Multifactorial monitoring of training load in elite rugby sevens players: cortisol/cortisone ratio as a valid tool of training load monitoring

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ABSTRACT: The effectiveness of selected physiological and perceptual measures for monitoring training load and fatigue was studied in 16 male elite rugby sevens players during a 6-week intense training block (IT) and 2-week tapering (TAP). Daily training load (TL) and strain (TS) as well as weekly total score of fatigue (TSF) were quantified respectively by the session-rating of perceived exertion (RPE) method and an 8-item questionnaire. Also, testing was performed and 24 h urinary cortisol (C), cortisone (Cn), adrenaline (A) and noradrenalin (NA) excretion was measured before (T0) and after the IT (T1) and after the TAP (T2). The TL, TS and TSF increased during the IT and decreased during the TAP, in conjunction with a significant drop and improvement, respectively, of performance standards during the two periods. At T1, C and Cn levels increased while A and NA levels decreased, resulting in a higher C/Cn ratio and lower A/NA ratio, respectively. At T2, both C/Cn and A/NA returned to baseline values. The changes in C/Cn ratio, after the 6-week IT, were more closely related to mean TL, TS and TSF (r=0.75-0.76 vs. r=0.48-0.58, p<0.01) and to changes in the majority of performance measures than to A/NA ratio. Only the changes in C/Cn ratio after the 2-week TAP were related to mean TL, TS and TSF (r=0.61-0.68, p<0.01). The changes in hormone levels, training strain and performance standards reflected the physical and mental stressors of training, with complete recovery, as indicated by physiological homeostasis, achieved after an appropriate tapering period.

INTRODUCTION

The seven-a-side version of rugby union has grown in popularity and international standing in the sporting community, leading to its integration in the Olympic Games starting in 2016. While rugby sevens' basic rules are substantially the same as for the 15-a-side rugby match (rugby union), some major exceptions such as reduced number of players, i.e. seven per team, and shorter match duration, i.e. two seven-minute halves (with one minute of recovery in between), exist. The major dissimilarity in match demands in conjunction with differences in the competition structure between the two codes suggests that rugby sevens generates potentially higher exercise loading [1]. Usually, more than two games are held on the same day with only few hours of recovery in between, leading to the assumption that rugby sevens players may experience higher levels of psychological and physiological stresses compared to rugby union [2]. In this context, rugby sevens training develops the physical requisites for competition and consists of a high volume of resistance training and anaerobic and aerobic conditioning leading to high levels of perceived fatigue [3]. The objective in training competitive athletes is to provide training loads that are effective in improving performance. At some stages during the training process, athletes may experience an unexplainable decrease in performance which might happen when prolonged excessive training takes place concurrent with other stressors and insufficient recovery [4,5]. To prevent overtraining and to ensure that the athletic training programme will result in performance improvements, or at least in the maintenance of performance standards, it is advised to assess the effectiveness of the training process, and sports coaches are required to monitor training load (TL) and training strain (TS). While TL assessment via heart rate measures is well accepted in endurance sports, this method is questionable and presents sev-

eral limitations especially during weight, interval, intermittent, and plyometric training [6].

Fortunately, the session rating of perceived exertion (RPE) method for quantifying TL and TS has emerged as an alternative approach, and recent data have extended its application for monitoring training periodization in both team and individual sports [6-9]. Additionally, a stronger relationship was reported between the increase of stress induced by exercise training (as expressed by physiological and bio-chemical changes) and the psychological alterations [10-13]. In fact, psychological measures have been proven to be as effective as physical measures in diagnosing training stresses [12,14]. Accordingly, several psychological questionnaires have been employed for monitoring changes in training stress, strain and recovery with the aim of detecting early signs of tiredness and/or overtraining [10-12,15].

Moreover, the use of urinary hormone excretion such as cortisol, cortisone and catecholamines, which reflect both hypothalamo-pi-tuitary-adrenal (HPA) and sympatho-adreno-medullar (SAM) systems, has also increased in monitoring training load, largely because of its non-invasive nature [16-20]. Interestingly, it has been pointed out that both glucocorticoids and catecholamines exert many beneficial actions in exercising humans, increasing availability of metabolic substrates for the need of energy of muscles, maintaining normal vascular integrity and responsiveness, and protecting the organism from an overreaction of the immune system in the face of exercise-induced muscle damage [21,22]. Given the adjustment of both HPA and SAM during exercise training, both cortisol/cortisone (C/Cn) ratio and adrenaline/noradrenalin (A/NA) ratio have been suggested as useful indicators for monitoring the physical and psychological stress of training and its recovery [16,17].

While the physiology of these hormones has been studied for a variety of physical activities [16-18,20], with the emphasis on con-tinuous and regular activities such as swimming [16,17] and middle and long-distance running [23], sparse data are available on the endocrine responses to intermittent high intensity activity and its concomitant performance variations in sport-team athletes involved in various categories of training, i.e. endurance, strength, power and sprint. Moreover, the findings of previous studies are not conclusive concerning the performance of these two indices. Consequently, the aim of this study was to examine the effects of training changes on psychometric measures and 24 h urinary glucocorticoids and cate-cholamines in elite rugby sevens players and to determine the ef-fectiveness of these selected variables for monitoring training load, fatigue and performance changes over an 8 week training camp, including a 6-week intense training block (IT) and 2-week tapering (TAP).

MATERIALS AND METHODS

Participants. Sixteen players from the Tunisian national rugby sevens team volunteered to participate in this study. After being informed about the experimental procedures, subjects agreed to participate in this study and filled in a written informed consent form. The study protocol was performed in accordance with the Declaration of Hel-sinki 1975 and was approved by the local University Ethical Com-mittee. All players regularly participated in national and interna-tional competitions. They were training with their clubs on average 5 to 6 times per week, i.e., 10 to 12 hours weekly. Between the preparation periods and the international meetings, they used to train with the national team twice a day from Monday to Friday, with a corresponding training volume of 3 to 4 hours per day in addition to two rugby sevens games played at the weekend. Moreover, these players participated in five sevens World Tour tournaments per year which were organized by the International Rugby Board. During the whole training period, the dietary intake was assessed and admin-istrated by the team's nutritionist, who supervises all nutritional menus for the players. None of the subjects was taking medication or exhibited metabolic and/or endocrine dysfunctions that could im-pede or limit their ability to fully participate in the study.
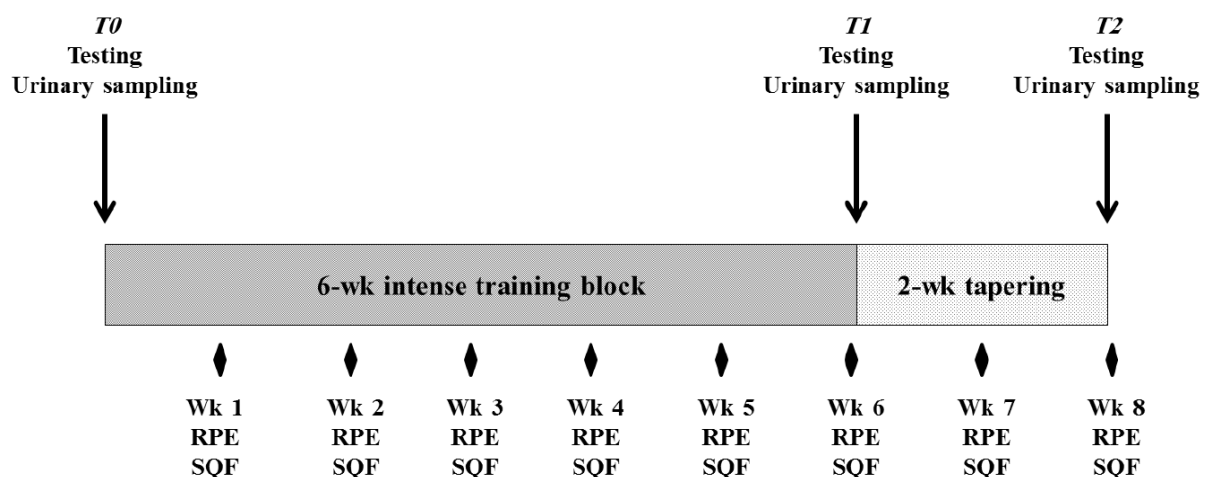
FIG. 1. Schematic overview of the study design.
Note: RPE: session-rating of perceived excretion; SQF: short questionnaire of fatigue.

Procedures and tests

The study was conducted during the preparation period for the rugby sevens World Cup, for which the team prepared by participating in 5 international tournaments, in which the best teams in the world were participating.

Anthropometric measurements and performance testing were performed at the same time of the day at the National Center of Medicine and Science in Sports, Tunis (mean temperature: 18 ± 2°C, mean relative humidity 44 ± 8%) as follows:

1) Before the start of the training programme (T0),
2) After a 6-week intense training block (T1),
3) After 2-week tapering (T2).

These tests were part of the prospect of controlling the players' fitness level for a tournament that was part of the sevens World Cup (Figure 1).

Body mass and height were measured with calibrated devices (Tanita, Model, accuracy 100 g, and Harpenden Portable Stadiometer, accuracy 1 mm, respectively). Percent body fat (% BF) was estimated by the four skinfolds method (supra-iliac, biceps, triceps, and sub-scapular) using the formula of Durnin and Womersley [24]. The measurement of these skinfolds was done by the same technician with a clamp mark Harpenden caliper (Holtain Ltd Bryberian, UK).

Subjects were assessed three times (T0, T1, and T2) during the training period by means of tests that reflect the different qualities sought in a rugby competition. These tests, which measured speed, power, leg explosiveness, and agility, along with aerobic and anaerobic capacities, were selected for their relevance, validity and reproducibility.

The players performed three maximal 30-m sprints with intermediate 10 and 20-m split times on indoor synthetic court. The five-jump test (5JT) consists of 5 consecutive strides to assess lower limb power [25]. Agility was assessed using the agility test (AGT) "Illinois agility run" [26]. During the 2-3 min recovery period in between, players walked back to the starting line and then waited for the next sprint. Timing was automatically recorded using photocell gates (Brower Timing Systems, Salt Lake City, Utah, USA, accuracy of 0.01 s) placed 0.4 m above the ground. The lactic anaerobic capacity was assessed using the lactic test (LT) "Australian lactic test" according to the protocol described by Maso et al. [27]. Aerobic capacity was assessed using the Yo-Yo intermittent recovery test level 2 (Yo-Yo IRT2) according to the protocol proposed by Krustrup et al. [28]. It has been well demonstrated that the performance achieved in Yo-Yo IRT2 is strongly correlated with maximal oxygen uptake (VO2max) [28]. Strength was assessed using the bench press and half squat exercises using methods previously outlined [29]. Briefly, each participant was required to perform three sub-maximal sets (2–6 repetitions; 30%, 50%, 70%, 90% of perceived maximum strength) before one maximal set of 1 repetition (1-RM). Sets were separated by a 2-min rest period. For the bench press and half squat, participants used a self-selected handgrip and foot position, respectively, and lowered the bar to a 90° angle at the elbow and the knee, respectively.

Tests were performed over two days with 5 min of recovery in between in the following order: speed, agility and power first, anaerobic second and strength third. Each participant was instructed and verbally encouraged to make a maximal effort during all tests. Additionally, all physical tests were performed on an indoor court by the same investigator throughout the study.

Training load monitoring

Training load, monotony and strain for each participant were calculated according to the session-RPE method proposed by Foster et al [6]. Throughout the study, the duration (expressed in minutes) and the intensity of each training session were recorded for every player. Each participant's perception global intensity was rated on a modified Borg's category ratio scale [6] approximately 30 min after each session. Briefly, training load for each session of each player was calculated from the product of the session duration and the player's perception of global training intensity (training load = duration × intensity). The training monotony was also calculated from the average daily training load divided by the standard deviation of the daily training load calculated over a week. The weekly training strain was then calculated as the product of weekly training load and monoto-

TABLE 1. Description of the eight items of the short questionnaire of fatigue.

	During the preceding week:	Not at all			Normal			Very Much
1	I found training more difficult than usual	1	2	3	4	5	6	7
2	I slept more	1	2	3	4	5	6	7
3	My legs felt heavy	1	2	3	4	5	6	7
4	I caught a cold/infection/flu	1	2	3	4	5	6	7
5	My concentration was poorer than usual	1	2	3	4	5	6	7
6	I worked less efficiency than usual	1	2	3	4	5	6	7
7	I felt more anxious or irritable than usual	1	2	3	4	5	6	7
8	I had more stress at home/school/training/work	1	2	3	4	5	6	7

ny. The mean training load and strain were also calculated for the 6-week IT and the 2-week TAP. The training load, monotony and strain are expressed in arbitrary units (AU).

Short questionnaire of fatigue

The short questionnaire of fatigue (SQF) as previously described by Atlaoui et al. [16] consists of eight questions which focus on the following items: perception of training, sleep, leg pain, infection, concentration, efficacy, anxiety, irritability, and general stress. Each question was assessed on a 7-point scale: from not at all (1 point) to very much (7 points) (Table 1). The responses to the questions were summed to obtain the total score of fatigue (TSF). Finally, the TSF was weighted and calculated according to the relative importance of each question in the score [16]. The lower the score was, the better was the perception of general well-being. The higher the score was, the higher was the perception of fatigue. The participants' variability of the TSF assessed in 16 rugby sevens players from the coefficient of variation of difference between double measurements within half a day was 2.1%.

The TSF, TL and TS during the 6-week IT and the 2-week TAP were averaged in order to assess the relationship between these variables and the changes in physical performance and the 24 h urinary hormonal excretion recorded during these two periods.

Training

The training programme consisted of 6-week IT and of 2-week TAP. Of the 6-9 weekly training sessions, 2 focused on the development of the physical conditioning of the players. The work during these sessions focused on improvement of the aerobic capacity. Therefore, players performed high-intensity interval runs, physical-technical circuits, and game-like activities with small groups and large spaces, with the intent that the intensity during the 4- to 6-minute series would be very high. The intensity and duration of sessions gradually increased during the period of IT and declined steadily during the period of TAP. Sessions of speed and coordination were also performed by the players. During these sessions, speed and agility and coordination circuits were prescribed to improve sprinting performance, agility and coordination, respectively. The training was completed by 2 specific-strength training sessions in the gymnasium (duration of 30-45 minutes) before the field training. Strength training was developed using essential exercises such as squat and overhead split squat with or without external loads, box crossover and box jump, push-ups, draw chest, bench and inclined bench presses, abdominals and a variety of plyometric exercises for developing force-velocity of both lower and upper limbs.

Urine samples

All urinary samples were collected over a 24 h period, the diuresis was noted, and 100 mL aliquots were frozen at -80°C until further analysis. Concentrations of the urinary glucocorticoids and catecholamines were determined by high performance liquid chromatography (HPLC) with electrochemical detection according to the method of Hay and Mormede [30,31]. The intra-assay and inter-assay coefficients of variation were <1% for glucocorticoids and <3% for catecholamines. Both glucocorticoids and catecholamines were expressed in μg.mg-1 of creatinine per 24 h period and determined in duplicate.

Statistical analyses

To test for the normality of distribution, the Shapiro-Wilk test was applied prior to statistical analyses. Data were presented as mean $\pm$ SE. One-way, repeated ANOVA tests were performed to check the differences between the three assessments (T0, T1, T2). When the differences were significant the F-test was followed by a post-hoc procedure (Fisher's protected least significant difference test). The relationships between changes in percentage of the hormonal concentrations and training load and strain, physical performance, and scores of fatigue were determined using the Spearman coefficient of correlation. Effect sizes (η^2) were also calculated and reported according to Batterham and Hopkins [32] (small: $\eta^2 \leq 0.2$, moderate: $0.2 > \eta^2 < 0.8$, and large: $\eta^2 \geq 0.8$). Statistical analyses were performed using the SPSS package (SPSS Inc., Chicago, IL, version 16.0), and the level of significance was set at $p \leq 0.05$.

RESULTS

Table 2 summarizes the anthropometric and physical characteristics of the rugby players before the beginning and during the different moments of the training programme. The training programme, in both periods IT and TAP, was associated with a significant decrease of body mass and fat mass percentage. The lean body mass did not significantly increase throughout the training period. After the IT period (T1), all performances significantly decreased. Conversely, the TAP (T2) generated a significant increase in all testing performances. The training load and strain as well as the total score of fatigue are presented in Figure 2. Training load and strain increased until reaching a maximum value for the 5th week during the 6-week IT period. This increase was associated with simultaneous increased values of the total score of fatigue, with the highest score recorded in the 5th week. Conversely, all the parameters decreased significantly during the 2-week TAP. The mean of both training load and strain decreased significantly during the TAP (all $p < 0.001$). The mean total score of fatigue followed the same time course as the training load and strain, with lower values recorded during the period of TAP ($p < 0.001$).

Figures 3 and 4 present the effect of an 8-week training programme on urinary glucocorticoid and catecholamine levels. After the 6-week IT, the C, Cn and C/Cn ratio increased significantly (+27%, +13% and +22%, respectively, $0.01 < p < 0.001$, $\eta^2 = 0.93$, $\eta^2 = 0.84$ and $\eta^2 = 0.80$, respectively) (Figure 3A-3C), while A and NA levels decreased significantly (-30% and -25%, $p < 0.01$, $\eta^2 = 0.67$, $\eta^2 = 0.97$, respectively) from the baseline value (Figure 4A-4C). Compared to T0, the C, Cn and C/Cn ratio in T2 returned to baseline values, whereas A and NA became significantly higher (+13% and +10% respectively, $p < 0.05$).

TABLE 2. Anthropometric and physical performance data over the 8-week training period.

Measures	T0 (n=16)	T1 (n=16)	T2 (n=16)	η^2
Age (year)	23.8 ± 0.8			
Height (cm)	183.1 ± 0.02			
Body mass (kg)	87.3 ± 1.8	85.7 ± 1.7 *	85.8 ± 1.7 *	0.72
Fat mass (%)	13.1 ± 0.7	11.3 ± 0.6 *	11.2 ± 0.6 *	0.79
Lean mass (kg)	75.9 ± 1.5	76.0 ± 1.5	76.1 ± 1.6	0.33
10-m sprint (s)	1.82 ± 0.02	1.86 ± 0.02 *	1.80 ± 0.02 *‡	0.54
20-m sprint (s)	3.12 ± 0.02	3.16 ± 0.02 *	3.09 ± 0.02 **	0.62
30-m sprint (s)	4.29 ± 0.04	4.39 ± 0.03 *	4.28 ± 0.03†	0.41
AGT (s)	16.72 ± 0.08	17.12 ± 0.09 *	16.34 ± 0.10 *†	0.62
5JT (m)	11.6 ± 0.16	11.3 ± 0.14 *	12.7 ± 0.24 **‡	0.62
LT (m)	709.1 ± 9.2	702.3 ± 8.8	727.1 ± 7.5 **‡	0.73
Yo-Yo IRT2 (m)	1730.0 ± 78.7	1625.0 ± 78.1 *	1925.0 ± 83.2 **‡	0.91
1RM Squat (kg)	166.1 ± 4.0	155.3 ± 4.0 **	170.4 ± 3.8 **‡	0.83
1RM Bench press (kg)	114.8 ± 2.4	107.3 ± 2.6 **	118.0 ± 2.6 **‡	0.87

Note: AGT: agility test, 5JT: five-jump test, LT: lactic test, Yo-Yo IRT2: Yo-Yo intermittent recovery test level 2, 1RM: Maximum repetition.
* Statistical difference from T0; * $P<0.05$, ** $P<0.01$. † Statistical difference from T1; † $P<0.05$, ‡ $P<0.01$.
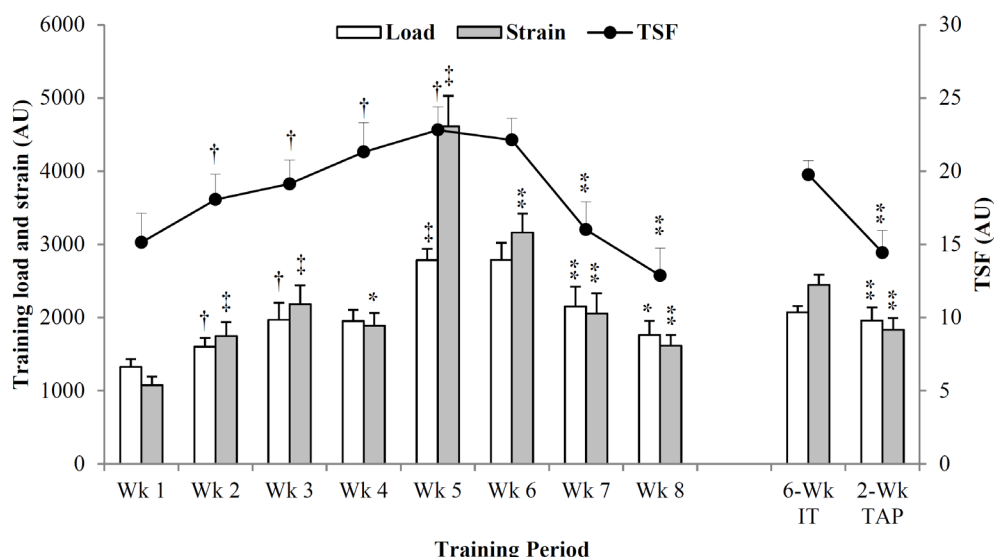

FIG. 2. Training load and strain and total score of fatigue recorded over the 8-week training programme.
Note: † and ‡: higher than the precedent value; †$P<0.05$, ‡$P<0.01$; *: lower than the precedent value;* $P<0.05$, ** $P<0.01$

TABLE 3. Correlation between changes in different parameters over the 8-week training programme.

T1 vs. T0	TL of 6-wk IT	TS of 6-wk IT	TSF of 6-wk IT	Δ 10m sprint	Δ 20m sprint	Δ Yo-Yo IRT2	Δ 1RM squat	Δ 1RM bench press
Δ A levels	0.37	0.50*	0.55*	0.24	0.50*	0.32	0.20	0.46*
Δ A/NA ratio	0.48*	0.52*	0.58*	0.51*	0.53**	0.33	0.40*	0.31
Δ C levels	0.63**	0.50*	0.68**	0.54*	0.44*	0.38	0.54*	0.36
Δ Cnlevels	0.69**	0.94***	0.62**	0.30	0.39	0.65**	0.42*	0.59*
Δ C/Cn ratio	0.75**	0.76**	0.76**	0.52*	0.49*	0.56*	0.59*	0.52*
T2 vs. T0	TL of 2-wk TAP	TS of 2-wk TAP	TSF of 2-wk TAP	Δ 10m sprint	Δ 20m sprint	Δ Yo-Yo IRT2	Δ 1RM squat	Δ 1RM bench press
Δ C/Cn ratio	0.68**	0.65**	0.61**	0.06	0.28	0.11	0.24	0.31

Note: Legend: TL: training load; TS: training strain; TSF: total score of fatigue; IT: intense training; TAP: tapering; Yo-Yo IRT2: Yo-Yo intermittent recovery test level 2; AGT: agility test; 5JT: five-jump test; Δ: variation in percentage.*$P<0.05$, **$P<0.01$, ***$P<0.001$.
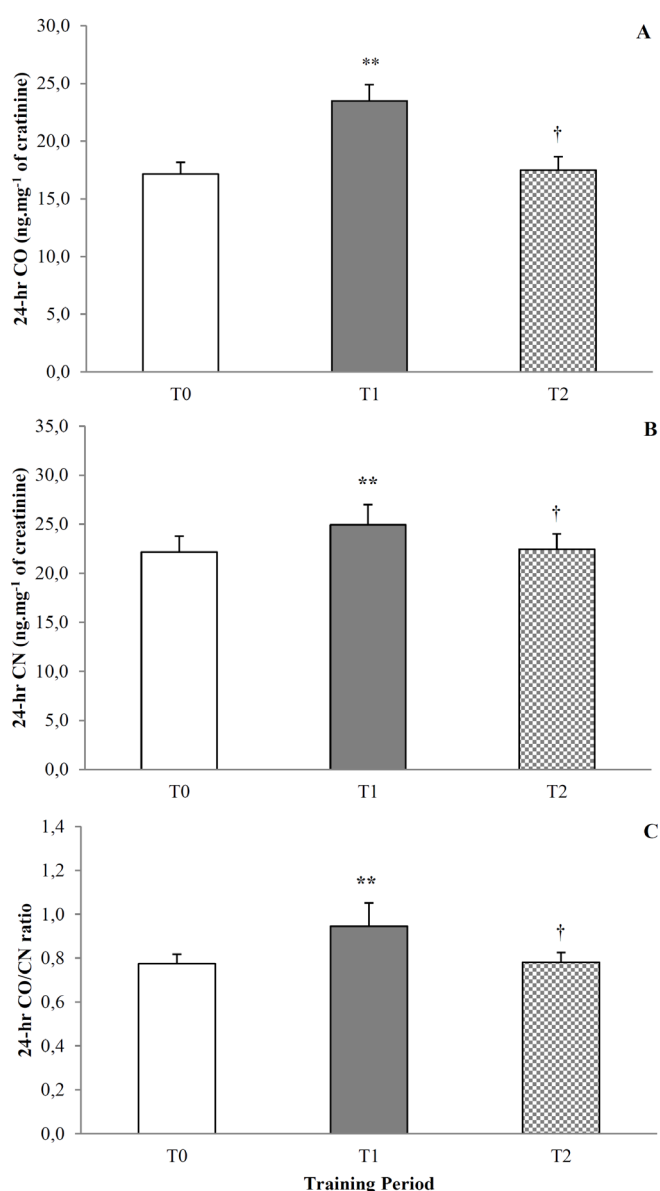
FIG. 3. Twenty-four hour urinary cortisol (A), cortisone (B) and C/Cn ratio (C) over training period.
Note: * Statistical difference from T0; ** P<0.01; † Statistical difference from T1; † P<0.01.
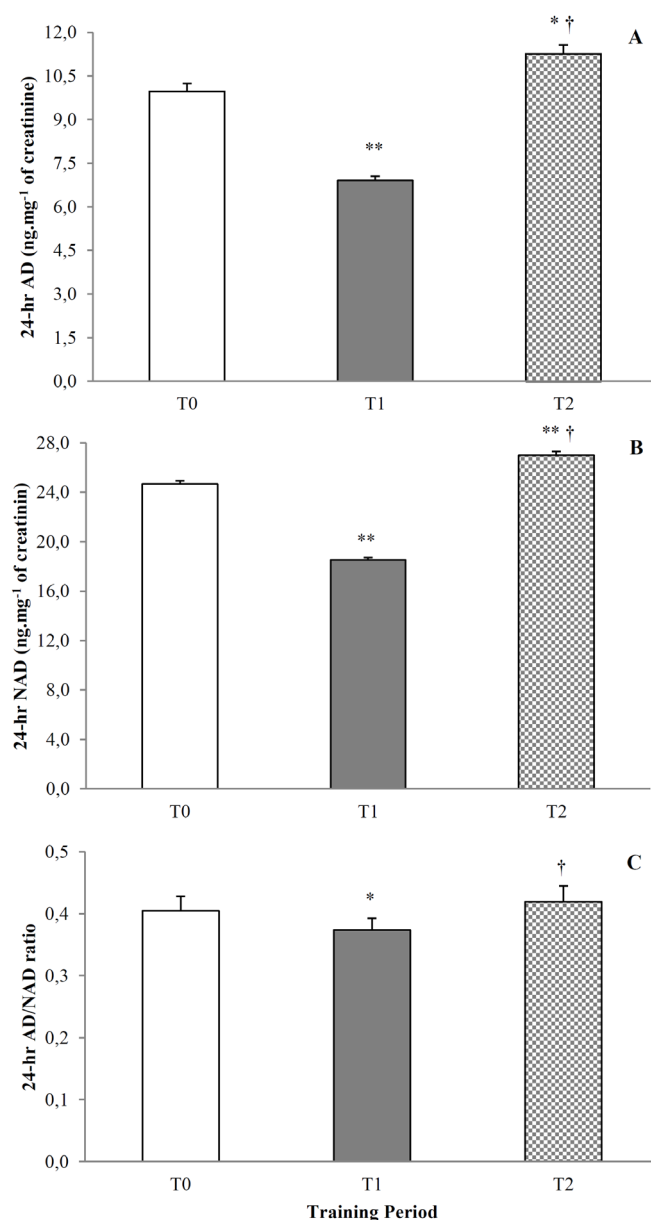
FIG. 4. Twenty-four hour urinary adrenalin (A), noradrenalin (B) and A/NA ratio (C) over training period.
Note: * Statistical difference from T0; * P<0.05, ** P<0.01; † Statistical difference from T1; † P<0.01.

Table 3 summarizes the significant relationships between different parameters through the training period. At T1, changes in C/Cn ratio and A/NA ratio were significantly related to mean TL, TS and TSF, with the correlation coefficient advantaging the C/Cn ratio (r=0.75, r=0.76 and r=0.76 vs. r=0.48, r=0.52 and r=0.58, respectively). In addition, the changes in C/Cn ratio were more strongly related to changes of the majority of performance standards than were the changes of A/NA ratio. At the same time, the changes in C and Cn levels were more strongly correlated with mean TL, TS and TSF as well as changes of certain physical performance parameters than were the changes in A and NA levels. At T2, only changes in C/Cn ratio were related to mean TL, TS and TSF (r=0.68, r=0.65 and r=0.61, p<0.01).

DISCUSSION

This study was intended firstly to examine the response to an 8-week training programme of psychometric measures and 24-h urinary C, Cn, A, and NA levels and their respective C/Cn and A/NA ratios, and secondly, to determine the most effective indices for monitoring training load, fatigue and performance changes. The main findings of the present study indicated that the training programme led to significant alteration in hormonal levels and physical performance in rugby sevens players. These changes were mainly characterized by a significant increase of urinary C and Cn levels and C/Cn ratio and a significant decrease of urinary A and NA levels during the 6-week IT. At the same time TL, TS and TSF increased and physical performance decreased. Our data also demonstrated that C and Cn levels

as well as C/Cn ratio returned to baseline values, while A and NA levels increased following the 2 weeks of TAP, coupled with an improvement of physical performance. Furthermore, several relationships were found between percentage changes of these hormones and TL, TS and TSF as well as percentage changes of selected physical performance parameters over the training period.

It is well recognized that the optimization of physical performance is viewed as a delicate and complex psychophysiological process, especially in highly trained athletes [14]. When prolonged excessive training stressors were applied, concurrently with inadequate recovery, many of the positive physiological adjustments associated with physical training were reversed, which possibly led to overreaching or even overtraining [5,23]. To prevent overtraining, it is necessary to monitor both psychological and physiological stress-related training and to include regular performance tests as a component of the training programme [15-17,20]. In the present study, we combined the session-RPE method and the SQF for monitoring TL and fatigue. The RPE method and SQF are simple, cost-effective, valid, and widely used as indicators for monitoring training stress and recovery in various sport activities such as soccer, rugby union and other sports [6-8,15-17,33]. Additionally, in rugby, a sport characterized by contact, impact and wrestle drills, with a lot of resistance and anaerobic efforts, it is difficult and mostly inappropriate to use heart rate monitors during training sessions.

The physical training programme of the current study resulted in a significant decrement in the majority of physical performance measures during the initial 6-week IT, which is the likely result of accumulating fatigue from multiple training sessions. Accordingly, these alterations were associated with higher TSF, which reflected the perception of training, sleep, leg pain, infection and general stress, and were suggested as a good marker of training stress in swimmers [16] and rugby sevens players [15]. These results are in agreement with previous studies using similar [7,10,19], short [16,17], or long duration programmes [11,34], suggesting that increased training load and strain were predisposing factors to homeostatic disruption and ultimately to performance impairment. The physiological mechanism of the performance changes observed during the 6-week IT could occur at the level of different systems (e.g., neural, muscular, neuroendocrine). In the present study, we explored the activity of both SAM and HPA systems, because they were closely reflected by 24 h urinary glucocorticoid and catecholamine excretion [35,36]. Moreover, our exploration allowed us to assess the adjustment of these axes against repeated physical and psychological stresses induced by high-intensity exercise training to establish a multi-level approach for training monitoring in elite athletes. The possible use of urinary sampling, as opposed to plasma, is a non-invasive, non-stressful, and reliable method to assess responses of both SAM and HPA axes to a large amount of training and competition stimuli.

As previously observed, the levels of urinary glucocorticoids and catecholamines of the participants were within the normal range reported in the literature [16,17]. The findings of this study showed that high TL and TS observed during the initial 6-week IT are concomitant with an increase of urinary C and Cn levels and C/Cn ratio and conversely with a decrease of urinary A and NA levels. Studies examining the effect of a training programme on salivary or plasma catabolic hormones have presented conflicting results in team sport athletes [7,11,19,33,37]. Filaire et al. [37], Kraemer et al. [33] and Coutts et al. [7,19] highlighted significant elevated resting saliva or plasma cortisol levels with performance impairments in soccer and rugby players. Conversely, Elloumi et al. [11] reported decreased performance in rugby league players during a 14-week training programme despite unaltered resting saliva cortisol levels. The discrepant results could be explained by several factors such as sampling method, circadian rhythms, and cortisol metabolism. It is well accepted that cortisol secretion follows a circadian rhythm with significant fluctuation of its plasma or salivary concentrations between awakening and its evening nadir. One of the major benefits of 24 h urinary collection is that the measure of the urinary hormone excretion is both a good reflection of hormonal secretion during the time of sampling and a non-stressful measurement [35,36].

The present study highlighted a significant increase of C and Cn levels as well as C/Cn ratio between T0 and T1 when TL, TS and TSF were high, together with a significant decline in physical performance. When taken together with the balance of previous findings examining C, Cn and C/Cn ratio changes over an intensified training period [16,17], it appears that the increase in these hormones may be explained by hyperresponsiveness of the HPA axis to physiological adaptation of the neuroendocrine system to chronic exercise demands. Interestingly, consistent with the finding of Atlaoui et al. [16] and Rouveix et al. [18], increased C/Cn ratio as well as C and Cn levels was associated with both increased TL, TS and TSF and decreased physical performance. As previously advanced [18], the increased activity of the HPA system in conditions of chronic stress can be interpreted from a physiological standpoint as either a coping mechanism to protect the body from severe and repeated stressors or may be maladaptive. The association of increased C and Cn levels as well as C/Cn ratio with decreased performance standards at T1 supports the second hypothesis and is in agreement with previous conclusions [16,18].

With respect to catecholamine responses, the training programme induces lowered urinary A and NA levels as well as A/NA ratio compared to pre-training values of the 6-week IT. The decreased catecholamine with IT was in agreement with previous research on both swimmers and tennis players [17,18,20] but inconsistent with data reported in 18 semi-professional rugby league players [19]. A possible reason for the differences between Coutts's findings and the present results is the training load and strain, which increased dramatically during the last two weeks of IT, whereas in Coutts's study, the athletes were intentionally overloaded with a progressive increase of training load and strain. It has been pointed out that repeated exposure to stressful conditions related to exercise training such as

the rugby training performed in the present study is frequently but not always accompanied by a diminution of stress-induced catecholamine secretion [17,18,20]. Because NA is mostly affected by physical stress and A by mental stress [38], we believe that the similar magnitude decrease of both catecholamines is due to both physical and mental stress-related training. As such, a panel of experts has suggested that the decrease of A/NA ratio reported after the initial 6-week IT can be explained by a reduction of sympatho-adrenomedullary activity with intensified training [17,20].

The results obtained from this study also demonstrated that the phenomenon of homeostasis disturbance was transient, because the study's participants showed an ability to improve their performance standards following a short-term regeneration period (i.e. 2-week TAP). Concurrently with these positive responses, C/Cn and A/NA ratios return to their baseline values. It has been astutely pointed out that exercise training session causes transient changes in physiological function that, when repeated over time, predispose the exercising organism to beneficial adaptations. The present findings showed altered urinary glucocorticoid and catecholamine following IT and a subsequent return towards pre-training levels following the taper. The short-term step taper completed in this study allows for overcompensation in the majority of physical performance, along with a return to a homeostatic environment. These data show that 2-week tapering, suggested as the most efficient strategy to maximize performance gains [39], generates physiological and psychological complete recovery. These results are in agreement with previous studies in team sport athletes [7,10,19]. The data of the present study showed that only changes in C/Cn ratio are significantly correlated with mean TL, TS and TSF, which is in agreement with Atlaoui et al. [16] and suggests that this index is a useful marker of TL and fatigue in team sports athletes. Overall, the responses of both HPA and SAM systems to changes in TL and TS may reflect the body's attempts to cope with the increased physiological demands of completing and recovering from training-related stress and fatigue.

CONCLUSIONS

The C/Cn ratio was found to be more sensitive to changes in stress-related training and recovery than the A/NA ratio in typical elite rugby sevens players during the preparatory period for major competition. Changes in hormonal levels, training strain and performance standards represent physical and mental stress generated by training constraints and complete recovery leading to physiological homeostasis at the end of the protocol. The significant relationships between hormone levels and perceived TL and fatigue suggest that metabolic and psychological changes should be carefully monitored to avoid unfavourable effects on the training status of elite rugby sevens players.

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