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Correlating testosterone and fighting in male participants in judo contests

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Abstract

The role of hormones in human aggression is open to debate, but takes on a new urgency owing to the alarming abuse of androgenic anabolic steroids by some sports participants. In this study, video-taped behavior exhibited by 28 male competitors during a judo fight was assessed to analyze its relation to serum testosterone and cortisol levels measured before and after the bouts. A positive relation between testosterone and offensive behaviors was obtained in the sense that the greater the hormonal titer, the greater the number of threats, fights, and attacks. These findings coincide with the pattern of relationships found using observational scales. Conversely, cortisol also presented positive correlations with some of these behavioral categories but did not moderate the relationship between testosterone and competitive behavior. The present results corroborate and extend earlier findings on the role of these hormones in human behavior, giving support to the view that testosterone can be linked to the expression of competitive aggression.

Keywords: Combat behavior; Testosterone; Cortisol; Serum hormones; Judo competition; Men

1. Introduction

Over the last 2 decades, the so-called anabolic-androgenic steroids have been increasingly employed, especially by sports enthusiasts to increase their aggressiveness and competitiveness, and, consequently, their performance [1]. This, despite the fact that although, the role of testosterone in competitive aggression has been demonstrated in several animal species, it is still open to debate in humans, with contradictory findings causing reviewers to draw different conclusions. Some authors [2] have suggested, on the basis of a narrative review, that human aggression does not have its biological roots in testosterone-dependent aggression. More convincingly, other authors [3,4] have confirmed, using meta-analysis, a small but significant relationship between testosterone and aggression in male humans. Most studies on this topic are correlational, and often involve comparisons between low and high aggressiveness groups. In only a few cases have experimental studies with administration of testosterone been carried out. A third group of studies is characterized by its interest in how behavior and its consequences can modify hormonal levels. This diversity of approaches reflects the basic assumption that hormones and behavior have reciprocal influences. It also reflects the difficulty of studying this topic in humans, mainly as a consequence of ethical limits on directly manipulating hormones and defining and measuring aggressive behavior in our species.

In general, a more consistent association between testosterone and aggression has been obtained in violent/criminal groups than in "normal" populations in most of the studies [3,5,6], although a recent meta-analysis does not support this assumption [7]. Many of the significant relationships are based on behavioral observations by staff or peers, as well as on institutional records. In fact, one clear conclusions extracted from thorough reviews is that direct behavioral observation (rather than trait assessments) of the incidence of aggression are preferable for this type of analysis. Indeed, direct observations may sometimes be possible [3,8]. Accordingly, it has recently been claimed that a main challenge for future research is the study of how testosterone is related to overt behavior [9] as well as identifying social situations that permit such studies [10].

Despite the fact that the probability of detecting hormone/behavior relations is maximized if assessment of both hormone levels and behavior are measured at the same time [11], few studies have analyzed concurrent hormonal levels and aggressive/competitive behavior. In one exception, ag-

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gressively predisposed subjects in alcohol—drinking situations had higher salivary testosterone titers than nonaggressively predisposed counterparts [12]. The former subjects also showed more neutral and negative communications. They showed more communications within their own group and to nonaggressive subjects as well as more social activity (episodes per minute) during group discussions. More recently, a positive relationship was reported between salivary testosterone levels and direct physical aggression in a competitive task in the laboratory. The high-testosterone subjects were reported to be significantly more motivated during the competitive task, and were observed to set more intense levels of shock for their opponent than subjects with low levels of testosterone [13]. The relationships between dominance measures (evaluated by ratings and video-taped social interactions) in women and basal sex steroid levels (estradiol, total and free testosterone, and dihydroepiandrosterone sulfate) have been studied [14]. It was concluded that there were significant, positive relationships between assertive behavior and all hormones studied except dihydroepiandrosterone sulfate. Only total testosterone was, however, negatively correlated with smiling, which is considered a submissive behavior by human ethologists. More recently, higher testosterone salivary levels have been associated with reduced smiling in men within the research, linking testosterone to face-to-face dominance [15].

There have also been attempts (reviewed in [16]) to relate cortisol values to human aggression. In general, low cortisol levels have been associated with aggressive behavior in children and adults in a number of studies. A hypothesis connecting stress, cortisol, and testosterone suggests that cortisol moderates the testosterone/aggressiveness link.

The present study examined the relationships between testosterone, cortisol, and behavior shown during judo contests. In addition to hormonal level, the changes in titers were considered, as they might better represent the relationship between hormones and behavioral responses to specific situations.

2. Materials and methods

Judo contests were videotaped and evaluated using an observational scale based on the behavior usually shown by the fighters. All subjects gave written consent to participate in the study, and were financially remunerated for their involvement. They were not taking any drugs or medication, and had no history of endocrine disorders before or during the study.

2.1. Sample

The sample was composed of 28 male judo fighters (mean = 18.32 years, SD = 2.59), who were recruited from several Sports Clubs of Valencia (Spain). Body weights were between 51 and 95 kg (mean) = 70.01, SD = 11.39), and heights between 1.57 and 1.89 m (mean = 1.73, SD = 0.08). Their technical abilities ranged between brown belt and third Dan black belt, and they trained for an average of 2 h per day.

2.2. Procedure

Subjects participated in a competitive session carried out in a Sports Club between 0900–1330 h. Blood samples were collected between 0930 and 1230 h. An official referee on the basis on the international rules of judo competition judged the judo fights, which had a maximum duration of 5 min. Every judo competitor took part in only a single encounter. Venous blood samples were provided 10 min before and 10 min after the judo fight, and frozen until their analysis by RIA [17].

2.3.Behavioral variables

Recorded videotapes of encounters were evaluated by two judo specialists, using an observational scale designed in the Valencia laboratory from activities usually shown by fighters in judo contests. The scale included seven behavioral categories that grouped a number of different elements (Table 1). These categories were designed to cover the entire period studied. Some postures and gestures indicating provocation/challenge to the adversary along with shouts were grouped under the label “threat.” “Fighting” is applied to activities when the subject is struggling without success to obtain an advantage. “Domination” means the individual has obtained an advantage over his opponent. “Attack/counterattack” implies offensive responses using some technical resources characteristic to this sport, whereas in “defense,” the subject is trying to avoid or block the initiative of the opponent. The beginning of the combat involves “observation” of the opponent, an activity also seen after interruptions imposed by the referee (stop). No attempt was made to correlate observation and stop with hormonal variables.

The behavioral evaluation procedure was performed using a microprocessor and a custom-developed program that adapted software written to assess aggressive behavior in animals [18]. The computer program gives information of frequencies (number of occurrences of each category in the combat), total duration (accumulated time spent in each category), and percentage of time (percentage of total duration in each category). Interobserver reliability (using Pearson product-moment correlations) was greater than 0.75 for all categories (0.83, 0.77, 0.93, 0.96, and 0.92 for threat, domination, attack/counterattack, defense, and fight, respectively).

2.4. Hormonal measures

Each subject provided two 10-mL blood samples from the antecubital vein, which were processed to obtain the serum and then frozen at −80°C until their analysis in Laboratorios Montoro SCL (Valencia, Spain).

All samples of each subject were treated in duplicate in the same assay. Testosterone was analyzed by radioimmunoassay adding ^{125}I tracer to the highly specific antibodies provided by the commercial kit (^{125}I-Testosterone Coatria

Table 1
Behavioral observations

Behavioral categories	Elements included
Threat	—Stands erect without moving, looking hard at opponent —Runs into opponent —Extends, opens or lifts arms —Shouts
Fighting	—Both are struggling for an advantageous grasp (Kumi–Kata) but neither is dominant
Domination	—Grasps opponent and stands more erect, keeping adversary down —Moves the opponent pushing or pulling vigorously —Grasps adversary firmly
Attack/counterattact	—Standing up: tries to throw opponent (Nage–Waza) —On the ground: tries to immobilize (Osae–Waza), strangle (Shime-Waza) or apply an arm-lock (Kansetsu–Waza) —Standing up: when attacked applies a counter-technique (Kaeshi–Waza) —On the ground: moves to an offensive from a defensive position
Defense	—Stays dominated by opponent, while takes a defensive position standing or on the ground (face downwards, grasping opponent's leg or body) —Tries to avoid (Tai–Sabaki) or block the other's attacks —Simulates an attack without really trying to throw his opponent
Stop	—The referee halts the combat for technical reasons (Matte, Sonomama, or Soremade)
Observation	—Observes adversary, from a distance —Moves around opponent

Kit of Bio-Mérieux, France). Cortisol was analyzed with fluorescence polarization technology using immunoassay methodology (TDx of Abbott Laboratory Diagnostic Division, Chicago, IL). All intra- and interassay variation coefficients were below 9%, apart from the interassay variation coefficient for testosterone (12.2%).

2.5. *Statistical analyses*

Pearson correlations were calculated analyzing the relationships between the hormonal measures and occurrences, total duration, percentage of time, and latency of behavioral categories revealed in combat. Pre- and postcombat levels were used for both hormones (T1 and T2 for testosterone and C1 and C2 for cortisol). Percentage changes were calculated using precombat level as baseline (these were designated TC for testosterone and CC for cortisol). Multiple regression analyses were carried out in which each behavioral category was regressed on testosterone, cortisol, and the interaction between the two to examine whether cortisol moderates the relationship of testosterone to competitive behavior [19].

Values of p equal to or less than 0.05, in two-tailed tests, were considered significant. Effect size was estimated for a power established at 0.80, $n = 27$ and $\alpha = 0.05$ according to Cohen [20]. The magnitude of effect size was estimated 0.46.

3. Results

Hormonal concentrations were within reference values reported for the different kits employed. Only one subject who showed very high testosterone values before competition (more than twice the SEM value) was eliminated in the analyses.

Correlations of hormonal variables and occurrences of behavioral categories are shown in Table 2. Previous testosterone levels were positively associated with the number of threats, fights, and attacks; these latter categories were also related to postcombat testosterone. In addition, domination was positively related to postcombat cortisol levels. Cortisol response was associated with the number of fights and attacks.

Total duration of attacks correlated positively to pre- ($r = 0.40$, $p < 0.04$) and postcombat ($r = 0.39$, $p < 0.04$) testosterone.

In this study, testosterone and cortisol precombat levels were significantly correlated to postcombat levels ($r = 0.93$, $p < 0.001$; and $r = 0.79$, $p < 0.001$). Precombat cortisol was negatively correlated to cortisol changes ($r = -0.71$, $p < 0.001$). Pre- and postcombat testosterone levels were positively correlated to cortisol changes ($r = 0.48$, $p < 0.01$; $r = 0.39$, $p < 0.05$, respectively). No other significant correlations were found between hormonal measures.

3.1. *A moderating role of cortisol on the testosterone-competitive behavior relationship?*

Because in this study an important number of significant correlations were found concerning cortisol, regression analyses were carried out to ascertain if cortisol modulated the relationship between testosterone and competitive behavior. As there were no significant interactions between testosterone and cortisol, it does not appear that cortisol has a moderating influence.

Table 2
Correlation of hormonal variables with behavioral categories

	T1	T2	TC	C1	C2	CC
Threat	0.40*	0.29	−0.16	0.06	0.27	0.14
Fighting	0.45*	0.39*	−0.01	−0.05	0.30	0.39*
Domination	0.18	0.18	0.17	0.22	0.47*	0.11
Attack	0.54**	0.48*	−0.02	−0.001	0.32	0.40*
Defense	0.35	0.30	−0.06	−0.10	0.28	0.38

T1:Testosterone precombat levels, T2: testosterone postcombat levels, TC: testosterone changes, C1: cortisol precombat levels, C2: cortisol postcombat levels, CC: cortisol changes.

*$p < 0.05$.

**$p < 0.01$.

4. Discussion

In humans, most studies linking hormones and aggressive behavior are correlational, which imposes important limitations on interpretation. An experimental approach, involving manipulation of hormone levels, to demonstrate the link between androgens and aggressive behavior has been recommended and initiated recently [21–23]—largely as a consequence of the interest in the abuse of anabolic-androgenic steroids—but the results have been thus far inconclusive. Such studies have important ethical limitations, and do not preclude the dual requirements needed to improve behavioral measures and to identify relevant situations in which one may carry out analyses elucidating the hormonal/behavioral links.

In the present study, a natural setting was used to improve the knowledge of the relationships between the behavior displayed and the concurrent changes in hormone levels. Judo combat is a competitive situation where the direct observation of some behavioral responses involved in the aggressive/offensive activities of a person may be made as well as his/her competitive motivation assessed. The value of this kind of sports situation in adolescent and young men in attempts to find parallels with the social/competitive aggression displayed in other species has been argued from an evolutionary approach [24]. However, competitive situations are stressful, and will, consequently, modify hormonal levels. Anticipatory responses of both hormones studied to such situations as well as different changes, depending on the outcome of the contest, has been reported [3,8]. For these reasons, pre- and postlevels as well as the hormonal response (percentage changes) were considered separately in the analyses. It is worth noting that no significant differences in hormonal responses were evident between winners and losers [17].

The present study showed a positive relationship between testosterone levels and number of fights during the combat, suggesting an active participation, persistence or a failure to "give up." Testosterone was also positively correlated to the number of attacks. Thus, testosterone appears associated with offensive behavior. Interestingly, testosterone levels measured before encounters were positively correlated to occurrence of threats and fights, and to occurrence and total duration of attacks displayed during competition. This relationship supports the view that the preparatory character of competition produces an anticipatory testosterone rise [25], which is greatest in individuals who go on to fight vigorously.

Direct behavioral measures, in addition to the simultaneous use of several methods, have been claimed to be advantageous in different revisions on this topic [3,26]. A 16-item scale modified from that used with sports subjects [27], was used on the present sample of judo fighters. The mean levels and changes in free and total serum testosterone were positively associated with items linked with involvement and anger displayed during contests as assessed by the coaches [28]. Previously, similar relationships were found in a small sample of 12 judo fighters using the same scale [29]. These results suggest a relationship between reactivity of testosterone, and a tendency to express aggressivity. Emotional expressiveness has been significantly related to high levels of testosterone [30]. For example, giving testosterone to 22 female-to-male transsexuals incremented their anger proneness, although they showed no increases in overt anger and aggressive behavior [31]. Furthermore, the fact that testosterone was associated with threats observed during the videotaped combats and with anger usually observed by coaches suggests that behavior during combat is a fairly stable characteristic of the subjects.

In the earlier pilot study [29], cortisol changes correlated negatively with aggressive responses (behaviors such as insults and threats to friends evaluated by coaches), whereas they were positively correlated with the acceptance of decisions without protests. It must be emphasized in the present study that cortisol changes were significantly associated with the number of fights and attacks. Perhaps the short interval (10 min) between the end of the competition and the measure of hormonal levels employed influenced the currents findings. Possibly cortisol reflects the physical exertion developed throughout the contest, and thus, may be associated with behaviors involving a greater effort. Furthermore, cortisol changes were positively correlated to both pre- and postcombat testosterone levels.

There are data from animal research that indicate that corticosterone interferes with aggressive behavior by promoting submissive displays (reviewed in [8]). In humans, it has been suggested that cortisol may directly moderate the behavioral effects of testosterone, and might be expected to inhibit behaviors such as violence. If this were true, the testosterone/violence relationship would be clearest at low cortisol levels [32]. However, our results did not support this moderator role of cortisol.

The statement that "testosterone may prove more successful in predicting critical moments of behavior than mean baseline levels of behavior, thus making it necessary to identify the settings associated with changes in testosterone, and the subsequent effects of these changes on behavior" [10], is generally supported by the present study. It also reveals a positive relationship between overt offensive behavior and the testosterone in a competitive situation, a finding consistent with other measures in other studies. Although the effect sizes obtained are high according to Cohen's criteria, the possibility of type 2 errors due to the small size of sample should be controlled in further studies. Sports competitions indeed appears to be a socially accepted situation [33] that may be used to obtain information about behavior/hormone relationships to complement other methods in our species.

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