Relationship Between Midweek Training Measures of Testosterone and Cortisol Concentrations and Game Outcome in Professional Rugby Union Matches

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ABSTRACT

Gaviglio, CM and Cook, CJ. Relationship between midweek training measures of testosterone and cortisol concentrations and game outcome in professional rugby union matches. J Strength Cond Res 28(12): 3447–3452, 2014—The aim of this study was to assess the response of salivary-free testosterone and cortisol concentrations across selected midweek skill-based training sessions and their association with subsequent match outcome 3 days later. Twenty-two rugby union players were assessed for salivary-free testosterone and cortisol concentrations before and after a midweek training session over 6 consecutive weeks. The relative percentage change (response) in the testosterone and cortisol concentration and the testosterone to cortisol (T/C) ratio was also determined. Game-day analysis consisted of prematch testosterone concentrations and match outcome. Data were pooled across the winning (n = 3) and losing (n = 3) outcomes. The midweek pretraining T/C ratio was significantly lower (p < 0.01) before a win than a loss and the increase in the pre- to post-T/C ratio before a win was significant (p < 0.001). The increase in the pre- to post-testosterone concentration before a win was also shown to be significant (p < 0.01). However, the relative changes in testosterone before games that were won were not statistically different to that of games lost (p > 0.01). Significant relationships were also demonstrated between game-day pre-testosterone concentrations and the midweek cortisol response (r = −0.90, p = 0.01) and midweek T/C ratio response (r = 0.90, p = 0.01). In conclusion, a midweek measurement of the T/C ratio against a skill-based training session seems to show some potential as an early indicator of subsequent successfully executed performances in competitive rugby union. If this work is subsequently validated, further monitoring of midweek hormone concentrations in response to a mixed psychological-physical training session may assist with assessing competitive readiness leading up to competition.

KEY WORDS endocrine, readiness, winning, sport, competition

INTRODUCTION

Testosterone and cortisol concentrations have previously been studied in relation to training and performance outcomes in sport (6,15,21,31). In particular, increases in concentrations of endogenous testosterone have been shown to correlate positively with elements of athletic performance (11,15,33). Likewise, cortisol concentrations have also been linked to competitive behavior and performance (19,33,34). However, the relationship between testosterone and cortisol concentrations and successful competition outcomes remains equivocal (8,19,21,22).

The testosterone to cortisol (T/C) ratio has traditionally been viewed as a putative marker of the anabolic to catabolic hormonal balance within the body (5,10); however, it is unclear how this may directly link to performance. The T/C ratio has further been suggested as a useful tool in the early detection of overtraining (1,4) and as a measure of recovery from intensive physical activity (5,37). Few studies have investigated the relationship between the T/C ratio and performance outcomes in sport (17,18,24).

Data on endogenous hormones and competition have historically focused on the acute response around the timing of the competition event, with little focus on the interplay of midweek hormones to subsequent competitive performance a few days later. The role and interaction of testosterone and cortisol is complex in nature, with both hormones affected through multiple mechanisms including, physiological (2,3), social (2,27), and competitive (8,19,34) events. A recent study in rugby league demonstrated that...
testosterone responses to midweek resistance training workouts showed significant associations with subsequent game outcome a few days later (16). To the best of our knowledge, this is the only study to date that has shown such a relationship.

Having data to better understand the preparation of a sporting team for an upcoming competition has important implications in advancing the management, recovery, and training of the athletes leading into an event. In rugby union, this preparation encompasses both mental and physical components (32). Therefore, this study of professional rugby union players assessed the relationship between absolute concentrations of salivary testosterone, and cortisol, and the T/C ratio across selected midweek skill-based training sessions and the subsequent game-day performance outcome 3 days later. It is hypothesized that the comparison of midweek pre- and post-testosterone concentrations and T/C ratio values would be greater when rugby union matches were won rather than lost.

**METHODS**

**Experimental Approach to the Problem**

There is limited information on the use of salivary testosterone and cortisol as a measurement tool to identify likely

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Event</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>Pre saliva sample</td>
<td>Relevant musculoskeletal treatment</td>
</tr>
<tr>
<td>2–10</td>
<td>Preparation</td>
<td>Review of upcoming game</td>
</tr>
<tr>
<td>10–30</td>
<td>Meeting</td>
<td>Vision (video) used to assist in the meeting</td>
</tr>
<tr>
<td>Outline of rugby skill session</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–15</td>
<td>Warm-up</td>
<td>General movement and jogging</td>
</tr>
<tr>
<td>15–25</td>
<td>Units</td>
<td>Backs and forwards split into their respective playing groups to practice their specific plays and routines</td>
</tr>
<tr>
<td>25–35</td>
<td>Attack</td>
<td>The backs and forwards rejoin to practice moves the team will use when attacking against the opposition</td>
</tr>
<tr>
<td>35–45</td>
<td>Defense</td>
<td>Defensive moves to be used against the opposition</td>
</tr>
<tr>
<td>45</td>
<td>Conclusion of session</td>
<td>Brief discussion about the training session</td>
</tr>
<tr>
<td>55</td>
<td>Post saliva sample</td>
<td>After post saliva sample, players commence recovery modalities (i.e., ice baths, physiotherapy, and massage)</td>
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**Table 1. Midweek skill training session outline and timing of events.**

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</table>

**Table 2. Subsequent competitive game performance after the midweek skill-based training session.**

<table>
<thead>
<tr>
<th>Midweek training session</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-T (pg·ml⁻¹)</td>
<td>78 (22)</td>
<td>99 (31)</td>
<td>126 (44)</td>
<td>95 (32)</td>
<td>105 (41)</td>
<td>111 (31)</td>
</tr>
<tr>
<td>Venue</td>
<td>Home</td>
<td>Away</td>
<td>Home</td>
<td>Away</td>
<td>Home</td>
<td>Away</td>
</tr>
<tr>
<td>Win%</td>
<td>70</td>
<td>37</td>
<td>50</td>
<td>50</td>
<td>48</td>
<td>63</td>
</tr>
</tbody>
</table>

*Outcome = match result; Pre-T = pregame testosterone concentrations; Win% = historical win percentage (http://www.premiershiprugby.com) from all of the games played previously against that relevant opposition.
†Data represented as mean (SD).
outcomes in competitive team sport. Therefore, this study focused on the salivary-free testosterone and cortisol responses to midweek skill-based training sessions and subsequent outcomes of professional rugby union games. Game-day outcomes included match results (win or loss) and pregame testosterone concentrations. Pregame testosterone levels were assessed because of higher concentrations being previously associated with successful outcomes in this team (20). Saliva was used because of its ease of compliance, low invasiveness, and ability to track the biologically active “free” hormone (13). As this was an in-season professional rugby environment, all testing was performed under normal training conditions, which improved the internal validity of the study findings and their applications within elite sport.

Subjects
This study involved 22 elite male players from a professional rugby union team (age, 27.8 ± 4.0 years; height, 1.87 ± 0.08 m; and mass, 103.4 ± 11.6 kg). This team competed in both the English Rugby Union Premiership and the European Championship, and a number of the subjects were also playing at international level. Subjects were volunteers. They were informed of the study protocols, and they signed written informed consent documents before testing began. All subjects were above 18 years of age. Ethics approval was obtained from a University Ethics Health Sciences committee in compliance with national legislation and The Code of Ethical Principles for Medical Research involving Human Subjects of the World Medical Association (Declaration of Helsinki).

Assessment Procedures
This study was conducted midseason over the course of 6 weeks between the months of November to January. Players continued to train midweek according to their usual training schedules, and the games were played during the weekend on a home and away basis. Weekly training sessions at the time of this study generally involved 2 gymnasium sessions, 4 rugby skill training sessions and recovery work after these skill-based sessions. As this was an in-season professional rugby environment, there were practicalities of normal training that had to be adhered to. On each of the days immediately before testing, players were encouraged to sleep well (>7 hours), consume a nutritionally sound breakfast (each player standardized across testing sessions), and maintain their fluid intake (at least 750 ml) during the 2 hours before each testing session. No food was consumed within 30 minutes of sessions.

Midweek Skill-Based Training Session
Participants were monitored once a week across 6 midweek skill-based training sessions during the competitive season. These sessions were designed to assist with the team preparation for the subsequent game on the weekend. A skill-based training session was chosen because of the specificity of the training session to the actual game requirements. The training sessions were performed 4 days after each match-day game, to ensure that hormonal and neuromuscular recovery had been achieved (28,29) and 3 days before the next game. Each session was conducted at the same time each week to account for diurnal variation (25) and formed the main rugby skills session for the week. Because of the importance of this session to the upcoming game, session time and content were kept as consistent as possible (Table 1). Session intensity and effort were monitored using a rate of perceived exertion (RPE) measurement scale, where 1 = very light and 10 = maximal (9).

Game Day Performance
Two factors were assessed on game day, namely, match outcome of win or loss and pregame testosterone concentrations (Table 2).
Midweek Hormone Concentrations and Game Outcome

**Table 3.** Correlations between the relative (%) hormonal changes across each skill-based training session and pregame testosterone concentration.*

<table>
<thead>
<tr>
<th></th>
<th>Pre-T (pg ml⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testosterone (% change)</td>
<td>0.09</td>
</tr>
<tr>
<td>Cortisol (% change)</td>
<td>−0.90†</td>
</tr>
<tr>
<td>T/C ratio (% change)</td>
<td>0.90†</td>
</tr>
</tbody>
</table>

*Pre-T = pregame testosterone concentrations.
†p = 0.01.

**Hormone Assessment**
Saliva samples were collected at times chosen to minimize any interruption to the players’ training and game preparation. Presession samples were taken 30 minutes before the start of the training session or match. Postraining samples were taken 10 minutes after the conclusion of the midweek training session. For each test, approximately 2 ml of saliva was collected by passive drool into sterile containers and stored for less than 3 months at −20°C (23) before analysis. Saliva was assayed for testosterone (pg ml⁻¹) and cortisol (µg dl⁻¹) concentrations by a private commercial laboratory (HFL Sport Science Laboratories, Fordham, United Kingdom) using commercially available kits (Salimetrics Enzyme Immunoassay Kits; Salimetrics, State College, PA, USA) and were run in duplicate according to the manufacturer’s instructions. Interassay coefficients of variation based on low and high control samples for testosterone and cortisol were both <10%.

**Statistical Analyses**
Pre- and post-midweek hormone concentrations were pooled according to subsequent outcome (wins and losses) and compared using dependent t-tests. The testosterone to cortisol (T/C) ratio and percentage change in pre to post hormone concentration variables were also calculated and used during the analysis. The bivariate relationships between the midweek hormonal variables and pregame testosterone concentrations were assessed using Pearson’s product moment correlations. An alpha level of α = 0.01 was set a priori.

**Results**

**Hormone Concentrations vs. Wins and Losses**
A significant increase in pre- to post-testosterone concentrations was observed in midweek training sessions when subsequent games were won (p < 0.01). No significant difference was observed when the match was lost (p > 0.01; Figure 1).

Cortisol concentrations did not demonstrate significant change (p > 0.01) across midweek training sessions before subsequent wins (pre, 0.23 ± 0.14 vs. post, 0.18 ± 0.12) and subsequent losses (pre, 0.19 ± 0.15 vs. post, 0.21 ± 0.16). For both testosterone and cortisol, there were no significant differences when either the preskill or postskill sample values were compared in isolation in either games won or lost. A significant increase in the T/C ratio from pre to post values was noted before winning games (p < 0.001; Figure 2). The preskill T/C ratio before a win was significantly lower (p < 0.01) than when compared with a loss.

**Hormone Responsiveness vs. Wins and Losses**
The relative changes in hormone concentrations across the midweek training session did not highlight any significant differences (p > 0.01) between games won and lost; testosterone (win, 37 ± 60%; loss, 30 ± 64%), cortisol (win, 1.4 ± 65%; loss, 62 ± 167%), and the T/C ratio (win, 81 ± 110; loss, 38 ± 116%).

**Midweek Hormones vs. Pregame Testosterone**
The cortisol and T/C ratio responses (%) to the midweek skill session displayed strong and significant correlation to pregame testosterone concentrations (Table 3). We also found no significant correlations between preskill or postskill training session hormones and pregame testosterone concentrations (data not presented).

**Discussion**
The main finding of this study was that the T/C ratio of professional rugby union players before a midweek skill training session was significantly lower preceding winning games than preceding games that were lost. In addition, the comparison with pre and post absolute values for both salivary testosterone and the T/C ratio was greater before a win than a loss. Furthermore, the relative change in the midweek T/C ratio and cortisol concentrations demonstrated significant relationships with subsequent pregame testosterone concentrations. In this group of players, pregame testosterone concentrations have been previously associated with successful game outcomes (20).

Midweek concentrations of the T/C ratio as an indicator of competition match outcomes in rugby union have not been presented previously. In a recent study of rugby league players, an elevated midweek testosterone response across a resistance training workout was able to highlight successful outcome in games played a few days later (16). Although salivary testosterone and cortisol demonstrated an ability to highlight successful outcomes in this current study, the T/C ratio was a more comprehensive indicator of competition success.

A number of studies have described the interaction of testosterone and cortisol in relation to psychophysiological stressors (39). Therefore, the T/C ratio observations may be due to the stronger cognitive requirements of a skill-based training stimulus (32) as opposed to that required across a resistance training workout (16). As such, it could be suggested that the dual mechanism of a testosterone and cortisol ratio might have more robustness across a range of midweek psychophysiological stressors.
It has been suggested that the T/C ratio is an indicator of physiological strain in training (36) and a marker of the anabolic-catabolic status of the athlete (5,10). Hence, it could be possible that before a win, the increase in the midweek T/C ratio highlighted a positive endocrine response to the training session, which was carried through to the subsequent game as indicated through the association with game-day pre-testosterone concentrations.

The relationship between the midweek cortisol response and pregame testosterone concentrations further highlights the interactive factor between midweek hormones and competitive performance. Typically, an increased concentration of cortisol is known to have a protein-catabolic effect on skeletal muscle (36). Therefore, the lower midweek cortisol response observed before a win may have indicated an ideal response to an in-season rugby training session also supporting the results seen with the T/C ratio.

The hormonal response to the midweek training session may have also been a result of other factors such as the pretraining session meeting or coaching style. For example, cautionary coaching feedback in rugby union players has previously resulted in larger increases in salivary cortisol concentrations when compared against positive coaching feedback (14). In this study, a large relative increase in cortisol concentration was observed before a loss. Although the difference to that of a win was not significant, the difference was still large and worthy of note. Although the coaching staff did not change during the testing period, their coaching style was not monitored for any variances in feedback, language, or communication. Pretraining sessions were traditionally preceded with a team meeting discussing the upcoming game-day tactics incorporating video clips to assist with explanations. It is possible that these factors may have impacted on hormone concentrations (12); however, this warrants further investigation. Nonetheless to our knowledge, this is the first study to demonstrate midweek values of the T/C ratio across a mixed psychological-physical stressor to distinguish between competitive performance outcomes a few days later.

A limitation of this study is that only a small number of training sessions and games (n = 6) were monitored, although this number is comparable with other research in rugby union (16,26,35) and rugby league (28). We also acknowledge that training load volume and intensity can influence testosterone and cortisol responses (7). Therefore training sessions were diligently planned to ensure that the starting time and duration were kept as consistent as possible. Though the level of participation could have varied slightly between player and between sessions, the RPE data indicated that there was no significant difference when grouped according to their subsequent game outcome (win, 5.9 ± 1.3; loss, 6.1 ± 1.1). Despite the proposed effects of game venue (home vs. away) and historical performance statistics (i.e., win %) against the opposition (30), neither had a discernable effect on game outcome in this study. The results presented here, whilst preliminary, warrant further investigation employing a larger sample of midweek skill and game outcomes whilst taking into account coaching techniques, training session content, and individuals. Valuable information that is lacking in current literature has been obtained from this study, namely the descriptive endocrinological data of elite level performing athletes under real training and competitive situations. In a team sport where skill-based training sessions form a large portion of a training week, the findings from this study may better help to better understand the overall response to training sessions and their impact on competition results a few days later.

**Practical Applications**

Our findings support the use of midweek measurements of salivary hormones in response to a psychophysiological stressor and as a tool for examining potential game readiness in professional rugby union. Specifically, in this study, more responsive changes in the T/C ratio across a skill-based training session would seem to be a factor predicting readiness to compete. The practical application to the strength and conditioning professional presents itself in the form of how the training week is planned and how the information around the training week is presented (i.e., meetings, vision, coaching styles). Assessing the potential of neuromuscular measures (e.g., vertical jump) may also provide an alternative to sampling salivary hormones (11,15). However, a longitudinal approach to collecting these data around subjective and objective training and competition parameters would be required to identify such relationships. This information may assist in diagnosing midweek training responses and help with match-day and training week interventions (passive and active) to increase the probability of competitive readiness and outcome in competition.

**Acknowledgments**

The authors declare that they have no conflict of interest, and the results of the present study do not constitute endorsement of any products by the authors or the National Strength and Conditioning Association.

**References**


Midweek Hormone Concentrations and Game Outcome


