Hormonal responses to a rugby match

Slimani, Maamer; Cheour, Foued; Moalla, Wassim; Baker, Julien

Published in:
The Journal of Sports Medicine and Physical Fitness

DOI:
10.23736/S0022-4707.17.07187-0

Published: 05/05/2017

Document Version
Peer reviewed version

Hormonal responses to a rugby match: A brief review

Maamer Slimani[1], Foued Cheour[2], Wassim Moalla[3], Julien Steven Baker[4]

[1]Tunisian Research Laboratory ‘‘Sport Performance Optimization’’, National Centre of Medicine and Science in Sports (CNMSS), El Menzah, Tunisia

[2]High Institute of Applied Biology of Médenine, Medenine, Tunisia

[3]UR15JS01: Education, Motricity, Sport and Health, High Institute of Sport and Physical Education, University of Sfax, Tunisia

[4]University of the West of Scotland, Institute of Clinical Exercise and Health Science, Hamilton Campus, United Kingdom

Running head: Stress during rugby match

Acknowledgment

The authors would like to declare that no sources of funding were used in the preparation of this review. They would also like to affirm that they have no conflict of interest that is directly or indirectly relevant to the content of the present review.

Corresponding author:

Maamer Slimani

Tunisian Research Laboratory ‘‘Sport Performance Optimization’’, National Centre of Medicine and Science in Sport (CNMSS), El Menzah, Tunisia

Phone: + 216-97067695

E-mail: maamer2011@hotmail.fr

Abstract

BACKGROUND: Rugby is an intermittent team sport, commonly stressing the endocrine system by physiological efforts. However, no review has synthesized the available literature on the hormonal responses to a rugby match. The purpose of this review was to examine the hormonal responses to a rugby match. Mediator and moderator variables for the rugby match-hormonal responses relationship were also discussed. ***METHODS:*** The systematic search was conducted using different databases and according to the Population/Intervention or Exposure/Comparison/Outcome(s) [PICO] criteria. ***RESULTS:*** The data obtained in the present review shows that match contests was the moderator variable between rugby match-testosterone changes relationship. Particularly, official matches decreased pre-to-post testosterone levels by 43.9%, while simulated matches increased pre-to-post testosterone levels by 33.6%. There were no significant differences between official and simulated contests for the cortisol response to a rugby match which could be explained in part by the small numbers of included studies and participants (71 high-level male players). Thus, it has been shown that a rugby match provides considerable stress to the endocrine system, which lasts up 38-48 h into the recovery period. ***CONCLUSIONS:*** The hormonal assessment of rugby players is a valid tool for monitoring stress during a rugby match and provides the opportunity to identify how athletes cope with stress induced by a competition. The information also provides potential for various mental/recovery strategies that may contribute to performance enhancement.

Key words: stress, psychophysiology, rugby, competition.

Introduction

Rugby is an intermittent team sport which is characterized by high-intensity activity periods (e.g., high-speed running, sprinting, and physical collisions) and low-intensity recovery (e.g., standing, walking, and jogging) performed over two 40-minute halves.[1] Thus, it is likely that the high-intensity demands, may cause perturbations to the muscular, endocrine, and immune systems. In this context, the hormonal responses, particularly the testosterone, cortisol and testosterone/cortisol ratio, during a rugby competition may be an valid tool to monitoring player stress *per se* and athletic performance recovery.[2,3,4,5]

Testosterone is a steroid hormone secreted from the Leydig cells of the testes under hypothalamic and pituitary control defining the hypothalamo-pituitary-testicular (HPT) axis.[3] Testosterone has many physiological roles within the body, all of which can be placed into two categories: androgenic and anabolic. However, cortisol is a steroid hormone, secreted from the adrenal cortex via the hypothalamus-pituitary-adrenal (HPA) axis, which increases in response to stressors including exercise.[2,3] Increased or decreased cortisol and testosterone levels are related to various factors, e.g., psychological status, athletes' characteristics and exercise intensity. For instance, hormonal responses to stressors, including exercise and training have been extensively studied.[2,3,6] However, little is known concerning the hormonal responses to competition, particularly to rugby match.

In the last two decades, previous studies have examined the hormonal changes during a rugby match.[4,5] McLellan et al.[4] showed a significant increase in salivary cortisol concentration immediately post-match, while testosterone/cortisol ratios decreased substantially post-match and 24 h post- compared with pre-match values. The increase in cortisol is similar to the findings of Ispirlidis et al.[7] who found that cortisol concentrations were significantly elevated following a soccer match. However, with respect to testosterone, conflicting results have been reported.[5,8,9] These discrepancies may be explained by match differences (fitness, level of activity) and the large intra- and inter-individual variability in responses. Consequently, the hormonal response to a rugby game relative to key moderator variables such as match outcome, gender, type of contest (*i.e.*, official vs. simulation) and competitive level would provide important and useful information for monitoring stress and recovery states. Therefore, the aim of the present review was to determine the influence of a rugby match on hormonal (i.e., testosterone and cortisol) responses.

Methods

Search strategy

The systematic search was conducted using different databases, as recommended by the Cochrane Association, namely PubMed/MEDLINE, Scopus (Elsevier), ScienceDirect (Elsevier), SPORTDiscus, and Google Scholar with dates ranging from the earliest record to April 2016. All study designs were included. The search terms contained the following keywords: "rugby match", "hormonal response", "cortisol", "testosterone", "endocrine" and "stress". The full search strategy is detailed in Table 1 and has been adapted to each mined database. Target journals have been hand-searched for capturing all potentially relevant studies.

***** Table 1 here*****

Inclusion and exclusion criteria

According to previous reviews,[10,11] studies were included in the review if they met all the following Population/Intervention /Comparison/Outcome(s) (PICO) criteria:

(1) Population: studies recruiting male and female novice and/or elite rugby players at any age category as participants;

(2) Intervention or Exposure: investigations studying the hormonal (i.e., testosterone and cortisol) changes over the duration of a rugby match using any hormonal measurements methods and collecting blood, urine or saliva samples. According to Archer's,[12] Book et al.[13] and Wang et al.,[14] salivary and serum methods are equally valid exhibiting strong positive correlations with one another. Moderator and mediator variables were also examined;

(3) Comparison: hormonal changes (1) before and after a rugby match and (2) between simulated and official matches;

(4) Outcome(s): the degree of hormonal (i.e., testosterone and cortisol) changes (e.g., immediately and 30 min post-match) after a rugby match;

(5) Design: original investigations published in peer-reviewed journals;

(6) Language filter: English.

Studies were excluded if:

(1) Reviews, comments, opinions and commentaries, interviews, letters to editor, editorials, posters, conference abstracts, book chapters, and books were excluded; Focusing on methodological issues (for example, comparing endocrinological assays);

(2) Studying hormonal changes in a sport other than a rugby match;

(3) Lacking quantitative information and details.

For further details concerning the systematic search strategy, the reader is referred to Table 1.

Statistical analysis

The hormonal changes between official and simulated contests were compared using a two-way ANOVA. Statistical analyses were performed using the SPSS 16.0 software (SPSS Inc., Chicago, IL, USA). All significance tests were 2-tailed, and p values less than 0.05 were considered statistically significant.

Results

Study selection

The search strategies yielded a preliminary pool of 921 possible papers. The full text of 15 articles were retrieved and assessed for eligibility against the inclusion criteria. After a careful review of their full texts, 10 articles were excluded and the remaining 5 articles were eligible for inclusion in the review.

Excluded studies

Table 2 lists all excluded studies with reasons for their exclusion. The reader is referred to the table for further details.

*****Table 2 here*****

Characteristics of included studies

A total of 5 articles were identified in the present research, the characteristics of the study population included elite male players (Table 3). However, there was an uneven distribution between male (100%) and female (0%) participants, with all interventions involving males only. In addition, 5 studies included high-level male players as participants. The total number of participants included in this review was 71. Furthermore, the number of participants per study ranged between 10 and 17. The subject's age within the selected studies was 21.9 years. All studies were cross-sectional with pre and post-match hormonal analysis (Table 3).

Participant's characteristics, such as gender and age and percent changes (Δ%) from pre to post match of cortisol and testosterone were extracted and tabulated for each selected study (Table 3). Thus, the values of testosterone and cortisol were presented in nm/L in the analysis of results (Tables 4 and 5).

***** Table 3 here*****

***** Table 4 here*****

***** Table 5 here*****

Potential moderator variable

Official rugby matches reported a slightly lower percentage increase in cortisol levels (Δ%=69.3) than simulated rugby matches (Δ%=86.4) (Table 4), although the difference was not statistically significant ($p>0.05$).

Concerning the changes in testosterone, regardless of differences in gender, the data showed that official matches decreased pre-to-post testosterone levels by 43.9%, while simulated matches increased pre-to-post testosterone levels by 33.6%.

Discussion

The aim of this review was to examine the hormonal responses to a rugby match. Our results show that a rugby match induces significant hormonal stress in male players. More specifically, the data showed significant differences in the testosterone response to rugby games between official and simulated contests, with positive and negative changes in simulated and official matches, respectively. Cortisol concentrations did not vary with the match contest.

Previous studies have demonstrated that testosterone decreased by 43% with a corresponding increase in cortisol by 70.6% from pre-match to post-match.[9] Accordingly, studies investigating soccer matches have shown increases in cortisol levels.[7,27,28] Thus, no investigation has studied hormonal changes after a rugby match in female players. Furthermore, previous studies have reported large increases in cortisol during basketball [29] and soccer,[30] although none of these acute cortisol responses were as great as in rugby competition. Particularly, Souglis et al.[31] showed the greater increases in cortisol levels immediately after a soccer match (105% higher than baseline) than basketball and handball (~70% higher than baseline) and 50% higher than baseline in volleyball. In addition, higher cortisol response after official rugby match (70.6%) has been reported by Cunniffe et al. [9] than

the previous studies. Because of these physical and physiological demands of a rugby match there is a greater physiological emphasis observed than for many other sports.

An increase in salivary cortisol from 30 min pre-match to 30 min post-match has been found [26] which is consistent with the results of others,[5,19,32] who have identified a significant increase in cortisol ($p < 0.001$) after competitive performance. Several performance-related factors associated with elite Rugby League match play provide an explanation for significantly increased salivary cortisol 30 min post-match.[4] After the peak in salivary cortisol 30 min post-match a significant reduction in salivary cortisol was found 24 h post-match, followed by a further decrease in salivary cortisol at 48 h post-match to below 24 h pre-match salivary cortisol,[4,19,32] although increases in cortisol level were observed longer into the recovery period in the study of Cunniffe et al. [9]. It is possible that the differences in playing levels (higher in the study of Cunniffe et al. [9]) and playing environment contributed to this greater stress response.

Regarding the testosterone change after a rugby match, significant decreases in testosterone levels (43%) were observed immediately after the game.[9] This change resulted in a large decrease in testosterone/cortisol (T/C) ratio, with values still not recovered after 14 h of recovery. Such findings corroborate those of a previous study in top-level rugby union.[19] Thus, further increases of testosterone and T/C ratio have shown below resting values 38 h into recovery.[19]

Moderator variable

Match contests

The data obtained in the present review shows that match contests was the moderator variable between rugby match-testosterone changes relationship. Particularly, Cunniffe et al.[9] showed that official rugby match decreased pre-to-post testosterone levels by 43.9%, while simulated match increased pre-to-post testosterone levels by 33.6%.[8] This contradiction may be due to the differences of type of contest and psychological responses (e.g., perceptual of effort, motivation, anxiety) between official and simulated matches. Moreover, as other moderator variable, previous investigations have suggested that males demonstrate greater levels of stress response than do females.[33] This can be explained by the (a) higher levels of both state and trait anxiety in females than males in sport contexts,[34] (b) higher hormone concentrations for men at rest (particularly testosterone levels) and (c) the differences in body composition (e.g., higher fat mass in women) and/or in sexual hormonal status.[35] Future research is required to understand and compare the responses of males and females.

Psychological mediators

The alterations in the hormonal and psychological variables over the duration of a rugby game, suggest that combined psychological and hormonal changes during competition are of primary interest to monitor the competition stress in relation to rugby performance. It has been speculated that a combination of hormonal and psychological stressors imposed by competition are major factors contributing to these responses. To date, limited studies in this topic have been reported, researchers are encouraged to examine the psychological mechanisms of competitive situation-hormonal responses relationship. In the likelihood intrinsic motivation, individual self-confidence, perceptual of effort, anger, mental toughness, and competitive anxiety are the psychological variables related to a competitive event.

It has been argued that hormonal changes in response to a soccer competition are driven by changes in mood state and/or by other psychological states elicited by the competitive event.[36] Particularly, changes in mood state and the fluctuation in anxiety status over the game was correlated with testosterone change, but not with cortisol change.[37] Haneishi and collaborators[28] indicate that the subjects perceived greater psychological stress as measured by somatic anxiety during the soccer game than during practice. They showed no significant correlations were observed between salivary cortisol and competitive state anxiety, with the exception of a relationship (r=0.70) between salivary cortisol and cognitive anxiety at pre-practice for the starters. Thus, changes in mood and anxiety state were also found between winners and losers, with more positive states being observed in winners and more negative states being observed in losers at the end of the match.[36] Overall, this finding supports the concept that perceived psychological responses, such as somatic and cognitive anxiety, and actual physiological responses, such as hormone response, affect performance independently. Accordingly, Filaire et al.[37] showed the positive relationship between salivary cortisol and somatic and cognitive sport anxiety during judo competition. In contrast, no significant correlations were found between rating of perceived exertion (RPE) and salivary cortisol absolute changes during an official soccer game.[38]

The mains limitations of the present review were the small numbers of included studies and participants. For that reasons, this brief review could not identify the moderating role of type of contest (i.e., simulated vs. official) between rugby match-cortisol change relationship. It might be possible that other factors that were not involved and assessed could also moderate the relationship between a rugby match and hormonal responses. For example, the time of the day when the competition was played can affect hormonal stress and

differences in the chronobiological system, relating to time of day may have been observed. Also, other factors, such as sleep, nutrition and psychological mediators which were not controlled before matches, could also influence hormonal responses. Future studies should monitor the aforementioned variables to improve the knowledge in this specific field. In addition, future research including psychological status in conjunction with the assessment of hormonal responses, in both simulation and official rugby competitions, are important considerations, that may provide greater understanding of the endocrine physiology that contributes to the positive or negative relationship observed.

Conclusions

The measurement of psychological and hormonal parameters offers a unique opportunity to achieve a more comprehensive evaluation of the stress responses of the individual in competitive situations. Furthermore, this review provides readers with the first rigorous analytical synthesis of data concerning hormonal changes during rugby matches. For instance, it has been shown that a rugby match is a stressful situation for the endocrine system which lasts up to 38-48 h into the recovery period. Particularly, the present review shows that match contest was the moderator variable between rugby match-testosterone change relationship. The challenge for future researchers would be to determine the hormonal responses of female and male players during a rugby match according to match contests, time of day, competitive levels and match outcome and to identify the mediator variables (e.g., self-confidence, mood state, motivation and anxiety) between rugby match-hormonal responses relationship. Finally, the psychological and hormonal assessment of rugby players will give the opportunity to identify how an athlete copes with stress induced by a competition and various mental/recovery strategies should be considered for performance enhancement.

References

1. Gabbett TJ. Science of rugby league football: a review. J Sports Sci 2005;23:961-76.
2. Kraemer WJ, Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. Sports Med 2005;35:339-61.
3. Mastorakos G, Pavlatou M, Diamanti-Kandarakis E, Chrousos GP. Exercise and the stress system. Hormones (Athens) 2005;4:73-89.
4. McLellan CP, Lovell DI, Gass GC. Biochemical and endocrine responses to impact and collision during elite rugby league match play. J Strength Cond Res 2011;25:1553-62.
5. Cormack SJ, Newton RU, McGuigan MR. Neuromuscular and endocrine responses of elite players to an Australian rules football match. Int J Sports Physiol Perform 2008;3:359-74.
6. Slimani M, Taylor L, Baker JS, Elleuch A, Ayedi FM, Chamari K, et al. Effects of mental training on muscular force, hormonal and physiological changes in kickboxers. J Sports Med Phys Fitness 2016 [Epub ahead of print]
7. Ispirlidis I, Fatouros IG, Jamurtas AZ, Nikolaidis MG, Michailidis I, Douroudos I, et al. Time-course of changes in inflammatory and performance responses following a soccer game. Clin J Sport Med 2008;18:423-31.
8. Barnes MJ, Mundel T, Stannard SR. The effects of acute alcohol consumption on recovery from a simulated rugby match. J Sports Sci 2012;30:295-304.
9. Cunniffe B, Hore AJ, Whitcombe DM, Jones KP, Baker JS, Davies B. Time course of changes in immuneoendocrine markers following an international rugby game. Eur J Appl Physiol 2010;108:113-22.
10. Slimani M, Bragazzi NL, Tod D, Dellal A, Hue O, Cheour F, et al. Do cognitive training strategies improve motor and positive psychological skills development in soccer players? Insights from a systematic review. J Sports Sci 2016;34:2338-49.
11. Slimani M, Chaabène H, Davis P, Franchini E, Cheour F, Chamari K. Performance aspects and physiological responses in male amateur boxing competitions: A brief review. J Strength Cond Res 2017 [Epub ahead of print]
12. Filaire E, Alix D, Ferrand C, Verger M. Psychophysiological stress in tennis players during the first single match of a tournament. Psychoneuroendocrinology 2009;34:150-57.
13. Archer J. The influence of testosterone on human aggression. Br J Psychol 1991;82:1-28.

14. Book AS, Starzyk KB, Quinsey VL. The relationship between testosterone and aggression: A meta-analysis. Aggress Violent Behav 2001;6:579-99.
15. Wang C, Plymate S, Nieschlag E, Paulsen CA. Salivary testosterone in men: further evidence of a direct correlation with free serum testosterone. J Clin Endocrinol Metab 1981;53:1021-4.
16. Cook CJ, Crewther BT. The effects of different pre-game motivational interventions on athlete free hormonal state and subsequent performance in professional rugby union matches. Eur J Appl Physiol 2010;108:113-22.
17. Crewther BT, Cook CJ. Effects of different post-match recovery interventions on subsequent athlete hormonal state and game performance. Physiol Behav 2012;106:471-5.
18. Crewther BT, Al-Dujaili E, Smail NF, Anastasova S, Kilduff LP, Cook CJ. Monitoring salivary testosterone and cortisol concentrations across an international sports competition: data comparison using two enzyme immunoassays and two sample preparations. Clin Biochem 2013;46:354-8.
19. Elloumi M, Maso F, Michaux O, Robert A, Lac G. Behaviour of saliva cortisol [C], testosterone [T] and the T/C ratio during a rugby match and during the post competition recovery days. Eur J Appl Physiol 2003;90:23-8.
20. Elloumi M, Ben Ounis O, Tabka Z, Van Praagh E, Michaux O, Lac G. Psychoendocrine and physical performance responses in male Tunisian rugby players during an international competitive season. Aggress Behav 2008;34:623-32.
21. McLean BD, Coutts AJ, Kelly V, McGuigan MR, Cormack SJ. Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. Int J Sports Physiol Perform 2010;5:367-83.
22. Murphy AP, Snape AE, Minett GM, Skein M, Duffield R. The effect of post-match alcohol ingestion on recovery from competitive rugby league matches. J Strength Cond Res 2013;27:1304-12.
23. Shearer DA, Kilduff LP, Finn C, Jones RM, Bracken RM, Mellalieu SD, et al. Measuring recovery in elite rugby players: the brief assessment of mood, endocrine changes, and power. Res Q Exerc Sport 2015;86:379-86.
24. West DJ, Finn CV, Cunningham DJ, Shearer DA, Jones MR, Harrington BJ, et al. Neuromuscular function, hormonal, and mood responses to a professional rugby union match. J Strength Cond Res 2014;28:194-200.

25. McLellan CP, Lovell DI, Gass GC. Creatine kinase and endocrine responses of elite players pre, during, and post rugby league match play. J Strength Cond Res 2010;24:2908-19.
26. McLellan CP, Lovell DI, Gass GC. Markers of postmatch fatigue in professional Rugby League players. J Strength Cond Res 2011;25:1030-9.
27. Carli G, Bonifazi M, Lodi L, Lupo C, Martelli G, Viti A. Hormonal and metabolic effects following a football match. Int J Sports Med 1986;7:36-8.
28. Haneishi K, Fry AC, Moore CA, Schilling BK, Li Y, Fry MD. Cortisol and stress responses during a game and practice in female collegiate soccer players. J Strength Cond Res 2007;21:583-8.
29. Moreira A, Crewther B, Freitas CG, Arruda AF, Costa EC, Aoki MS. Session RPE and salivary immune-endocrine responses to simulated and official basketball matches in elite young male athletes. J Sports Med Phys Fitness 2012;52:682-7.
30. Thorpe R, Sunderland C. Muscle damage, endocrine, and immune marker response to a soccer match. J Strength Cond Res 2012;26:2783-90.
31. Souglis A, Bogdanis GC, Giannopoulou I, Papadopoulos Ch, Apostolidis N. Comparison of inflammatory responses and muscle damage indices following a soccer, basketball, volleyball and handball game at an elite competitive level. Res Sports Med 2015;23:59-72.
32. Kraemer, WJ, Spiering, BA, Volek, JS, Martin, GJ, Howard, RL, Ratamess, NA, et al. Recovery from a national collegiate athletic association division 1 football game: Muscle damage and hormonal status. J Strength Cond Res 2009;23:2-10.
33. Weekes NY, Lewis RS, Goto SG, Garrison-Jakel J, Patel F, Lupien S. The effect of an environmental stressor on gender differences on the awakening cortisol response. Psychoneuroendocrinology 2008;33:766-72.
34. Jones G, Hanton S. Pre-competitive feeling states and directional anxiety interpretations. J Sports Sci 2001;19:385-95.
35. Zouhal H, Jacob C, Delamarche P, Gratas-Delamarche A. Catecholamines and the effects of exercise, training and gender. Sports Med 2008;38:401-23.
36. Oliveira T, Gouveia M, Oliveira RF. Testosterone responsiveness to winning and losing experiences in female soccer players. Psychoneuroendocrinology 2009;34:1056-64.
37. Filaire E, Sagnol M, Ferrand C, Maso F, Lac G. Psychophysiological stress in judo athletes during competitions. J Sports Med Phys Fitness 2001;41:263-8.

38. Moreira A, Arsati F, de Oliveira Lima Arsati YB, da Silva DA, de Araújo VC. Salivary cortisol in top-level professional soccer players. Eur J Appl Physiol 2009;106:25-30.

Table 1. Search strategy of the present review.

Search strategy	**Details**
Used keywords	(rugby OR football) AND (hormone OR hormonal OR "stress response" OR "T/C ratio" OR endocrine OR neuroendocrine OR endocrinological)
Searched databases	PubMed/MEDLINE, Scopus (Elsevier), ScienceDirect (Elsevier), SPORTDiscus, Google Scholar
Time filter	Dates ranging from the earliest record to April 2016
Language filter	English
Included article types	Original, primary research articles
Excluded article types	Reviews, commentaries, opinion articles, methodological articles, letters to the editor, editorials, conference abstracts, book chapters and books, theses and dissertations
Target journals	Applied Physiology, Nutrition and Metabolism; Biochemia Medica; Biology of sport; British Journal of Sports Medicine; Endocrine; Endocrine Research; European Journal of Applied Physiology; Experimental and Clinical Endocrinology; International Journal of Sports Physiology and Performance; Journal of Athletic Training; Journal of Endocrinological Investigation; Journal of Exercise Physiology Online; Journal of Physical Therapy Science; Journal of Sports Medicine and Physical Fitness; Journal of Sports Sciences; Journal of Strength and Conditioning Research; Medicina dello Sport; Medicine and Science in Sports and Exercise; Neuroendocrinology Letters; Physiology and Behavior; Psychoneuroendocrinology; Research in Sports Medicine; Science and Sports; Stress

Table 2. List of excluded studies with reasons for exclusion.

Excluded study	Reason for exclusion
Cook and Crewther [16]	Studied the effects of different pre-match motivational interventions on hormonal responses
Cormack et al. [5]	Did not specify the hormonal value
Crewther and Cook [17]	Studied the effects of different post-match recovery interventions on hormonal responses
Crewther et al. [18]	Did not specify the hormonal value
Elloumi et al. [19]	Did not specify the hormonal value immediately after match
Elloumi et al. [20]	Did not specify the hormonal value immediately after match
McLean et al. [21]	Did not specify the hormonal values
Murphy et al. [22]	Did not specify the hormonal values
Shearer et al. [23]	Did not specify the hormonal values immediately post-match
West et al. [24]	Did not specify the hormonal values immediately post-match

Table 3. Hormonal responses from pre- to post- rugby match (mean ± SD and/or relative effect %).

Study	Type of competition	Athletes characteristics (level; gender; age; n)	Collection method	Unit	Testosterone	Cortisol	T/C
Barnes et al. [8]	Simulated	Senior grade club; male; 21.3+2.4 ; 10	Plasma	T : nmol/L C : nmol/L	Pre 11.0+4.6 Imm post 14.7+6.9	Pre 333±154 Imm post 621±247	
Cunniffe et al. [9]	Official	Elite; male; 26.4±0.7 ; 10	Plasma	T : nmol/L C : nmol/L	Pre 24.6±0.6 Imm post 13.8±1.3 14 h post 20.2±1.3	Pre 313±6.3 Imm post 534±47 14 h post 400±21	
Mclellan et al. [4]	Official	Elite; male; 24.2 ± 7.3; 17	Salivary	C: nmol/L		30 min pre 13.1±2.6 Imm post P<0.05 30 min post 21.9±4.4	

Mclellan et al. [25]	Official	Elite; male; 19.0±1.3 ; 17	Salivary	C: nmol/L	+68% from 30 min pre to 30 min post
Mclellan et al. [26]	Official	Elite; male; 19.0±1.3; 17	Salivary	C : nmol/L	24h pre: 10.1±1.3 30min pre:13.1±2.6 30min post: 21.9±4.4 24h post: 15.3±3.5 48h post: 9.5±1.4 72h post: 9.5±1.6 96h post: 7.0±1.1 120h post: 9.2±1.5

T: testosterone; C: cortisol; T/C: testosterone/cortisol ratio; Imm.: immediately; pre: pre-match; post: post-match.

Table 4. Pre- and post- rugby match value and percentage change (Δ%) of cortisol (nm/L).

Study	**Nature of competition**	**Cortisol**				**Δ%**
		30 min Pre	**Pre**	**Imm Post**	**30 min Post**	
Barnes et al. [8]	Simulated		333±154	621±247		+86.4
Cunniffe et al. [9]	Official		313±6.3	534±47		+70.6
Mclellan et al. [4]		13.1±2.6			21.9±4.4	
Mclellan et al. [25]	Official					+68

Imm: immediately

Table 5. Pre- and post- rugby match value and percentage change (Δ%) of testosterone (nm/L).

Study	Nature of competition	Testosterone				Δ%
		30 min Pre	Pre	Imm Post	30 min Post	
Barnes et al. [8]	Simulated		11.0+4.6	14.7+6.9		+33.6
Cunniffe et al. [9]	Official		24.6±0.6	13.8±1.3		-43.9

Imm: immediately