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Testosterone, cortisol, training frequency and playing time in elite basketball players

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Abstract

Background: The aims of this study were firstly, to describe the variation in total testosterone (TT) and cortisol (C) through the course of a complete season in elite male basketball players and secondly, to analyse their relation to training frequency and playing time. **Type of study:** Observational descriptive with repeated measures and non-randomised sampling. **Methods:** Eight professional male basketball players (27.8 ± 4.9 years; 97.0 ± 9.5 kg; 197.2 ± 7.3 cm; 24.7 ± 1 BMI) participated in the study. Firstly, blood samples were collected just after the off season period. These values were considered as baseline. During the competitive season, samples were taken periodically every four to six weeks, in a resting state, always after 24-36 hours break following the last game played,. Eight samples were collected from August to April. **Results:** TT concentration showed significant variations amongst blood samples: April vs. September (-4.4 nMol/l, p=0.010, *d*=1.1), April vs. October (-4.9 nMol/l, p=0.004, *d*=1.27) and April vs. February (-6.8 nMol/l, p=0.013, *d*=2.08). TT did not correlate with playing time. C concentration and the TT/C ratio did not show any significant variation throughout the season and also did not correlate with playing time. **Conclusions:** The effect of a basketball season can be reflected in TT. It is interesting to differentiate between the three phases of the season: 1) pre-season, 2) first two-thirds of the regular season and 3) last third of the regular season, where fatigue accumulation at a metabolic level occurs. TT could be an indicator of players' state, which would justify, in conjunction with other indicators, the necessity to optimise players' workload and to individually prevent overtraining. **Keywords:** elite, performance, physiology, fatigue, endocrine

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Introduction

Elite team sports players are confronted with fatigue due to their competitive schedule, with high levels of training and competition, interspaced by too little recovery[1]. The monitoring of training and match load, in particular, the effects of internal loading, are important for the periodisation of training and assessment of the physiological response to the workload during the season[2]. Therefore it is essential to use a valid measure for the internal training load to monitor individuals and to manipulate the training process.

Fatigue-related mechanisms are still debated in the literature[3], but the importance of the hypothalamic-pituitary-adrenal/gonadal axis in the regulation of metabolism and homeostasis is well documented[3-4]. Generally, in anabolic processes (predominant in the recovery phases) there is an increase in testosterone, growth hormone, somatomedin and insulin, while in the catabolic processes (necessary to maintain energetic availability) there is an increase in catecholamines, cortisol, glucagon and endorphines [2].

Testosterone (T) is a steroid hormone that has an anabolic effect on several areas. Its synthesis is controlled by the hypothalamus-hypophysis-gonadal axis, and its precursor hormone is the luteinising hormone (LH) [2]. Similarly to cortisol (C), its concentration increases in response to exercise at an appropriate threshold of intensity[5]. However, when exercise extends beyond exhaustion, decreases up to 40% have been observed[6]. It is interesting to note that after exercise, total testosterone (TT) negatively correlates with free testosterone (FT), and with C; the greater the concentration of C, the smaller the synthesis of TT[7]. Low levels of testosterone could affect an athlete's health: cardiovascular morbidity, loss of body hair, loss of muscle bulk and strength, accumulation of body fat, osteoporosis and mood changes.

Cortisol, also steroidal, is secreted from the suprarenal glands, under the stimulus of the adrenocorticotropic hormone (ACTH) [2]. This hormone responds to physical, as well as psychological, stress[8]. It has a catabolic effect in all cells, including muscular cells, and participates in the maintenance of blood glucose levels during exercise. This mechanism is essential to metabolic processes and to allow a complete recovery from exercise[8].

TT/C ratio has been employed as an indicator of anabolic-catabolic balance[9]. In 1986, Adlercreutz et al., suggested that decreases in FT/C ratio higher than -30% in comparison to basal values, or lower than $0.35x10^{-3}$, could indicate overtraining [9]. Hypothetically, a decrease in this quotient would indicate a predominance of catabolic processes which could decrease performance and possibly deteriorate health. An increase in the TT/C ratio, would translate as a predominance of anabolic processes (overcompensation)[3, 9-10]. However, this approach still generates controversy and nowadays, several authors disagree with the relationship between TT/C ratio and performance[10-13]. Some of them even consider that this parameter does not reflect the real metabolic state[14].

The endocrine studies have been carried out mostly in individual sports and there are scarce investigations in relation to team sports. In basketball, a few publications deal with hormonal response after a game or effect of a

period of competition or training[15-18]. However, despite their importance in relation to performance and health, to these authors' knowledge, there is only one international publication that studied these parameters individually during an entire season in an elite basketball team[16] and it did not provide scientific evidence of the influence of training frequency or workload in hormonal responses.

Therefore the aim of the present study is to describe the variation of total testosterone and cortisol through the course of a complete season in elite male basketball players, and secondly, to analyse their relation to training frequency and playing time.

Methods

Study design

This is an observational-descriptive and longitudinal study with accidental sampling (non-randomised). Repeated measures were conducted.

Subjects

Eight professional male basketball players (age: 27.8 ± 4.9 years; weight: 97.0 ± 9.5 kg; height: 197.2 ± 7.3 cm; body mass index: 24.7 ± 1.0; experience: 8.2 ± 4.5 years in elite competition competing in the Spanish 1st Division-ACB league (Table 1) participated in the present study.

Table 1: Players' physical characteristics and experience

	AGE (years)	BODY MASS (Kg)	HEIGHT (cm)	BMI BM/height^2	min./G	EXP. (years
GUARD-1	28	81	188	22.9	0024:23	9
GUARD-2	32	88	189	24.6	0015:23	12
SMALL FORWARD-1	25	92	190	25.5	0027:46	5
SMALL FORWARD-2	39	90	193	24.2	0009:55	18
SMALL FORWARD-3	24	92	197	23.7	0011:21	3
FORWARD	29	96	196	25.0	0012:04	9
POWER FORWARD-2	25	105	203	25.5	0023:06	5
CENTER-1	28	110	206	25.9	0018:36	10
AVG	28.5	96.4	197.2	24.7	0018:09	8.2
SD	*4.4*	*9.6*	*7.3*	*0.9*		*4.5*

AVG: Average; *SD*: Standard deviation; BMI: Body mass index; min./G: playing time per game (minutes); EXP.: ACB league experience

General protocol

Data were collected during the 2007-2008 season. All subjects were thoroughly informed of the experimental procedures and signed a consent form. During the investigation period all athletes carried out their usual team training programme. Technical staff were informed of the experimental procedures and of the possible risks and benefits of the project. These procedures were applied in accordance with Helsinki Declaration (Seoul, 2008) and were approved by the Ethics Committee for Clinical Research of Sports Administration of Catalonia (00998/11722/2011).

Blood samples were collected on the first training day, just after the off-season period, and these values were considered as baseline. During the competitive season, samples were taken periodically, every 4 to 6 weeks in a resting state, always after a 24-36 hour break following last game played (Table 2). A total of 8 samples were collected per player from August to April.

Table 2: Weekly training frequency and average training frequency every 6 microcycles

	Phase	**PRE-SEASON**						**REGULAR SEASON**																																					
	Month	**August**		**September**				**October**				**November**					**December**				**January**					**February**				**March**				**April**				**May**	
	Microcycle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	(25)	26	27	28	29	30	31	32	33	34	35	36	37	38
	Blood sample	▲				▲				▲						▲					▲						▲					▲					▲									
	PT	11	8	7	4	5	4	2	2	1	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	3	2	2	2	2	2	2	0	2	2	2	1	0	0
	CP	0	7	8	8	6	5	6	7	4	5	6	6	6	7	6	6	7	6	4	6	4	7	5	6	5	6	4	6	6	6	6	4	6	5	7	4	4	4
	G	0	1	0	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	0	1	2	1	1	1	1	2	1	1	1	2	1	1
	TP	11	16	15	14	12	11	9	10	7	8	9	9	9	10	9	9	10	8	7	9	8	10	8	9	8	9	8	9	9	9	9	6	9	8	10	7	5	5
Average	*PT*	6.5						1.8 [a]				1.8 [a]					1.8 [a]				2.2 [a]					1.5 [a]											-								
	CP	5.7						5.7				6.3					5.3				5.5					5.3											-								
	G	1.0						1.2				1.0					1.3				1.0					1.3											-								
	TP	13.2						8.7 [a]				9.2 [a]					8.5 [a]				8.7 [a]					8.2 [a]											-								

CP: court practices; PT: physical training; G: games; TP: total practices [CP + PT + G]; ▲: Blood sample; (25): Resting microcycle by not competing in the Cup championships (Copa del Rey); [a]: Significant differences vs. Pre-season ($p<0.05$)

Training frequency monitoring

All training sessions were recorded daily, distinguishing between court practices (CP), physical training (PT), games (G) and total practices (TP, CP + PT + G) (see Table 2).

The weekly training during the regular season generally involved: 2 strength sessions (90 min./week), 1 'high intensity interval training' session (30-45 min./week), 1-2 shooting sessions (45-90 min./week), 5-6 technical-tactical whole team sessions (525-625 min./week), 1 game and 1 recovery session the day after the game (consisting of water-based contrast therapy, stretching and physiotherapy).

Blood sampling and analyses

Subjects came to the laboratory between 08h00-09h00 in a fasted state. While blood was drawn, the subjects were seated on a reclining chair, with an arm support structure. The schedule was always the same to avoid hormonal alterations due to nycthemeral rhythm[19-20]. Blood samples, used to measure TT and C, were obtained from the antecubital vein and collected in dry test tubes, with no anticoagulants for immediate analysis. TT concentration was determined by electrochemiluminescence immunoassay (ECLIA, Tesosterone II, 05200067 190, Cobas®) with a measuring range of 0.087-52.0 nMol/L, and a coefficient of variation (CV) between measurements of 1.2-4.7%. C concentration was also determined by ECLIA (Cortisol, 11875116 122, Cobas®) with a measuring range of 0.0005-1.750 µMol/L, and a coefficient of variation (CV) between measurements of 1.1-1.7%. Immunoassays were analysed using a Modular Analytics E170 (Roche Diagnostics Ltd., Burgess Hill, UK). All procedures were carried out in a specialised laboratory (Laboratorios Nogueras, Manresa, Spain).

TT/C ratio estimation:

TT/C ratio was estimated from total molar concentrations[15, 17, 21-23] (TT in nMol/l and C in µMol/l)[24].

Statistical analysis:

Values were expressed as mean and standard deviations. Both absolute and relative concentration values of each hormone (TT, C) or ratio (TT/C) and percentage of variation[25] were considered (varTT, varC y varTT/C), with the 1st sampling representing 0%. Training frequency was determined by the number of each type of session (physical, court, game and total). Average game playing time was also calculated between blood samples (TPavg), as well as game playing time prior to each blood sampling (TPpg).

The Kolmogorov-Smirnov test was used to analyse the normality of the data. An ANOVA with repeated measures (Bonferroni's method) was used to check significant variations between blood samples. A Pearson's correlation was carried out to examine the relationship between variables, and a T test for dependent samples was used to compare training frequency (pre-season vs. season). The effect size was assessed with the partial eta-squared ($\eta^2_{par.}$) and the Cohen's *d*. Statistical significance was set at an alpha of 0.05. The data were analysed by using the SPSS v.15 for Windows (SPSS Inc., Chicago, IL, USA).

Results

A total of 64 peripheral blood samples were analysed (see Tables 2, 3 and 4)

Table 3: Testosterone, cortisol and TT/C ratio in each blood sample. Data expressed as AVG ± SD

	PRE-SEASON		REGULAR SEASON							
	August	**September**	**October**	**November**	**January**	**February**	**March**	**April**	**p**	**$\eta^2_{par.}$**
TT (nMol/l)	21.0 ± 4.8	22.4 ± 4.2	22.9 ± 4.0	21.5 ± 4.5	21.4 ± 3.6	24.9 ± 2.9	20.6 ± 2.8	18.0 ± 3.7 [a b c]	p<0.01	0.98
VarTT (%)	0.0 ± 0.0	9.9 ± 22.9	11.8 ± 19.7	3.9 ± 15.2	4.8 ± 20.0	23.8 ± 30.3	1.1 ± 17.8	-12.2 ± 17.2 [a b]	p>0.05	0.13
C (µMol/l)	0.399 ± 0.16	0.451 ± 0.08	0.439 ± 0.10	0.393 ± 0.13	0.438 ± 0.13	0.441 ± 0.09	0.441 ± 0.09	0.516 ± 0.06	p<0.01	0.98
VarC (%)	0.0 ± 0.0	33.3 ± 69.2	33.1 ± 83.0	18.7 ± 84.3	30.1 ± 80.5	35.6 ± 84.5	29.2 ± 64.8	57.4 ± 87.0	p>0.05[G]	0.20[G]
TT/C ratio	58.0 ± 17.7	50.8 ± 11.3	54.8 ± 17.1	61.7 ± 26.8	54.8 ± 26.6	58.4 ± 12.1	48.6 ± 13.6	35.4 ± 8.5	p>0.05[G]	0.26[G]
VarTT/C (%)	0.0 ± 0.0	-6.6 ± 28.5	1.4 ± 39.3	15.6 ± 59.0	3.3 ± 61.1	8.1 ± 35.6	-10.9 ± 32.4	-33.7 ± 24.0	p>0.05[G]	0.26[G]
	Number of players with VarTT/C less than 0%									
VarTT/C < 0%	0	5 (62.5%)	5 (62.5%)	3 (37.5%)	5 (62.5%)	3 (37.5%)	6 (75%)	8 (100%)		
VarTT/C < -30%	0	1 (12.5%)	1 (12.5%)	1 (12.5%)	3 (37.5%)	2 (25%)	2 (25%)	4 (50%)		

TT: total testosterone; varTT: percentage variation of TT; C: cortisol; varC: percentage variation of C; TT/C ratio: total testosterone-to-cortisol ratio; varTT/C: percentage variation of TT/C ratio. Significant changes (p<0.05): [a]: vs. September; [b]: vs. October; [c]: vs. February; $\eta^2_{par.}$ (eta squared partial); [G] (value with Greenhouse-Geisser correction

Table 4: Correlation between total testosterone, cortisol and TT/C ratio

	TTC-TT	**TTC-C**	**TT-C**	**TTC-TPavg**	**TT-TPavg**	**C-TPavg**	**TTC-TPpg**	**TT-TPpg**	**C-TPpg**
Pearson (r)	0.354	-0.839	0.123	0.033	0.073	-0.042	0.131	0.265	-0.050
Sig. (bilateral)	0.004*	0.000*	0.333	0.826	0.621	0.779	0.373	0.069	0.737
n	64	64	64	48	48	48	48	48	48

TT: Total testosterone; C: Cortisol; TTC: TT/C Ratio; TPavg: Average of minutes played per game between blood extractions; TPpg: Minutes played in the game previous to blood extraction; n: sample; Sig.: Significance; *: p<0.01.

Average values of TT, C and TT/C ratio concentration

TT concentration showed significant variations between blood samples: April *vs.* September (-4.4 nMol/l, p=0.010, *d*=1.1), April *vs.* October (-4.9 nMol/l, p=0.004, *d*=1.27) and April *vs.* February (-6.8 nMol/l, p=0.013, *d*=2.08). TT did not correlate with playing time (TT-TPavg, r=0.073; TT-TPpg, r=0.265) nor with C (r=0.123). C concentration did not show significant variations throughout the season. C did not correlate with playing time (C-TPavg, r=-0.042; C-TPpg, r=-0.050) nor with TT (r=0.123). Finally, TT/C ratio did not show significant variations throughout the season. TT/C correlated positively with TT (r=0.354, p=0.004) and negatively with C (r=-0.839, p=0.000), but did not show any correlation with playing time (TPavg, r=0.033; TPpg r=0.073) (Tables 3 and 4).

Average values of percentage (%) variation of TT, C and TT/C ratio

TT Variation showed significant differences between blood samples: April vs. September (-22.1%, p=0.034, *d*=1.09) and April vs. October (-23.9, p=0.010, *d*=1.30). C and TT/C ratio variation did not show significant differences throughout the season. With regards to players showing a negative varTT/C, in September (pre-season) 62.5% of players were below 0% threshold and 12.5% of them showed values inferior to -30%; in Mar, 75% of players were below 0% and 25% of them showed values inferior to -30%; in April, 100% of players were below 0% and 50% of them showed values inferior to -30% (see Table 3).

Training frequency and playing time

The total frequency of sessions per week was 14 during the pre-season and 8.2-9.2 during the regular season. PT sessions showed the highest frequency during the pre-season (microcycles 1 to 6), with 6.5 sessions per week compared to 1.5-2.2 during the regular season (microcycles 7 to 36). CP sessions showed a frequency of 5.7 sessions per week during the preseason as well as the regular season. G sessions showed an average of 1 per week during the pre-season and 1.1-1.3 during the regular season. Microcycles with two G previous to blood samples (microcycles 9 and 19), when it was intended to decrease workload volume and increase intensity (tapering), showed: 2 G, 1 PT, 4 CP, a total of 7 sessions. The resting microcycle corresponding to Copa del Rey (microcycle 25), with a high workload volume followed by 2.5 days of rest, showed 0 G, 3 PT, 5 CP, a total of 8 sessions. During the pre-season (August and September) a greater frequency of physical training sessions (p=0.010) and total practices (p=0.007) was observed in comparison to the regular season; in relation to court practices, there were no significant differences (see Table 2).

Discussion

The present study is one of the few investigations that analysed the cumulative effect of an entire season of TT and C in elite basketball players. Furthermore, to our knowledge, this is the first study that analysed the influence of training frequency on these variables.

The results from this present study for TT and C fall within laboratory reference values in all eight samples, but do not follow a normal circannual rhythm[20]. This observed alteration suggests that the sport season (workload volume, stress, fatigue, etc.) may be an instigating factor.

Chronobiology indicates that C should display its highest values in autumn and winter and its lowest values in spring and summer. In the present study, C shows its lowest values in November (autumn) and its highest values in April (spring), increasing progressively throughout the season, even if not significantly. These results would coincide with the hypothesis that C increases in relation to workload volume and stress[2, 7]. This is in accordance with the investigation of González-Bono et al., where an increase in C related to increases in workload volume was found in professional basketball players[18] and with the results of Argus et al. where an increase was observed during a 13-week rugby competition[26]. Nevertheless, the results from this present study do not coincide with those provided by Hoffman et al. who studied a national team training camp, showing an increase in C after a decrease in workload volume [15]. Hoffman and his co-workers[23] explained their results as overtraining or an incomplete recovery of their subjects, given that the training camp was held after the end of the regular season, with possible alterations in hypothalamus-hypophysis-adrenal axis[3]. This present study's results also disagree with those obtained by Martínez et al., who showed significantly lower concentrations of C in April than in October, despite the fact that ACTH showed higher value in April[16]. This could be explained by the type of periodisation, because

the group studied by Martínez and colleagues participated in play-offs in May and June (tapering phase[27]), while the present study's group ended the season on May 15th. ACTH concentration is usually associated with acute stress[28]. On the other hand, C concentration is usually associated with cumulated stress[4, 19]. It is worth noting that, in this study, the first blood test (baseline) was carried out in October, when the season had already begun (August), so baseline actually represented changes corresponding to two months of training (August and September).

Previous studies demonstrated that TT shows its highest values in summer. However, in this present investigation the highest values of TT were obtained in February (winter), and the lowest in March and April (spring). TT (concentration and variation) showed significant changes during the season, which suggests a possible relation between these results and workload. It has been suggested that this hormone is a potential indicator of fatigue, due to its relation with anabolic processes[29]. In this present study, similarly to what has been observed in other sports[21], the lowest values of TT are obtained at the end of season, both in concentration values: April vs. September (-4.4 nMol/l, p=0.010, *d*=1.1), April vs. October (-4.9 nMol/l, p=0.004, *d*=1.27) and April vs. February (-6.8 nMol/l, p=0.013, *d*=2.08), and in % of variation values: April vs. September (-22.1%, p=0.034, *d*=1.09), April vs. October (-23.9, p=0.010, *d*=1.30). These results could indicate an accumulation of fatigue throughout season[15]. However, these results contradict those obtained by Martínez et al., where TT showed significantly higher values in March and April in comparison to October, and FT showed more regularity without significant variations[16]. As previously mentioned, differences in relation to the results of this study could be due to planning. Results provided in this investigation could reflect the accumulation of fatigue throughout the season[21] and, in conjunction with other indicators (physical, emotional, physiological, etc.)[12], could be useful to assess player's state[29].

TT/C ratio has been proposed by various authors as a potential indicator of training load[9], a tool that permits intervention before pathological physiologic alterations affect athletes[3, 16]. The results of the present study did not confirm this concept, as they did not show significant changes over the course of the study, but these authors would like to point out the decrease in TT/C ratio at the end of season. This decrease coincides with the values obtained by Handziski et al. in elite soccer players[21] or those obtained by Argus et al. in rugby players[26], that may constitute an indication of the season's accumulated fatigue. However, even though some of this present study's individual values reached -30% (especially in January and April), these authors do not necessarily consider these results to be a consequence of overtraining or a cause for a decrease in performance[11-12]. They should have more indicators in order to confirm this[12, 15, 30]. As proposed by Vervoorn et al., these authors can interpret this decrease as incomplete recovery[24], which could involve an alteration in the hypothalamus-hypophysis-adrenal axis[3].

Results obtained on the relation between TT and C are in contrast with those obtained by Brownlee et al., who showed a negative post-exercise relation between two hormones: the greater the concentration of C, the smaller the concentration of TT[7]. This present study's results do not reflect this relation, probably because of a different delayed response[12], given that the present investigation focused on accumulative effect as opposed to acute effect. As anticipated, TT/C ratio correlates positively with TT and negatively with C, as the TT/C ratio corresponds to the quotient between both hormones and its value depends directly on their values. These results coincide with those provided recently by Martínez et al, also related to elite players[16]. However, the negative correlation that TT/C showed with C recounts that the result of the ratio depends to a large degree on C[31]. Unlike the investigation of Hoffman et al, these authors did not observe a relation between playing time (TPavg, TPpg) and the hormonal variables studied. In the Hoffman and co-workers study, blood was drawn in the middle of a week, 15 hours after the last training session, which could alter the results because of the influence of previous sessions and this could represent a limitation of their investigation. In the present study, blood samples were obtained early in the week, 24 to 36 hours after a game, without previous training sessions.

In practical terms, these data provide useful information to develop appropriate planning of the season. In particular, the present authors suggested that it is necessary to divide the season into 3 different phases according to hormonal responses. The 1st phase takes place during pre-season (August and September), and during which there is a prevalence of the catabolic state due to a high

volume of training[30]. In this period the workload is high and there is a predominance of physical sessions. Controlling fatigue accumulation is one of the objectives of this part of the season. The 2nd phase, which covers the first two-thirds of the regular season (from October to February), shows an initial overcompensation of the pre-season workload (October), with a prevalence of an anabolic state, to be maintained until February. During the 3rd phase, which covers the last third of the regular season (March and April), fatigue accumulation at a metabolic level occurs, with the risk of jeopardising players' performance and health[21, 30]. It is necessary to take into account this last phase in order to individually prescribe recovery interventions, through specific sessions, ergogenic and/or physical aids. Moreover, the metabolic state showed by players at the end of the regular season, invites reflection on the specific situation of international players who, once the season is over, have only two-three weeks of recovery (less, for play-off teams), before attending national training camps, in a probable incomplete recovery state[15]. This fact highlights the importance of post-season recovery (physical and psychological) and supports the necessity for recovery time between the end of season and the beginning of international competition with national teams[15]. In addition, after national training camps, players begin the pre-season schedule with their own teams, which could entail, again, incomplete recovery states. Finally, the interpretation of the above-mentioned studied parameters has to be made individually, not as an attempt to evaluate a team's general state. Frequency training is a limited variable and future investigations should analyse other modulator variables (mood state, training intensity, diet, sleep, etc.) in relation to endocrine markers.

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