the protocol (Orion Diagnostica, Espoo, Finland). Saliva sample (100 ml) was mixed with ^{125}I-Cortisol tracer and high specific antibody. The lyophilized C antiserum provided in the kit is produced in rabbits by immunizing a BSA conjugate of C-3-carboxy-methoxylamine. The tubes were bath incubated at 37 ºC for 1 hour. Subsequently, polyethylene glycol was added and samples were centrifuged at 5000 rpm for 15 minutes (10 ºC). Finally, samples were decanted and counted for 1 minute. Cortisol levels were expressed in ng/ml and internal and external controls were included in the assays. Good precision was obtained with intra and interassay variation coefficients of 2.2 and 8.2 %, respectively, with a sensitivity of 1 nmol/l.

Exertion measurements

20µ of capillary blood was obtained from the ear lobe to determine blood lactate. The samples were frozen at -27 ºC and analyzed by means of an enzymatic method (Boehringer, Mannheim, Germany). The measurements used were: LAbasal (level of lactate before the competition); and LAmax (maximal level of lactate reached between minutes 1 and 3 of the recovery).

Perceived exertion was measured with the CR-10 scale (Borg, 1982), which ranged from 0 to 10 with verbal anchors every two points, starting from 'very, very light' to 'very, very hard'. The CR-10 scale is considered especially useful to measure anaerobic efforts (Noble, 1982) such as judo fights.

Self-report measurements

Mood states were measured by the Spanish version of the POMS conveniently validated (Balaguer, Fuentes, Meliá, Garcia-Merita and Pérez-Recio, 1993). This questionnaire contains 58 Likert-point items distributed in six subscales: Tension/Anxiety; Depression; Anger; Vigor; Fatigue; and Confusion (McNair, Lorr and Droppelman, 1971). All subscales but Vigor express negative mood. A total score is calculated adding the negative scales and subtracting Vigor (POMS-t).

After the competition three questions were asked. The first about satisfaction with the result (item 1) and the second one concerning self-appraised performance (item 2). The third question referred to the attribution of the outcome which included different factors regarding external attributions (mistakes made by the opponent, luck and the referee's decisions), and internal attributions (personal effort and physical and technical abilities). All of these questions were answered using a 5 point Likert-type scale.

Statistical Analyses

Ancovas of repeated measures were performed to analyze hormonal levels by outcome, using the first value as covariate. Comparisons between groups were carried out by means of one-way Anovas. Hormonal response was measured by percent changes: T changes (TC) calculated with the different samples were denoted TC21, TC31, TC41 and TC51; and C changes (CC), denoted CC21, CC31, CC41 and CC51. Spearman correlations were calculated to analyze the relationships between hormonal responses and the variables studied.

A two-tailed significance level of p=0.05 was established. All data are presented with mean SEM (except where indicated SD). SPSS 4.0 for Macintosh was employed.

Results

Hormonal response to the outcome

On the whole, winners displayed increases in T along the consecutive samples until 30 min after the competition, whereas losers showed decreases (Figure 1). Ancovas of repeated measures reve-

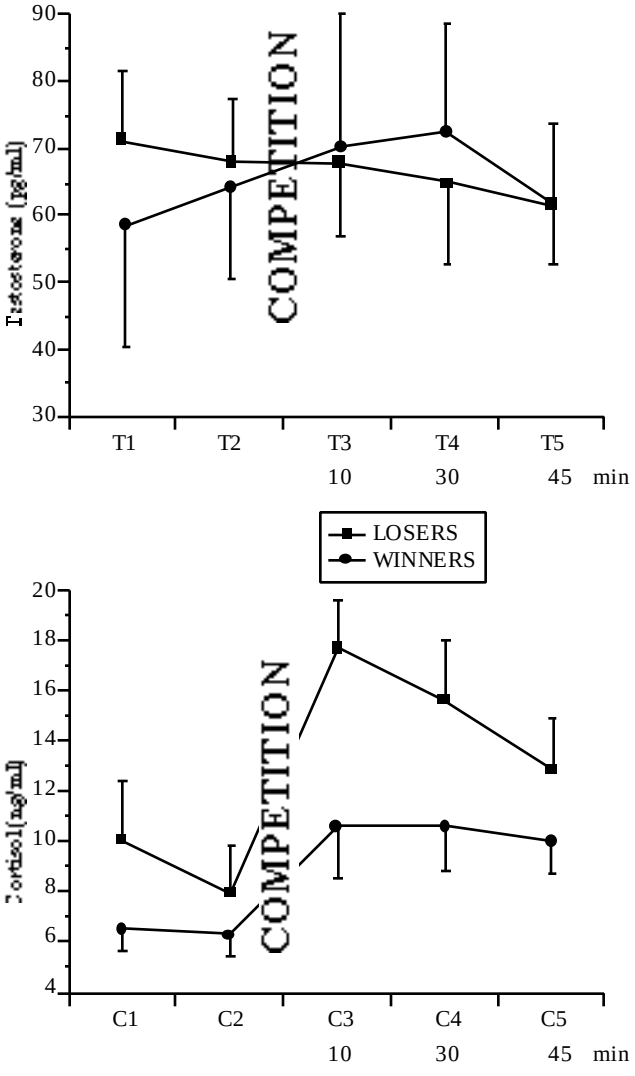

Figure 1. *Mean (SEM) of testosterone and cortisol levels before and after the competition*

aled no significant effects of 'outcome', 'moment' and 'outcome*moment' interaction on T levels. With regard to C, only a significant effect of 'moment' ($F_{3,30}=8.71$; $p<0.001$) was found.

The main effect of 'outcome' on T changes was not significant ($F_{1,10}=3.68$; $p<0.08$), the closest to statistical significance being at 10 and 30 min post-competition ($F_{1,11}=3.742$, $p<0.08$ and $F_{1,11}=3.862$, $p<0.08$, respectively). Only 'moment' ($F_{3,30}=4.11$; $p<0.01$) showed a significant effect on C changes.

Exertion measurements

Winners showed slightly lower values than losers in Lamax (10.24±1.31 vs 10.80±0.60 mmol/l, respectively) and CR-10 (7±0.32 and 7.57±0.48, respectively), these differences not being statistically significant ($p>0.39$ for both).

The correlation between both objective and subjective measurements for the entire group was significant but moderate ($r=0.528$; $p<0.05$).

Psychological measurements

No statistically significant differences between winners and losers were found in total of POMS, either before or after competition or in changes. Interestingly, winners showed a worse mood than losers in the competition, especially before it (Table 2).

As expected, winners presented significantly higher satisfaction with the outcome ($F_{1,11}=10.74$, $p=0.01$), although they did not have a higher appraisal of their performance than losers ($p>0.29$). No significant differences between winners and losers in internal and external attributions were found. The higher probability was found in the item concerning personal effort ($F_{1,11}=2.55$, $p<0.14$), winners showing higher values.

Relationships between effort and psychological variables with hormonal changes

Lamax, but not CR-10, correlated highly but not significantly with hormonal changes measured at 10 min after the competition ($r=0.44$ for TC31 and $r=0.35$ for CC31, respectively).

However, self-appraisal of performance significantly correlated with TC41 ($r=0.53$, $p=0.04$) and TC51 ($r=0.63$, $p=0.01$). In addition, attribution of outcome to personal effort was also positively correlated with TC31 ($r=0.47$, $p=0.06$), TC41 ($r=0.53$, $p=0.04$) and TC51 ($r=0.64$, $p=0.01$).

Table 2
Mean and SEM of the mood scores before and after the competition

	Winners				Losers			
	Pre		Post		Pre		Post	
	MEAN	SEM	MEAN	SEM	MEAN	SEM	MEAN	SEM
Tension	10.00	2.43	6.80	3.06	6.86	2.18	4.43	1.70
Depression	4.40	2.77	5.00	2.93	0.71	0.57	2.43	1.53
Anger	9.60	2.38	8.20	3.07	4.57	0.90	3.14	1.49
Vigor	21.60	0.98	20.20	0.73	19.00	2.39	15.00	2.23
Fatigue	2.40	1.47	3.60	2.66	1.00	0.31	4.14	1.81
Confusion	4.80	1.77	3.60	1.40	2.29	0.57	3.14	0.80
Poms-t	111.60	8.98	107.00	12.24	96.43	3.77	102.29	6.28

Finally, negative mood, estimated by POMS-t, was significantly correlated with CC31 ($r=0.89$, $p=0.001$), CC41 ($r=0.68$, $p=0.008$) and CC51 ($r=0.78$, $p=0.001$).

Discussion

Our results show a non-significantly different pattern of T depending on outcome, despite the fact that winners displayed increases and losers decreases along the competition. The greatest differences appeared at 10 and 30 min post-competition, whereas at 45 min they were much smaller, which agrees with other studies concerning judo combats (Salvador et al., 1987; 1990). In our study, losers showed higher C levels than winners, although they did not reach statistical significance. On the whole, no differences in C between winners and losers have repeatedly been found (Salvador et al., 1987, 1990; Booth et al., 1989; Gladue et al., 1989; McCaul et al., 1992).

The fact that the greatest effects on hormones have been found in short periods immediately after competitive encounters, stresses the need to eliminate the potential influence of physical effort developed during the competition. Elias (1981) discarded this influence based on the approximately equal strength/ability of opponents and the close results obtained, although this assumption is rather weak. We used lactate concentration to estimate the intensity of the effort developed in competition in addition to the perceived effort. Our results, showing the absence of differences depending on outcome in both objective and subjective measurements, indicate that the different hormonal changes experienced by subjects were not due to differences in physical exertion: winners and losers expended a similar effort. These results confirm previous findings found in a laboratory study: serum T and C responses to outcome of a judo fight were compared with those shown in an ergometric test with a similar energetic cost; no significant differences between winners and losers were found in serum T or in psychobiological impact of physical effort measured by means of lactate and self-reports of fatigue and vigor (Suay et al., 1999). In the present study, Lamax values obtained by our subjects were a little higher than those found after just one judo combat (Sanchís et al. 1991) and similar to those reported in karate competition (Angulo et al., 1990), whereas subjective assessment provided a score of approximately 7 («Very hard») on the perception of physical exertion scale employed, both measures indicating the important effort made in the competition.

We have found non-significant differences between winners and losers in negative mood, as measured by POMS; this lack of effects of outcome on mood contrasts with previous results in real sports team competitions (González-Bono et al., 1999). However, in the present study significant differences appeared when positive mood (satisfaction with the outcome) was considered, which agree with findings obtained by McCaul et al. (1992) and González-Bono et al. (1999). It is worth noting that winners showed worse mood and lower testosterone levels before the event than losers; this result had been found previously in real competitive situations (González-Bono et al., 1999) although it contrasts with the suggestion of Booth et al. (1989) that a preparatory response is characterized by increases of T prior to the competition. Further research is necessary to examine the importance of the anticipatory hormonal responses and their relationships with psychological states.

In the light of our results, it seems that variables other than mood, contribute to explain competition-induced T response, as was

suggested by McCaul et al. (1992). Specifically, in a highly competitive situation as was the case of the inter-club competition studied, T showed a strong association with the self-appraisal of performance and internal causal attribution of the result. That is, the higher the self-appraised performance and the higher the attribution of the outcome to personal effort, the higher the T response, in consistency with the findings of a previous study which indicated negative correlations between attribution of the result to luck and post-competition T levels after basketball matches (González-Bono et al., 1999). On the other hand, C response consistently appeared to be related to negative mood experienced in the competition, as has been reported in different sports situations (Harris, Cook, Walker, Read and Riad-Fahmy, 1989; O'Connor, Morgan, Raglin, Barksdale and Kalin, 1989).

Animal research on this topic is carried out in situations where the contribution of the subjects' characteristics to its outcome is clear and direct. In rodents, offensive behaviors usually lead to victory whereas more submissive postures do not. Hypothetically, increases in testosterone associated with successful outcome have an important influence on the future behavior of the subject. Recent findings show the rewarding properties of testosterone, which could explain this influence (Arnedo, Salvador, Martínez-Sanchís and González-Bono, 2000; for revision see Arnedo, Martínez-Sanchís and Salvador, 1999).

In conclusion, our results show the influence of physical effort on hormonal responses to outcome did not seem to be important and nor was it related to hormonal changes. Furthermore, T and C responses were not significantly affected by the outcome of the competition, but appeared to be related to specific psychological aspects: T was associated with cognitive appraisal of performance, whereas C was related to negative mood.

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