Relationships between weekly changes in salivary hormonal responses and load measures during the pre-season phase in professional male basketball players

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ABSTRACT: The aim of this study was to assess the relationships between weekly changes in external and internal load considered separately and jointly and salivary hormonal responses during the pre-season phase in professional male basketball players. Twenty-one professional male basketball players (mean ± standard deviation, age: 26.2 ± 4.9 years; height: 198.7 ± 6.7 cm; body mass: 93.2 ± 10.0 kg) were assessed during 5 weeks of the pre-season phase. External load was measured using microsensors and reported as PlayerLoad (PL) and PL/min. Internal load was calculated using the session rating of perceived exertion scale (sRPE-load), summated heart rate zones (SHRZ) and percentage of maximal heart rate (%HRmax). Salivary hormone responses were monitored weekly by measuring testosterone (T), cortisol (C), and their ratio (T:C). The relationships between weekly changes in load measures considered separately and jointly and hormonal responses were assessed using linear mixed model analysis. No significant (p > 0.05) relationships were evident between weekly changes in T, C or T:C with external and internal load measures considered separately (R²-conditional = < 0.001–0.027) or jointly (R²-conditional = 0.028–0.075). Factors other than measured loads might be responsible for weekly hormonal responses and therefore external and internal load measures cannot be used to anticipate weekly hormonal responses during the pre-season phase in professional basketball players.


INTRODUCTION

In basketball, the pre-season is a crucial phase during which coaches aim to prescribe optimal loads and a sufficient amount of sport-specific training for their players to obtain the best possible physical condition for the upcoming in-season phase [1–3]. The implementation of the aforementioned goals necessitates having precise control of the training and recovery process to avoid inappropriate loading that may lead to an insufficient physiological or psychological response, too high stress, increased risk of injuries, illnesses, overtraining or overreaching [4, 5]. Therefore, the prescription of appropriate loads and recovery interventions seems to be a key factor of the pre-season phase, thus emphasizing the importance of systematically monitoring the load sustained by the basketball players.

Load monitoring in basketball can be categorized as measures of external and internal load [5, 6]. External load is described as the imposed physical load, stimuli or dose, while internal load is considered as the physiological, psychological or perceptive response [5, 6]. Previously, the dose-response relationship between load measures during the pre-season and the in-season phases in semi-professional male basketball players has been investigated [6]. The findings revealed strong (r = 0.53–0.69) to very strong (r = 0.74–0.88) relationships between external (i.e. PlayerLoad [PL]) and internal (i.e. summated-heart-rate-zones model [SHRZ]; session rating of perceived exertion load [sRPE-load]) load measures, with stronger relationships occurring during training sessions (r = 0.69–0.88) than basketball matches (r = 0.53–0.69) [6]. These findings suggest a better anticipation of internal loads in response to the prescribed external loads and can enhance the possibility to organize properly the training and recovery process.

In addition, the analysis of hormonal responses in basketball has been suggested as fundamental to determine the level of stress and recovery, and in monitoring the risk of overtraining and non-functional overreaching [7]. Specifically, testosterone (T), cortisol (C), and their ratio (T:C) were indicated as useful markers to determine the balance between anabolic and catabolic processes [8], allowing a better understanding of training and recovery processes in basketball to be attained. Increased levels of T were reported to show an appropriate recovery, while decreased levels of T and increased levels of C indicate possible risk of overtraining, non-functional overreaching and reduced performance [9]. Consequently, the comprehension of the influence of changes in load measures on changes in

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hormonal responses would help in the process of monitoring basketball players and designing and implementing sound training sessions during the pre-season phase.

Despite the relevance of this topic, only one study has analysed the relationships between changes in hormonal responses and changes in external and internal load measures in semi-professional, male basketball players during the in-season phase [10], with non-significant trivial-to-moderate ($p > 0.05; r = -0.01–0.36$) relationships found [10]. Nevertheless, the applicability of these results for professional male basketball players during the pre-season phase is questionable. Indeed, it was previously reported that professional male basketball players usually experience higher loads than do semi-professional male players [1]. Moreover, it was reported that the pre-season phase in male basketball is characterized by higher loads compared to the in-season phase [2]. Thus, in order to determine whether load measures can be used for anticipation of changes in hormone levels in other basketball populations during different phases of the season and specifically during the pre-season phase in professional male basketball players, it is important to assess whether weekly changes in hormonal responses are influenced by weekly changes in external and internal load measures. Therefore, the aim of this study was to assess relationships between weekly changes in hormonal responses and salivary hormonal responses during the pre-season phase in professional male basketball players.

**MATERIALS AND METHODS**

**Subjects**

Twenty-five professional male basketball players from two teams competing in European level leagues (Team 1: FIBA Basketball Champions League, $n = 12$; Team 2: EuroCup Basketball League, $n = 13$) were recruited for the initial study sample. Due to attendance of training sessions being lower than 75%, four players (Team 1: $n = 2$; Team 2: $n = 2$) were excluded from the analysis and the final study sample consisted of 21 players (mean ± standard deviation [SD], age: $26.2 ± 4.9$ years; height: $198.7 ± 6.7$ cm; body mass: $93.2 ± 10.0$ kg). All investigated players were over 18 years of age and were familiarized with the aims, procedures, requirements, possible risks, and benefits of the study, providing written consent before participating. Ethical approval was obtained from the Kaunas Regional Research Ethics Committee review board (No. BE-2-97).

**Design**

An observational study took place during 5 weeks of the pre-season phase for Team 1 (2019–2020 FIBA Basketball Champions League; August 16 to September 20, 2019) and Team 2 (2020–2021 EuroCup Basketball League; August 10 to September 13, 2020). Players were familiarized with all study procedures two weeks before the start of data collection. During the monitoring period, internal and external load measures were assessed across 45 training sessions and 6 pre-season matches (5 wins by $20.8 ± 16.6$ points; 1 tie match) for Team 1 and 37 training sessions and 5 pre-season matches (3 wins by $35.3 ± 18.2$ points; 2 losses by $13.0 ± 15.6$ points) for Team 2. An experimental day for saliva collection was selected individually for both teams, considering their day 1 of the pre-season phase. Saliva samples were collected during an experimental day at the beginning of each week of the pre-season phase, and specifically, hormonal responses for Team 1 were monitored every Friday, and for Team 2 every Monday.

**Procedures**

Salivary analysis were conducted to measure weekly changes in T, C and T.C. To avoid any possible variation due to the circadian rhythm, saliva samples were collected at the same time of the day (17:00) [11]. Players were instructed not to eat, brush their teeth, or consume any drinks other than still water during the 90 min prior to saliva collection [12]. Before collection, players rinsed their mouth with distilled water [13], remained seated for 30 s, then spat all saliva from their mouth. Afterwards, players waited in a seated position for $10$ min before starting collection of the saliva sample by spitting into 15-ml ultrapure polypropylene SaliCap tubes through a polypropylene straw (IBL International, Germany) [14]. Collected saliva samples were stored at $-20°C$ for subsequent analysis. T and C were determined in duplicate using an enzyme-linked immunosassay (IBL International, Germany) following the manufacturer’s instructions. The intra-assay coefficient of variation for T and C was $2.35%$ and $3.14%$ for Team 1, and $2.51%$ and $3.22%$ for Team 2, respectively.

To assess external load during training sessions and matches, PlayerLoad (PL) and PlayerLoad per minute (PL/min) were measured using triaxial accelerometers ClearSky T6 (Catapult Innovations, Melbourne, Australia) sampling at 100 Hz to calculate instantaneous movement demands (in arbitrary units, AU) [6]. PL is a modified vector magnitude determined as the square root of the sum of the squared instantaneous rate of change in acceleration across three motion planes [6]. Data were processed using OpenField software (version 1.18, Catapult Innovations, Melbourne, Australia) and downloaded for statistical analysis.

The session rating of perceived exertion method (sRPE) was used for the assessment of internal load measures as previously used in basketball [15–17]. Approximately 30 min after each investigated training session or pre-season match, players were asked to rate their sRPE in the absence of peers using the modified Borg 10-point RPE scale (CR-10) [18] via cloud-based software (Google Docs, Microsoft, California, USA). Participants’ compliance was $93%$ for both Team 1 and Team 2. Players’ sRPE values and the total duration (min) of each investigated training session or pre-season match (including warm-up, breaks, and stoppage time in play) were used to calculate sRPE load (sRPE-load), using the following formula: sRPE-load = sRPE × total duration (min) [18].

Internal load was monitored using heart rate (HR) collected using Polar HR sensors and straps (Polar H10, Polar Electro, Kempele, Finland) at a sampling rate of 1 s, and with data downloaded and
processed using OpenField software. The summated-heart-rate-zones model (SHRZ) was then calculated as: SHRZ (AU) = duration in zone 1 × 1 + (duration in zone 2 × 2) + (duration in zone 3 × 3) + (duration in zone 4 × 4) + (duration in zone 5 × 5), where zone 1 = 50%–59.9% of maximum HR (HRmax), Zone 2 = 60%–69.9% HRmax, Zone 3 = 70%–79.9% HRmax, Zone 4 = 80%–89.9% HRmax, Zone 5 = 90%–100% HRmax, and duration is time in min [19]. The average %HRmax response was calculated for each training session and match. The HRmax was determined as the peak HR response during a 30–15 Intermittent Fitness Test performed prior to the monitoring period on a basketball court and updated using the peak response evident during training or matches if it exceeded that achieved during the testing session [20].

Statistical analysis

Mean and SD were calculated as descriptive statistics. Linear mixed model (LMM) analysis, which has been previously suggested to be suitable to assess the relationship across load measures in team sports [17, 21] was used to assess how weekly changes in different external and internal load measures affect separately (i.e. load measures considered singularly) and jointly (i.e. combining the internal and external load measures) weekly changes in hormonal responses. Weekly changes in T, C and TC were used as dependent variables, while weekly changes in load measures indicating training volume (PL, sRPE-load and SHRZ) and weekly averaged values of load measures indicating training intensities (PL/min, %HRmax) were used as fixed effects. Player was then used as a random effect with a random intercept and fixed slope. An alpha level of p < 0.05 was set a priori for statistical significance. All data were analysed using Jamovi software (version 1.2.27, 2020). Descriptive statistics of weekly load measures and hormone concentration are presented in Table 1. The results of the effect of separate weekly changes in external and internal load measures on weekly changes in hormonal responses are presented in Table 2. The LMM analysis showed no significant effect of weekly changes in load measures on changes in hormonal levels.

The effect of weekly changes in joint load measures on weekly changes in hormonal responses are presented in Table 3. The LMM analysis showed that weekly changes in T, C, and TC responses are not affected by joint weekly changes in PL, PL/min, sRPE-load, %HRmax and SHRZ (p > 0.05).

### RESULTS

Descriptive statistics of weekly external and internal load measures and hormonal responses are presented in Table 1. The results of the effect of separate weekly changes in external and internal load measures on weekly changes in hormonal responses are presented in Table 2. The LMM analysis showed no significant effect of weekly changes in load measures on changes in hormonal levels.

### DISCUSSION

This is the first study assessing the effect of separate and joint weekly changes in external (PL, PL/min) and internal (sRPE-load, %HRmax, SHRZ) load measures on weekly changes in salivary hormone responses (T, C, TC) during the pre-season phase in professional male basketball players. The LMM analysis revealed that weekly changes in T, C, and TC responses are not affected by weekly changes in load measures considered separately or jointly.

The use of salivary markers as a tool to analyse the balance between anabolic and catabolic processes in different basketball training typologies has grown during the last decade [8, 11, 22–26]. High levels of T were characterized as an indicator for optimal recovery, whereas decreased levels of T and increased C concentrations were indicated as markers of overtraining and reduced performance [9]. Understanding whether load measures might play a role as potential predictors of hormonal responses might be important in order to help in the process of monitoring weekly load and

### TABLE 1. Descriptive statistics of weekly load measures and hormone concentration.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workload variables</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PlayerLoad™ (AU)</td>
<td>3495 ± 1009</td>
<td>3915 ± 782</td>
<td>3555 ± 706</td>
<td>3469 ± 835</td>
<td>3442 ± 780</td>
</tr>
<tr>
<td>PlayerLoad™/min (AU)</td>
<td>3.8 ± 0.6</td>
<td>4.3 ± 0.7</td>
<td>4.6 ± 0.6</td>
<td>4.0 ± 1.1</td>
<td>4.3 ± 0.7</td>
</tr>
<tr>
<td>sRPE-load (AU)</td>
<td>4991 ± 1913</td>
<td>5125 ± 811</td>
<td>4870 ± 966</td>
<td>5597 ± 1392</td>
<td>4875 ± 1306</td>
</tr>
<tr>
<td>SHRZ (AU)</td>
<td>1412 ± 528</td>
<td>1470 ± 405</td>
<td>1387 ± 303</td>
<td>1415 ± 426</td>
<td>1292 ± 323</td>
</tr>
<tr>
<td>%HRmax (%)</td>
<td>61.9 ± 3.9</td>
<td>61.5 ± 3.1</td>
<td>62.4 ± 4.0</td>
<td>60.9 ± 3.8</td>
<td>61.2 ± 3.0</td>
</tr>
<tr>
<td><strong>Hormonal responses</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Testosterone (nmol/l)</td>
<td>0.25 ± 0.12</td>
<td>0.32 ± 0.14</td>
<td>0.28 ± 0.17</td>
<td>0.38 ± 0.17</td>
<td>0.39 ± 0.16</td>
</tr>
<tr>
<td>Cortisol (nmol/l)</td>
<td>3.49 ± 1.98</td>
<td>3.12 ± 1.54</td>
<td>2.71 ± 1.43</td>
<td>2.90 ± 1.48</td>
<td>2.58 ± 1.03</td>
</tr>
<tr>
<td>Testosterone:Cortisol</td>
<td>0.09 ± 0.06</td>
<td>0.14 ± 0.09</td>
<td>0.12 ± 0.08</td>
<td>0.15 ± 0.08</td>
<td>0.17 ± 0.12</td>
</tr>
</tbody>
</table>

Notes. Data presented as mean ± SD. sRPE-load – training load from session rating of perceived exertion scale; SHRZ – summated heart rate zones; %HRmax – average percentage value from attained maximum heart rate.
consequently planning basketball training sessions. To the best of our knowledge, no previous investigation has assessed whether weekly changes in load measures influence changes in hormonal responses during the pre-season phase in professional male basketball players. Our findings revealed that separate weekly changes in external (PL, PL/min) and internal (sRPE-load, %HR\text{max}, SHRZ) load measures have no influence on changes in salivary levels of T, C and T:C. These results are in line with a previous investigation on semi-professional male basketball players monitored during the in-season phase, in which trivial-to-moderate relationships were found between changes in levels of T, C, T:C and various external and internal load measures have no influence on changes in salivary levels of T, C and T:C. These results are in line with a previous investigation on semi-professional male basketball players monitored during the in-season phase, in which trivial-to-moderate relationships were found between changes in levels of T, C, T:C and various external and internal load measures.

Note. AIC – Akaike information criterion; CI – confidence interval; SE – standard error. Abbreviations. %HR\text{max} – percentage of maximum heart rate; SHRZ – summed-heart-rate-zones; sRPE-load – session rating of perceived exertion load.
Relationships between salivary hormones and load measures

during both in-season and pre-season phases and for both levels of competition (i.e. semi-professional and professional players), changes in hormone concentrations and load measures possess a low commonality in basketball. It should be noted that our results are also in line with other studies investigating different sports [27–29]. Indeed, moderate ($p = 0.025$; $r = 0.551$) relationships between internal load (sRPE) and salivary C were found in high-level male and female middle and long-distance runners [27], and non-significant ($p > 0.05$) associations between internal load (sRPE) and weekly C levels were found in elite male Rugby Union players [28]. Moreover, one previous investigation documented no relationships between weekly measures of external and internal load variables and T and C levels in professional football players during the competitive season [29]. Overall, the results demonstrated that factors other than weekly changes in external and internal load measures considered separately are responsible for weekly changes in hormonal responses in team and individual sports athletes.

The second part of our study was designed to investigate whether weekly changes in load measures considered jointly might have an influence on weekly changes in hormonal responses. In fact, basketball players during training periods undergo different combinations of external and internal load measures that should be taken into account during the monitoring process [30]. Therefore, the use of several measures combined can be expected to provide a clearer picture about players’ loads during specific training periods, and potentially might affect the hormonal responses. Nevertheless, similarly to the separate responses, no influence of joint weekly changes in external (PL, PL/min) and internal (sRPE-load, %HR$_{max}$, SHRZ) load measures on weekly changes in T, C and T:C concentrations was found. Therefore, these findings imply that the investigated physical, physiological, and perceptive load measures have no influence on hormonal responses, suggesting that other measures such as psychological factors should be taken into consideration. Indeed, Moreira et al. [25] found an increase in C levels, despite a significant decrease in perceived exertion load (sRPE-load), during a 4-week in-season phase training period in professional male basketball players, suggesting that salivary hormone concentrations increased due to the high psychological stress of the upcoming playoff phase. Moreover, two review articles indicated that both acute and chronic hormonal responses to training are influenced by physiological (e.g. heart rate, oxygen consumption) and psychological (e.g. self-confidence, pressure) factors [5, 31]. Physiological, psychological, and behavioural stressors of sports training were indicated as the main factors activating or inhibiting the release of T and C [31]. Therefore, a possible explanation of our findings might be that changes in T, C and T:C levels are influenced by a combination of factors other than commonly used external and internal load measures, indicating that measures of hormonal responses might provide an additional insight about players’ responses to the pre-season phase training. Overall, separately or jointly considered factors influencing changes in T, C and T:C levels remain unclear, requiring more investigations to reveal factors having an impact on changes in salivary hormonal levels during training periods in basketball.

Our investigation provides innovative and useful findings for basketball coaches and sports scientists, but there are some limiting factors that should be considered. Firstly, the investigated players participated in data collection after the off-season, in which their load was not monitored, making it difficult to compare the initial fitness level and adaptation progress in relation to its capacity between players, which might influence different internal and hormonal responses during the pre-season phase. Secondly, only external (PL, PL/min) and internal (sRPE-load, %HR$_{max}$, SHRZ) load measures were included in the analysis, while other physiological and psychological factors, or changes in players’ well-being, might be influencing changes in hormonal responses. Therefore, further research to analyse the effect of separate and joint weekly changes in other measures on changes in hormonal responses in professional male basketball players is required.

The findings of the current investigation provide some interesting practical recommendations. Firstly, basketball coaches and scientists should be aware that weekly changes in hormonal responses during the pre-season phase in professional male basketball players are independent from the separate and joint weekly changes in external and internal load measures. Therefore, changes in hormonal responses cannot be anticipated by load measures, and to have a full picture of players’ responses to load, salivary analysis should be included in the process of monitoring basketball players as a separate monitoring tool.

CONCLUSIONS

The current investigation did not detect a significant relationship between separate and joint weekly changes in external and internal load measures and weekly changes in T, C and T:C during the pre-season phase in professional male basketball players, suggesting that other factors or a combination of them might affect hormonal responses. These results suggest that external and internal load measures cannot be used to anticipate weekly hormonal responses during the pre-season phase in professional male basketball players.

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Declaration of interest

The authors declare that they have no conflict of interest with the content of this original research article.
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