ORIGINAL ARTICLE

Salivary testosterone and cortisol in rugby players: correlation with psychological overtraining items

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Background: A psychocomportemental questionnaire has been devised by the consensus group of the Société Française de Médecine du Sport to characterise and quantify, using a list of functional and psychocomportemental signs, a state of ''staleness'', for which no biological indicator is unanimously recognised.
Objectives: To determine the relation between this diagnostic method and two hormones (cortisol and testosterone) often used as indicators of a state of fitness or staleness.
Methods: The subjects were young rugby players. They were asked to complete the overtraining questionnaire and gave three saliva samples (at 8 am, 11 am, and 5 pm) during a rest day. Concentrations of cortisol and testosterone in the saliva were determined by radioimmunoassay.
Results: A preferential relation was found between the questionnaire score and testosterone concentration but not between the questionnaire score and cortisol concentration.
Conclusions: The questionnaire may be a useful tool for screening subjects at risk of overtraining. Testosterone concentration is influenced by tiredness, and is therefore a valid marker of tiredness.

The obvious goal of athletic training is to enhance performance. However, training too heavily (overtraining) and undertraining both have the opposite effect—that is, performance decrement. The overtraining syndrome has been attributed to excessive volume and/or high intensity of training with inadequate periods of rest, eventually leading to an inability to train and perform at optimal levels.[1]

Many indicators have been proposed to characterise haematological, physiological, and psychological symptoms that indicate a state of overtraining.[2–4] Several studies have shown increased mood disturbance coinciding with increased training loads.[5 6] Self reports of fatigue after training may allow overtraining to be monitored.[7] The French consensus group on overtraining of the Société Française de Médecine du Sport has proposed a new standardised questionnaire of early clinical symptoms of this elusive syndrome, allowing the calculation of a score that may help to indicate the level of tiredness in sportsmen carrying out a heavy training programme.[8] This score appears to correlate with indications of muscular damage (creatine kinase, myosin) and some haematological variables (blood viscosity, packed cell volume, plasma viscosity, ferritin).[9 10] However, few studies have shown a relation between the questionnaire and hormonal changes.

Depending on the intensity and duration of a preceding physical load, hormones with anabolic or catabolic properties, such as testosterone and cortisol respectively, show quantitative changes signalling a catabolic state.[11] The ratio between plasma concentrations of free testosterone and cortisol has been used to evaluate training responses and to predict performance capacity.[12 13] This ratio is considered to reflect states of anabolism and tapering off when it is high and, inversely, states of catabolism and overreaching when it falls by 30% or more. Moreover, a single bout of exercise induces transient changes in the anabolic-catabolic balance, depending on the intensity and duration of the exercise bouts. Repeated heavy endurance exercise without a sufficient period of recovery can cause a persistent disturbance in this balance. This ratio has been determined in long distance runners and swimmers, but, to our knowledge, no information is available for a team sport such as rugby.

The purpose of this study was to investigate a possible relation between the score obtained from the questionnaire and the concentrations of cortisol and testosterone in saliva. Saliva was used because this avoids the stress caused by venepuncture.[14]

METHODS

Subjects

Twenty five young international rugby players volunteered for the study. They were informed of the purpose and methods of the study before giving written consent to participate. None were taking any drugs. The study was performed during February, which is in the middle of the most intensive training and competition period for rugby players.

All measurements were made by the same investigator. The rugby players were weighed to the nearest 0.1 kg, and their height measured with a measuring rod to the nearest 0.1 cm. Percentage of body fat was estimated from four measurements of skinfold thickness as described by Durnin and Womersley.[15] A Harpenden caliper was used to measure the thicknesses—that is, biceps, triceps, subscapular, and suprailiac—on the right side of the body with the subject in a standing position. The main biometric characteristics of the group of subjects were (mean (SE)): age, 17.6 (0.5) years; height, 177.6 (2.9) cm; weight, 73.8 (2.4) kg; percentage body fat, 15.6 (1.8)%.

Training programme

The subjects trained for 15 hours a week plus one match a week. They performed endurance training sessions (running at varying intensity below and above the anaerobic threshold), fartleck (interval training), strength training sessions (with loads at 80–90% of one maximal repetition), sprint training sessions, technical training sessions, and rugby specific fight training sessions each week. Matches consist of two halves, each of 40 minutes, separated by a 10 minute recovery period, and are contested by two teams of 15 players (eight forwards and seven backs).

Physical performance measurements

To evaluate the performance of each subject, we chose tests to represent different aspects of physical fitness in rugby.[16] These were performed three minutes after anthropometric assessment. The order of the tests was always aerobic capacity followed by vertical jump.

Maximal oxygen consumption (V_{O_2}MAX)[17] was estimated using a bicycle ergometer; the mean (SE) value for the group was 55.6 (0.8) ml/kg/min.

Sprinting speed was measured over 10 m and 40 m. These two distances are thought to indicate the initial acceleration and maximum sprinting capabilities respectively.[18 19] After their usual warm up routine, the subjects performed two trials of maximum effort, sprinting over 40 m on their usual turf training surface. Light gates integrated to the timing system (DDHE, Bungendore, Australia) were placed at the 0, 10, and 40 m marks. Mean (SE) times were 1.8 (0.1) seconds for the 10 m run and 5.45 (0.3) seconds for the 40 m run.

Vertical jumping height was determined on a platform[20] connected to a digital timer. The test battery consisted of vertical jumps performed from a standing position (*a*) without a preliminary counter movement jump (squat jump; SJ) and (*b*) with a preliminary counter movement jump (CMJ). Mean (SE) performances were: SJ, 40.5 (0.5) cm; CMJ, 42.1 (0.9) cm.

The mechanical power of the lower limb extensor musculature was measured in a jumping test. The subjects performed successive maximal jumps (CMJ) on the platform during a period of 30 seconds keeping their hand on their hips. The cumulative flight time and the number of jumps performed formed the basis for the calculations of mechanical power.[21] Mean (SE) for 30 seconds of jumping was 28.2 (0.6) W/kg.

Hormone assays

Three saliva samples were taken from each subject during a rest day (24 hours without training). To avoid the effects of the circadian rhythm and variations in food intake on hormonal secretion, the three saliva samples were taken immediately after getting up (8 am), before breakfast (11 am), and in the evening (5 pm). These three points enabled us to determine a mean concentration over the day.

The saliva samples were stored in a freezer at −30℃. Concentrations of salivary cortisol and testosterone were measured using a radioimmunological method routinely used and validated in our laboratory: sensitivity, 15 pg; accuracy, 10.5%; intra-assay reproducibility, 6.1%.[14] All hormone samples were tested in the same series to avoid any variations between tests.

Questionnaire

A standardised questionnaire of early clinical symptoms of the overtraining syndrome was proposed. This psychological scale for overtraining was devised by the consensus group on overtraining of the French Society of Sports Medicine.[8] This French questionnaire contains 54 psychocomportemental questions requiring answers of "yes" or "no". The score is given by the sum of "yes" answers (fig 1). The questionnaire was administered on the day that the saliva samples were taken.

Statistical analysis

The data were analysed using the SPSS version 10.0 software. All values are expressed as mean (SE). Correlations between hormonal data and the score obtained in the overtraining questionnaire were determined using the Spearman correlation coefficient. $p<0.05$ was considered significant.

1	Mon niveau de performance sportive/mon état de forme a diminué	OUI	NON
2	Je ne soutiens pas autant mon attention	OUI	NON
3	Mes proches estiment que mon comportement a changé	OUI	NON
4	J'ai une sensation de poids sur la poitrine	OUI	NON
5	J'ai une sensation de palpitation	OUI	NON
6	J'ai une sensation de gorge serrée	OUI	NON
7	J'ai moins d'appétit qu'avant	OUI	NON
8	Je mange davantage	OUI	NON
9	Je dors moins bien	OUI	NON
10	Je somnole et baille dans la journée	OUI	NON
11	Les séances me paraissent trop rapprochées	OUI	NON
12	Mon désir sexuel a diminué	OUI	NON
13	Je fais de contre-performances	OUI	NON
14	Je m'enrhume fréquemment	OUI	NON
15	J'ai des problémes de mémoire	OUI	NON
16	Je grossis	OUI	NON
17	Je me sens souvent fatigué	OUI	NON
18	Je me sens en état d'infériorité	OUI	NON
19	J'ai des crampes, douleurs musculaires fréquentes	OUI	NON
20	J'ai plus souvent mal à la tête	OUI	NON
21	Je manque d'entrain	OUI	NON
22	J'ai parfois des malaises ou des étourdissements	OUI	NON
23	Je me confie moins facilement	OUI	NON
24	Je suis souvent patraque	OUI	NON
25	J'ai plus souvent mal à la gorge	OUI	NON
26	Je me sens nerveux, tendu, inquiet	OUI	NON
27	Je supporte moins bien mon entraînement	OUI	NON
28	Mon coeur bat plus vite qu'avant au repos	OUI	NON
29	Mon coeur bat plus vite qu'avant à l'effort	OUI	NON
30	Je suis souvent mal fichu	OUI	NON
31	Je me fatigue plus facilement	OUI	NON
32	Je suis souvant des troubles digestifs	OUI	NON
33	J'ai envie de rester au lit	OUI	NON
34	J'ai moins confiance en moi	OUI	NON
35	Je me blesse facilement	OUI	NON
36	J'ai plus de mal à rassembler mes idées	OUI	NON
37	J'ai plus de mal à me concentrer dans mon actitivité sportive	OUI	NON
38	Mes gestes sportifs sont moins précis, moins habiles	OUI	NON
39	J'ai perdu de la force, du punch	OUI	NON
40	J'ai l'impression de n'avoir personne de proche à qui parler	OUI	NON
41	Je dors plus	OUI	NON
42	Je tousse plus souvent	OUI	NON
43	Je prends moins de plaisir à mon activité sportive	OUI	NON
44	Je prends moins de plaisir à mes loisirs	OUI	NON
45	Je m'irrite plus facilement	OUI	NON
46	J'ai une baisse de rendement dans mon activité scolaire ou professionnelle	OUI	NON
47	Mon entourage trouve que je deviens moins agréable a vivre	OUI	NON
48	Les séances sportives me paraissent trop difficiles	OUI	NON
49	C'est ma faute si je réussis moins bien	OUI	NON
50	J'ai les jambes lourdes	OUI	NON
51	J'égare plus facilement les objets (clefs, etc..)	OUI	NON
52	Je suis pessimiste, j'ai des idées noires	OUI	NON
53	Je maigris	OUI	NON
54	Je me sens moins motivé, j'ai moins de volonté, moins de ténacité	OUI	NON

Figure 1 Questionnaire on early clinical symptoms of overtraining.

RESULTS

Psychological assessment

The mean score obtained in the overtraining questionnaire was 9.5 (0.8) (maximum 25 and minimum 0). In an assessment on 2000 questionnaires (unpublished study), a mean of 8.9 was found, and the 10th centile corresponded to a score of 20.

Hormones

Table 1 gives salivary cortisol and testosterone concentrations as well as the testosterone/cortisol ratio. The different salivary concentrations of cortisol and testosterone at different times of day (8 am, 11 am and 5 pm) give a good demonstration of diurnal rhythm. Both cortisol and testosterone are more concentrated at the beginning of the day (8 am) and less concentrated at the end of the afternoon (5 pm).

Table 1 Salivary cortisol, testosterone, and testosterone/cortisol ratio in 25 rugby players

	8 am	11 am	5 pm	Mean
Testosterone (pmol/l)	352 (26)	324 (14)	308 (15)	328 (13)
Cortisol (nmol/l)	14.8 (1.1)	10.8 (0.8)	7.8 (1.3)*	11.2 (1.3)
Testosterone/cortisol	25.4 (1.6)	35 (5.4)	42.5 (6.5)*	34.4 (3.6)

Values are mean (SE).
*Significantly different from the value at 8 am ($p<0.05$).

Table 2 Correlation between hormonal concentration and overtraining questionnaire score

Hormone	r Value	p Value
Testosterone		
8 am	−0.53	<0.01
Mean	−0.6	<0.01
T/C (8 am)	−0.43	<0.05

T/C, Testosterone/cortisol ratio.

A significant difference ($p<0.05$) was observed between 8 am and 5 pm for cortisol concentration and testosterone/cortisol ratio but not for testosterone.

Hormonal data/score correlation

Table 2 shows the correlations found between the hormonal data and the score from the overtraining test. The overtraining score correlated with testosterone concentration only, and the best correlations were obtained with the mean value and the value at 8 am (fig 2). The correlation between questionnaire score and testosterone concentration at 8 am is better than between questionnaire score and testosterone/cortisol ratio.

DISCUSSION

From their anthropometric data, the subjects examined in this study represent a homogeneous group of high level rugby players.[22 23] The study took place during February—that is, after at least two months of hard training and competition. This is the period when the players feel stale, and injuries and infectious illness most often occur. The aim of the study was to examine a possible relation between the score obtained from the overtraining questionnaire and salivary concentrations of cortisol and testosterone.

The two main findings are:

- The overtraining score correlates with testosterone concentration at 8 am ($r = -0.53$; $p<0.01$), mean testosterone concentration (8 am–11 am–5 pm) on the rest day ($r = -0.6$; $p<0.001$), and the testosterone/cortisol ratio at 8 am ($r = -0.43$; $p<0.05$).
- No correlations exist between cortisol concentration and the overtraining score.

The standardised questionnaire on signs of overtraining[8] was developed by the French consensus group in order to detect early disturbances in tolerance to intensive training. It allows the calculation of a score suggestive of symptoms of staleness or overtraining. We obtained a mean (SE) score of 9.5 (0.8) for our subjects. This corresponds to a value slightly higher (non-significant) than the mean (8.9 (0.9)) obtained from a more complete study (n = 1984) carried out on athletes from various sports at various levels.[24 25] This result indicates tiredness in our subjects without necessarily indicating overtraining.

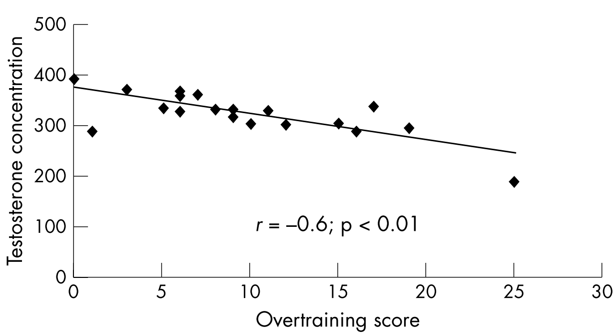

Figure 2 Correlation between testosterone concentration and overtraining score.

To our knowledge, few studies have examined the presence of a relation between overtraining and hormonal variations, in particular cortisol and testosterone concentrations.[26] However, there are many reports on the influence of training on these hormones. High level sport is known to cause an increase in cortisol. Testosterone concentration is also affected and may show either an increase or decrease.[27] The testosterone/cortisol ratio, which reflects protein anabolism/catabolism, often clearly delineates these variations.[28] In a study in our laboratory,[29] it appeared that intensive physical training over a long period induced an increase in testosterone and cortisol concentrations. Therefore the testosterone/cortisol ratio showed little modification with time. Cumulative tiredness, however, does produce a variation in the concentration of these hormones. A fall in the testosterone/cortisol ratio is regarded as an indication of tiredness.[12] However, this fall can have two different origins: cortisol increase and/or testosterone fall. To determine more accurately the influence of tiredness on these hormonal variations, it was necessary to address these two variables. To do this, we examined the existence of correlations between the overtraining score and the hormonal assessment.

In our study, cortisol concentration was not found to be related to the score obtained in the overtraining survey. In contrast, testosterone concentration did show a relation to the score. We noted a significant negative correlation between the testosterone/cortisol ratio and the score. These results show that it is more useful to follow variations in testosterone (an anabolic hormone) than variations in cortisol (a catabolic hormone) to determine the degree of tiredness. To confirm these results, this survey needs to be completed by a more heterogeneous population. In addition, the individual variations in the score should be examined in relation to changes in performance and biological markers throughout the sporting season. The best way to use this tool would be to carry out extensive follow up of an athlete during a sporting season, in order to compare various states of progressive tiredness with a baseline determined before the start of the season.

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REFERENCES

1 **Costill DL**. *Inside running*. Indianapolis: Benchmark Press, 1986:23–134.
2 **Lehmann M**, Foster C, Keul J. Overtraining in endurance athletes: a brief review. *Med Sci Sports Exerc* 1993;**25**:854–62.
3 **Hooper SL**, Mackinnon LT, Howard A, *et al*. Markers for monitoring overtraining and recovery. *Med Sci Sports Exerc* 1995;**27**:106–12.
4 **Fry RW**, Kraemer WJ. Resistance exercise overtraining and overreaching. *Sports Med* 1997;**23**:106–29.

5 **O'Connor PJ**, Morgan WP, Raglin JS. Mood state and salivary cortisol levels following overtraining in female swimmers. *Psychoneuroendocrinology* 1989;**14**:303–10.
6 **Flynn MG**, Pizza FX, Boone JB. Indices of training stress during competitive running and swimming seasons. *Int J Sports Med* 1994;**15**:21–6.
7 **Prapavessis H**, Berger B, Grove JR. The relationship of training and pre-competition mood states to swimming performance: an exploratory investigation. *Aust J Sci Med Sport* 1992;**24**:12–17.
8 **Brun JF**, Bouix O, Fédou C, *et al.* Analyse des signes subjectifs du surentraînement sportifs chez 6 adeptes du Tae Kwon Do. *Science et Sports* 1993;**8**:17–20.
9 **Aïssa Benhaddad A**, Bouix D, Khaled S, *et al.* Early hemorheologic aspects of overtraining in elite athletes. *Clin Hemorheol Microcirc* 1999;**20**:117–25.
10 **Monnier JF**, Aïssa Benhaddad A, Micallef JP, *et al.* Relationships between blood viscosity and insulin-like growth factor I status in athletes. *Clin Hemorheol Microcirc* 2000;**22**:277–86.
11 **Busso T**, Häkkinen K, Pakarinen A, *et al.* Hormonal adaptations modelled responses in elite weightlifters during 6 weeks of training. *Eur J Appl Physiol* 1992;**64**:381–6.
12 **Adlercreutz H**, Harkonen M, Kuoppasalmi K, *et al.* Effect of training on plasma anabolic and catabolic steroid hormones and their response during physical exercise. *Int J Sports Med* 1986;**7**(suppl):27–8.
13 **Mujika I**, Chatard JC, Padilla S, *et al.* Hormonal responses to training and its tapering off in competitive swimmers: relationships with performance. *Eur J Appl Physiol* 1996;**74**:361–6.
14 **Lac G**, Lac N, Robert A. Steroid assays in saliva: a method to detect plasmatic contaminations. *Arch Physiol Biochim Biophys* 1993;**101**:257–62.
15 **Durnin JVGA**, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measuremens on 481 men and women aged from 16 to 72 years. *Br J Nutr* 1974;**32**:77–97.
16 **McLean DA**. Analysis of the physical demands of international rugby union. *J Sports Sci* 1992;**10**:285–96.
17 **Astrand PO**, Ryhming I. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. *J Appl Physiol* 1954;**17**:218–23.
18 **Delecluse CH**, Van Coppenolle H, Willems E, *et al.* Influence of high-resistance and high-velocity training on sprint performance. *Med Sci Sports Exerc* 1995;**27**:1–7.
19 **Young W**, McLean B, Ardagna J. Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness* 1995;**35**:13–19.
20 **Bosco C**. Sei un grande athleta: vediamo cosa dice l'ergojump. *Pallavolo* 1980;**5**:34–6.
21 **Bosco C**. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol* 1983;**50**:273–82.
22 **Maso F**, Robert A. Evolution anthropométrique des joueurs de l'élite du rugby français. *Science et Sport* 1999;**14**:301–4.
23 **Berthon P**, Lac G. Etude des réactions du cortisol salivaire au déplacement en avion pour une équipe de rugby. *Science et Sports* 2001;**16**:45–7.
24 **Maso F**, Fabre F, Lac G, *et al.* Interprétation des items du questionnaire de surentraînement: relations avec l'intensité du trouble. XX^{e} international congress of sport medecine. *Science et Sports* 2000;**15**:287.
25 **Maso F**, Fabre F, Lac G, *et al.* Analyse multicentrique de 2000 questionnaires du groupe de consensus sur le Surentraînement. XX^{e} international congress of sport medecine. *Science et Sports* 2000;**15**:341.
26 **Urhausen A**, Gabriel HHW, Kindermann W. Impaired pituitary hormonal response to exhaustive exercise in overtrained endurance athletes. *Med Sci Sports Exerc* 1998b;**30**(3):407–14.
27 **Lac G**, Passelergue P, Robert A, *et al.* Influence du type de pratique sportive sur les taux de testostérone. *Science et Sports* 1995;**10**:157–8.
28 **Vervoorn C**, Quist AM, Vermulst LJM, *et al.* The behaviour of the plasma free testosterone/cortisol ratio during a season of elite rowing training. *Int J Sports Med* 1991;**12**:257–63.
29 **Passelergue P**, Lac G. Cortisol, testostérone et rapport testostérone / cortisol au cours d'un trimestre scolaire chez des lutteurs de haut niveau comparés à des étudiants non sportifs. *Science et Sports* 1998;**13**:295–6.

ECHO

High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes

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Please visit the *British Journal of Sports Medicine* website [www.bjsportmed.com] for a link to the full text of this article.

Objective: To identify the consequences of an anterior cruciate ligament (ACL) tear in a cohort of male soccer players 14 years after the initial injury with respect to radiographic knee osteoarthritis and patient relevant outcomes.

Methods: Of 219 male soccer players with an ACL injury in 1986, 205 (94%) were available for follow up after 14 years; 75% of the cohort (154/205) answered mailed questionnaires (KOOS, SF-36, and Lysholm knee scoring scale) and 122 of these consented to weight bearing radiographs.

Results: Radiographic changes were found in 95 (78%) of the injured knees, while more advanced changes, comparable with Kellgren-Lawrence grade 2 or higher, were seen in 50 (41%). In the uninjured knees more advanced changes, comparable with Kellgren-Lawrence grade 2 or higher, were seen in five knees (4%). No differences were seen between surgically and conservatively treated players. The patient relevant outcome was affected and did not differ between subjects with and without radiographic changes. Eighty per cent reported reduced activity level.

Conclusions: A high prevalence of radiographic knee osteoarthritis was seen in male soccer players 14 years after an ACL disruption. The injury and the osteoarthritis, irrespective of the treatment provided to these patients, often result in knee related symptoms that severely affect the knee related quality of life by middle age.

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