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Weekly Fluctuations in, and Associations Between, Salivary Hormone Responses, Load, and Well-Being During the Pre-season in Professional Male Basketball Players

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Abstract

Kamarauskas, P, Scanlan, A, Ferioli, D, and Conte, D. Weekly fluctuations in, and associations between, salivary hormone responses, load, and well-being during the pre-season in professional male basketball players. *J Strength Cond Res* 38(1): 128–135, 2024—This study aimed to (a) quantify weekly fluctuations in hormonal responses (testosterone [T], cortisol [C], and their ratio [T:C]), external (PlayerLoad [PL] and PL·minute^{-1}) and internal (session rating of perceived exertion load [sRPE-load], summated heart rate zones [SHRZs], and percentage of maximal heart rate [%HRmax]) load measures, and well-being measured using a self-reported questionnaire and (b) determine the associations between weekly changes in hormonal responses and load measures with weekly changes in well-being during the pre-season phase in basketball players. Twenty-one professional male basketball players (age: 26.2 ± 4.9 years) were monitored during a 5-week pre-season phase. Linear mixed models were used to determine weekly differences in each variable and associations between weekly changes in hormonal and load variables with weekly changes in well-being. Findings revealed that T ($p < 0.001$) and T:C ($p = 0.002$) increased toward the end of the pre-season phase. Moreover, higher ($p < 0.05$) external (PL·minute^{-1}) and internal (%HRmax) load intensities were evident during the first 3 weeks of the pre-season, with no significant fluctuations in other load variables. Weekly changes in PL and sRPE-load were negatively associated ($p < 0.05$) with weekly changes in well-being, albeit weak in magnitudes ($R^2 = 0.061$–0.105). These results highlight that a periodized approach was undertaken across the pre-season predominantly predicated on altering weekly load intensities, which coincided with positive hormonal responses toward the end of the pre-season. In addition, weak relationships were evident between weekly changes in hormonal responses and load measures with well-being, emphasizing that a low commonality may be present between these constructs.

Key Words: testosterone, cortisol, microsensor, heart rate, RPE, wellness

Introduction

Assessing hormonal responses in basketball players provides insight into the balance between anabolic and catabolic processes, which can be used in practice to gauge whether players are given optimal recovery and not exposed to excessive stress (5,32,45). In various samples of basketball players, analysis of salivary testosterone (T), cortisol (C), and their ratio (T:C) has been used to monitor recovery processes (7,27), detect overtraining and overreaching symptoms (7,38), and assess stress levels induced by training or matches (6,37). Indeed, C is an important stress hormone considered to signify the neuroendocrine response to exercise (47), whereas T is anabolic in nature and an important stimulus for muscle hypertrophic responses and muscle glycogen synthesis (43). When interpreting chronic changes in these hormones, an increase in T levels would be suggestive of positive recovery responses, whereas a decrease in T levels and concurrent increase in C levels are suggestive of heightened stress with a catabolic imbalance, bringing potential declines in performance (37,45).

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Hormonal assessments may be particularly important to plan training and recovery processes during the pre-season phase, which is a key period of the basketball season focused on the preparation of players for competition, characterized by high training loads (19,45). In this way, monitoring the loads placed on players during the pre-season phase alongside hormonal responses might provide useful insight given that these constructs may complement one another, as load data indicate the demands encountered whereas hormonal analyses indicate the underlying anabolic-catabolic responses to these demands. Load measures in basketball are typically categorized as external load, which represents the physical stimuli encountered, and internal load, which represents the physiological, psychological, and perceptual responses of players to the external load (24,29). Concomitantly monitoring hormonal responses and training loads in basketball players during the pre-season may indicate whether the encountered demands (i.e., load measures of interest) followed the preplanned periodization scheme and in turn induced desired responses (i.e., hormonal levels) in players, as demonstrated in other sports (13,26). In turn, these data could inform needed changes in the training program to ensure that players are in an optimal physiological state. Although monitoring player loads alongside hormonal responses might provide useful information for basketball practitioners, little information is available regarding the concomitant changes in these measures across seasonal phases among basketball players (34). Specifically, Kamarauskas et al. (34) documented significant weekly changes in hormonal responses (T levels) and internal load measures (session rating of perceived exertion load [sRPE-load], summated heart rate zone [SHRZ] load, and percentage of maximal heart rate [%HRmax]) with no significant associations ($p > 0.05$, $r = -0.26$ to 0.36) between these changes during the in-season phase in semiprofessional male basketball players. However, these findings are indicative of a single semiprofessional team ($n = 10$) across a 4-week period during the in-season where the weekly loading schemes are likely focused on maintaining player fitness and optimizing their preparedness for upcoming matches. By contrast, heavier loading schemes (3,42) and subsequently altered hormonal responses (2) are typically encountered during the pre-season among basketball teams when attempting to develop suitable player fitness and technical ability to meet the upcoming rigors of regular competition across the in-season. In this way, no study has concomitantly assessed fluctuations in hormonal responses and loads beyond a semiprofessional basketball team during a brief in-season period, creating a need for further investigation on this topic in professional basketball players during the pre-season.

In implementing a holistic, multifaceted monitoring system, measurement of perceptual well-being is advocated alongside the assessment of player responses (i.e., hormonal responses, sRPE, and heart rate) and external load (i.e., PlayerLoad [PL] and PL·minute^{-1}) in team sport environments (14,44). Accordingly, there has been increased interest in understanding player well-being among sports practitioners and researchers (14). Although various components encompassing emotional, mental, social, and physical domains may underpin player well-being (25), it is particularly useful for basketball practitioners to understand how specific measures collected through their monitoring system affect player well-being. In this regard, knowing how hormonal responses or loads influence well-being may allow basketball practitioners to optimally prescribe training and recovery plans for their players across specific seasonal phases. In this way, research has demonstrated strong relationships ($r = 0.60$–0.62) between weekly sRPE-load and well-being constructs (fatigue and delayed onset muscle soreness) (22), as well as worsened ($p < 0.05$) well-being constructs (fatigue and sleep quality) during congested weeks (i.e., multiple matches played) compared with single-game weeks (15) among professional male basketball players. However, only one study has assessed associations including various monitoring tools encompassing weekly changes in hormonal responses (T, C, and T:C), external load (PL and PL·minute^{-1}), and internal load (sRPE-load, SHRZ load, and % HRmax) with perceptual well-being in basketball players (34). Specifically, this study reported nonsignificant trivial to moderate associations ($r = 0.01$–0.36) between weekly changes in hormonal and load variables with weekly changes in well-being during a 4-week period of the in-season phase in semiprofessional male players (34). However, as discussed, these findings are indicative of weekly patterns during the in-season phase and therefore may not represent other seasonal phases such as the pre-season, which is characterized by higher loads (3,42) compared with the in-season phase (3), without official matches. Moreover, further research provided in professional basketball players is essential because they have been shown to experience a two-fold higher weekly sRPE-load volume during the pre-season phase compared with semiprofessional players (20), which might induce varied hormonal responses and changes in well-being than reported previously (34). Therefore, the aims of this study were to (a) quantify weekly fluctuations in hormonal responses, load measures, and well-being and (b) determine the associations between weekly changes in hormonal responses and load measures with weekly changes in well-being during the pre-season phase in professional male basketball players.

Methods

Experimental Approach to the Problem

This research explores a novel research question that extends on a previous study examining the influence of load variables on hormonal responses using the same data set (33). An observational study design encompassing 2 teams was conducted during the 5-week pre-season phase, consisting of strength and conditioning, basketball-specific on-court training sessions, and pre-season friendly matches (Table 1). No pre-season training camps were organized for either team before or during the monitoring period. Before data collection, all players were familiarized with saliva collection, load monitoring, and well-being reporting procedures. During data collection, hormonal responses were measured weekly on the first day of each pre-season week for both teams based on the beginning of the pre-season period (Friday for Team1 and Monday for Team2). These measures were performed on the first day of the pre-season period to have a baseline measure for further comparisons. Well-being was collected daily, whereas load measures were collected across 45 training sessions and 6 pre-season matches for Team1 and 37 training sessions and 5 pre-season matches for Team2. All sessions performed on court were monitored, whereas no internal and external load monitoring tools were adopted for the strength and conditioning sessions performed in the weight room.

Subjects

Twenty-five professional male basketball players from 2 teams competing in European competitions (FIBA Basketball Champions League [Team1], $n = 12$ and EuroCup Basketball League [Team2], $n = 13$) were monitored during the pre-season phase. Because of low participation in training sessions and matches (i.e., <75% of total training sessions and matches combined completed) (34), 2 players from each team were excluded from analyses, resulting in a final sample of 21 players (mean ± *SD*, age: 26.2 ± 4.9 years, range 20–37 years; stature: 198.7 ± 6.7 cm; body mass: 93.2 ± 10.0 kg) for a total sample of 903 samples from training sessions and pre-season matches. Training and pre-season match participation of the final study sample was 93% across both investigated teams. All players were notified of the aims, procedures, requirements, risks, and benefits of the study and provided written informed consent before participation. Ethical approval was obtained from the Kaunas Regional Research Ethical Committee Review Board (No. BE-2-97).

Procedures

Hormonal Measurement. To measure levels of T, C, and T:C, saliva samples were collected before the first training session of each week at the same time of the day (17:00) to avoid circadian variation in responses (40). Players were familiarized with and instructed to avoid eating, brushing their teeth, and consuming any fluids (except

Table 1

Pre-season schedule for the both professional male basketball teams monitored in this study.*

			Team1							Team2						
Week	**Session**	**Detail**	**Day1**	**Day2**	**Day3**	**Day4**	**Day5**	**Day6**	**Day7**	**Day1**	**Day2**	**Day3**	**Day4**	**Day5**	**Day6**	**Day7**
1	Morning	Type	—	SC	SC	—	PT	SC	SC	—	PT	—	SC	SC	FB	—
		Duration (min)		77	76		97	81	135		112		127	104	81	
	Afternoon	Type	SC	SC	FB	—	SC	BB	—	SC	SC	SC	BB	BB	—	—
		Duration (min)	76	79	109		86	120		78	109	109	118	104		
2	Morning	Type	—	SC	BB	—	SC	SC	BB	SC	SC	BB	SC	SC	FB	—
		Duration (min)		77	72		116	45	74	90	97	130	101	120	83	
	Afternoon	Type	BB†	BB	FM	—	BB	BB	FM	BB†	BB	—	BB	BB	—	—
		Duration (min)	135	118	114		95	146	127	130	103		112	120		
3	Morning	Type	SC	SC	SC	—	BB	—	SC	SC	—	—	SC	—	SC	—
		Duration (min)	92	47	110		62		89	118			102		109	
	Afternoon	Type	BB†	BB	BB	—	FM	—	BB	BB†	BB	—	BB	FM	—	—
		Duration (min)	103	142	113		143		125	130	106		116	178		
4	Morning	Type	BB	BB	—	—	SC	SC	—	SC	BB	SC	—	BB	—	SC
		Duration (min)	42	46			83	83		113	55	110		50		130
	Afternoon	Type	BB†	FM	FM	—	BB	BB	—	BB†	FM	—	BB	FM	—	—
		Duration (min)	113	145	139		86	100		106	187		95	194		
5	Morning	Type	BB	—	PT	SC	BB	—	SC	—	—	—	PT	SC	—	—
		Duration (min)	86		90	79	117		82				118	110		
	Afternoon	Type	FM†	—	BB	BB	FM	BB	BB	FM†	FM	—	—	BB	BB	BB
		Duration (min)	129		90	126	157	108	105	189	211			120	95	90

*SC = strength and conditioning session performed on court (not those performed in the weight room); PT = performance testing session; BB = basketball training sessions (i.e., technical and tactical); FM = pre-season friendly match; FB = football (soccer) session.

†The time points for saliva sample collection before training sessions.

water) 90 minutes before saliva collection (4). Before providing saliva specimens, players rinsed their mouth with distilled water removing all saliva from their mouth. Players then removed all saliva from their mouth again 30 seconds later before waiting in a seated position for ~10 minutes (4). Saliva specimens were collected into 15-mL SaliCap tubes through a polypropylene straw (IBL International; Hamburg, Germany), using a spitting method (34), and were stored at −20° C in laboratory settings for subsequent analysis. T and C were determined in duplicate using an enzyme-linked immunoassay (IBL International; Hamburg, Germany) following the manufacturer's instructions (REF for T: RE52631; REF for C: RE52611). The intra-assay coefficient of variation for T and C analyses was 2.4% and 3.1% for players in Team1 and 2.5% and 3.2% for players in Team2, respectively.

Load Measurement. Load variables were monitored during all court-based training sessions and matches across the pre-season. External load was measured using ClearSky T6 microsensors (Catapult Innovations; Melbourne, Australia). Before each training session or match, microsensors were affixed between the scapulae of each player through neoprene vests supplied by the manufacturer. The microsensors contained accelerometers sampling at 100 Hz to measure PL and PL·minute^{-1} in arbitrary units (AUs). PL is a modified vector magnitude determined as the square root of the sum of the squared instantaneous rate of change in acceleration across the 3 movement planes (10). PL·minute^{-1} was calculated considering the total duration of the training sessions and matches, which included warm-ups, breaks, and stoppages. Data were processed and exported using OpenField software (version 1.18, Catapult Innovations; Melbourne, Australia).

Internal load was measured using the sRPE method (23) and heart rate (HR) measures (9). In this way, players self-selected their individual sRPE ~30 minutes after each training session or match using the modified Borg 10-point Category Ratio Scale (23) through cloud-based software (Google Docs, Google; Mountain View, CA), using their smartphones. The reporting compliance from players for sRPE through their smartphones was 94% for Team1 and 91% for Team2. sRPE and the total duration (min) of each training session and match including warm-up, breaks, and stoppages were multiplied together to calculate sRPE-load in AU. These data were subsequently used to calculate weekly monotony and strain using the following formulae (23): monotony = weekly average (i.e., mean sRPE per session during the week) sRPE/*SD* of mean individual session sRPE and strain = weekly total sRPE-load (i.e., summed sRPE-load per player across all sessions in the week) × monotony.

Polar H10 chest-worn straps (Polar Electro; Kempele, Finland) were used to monitor HR in each player. Heart rate data were collected and processed through OpenField software (version 1.18, Catapult Innovations; Melbourne, Australia). Accordingly, SHRZ load (AU) was calculated from HR data as: (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% HRmax, zone 2 = 60–69.9% HRmax, zone 3 = 70–79.9% HRmax, zone 4 = 80–89.9% HRmax, zone 5 = ≥90% HRmax, and duration = session or match time including warm-up, breaks, and stoppages in minutes (18). Twenty-two (2.4%) individual heart rate data samples were not properly recorded during training sessions and matches because of technical problems in data collection (i.e., poor connection between Polar belts and Catapult microsensors). Moreover, average % HRmax was calculated for each training session and match. HRmax was determined as the peak HR attained during a maximal 30-15 Intermittent Fitness Test performed on a basketball court at the beginning of the monitoring period (12). The peak HR attained during this initial testing was updated to a new maximal value if it was superseded by HR responses recorded during training sessions or friendly matches throughout the monitoring period (8), and the calculation of the %HRmax was then updated for all data.

Well-Being Measurement An online questionnaire previously used to monitor basketball players (16,17,35) was adopted to assess player well-being. Every morning (before 10:00) across the pre-season phase, players reported their perceived fatigue, sleep quality, general muscle soreness, stress, and mood on a 5-point Likert scale (scores from 1 to 5) using cloud-based software (Google Docs, Google; Mountain View, CA). Well-being was calculated by summing the scores across each item assessed. The compliance for reporting well-being was 90% for Team1 and 99% for Team2.

Statistical Analyses

Estimated marginal means and standard error (*SE*) were calculated as descriptive statistics. To assess weekly fluctuations in hormonal responses, load, and well-being, separate linear mixed models (LMMs), which correctly deal with missing values, were used for each variable with week entered as a fixed effect and player entered as a random effect. Post hoc analyses with Bonferroni corrections were used when LMMs revealed a significant finding. Cohen's *d* effect sizes (ES) with 95% confidence intervals (CIs) were calculated from the *t* statistics derived in the LMM to quantify the magnitude of difference in pairwise comparisons. In turn, ES magnitudes were interpreted as trivial = <0.20; small = 0.20–0.59; moderate = 0.60–1.19; large = 1.20–1.99; and very large = ≥2.0 (28). To determine associations between weekly changes in variables, LMMs were used with weekly changes in well-being set as the dependent variable, alongside weekly changes in hormone (T, C, and T:C) and load (PL, PL·minute^{-1}, sRPE-load, sRPE monotony, sRPE strain, %HRmax, and SHRZ load) variables set as fixed effects and player set as a random effect. Weekly changes were calculated as delta changes (i.e., Δweek2 − week1; Δweek3 − week2; Δweek4 − week3; Δweek5 − week4). When determining delta changes, load variables indicating training volume were summated across all training sessions and matches in each week (PL, sRPE-load, and SHRZ load), whereas variables indicating training intensity (PL·minute^{-1}, %HRmax) were averaged (calculating the weekly average of the session values) across each week. Well-being variables were also averaged following the same procedure across each week. By contrast, single weekly measurements were used for T, C, T:C, monotony, and strain. The final study sample of 105 samples (i.e., weekly value) for PL, sRPE-load, monotony, strain, SHRZ, 899 samples (i.e., session values) for PL·minute^{-1}, 878 samples (i.e., session values) for %HRmax, 663 samples (i.e., daily values) for well-being, and 104 samples (i.e., weekly values) for T, C, and T:C were used in the analyses. The PL·minute^{-1}, %HRmax, and well-being values were averaged by week while running the LMM analysis. Random effects were considered in analyses with a random intercept and fixed slope. The assumption of normality for residual values was confirmed using Kolmogorov-Smirnov tests. An alpha level of ≤0.05 was set a priori to indicate statistical significance. Data were analyzed using Jamovi software (version 2.3.3, retrieved from https://www.jamovi.org), whereas the compute.es package in *R* software (R version 4.2.1) was used for ES calculations.

Results

Weekly changes in hormonal variables are presented in Figure 1. Significant weekly fluctuations were found in T levels ($p < 0.001$) and T:C ($p = 0.002$). Post hoc analyses showed that T was lower in week 1 compared with week 4 ($p = 0.002$; ES = −1.18 [−1.84, −0.53], moderate) and week 5 ($p = 0.001$; ES = −1.25 [−1.92, −0.58], large) and lower in week 3 than week 4 ($p = 0.03$; ES = −0.95 [−1.58, −0.31], moderate) and week 5 ($p = 0.02$; ES = −1.02 [−1.67, −0.37], moderate). T:C was lower in week 1 than week 4 ($p = 0.04$; ES = −0.91 [−1.55, −0.27], moderate) and week 5 ($p = 0.002$; ES = −1.21 [−1.88, −0.54], large).

Weekly fluctuations in load variables are shown in Figure 2. Significant weekly fluctuations were found in PL·minute^{-1} ($p < 0.001$), %HRmax ($p = 0.05$), monotony ($p < 0.001$), and strain ($p < 0.001$). Post hoc analyses revealed that PL·minute^{-1} was lower in week 1 than week 2 ($p = 0.03$; ES = −0.29 [−0.49, −0.1], small) and week 3 ($p < 0.001$; ES = −0.48 [−0.69, −0.27], small) and higher in week 3 than week 4 ($p < 0.001$; ES = 0.44 [0.22, 0.65], small). %HRmax was higher in week 3 than week 4 ($p = 0.04$; ES = 0.31 [0.1, 0.53], small). Training monotony was higher in week 1 than week 2 ($p = 0.003$; ES = 1.17 [0.52, 1.83], moderate), week 3 ($p < 0.001$; ES = 1.56 [0.87, 2.25], large), and week 4 ($p < 0.001$; ES = 1.82 [1.1, 2.54], large) and lower in week 3 ($p = 0.05$; ES = −0.9 [−1.53, −0.26], moderate) and week 4 ($p = 0.003$; ES = −1.15 [−1.81, −0.5], moderate) than week 5. Training strain was higher in week 1 than week 3 ($p < 0.001$; ES = 1.27 [0.61, 1.93], moderate) and week 4 ($p = 0.02$; ES = 1.01 [0.37, 1.66], moderate).

Weekly fluctuations in well-being are presented in Figure 3, with no significant differences evident between weeks. Associations between weekly changes in hormonal responses and load with weekly changes in well-being are presented in Table 2. Weekly changes in PL ($p = 0.002$), sRPE-load ($p = 0.02$), and strain ($p = 0.004$) were significantly associated with weekly changes in well-being.

Discussion

This study demonstrated that T and T:C levels increased toward the end of the 5-week pre-season phase, with higher loads in variables indicative of external (PL·minute^{-1}) and internal (%HRmax) intensities encountered during the first 3 weeks alongside higher monotony and strain in the first and last week of the pre-season phase. In turn, no significant fluctuations were found in C, PL, sRPE-load, SHRZ, %HRmax, and well-being. In addition, weekly changes in PL, sRPE-load, and strain were negatively associated with weekly changes in well-being.

The moderately higher T and T:C levels evident in latter weeks (4 and 5) compared with the first week of the pre-season demonstrate a desirable hormonal response to the stimuli experienced among the investigated players. In this regard, while high training loads are typically delivered to players during the pre-season, the upward trend in T:C suggests that adequate planning of the stimuli was likely afforded to players resulting in a positive anabolic-catabolic balance (1). In contrast to T and T:C, levels of C remained relatively consistent across the 5-week pre-season phase. These findings align with previous research showing no significant changes in C levels across the pre-season phase in professional male basketball players (46). The stable levels of C observed across the pre-season phase might be explained by the limited participation in official matches, which expose players to higher physiological and psychological stress than the limited friendly or simulated matches encountered during the pre-season (39). Furthermore, it should be considered that C levels have been shown to fluctuate more extensively toward the end of the in-season phase (45), suggesting that fatigue and stress accumulated longitudinally across the season may exert a greater impact on C levels than loads accumulated during the pre-season. Nevertheless,

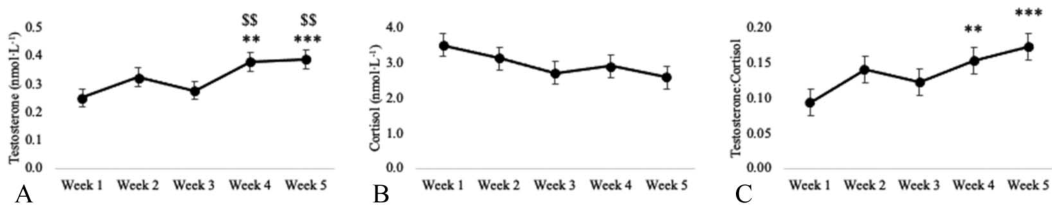

Figure 1. Weekly (estimated marginal mean ± *SE*) (A) levels of salivary testosterone, (B) levels of salivary cortisol, and (C) testosterone-to-cortisol ratios across a 5-week pre-season phase in professional male basketball players. ** indicates a significant ($p < 0.05$) and moderate difference from week 1; *** indicates a significant ($p < 0.05$) and large difference from week 1; \$\$ indicates a significant ($p < 0.05$) and moderate difference from week 3.

from a hormonal perspective, the coaching staff involved in this study likely delivered appropriate training stimuli with sufficient recovery across the pre-season phase.

Considering load monitoring, our findings revealed significant weekly fluctuations in PL·minute^{-1} and %HRmax. Indeed, moderate-to-large increases in PL·minute^{-1} were evident in weeks 2 and 3 compared with week 1. Moreover, both PL·minute^{-1} and %HRmax showed a significant decrease in week 4 compared with week 3. By contrast, no significant weekly differences were found in load variables indicative of volume (PL, SHRZ, and sRPE-load). It is difficult to explain these results given that it was not clear whether coaching staff planned a traditional periodization approach involving higher load volumes at the beginning of the pre-season, followed by a taper phase toward the end of the pre-season (41). Furthermore, it is hard to compare our results with previous studies given the lack of research quantifying load variables across the pre-season period in professional male basketball players. In this regard, the internal and external loads experienced by professional male basketball players during the pre-season phase were assessed by Aoki et al. (3). However, the external load data reported in our study are difficult to compare with that reported by Aoki et al. (3) given that different external load variables (PL and PL·minute^{-1} in our study compared with mechanical load and accelerations from gravitational forces used previously) were collected across studies derived using different hardware and mathematical formulae. By contrast, for internal load data, the weekly sRPE-loads we observed (5,092 ± 301 AU) are similar to those reported for professional male basketball players competing in Italian first- and second-tier leagues (5,241 ± 1787 AU) (20) and (5,058 ± 1849 AU) (19) but different when compared with professional, Brazilian, male players (2,621 ± 545 AU) (3). This discrepancy in findings for weekly sRPE-load across studies reflects the variations in the training plans implemented across teams. Indeed, our players were monitored across a number of training sessions (45 and 37 training sessions for Team1 and Team2, respectively) and pre-season matches (6 and 5 matches for Team1 and Team2, respectively) comparable with those reported for

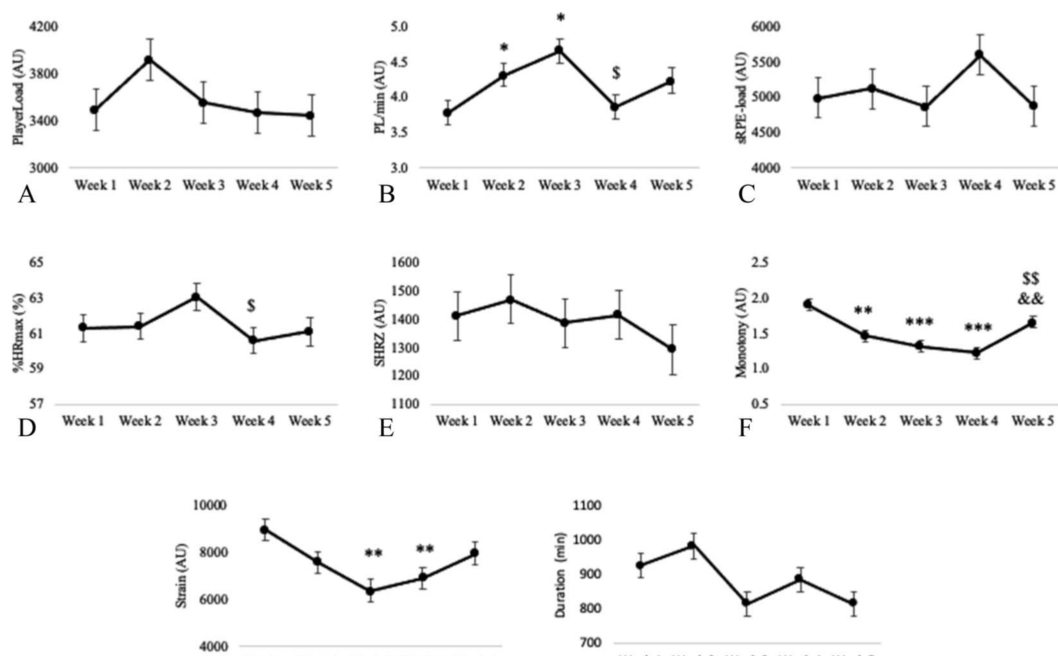

Figure 2. Weekly (estimated marginal mean ± *SE*) (A) PlayerLoad (PL), (B) PL·minute^{-1}, (C) session rating of perceived exertion load (sRPE-load), (D) summated heart rate zone load (SHRZ), (E) average percentage of maximum heart rate (%HRmax), (F) monotony, (G) strain, and (H) training duration across a 5-week pre-season phase in professional male basketball players. * indicates a significant ($p < 0.05$) and small difference from week 1; ** indicates a significant ($p < 0.05$) and moderate difference from week 1; *** indicates a significant ($p < 0.05$) and large difference from week 1; \$ indicates a significant ($p < 0.05$) and small difference from week 3; \$\$ indicates a significant ($p < 0.05$) and moderate difference from week 3; && indicates a significant ($p < 0.05$) and moderate difference from week 4. AU = arbitrary units.

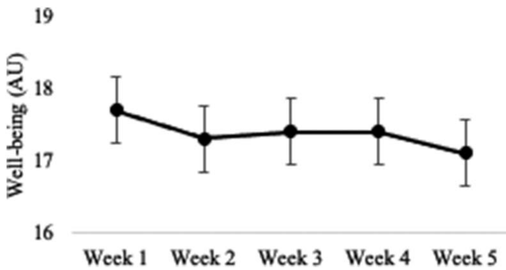

Figure 3. Weekly (estimated marginal mean ± *SE*) perceived well-being across a 5-week pre-season phase in professional male basketball players. AU = arbitrary units.

professional, Italian, male basketball players (~55 training sessions and ~8 matches) (19,20) and higher compared with those documented for professional, Brazilian, male basketball players (~30 on-court training sessions) (3). Nonetheless, our findings provide insight into potential strategies for planning and periodizing loading during the pre-season phase for practitioners working with professional male basketball teams.

When sRPE-load was used to determine training monotony and strain, significant weekly fluctuations emerged across the pre-season. Specifically, monotony was higher in week 1 compared with weeks 2, 3, and 4 and was lower in weeks 3 and 4 compared with week 5. Meanwhile, strain was higher in week 1 than weeks 3 and 4. These findings are difficult to compare with the past literature because load monotony and strain have been sparsely reported in basketball studies, especially during the pre-season phase (11). The weekly fluctuations we observed in these variables could be attributed to conditioning sessions being predominantly organized in the first week of the investigated period, with technical and tactical sessions and friendly matches being increasingly incorporated with progression of the pre-season phase. This structure may have promoted a higher monotony and strain at the beginning of the pre-season because the intense nature of the physical preparation sessions likely diminishes variability in loading from session to session, therefore lowering the average sRPE-load *SD* when calculating monotony. However, it should be noted that sRPE-load monotony and strain variables have only been validated through correlations with illnesses in speed skaters (23). Thus, further studies are warranted to investigate the validity of load monotony and strain variables in basketball players.

Monitoring well-being has been emphasized as a valuable method reflective of training effects (17,30). Our findings show that although hormonal responses and training stimuli fluctuated across the pre-season, no concomitant changes in well-being were observed from week to week. These results might be explained by the absence of official matches during the pre-season, resulting in players being less exposed to the high physiological and psychological stress accompanying competition that may affect their well-being (16). Moreover, our findings for weekly changes in hormonal and load variables suggest that an adequate loading strategy was applied to promote an anabolic hormonal status without excessive weekly spikes in stimuli across the pre-season. With this approach in mind, a consistent state of well-being might be expected in the players across each week during the pre-season.

Although weekly well-being remained stable across the 5-week pre-season phase, associations between weekly changes in hormonal responses and load with weekly changes in well-being revealed further insight. Specifically, weekly changes in well-being were significantly and negatively associated with weekly changes in PL, sRPE-load, and strain. However, despite reaching statistical significance, the significant associations were relatively weak in magnitude (R^2 = 0.061–0.105). In this way, similar results have been reported in under-20 years, national-level, female basketball players during a congested competition phase (7 matches in 9 days) with significant, small ($p = 0.04$, rho = 0.15) associations found between daily sRPE-load and well-being (35). Like load variables, weekly changes in hormonal responses demonstrated weak ($p > 0.05$, R^2 = <0.001–0.023) associations with weekly changes in well-being across the pre-season phase. This finding is in line with previous research reporting nonsignificant associations between weekly changes in perceived well-being scores and weekly changes in T (r = 0.11), C ($r = -0.11$), and T:C ($r = 0.23$) levels during a congested (12 matches) 4-week period of the in-season phase in semi-professional male basketball players (34). A potential reason for our findings might be the fact that a well-being score derived from summing several constructs (perceived fatigue, sleep quality, general muscle soreness, stress, and mood) is likely to be influenced by several stressors fitting emotional, mental, and social domains (25) in addition to physical stressors such as the imposed load and response to training and matches. Therefore, our findings indicate that well-being status, load, and hormonal responses may each provide unique

Table 2

Associations between weekly changes in hormonal responses and load measures with weekly changes in perceived well-being in professional male basketball players during a 5-week pre-season phase.*†

AIC	R^2 conditional	Fixed effects	Estimate (95% CI)	*p*
		Hormonal responses		
290.4	0.007	Testosterone (nmol·L^{-1})	0.723 (−1.045, 2.491)	0.425
289.1	0.023	Cortisol (nmol·L^{-1})	0.107 (−0.042, 0.257)	0.162
291.0	<0.001	Testosterone:cortisol	0.220 (−2.718, 3.159)	0.884
		Load measures		
281.8	0.105	PlayerLoad™ (AU)	$-4.77e^{-4}$ ($-7.77e^{-4}$, $-1.78e^{-4}$)	**0.002**
291.0	<0.001	PlayerLoad™·min^{-1} (AU)	−0.046 (−0.391, 0.300)	0.797
285.8	0.061	sRPE-load (AU)	$-2.01e^{-4}$ ($-3.70e^{-5}$, $-3.17e^{-5}$)	**0.022**
290.0	0.013	SHRZ (AU)	$-3.61e^{-4}$ (−0.001, $3.17e^{-4}$)	0.300
287.9	0.037	%HRmax (%)	0.064 (−0.006, 0.133)	0.077
290.9	0.002	Monotony (AU)	0.103 (−0.445, 0.650)	0.714
282.6	0.097	Strain (AU)	$-1.44e^{-4}$ ($-2.39e^{-4}$, $-4.92e^{-5}$)	**0.004**

*AIC = Akaike information criterion; CI = confidence interval; AU = arbitrary unit; sRPE-load = session rating of perceived exertion load; SHRZ = summated heart rate zone; %HRmax = percentage of maximum heart rate.

†Significant effects on changes in well-being are highlighted with bolded *p* values ($p < 0.05$).

insight when implemented in monitoring systems among professional male basketball players during the pre-season phase.

This study provides practical and useful information for basketball coaches and performance staff, but the limitations encountered should be considered. First, the basketball players investigated did not undergo fitness assessments following the off-season phase. These data would provide insight regarding the condition of players entering the pre-season phase, which in turn can influence the responses to training (21,36). Second, this study sought to examine associations between key monitoring data routinely gathered in basketball teams (i.e., hormonal responses, external loads, and internal loads) to understand how they each may affect player well-being during the pre-season phase. However, factors other than hormonal responses and load influence player well-being including emotional, mental, and social factors (25). Therefore, future studies should encompass wider variables when exploring variables that may be associated with changes in player well-being across the season in basketball players. Finally, although the well-being scales used in this study have been previously applied in the basketball literature (16,17,34) and may provide useful information for basketball practitioners, their use has been recently questioned because of a lack of validity (31). Consequently, future studies are needed to validate to identify the optimal practical approach to assess well-being in basketball players.

In conclusion, our results showed that the average weekly internal and external load intensities were increased in a periodized manner across the first 3 weeks with a subsequent decrease in the following weeks with no changes in weekly load volumes across a 5-week pre-season phase among professional male basketball players. This approach coincided with positive hormonal responses with increased T and T:C levels toward the end of the pre-season and a consistent weekly player well-being status. Finally, weak associations were evident between weekly changes in load and hormonal responses with weekly changes in well-being, emphasizing the low commonality between these constructs and the multifaceted nature of well-being status.

Practical Applications

The findings of this investigation provide useful insight for end users working with professional male basketball teams. Considering the descriptive nature of this study, the reported data demonstrate that acute, weekly fluctuations in load and hormonal levels likely occur during the pre-season in professional basketball players. In the specific teams we investigated, weekly loading fluctuations were evident through increased average intensities across initial weeks, coinciding with positive changes to hormonal levels and a consistent well-being status to suggest that this approach may be effective in eliciting favorable physiological and psychological responses among players. In turn, the weak associations we observed between weekly changes in load and hormone levels and weekly changes in well-being emphasize that load or hormonal data collected in players should not be used to anticipate acute changes in their well-being. Considering these findings, basketball practitioners should aim to embed separate tools to monitor the training stress experienced in the pre-season (i.e., load variables and hormone measurements) and player well-being to comprehensively understand the status of their players. Several lines of future research stem from our findings.

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