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Salivary Biomarker Monitoring of Elite Collegiate Female Basketball Players Across an NCAA Division-I Season

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ABSTRACT

The testosterone (T) to cortisol (C) ratio (T/C) has been considered an important endocrine marker used for monitoring training stress and performance in athletes. The purpose of this study was to monitor free T, C, and T/C of elite female basketball players throughout an entire season. Ten athletes gave a salivary sample before an afternoon practice, once per week, for a total of 29 weeks. Salivary immunoassay kits were used to analyze for T and C. A composite value composed of z-scores (COMP) for playing time, practice time, resistance-training volume, travel, and academic stress was used to quantify weekly cumulative stress. T, C, and T/C were different from the season average values on four different occasions. During Week 6, there was a decrease in T/C due to an increase in COMP as a final effort to peak the athletes before the taper used to transition from preseason to competition phase. The T/C return to the season average values during Week 7 demonstrated that the athletes were appropriately recovered. During Week 16, the week after a holiday break, T/C was below the season average despite the decrease in COMP. During Week 24, the decrease in T/C corresponded with an increase in COMP. During Week 27, before the first postseason competitive match, T/C decreased below the season average despite the decrease in COMP, suggesting an anticipatory effect. However, the athletes returned and remained at the individual season average values up to and beyond their fourth-round elimination, suggesting that they were physiologically prepared for the postseason play.

Keywords: *sport performance; hormones; recovery; team sports; stress; training*

INTRODUCTION

The testosterone to cortisol ratio (T/C) is the amount of the hormone testosterone, normally in its unbound or free form, found in a blood or salivary sample divided by the amount of the hormone cortisol found in the same blood or salivary sample. Studies suggest that strength, power, and athletic preparedness are positively correlated with T/C in male athletes [1-9]. The T/C is considered an important endocrine marker, but it is suggested to be an oversimplification which does not necessarily imply causality [10]. Still, it may be useful for monitoring fatigue management in athletes. Typically, in response to one stressful training session, testosterone (T) will increase or decrease slightly, while cortisol (C) will experience a significantly higher increase, thus leading to a decrease in T/C [11]. As training stress increases over time, T/C tends to decrease. With a taper or reduction in training stress, T/C will usually return to baseline or increase beyond baseline due to super-compensation [11]. However, with non-functional overreaching, performance and hormonal markers merely return to baseline after a taper [12], suggesting that T/C may be a way to help determine the effectiveness of a peak-taper cycle.

While many studies have addressed the relationship between T/C and training stress in strength and power athletes, there have also been studies [12-16] observing changes in T/C with athletes from sports with competing demands (i.e., anaerobic power and muscular endurance). Kraemer and colleagues [15] were able to use T/C to predict performance in the upcoming season for collegiate Division-I soccer players. They determined that collegiate Division-I male soccer players starting a competitive season with low T and elevated C may experience reductions in performance during that season, and that this phenomenon is worse for starters than for non-starters [15]. Vervoorn and colleagues [17] found a significant negative correlation (r = -.98) between training volume and T/C in elite Olympic rowers during a high-volume peaking period, so that as training volume increased, T/C decreased, and vice-versa. Fry and colleagues [13] found that T/C is not necessarily impacted by a stressful wrestling bout, despite changes in both T and C. Another study [18] used salivary T/C to successfully predict which collegiate Division-I football players would respond best to a resistance training program and found that those with the highest T/C had the greatest adaptation to the resistance training program. However, they did not address the stresses of a competitive football season.

Only a few studies [14,16,19] have attempted to monitor T, C, and T/C in elite male basketball players. While Hoffman et al. [14] found significant increases in C from the beginning of the four-week training camp to the end, no changes were observed for T or T/C. Schelling et al. [16] sampled serum T and C from elite professional basketball players at eight time-points throughout a competitive season and found that T levels and T/C were significantly lower at the later collection dates, while C remained the same throughout the season. In one of the recently published studies, Andre et al. [19] observed an increase in T/C after the preseason training phase indicating an adequate recovery regimen. Moreover, a negative relationship observed between T/C and playing time could suggest a potential detrimental physiological effect on athletes' during the second phase of the regular competitive season period [19].

While T and T/C have traditionally been used to evaluate performance in males, as women average only 10% T production of males, there are data [20-26] to suggest that T is also related to performance in elite female athletes. Healy et al. [25] evaluated hormonal profiles from 693 elite athletes (454 male, 239 female) and found that 13.7% of women had high T levels with complete overlap between the sexes, demonstrating that elite female athletes may be more impacted by T than the average female. Additionally, Cook and colleagues [22] found that international level female athletes from several Olympic sports had levels of T that were approximately double their national level teammates. Cardinale and Stone [20] observed a positive correlation between vertical jump height and T in elite female athletes. In female collegiate volleyball and tennis players, T was increased in anticipation of competition and also during sport practice [23], while elite female wrestlers also experienced an increase in T from pre- to post-bout [24]. In elite female basketball players, increases in T/C correlated with increases in improvement to an off-season resistance training program [26]. Considering these studies, further research directed towards using the T/C to monitor performance in female athletes is justified.

It is interesting to note that T may vary throughout the menstrual cycle. However, research is currently inconsistent in this area [27-29]. One study [27] observed no changes in T throughout the menstrual cycle, while another [29] saw an increase in T during the ovulatory phase, although both studies evaluated non-athletes. Another study [28] saw the greatest increase in T during the luteal phase (during the 20th through 26th days after menses) in women with a regular menstrual cycle, but also saw the highest increases in T during and surrounding ovulation (approximately the 14th day after menses) in women with an irregular menstrual cycle, suggesting that menstrual irregularity can affect T production in women. These studies suggest that further research is needed to understand the impact of the menstrual cycle on salivary T concentrations in elite female basketball athletes, as it may potentially impact T levels during a monitoring study.

To date, the majority of studies attempting to use T/C to monitor athletic performance have used serum or plasma to determine T/C. However, saliva is a safe, reliable, non-invasive method for measuring T and C and is strongly correlated with serum values [30-34]. Using saliva instead of serum allows researchers to collect samples simultaneously from a group of athletes in a non-laboratory setting, which would cause minimal interference in the athletes' training. Thus, it is more probable that a researcher will be able to collect weekly saliva samples with elite athletes, allowing a week-to-week monitoring program across an entire competitive season.

Currently, the literature has shown that T/C can relate to training stress in anaerobic athletes and team sport athletes with multiple physical demands, including male professional basketball players. However, no studies have addressed all aspects of stress (i.e., competition, practice, resistance training, academic, travel) weekly throughout an entire season in elite female National Collegiate Athletic Association (NCAA) Division-I basketball athletes. Therefore, the purpose of this study was to monitor free T, C, and T/C in elite female NCAA Division-I basketball athletes throughout an entire season and compare hormonal changes to variations in other measures of stress (i.e., practice minutes, game minutes, resistance training repetitions, academic stress, and travel stress).

METHODS

Experimental Approach to the Problem

This study was observational in nature. The athletes performed their normal duties as assigned, but each gave a salivary sample immediately upon arriving for a regularly scheduled afternoon practice, once per week, from preseason to after postseason during the entire season span. Changes in salivary hormones were then compared to changes in other measures of objective (i.e., minutes played in competition, minutes played in practice, repetitions in the weight-room) and subjective (i.e., travel, academic) stress to examine if any statistically significant relationships exist.

Saliva Collection

Ten elite female NCAA Division-I basketball athletes gave a salivary sample before an afternoon practice in the middle of each week for 26 different weeks within a period consisting of 29 consecutive weeks, beginning in the preseason and ending one week after the end of postseason competition. All saliva collections were conducted at rest, in the afternoon, in the middle of the week. Subjects were instructed not to eat, brush their teeth, or drink anything other than water for one hour prior to meeting. When the subjects arrived for mid-week afternoon practice, they were instructed to rinse their mouths out with water and sit quietly. Then, subjects held an oral swab (Salimetrics Oral Swab, Salimetrics, PA, USA) in their mouths for two minutes before releasing the swab into a centrifuge tube. Samples were frozen at -80°C and stored for later analysis.

Salivary Analysis

Using saliva instead of serum allowed simultaneous data collection, in-the-field, in a non-invasive manner. For the salivary T enzyme immunoassay kits (Salimetrics, PA, USA), a 96-well microtitre plate coated with rabbit T antibodies is used to analyze the saliva samples. Testosterone found in the pre-determined standards which accompany the kit and T in the salivary samples compete with a T conjugate (T linked to horseradish peroxidase) for the antibody binding sites within the wells of the microtitre plate. After a one-hour incubation, unbound components are washed away. After the wash, the substrate tetramethyl benzidine (TMB) is added, and bound T peroxidase is measured by the reaction of the peroxidase enzyme on the TMB, which produces a blue color. The plate is again incubated, this time for 30 minutes in the dark. Yellow color is formed after stopping the reaction using 2-molar sulfuric acid. The darkness of the yellow is inversely related to the amount of T present, so that a darker yellow well has a lower T than a paler shade of yellow. Optical density is then read on a standard plate reader at 450 nm. The amount of T peroxidase detected is inversely proportional to the amount of T present.

For the salivary C enzyme immunoassay kits (Salimetrics, PA, USA), a 96-well microtitre plate coated with monoclonal antibodies to C. Cortisol found in the pre-determined standards which accompany the kit and C in the salivary samples compete with a C conjugate (C linked to horseradish peroxidase) for the antibody binding sites within the wells of the microtitre plate. After a one-hour incubation, unbound components are washed away. After the wash, the substrate TMB is added, and bound C peroxidase is measured by the reaction of the peroxidase enzyme on the TMB, which produces a blue color. The plate is again incubated, this time for 30 minutes in the dark. Yellow color is formed after stopping the reaction using 2-molar sulfuric acid. The darkness of the yellow is inversely related to the amount of C present, so that a darker yellow well has a lower C than a paler shade of yellow. Optical density is then read on a standard plate reader at 450 nm. The amount of cortisol peroxidase detected is inversely proportional to the amount of C present.

A separate assay was used for each player with 10 assays per hormone, for 20 assays in total, with samples, standards, and controls all added in duplicate. Assay plates were read in a plate reader (KC4, Biotek Instruments, Winooski, VT, USA). The minimal concentration that can be distinguished from zero with this assay is <1.0 pg/mL and 0.007 µg/dL for T and C, respectively. Inter- and intra-assay variation was 4.2% and 1.7% for T, and 5.9% and 3.2%, for C, respectively.

Composite Stress

The following data were also recorded throughout the season: playing time (minutes), practice time (minutes), resistance-training volume (reps), travel stress (scale), academic stress (scale), and menstrual cycle (yes/no). Composite stress scores were developed based on discussions with a panel over experts with over 70 of combined coaching experience.

The travel scale was determined by the coaches so that a score of "1" was given for an overnight bus trip where they returned before midnight, a "2" was given for an overnight flight, and a "5" was given for a multiple day trip with flight, because the coaches felt that these numbers were fair representatives of how stressful the travel would be for the athletes. Travel scores were averaged for each week. The academic stress scale was generalized so that a score of "0" was given when classes were not held, a score of "2" was given during normal weeks, and a score of "4" was given during exams. Academic scores were averaged for each week. Menstrual status was observed and a "1" was marked if currently menstruating at the time of saliva collection, while a "0" was entered when an athlete was not currently menstruating at the collection time.

Composite value composed of z-scores (COMP) for playing time, practice time, resistance-training volume, travel stress, and academic stress was used in an attempt to quantify weekly cumulative stress so that an increase in COMP suggested an increase in cumulative stress. All variables were converted to z-scores to standardize each player's values, and a comprehensive score.

Statistical Analysis

Of 260 team samples for the 29-week period, 16 individual samples were missing due to players missing practice. As it has been previously suggested [35], missing values were replaced with the team average for that week. One-way repeated-measures analysis of variance with LSD pair wise comparisons were used to determine which weekly hormonal concentrations (i.e., T, C, T/C) were different from the individual season average values. Pearson correlations were also used to help determine relationships between hormones and COMP scores, and hormones and the presence of menses throughout the entire season. Statistical significance was determined a priori ($\alpha = .05$).

Results

The overall ANOVA models were significant for T ($F[26, 234] = 1.638$, $p = .031$), C ($F[26, 234] = 1.848$, $p = .009$), and T/C ($F[26, 234] = 1.933$, $p = .006$).

For T, Week 7 ($p = .034$), Week 17 ($p = .007$), Week 22 ($p = .004$), and Week 28 ($p = .003$) were different from the individual season average. For C, Week 3 ($p = .002$), Week 17 ($p = .001$), Week 24 ($p = .009$), and Week 29 ($p = .014$) were different from the individual season average. For T/C, Week 6 ($p = .004$), Week 16 ($p = .024$), Week 24 ($p = .003$), and Week 27 ($p = .008$) were significantly different from season average. The team season average values for T, C, and T/C across a full season span were 2.1 nmol/L, 6.5 nmol/L, and 0.42, respectively. Also, no significant correlations were observed between hormones and COMP and hormones and the presence of menses ($p > .05$). Please refer to Tables 1 and 2 and Figures 1-4 for all data.

During Week 6, one week prior to the first exhibition game, T/C dropped below the season average and corresponded with an increase in COMP. However, T/C returned to the season average levels by Week 7, which was the first week of exhibition play. During Week 16, which was collected the week after a holiday break, T/C was below the season average despite a decrease in COMP. During Week 24, T/C dropped below the season average and corresponded with an increase in COMP. During Week 27, which was collected immediately before the team's first match of the NCAA tournament, T/C was below the season average values and corresponded with a decrease in COMP. However, the athletes returned and remained at that level up to and beyond their fourth-round elimination.

Table 1. *Weekly hormonal concentrations (x̄±SD). T – testosterone (nmol/L); C – cortisol (nmol/L); T/C – testosterone to cortisol ratio.*

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**
T	2.4±0.9	2.4±1.3	2.0±0.7	2.2±0.7	2.2±0.7	2.1±0.8	1.7±0.7*
C	7.8±7.0	5.7±3.1	4.7±2.1**	7.3±3.3	8.8±4.7	7.0±2.0	5.4±2.5
T/C	.50±.30	.47±.18	.57±.50	.33±.12	.32±.21	.32±.14**	.39±.24
Week	**8**	**9**	**10**	**11**	**12**	**15**	**16**
T	1.9±0.6	2.4±0.6	1.9±0.6	3.2±2.1	2.5±1.7	1.9±.84	2.4±1.4
C	5.2±3.0	5.6±2.4	5.3±2.2	6.5±3.4	6.2±1.9	6.7±4.8	8.6±5.7
T/C	.45±.23	.48±.20	.41±.15	.55±.31	.44±.31	.37±.25	.33±.18*
Week	**17**	**18**	**19**	**20**	**21**	**22**	**24**
T	1.8±0.7**	2.2±.61	2.2±.71	2.3±.71	2.3±1.0	1.8±.61**	2.2±.51
C	4.1±2.4**	6.4±2.7	5.2±2.7	5.9±2.9	5.8±1.8	6.6±2.4	11.5±5.3**
T/C	.51±.22	.41±.23	.51±.24	.45±.18	.40±.14	.33±.22	.23±.11**
Week	**25**	**26**	**27**	**28**	**29**		
T	2.1±1.1	2.0±0.9	2.4±1.7	1.8±.91**	2.4±1.4		
C	6.1±3.1	5.2±2.3	9.2±6.4	8.0±6.3	4.6±1.6*		
T/C	.38±.15	.48±.36	.31±.17**	.40±.23	.61±.42		
*Note: *p < .05; **p < .01*							

Table 2. *Correlations between hormones and composite scores (COMP), and hormones and presence of menses. RT Volume – resistance training volume; T – testosterone (nmol/L); C – cortisol (nmol/L); T/C – testosterone to cortisol ratio.*

	Composite	**Game Minutes**	**Practice Minutes**	**RT Volume**	**Academic**	**Travel**	**Menses**
T	-.24	.03	-.24	.29	-.22	-.25	-.26
C	-.10	-.11	-.08	.18	-.14	-.07	-.09
T/C	-.19	.09	-.31	-.09	.06	-.01	-.21

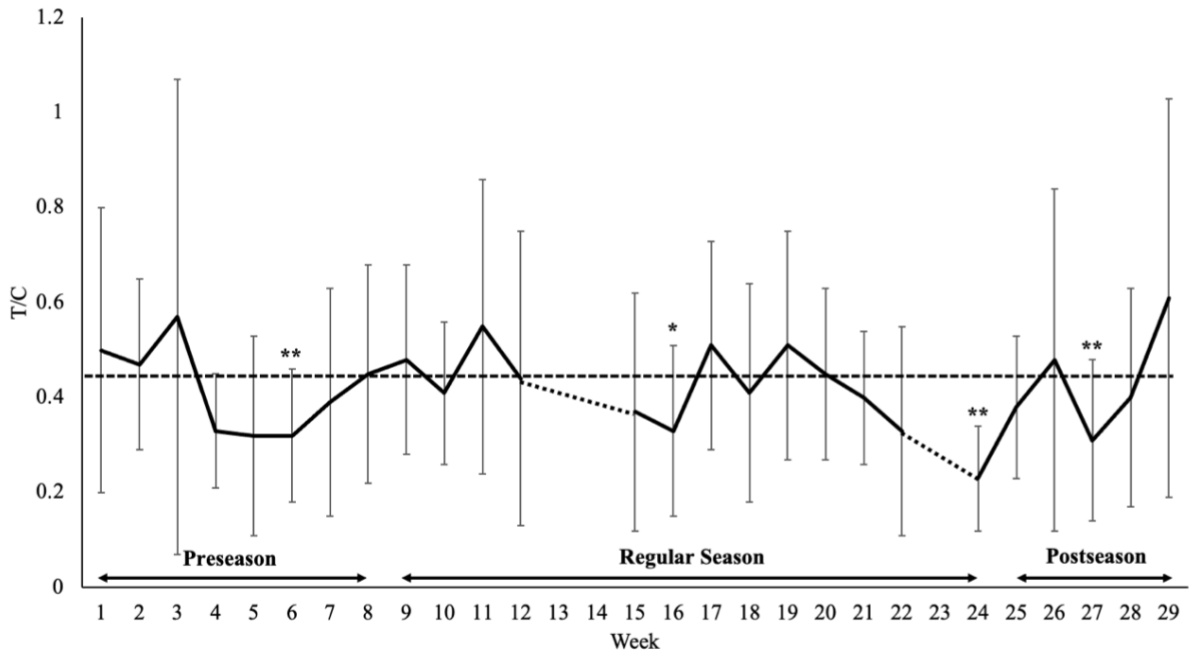

FIGURE 1. *Testosterone to cortisol ratio (T/C; x̄±SD). Dashed line represents season average for the team. Note: *p < .05; **p < .01.*

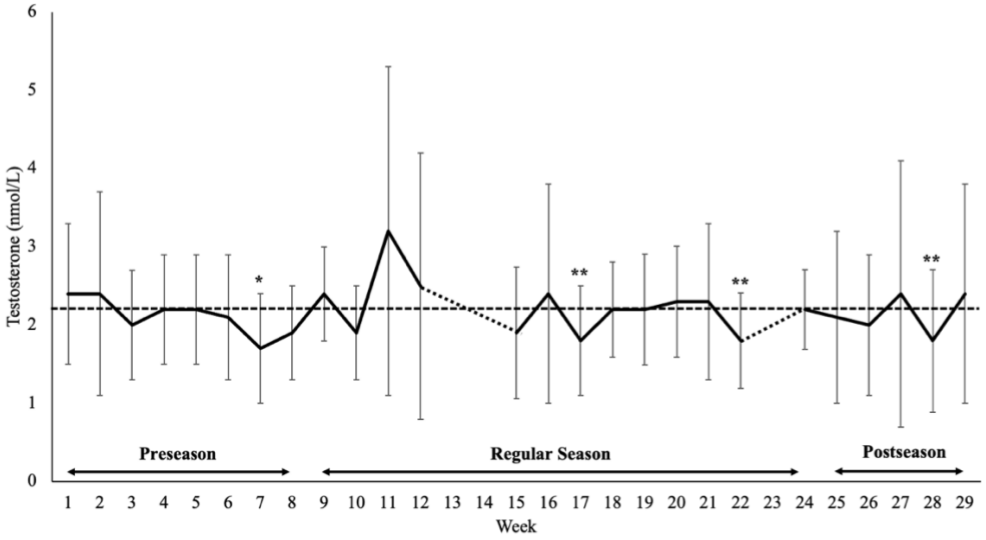

Figure 2. *Testosterone concentrations (x̄±SD). Dashed line represents season average for the team. Note: *p < .05; **p < .01.*

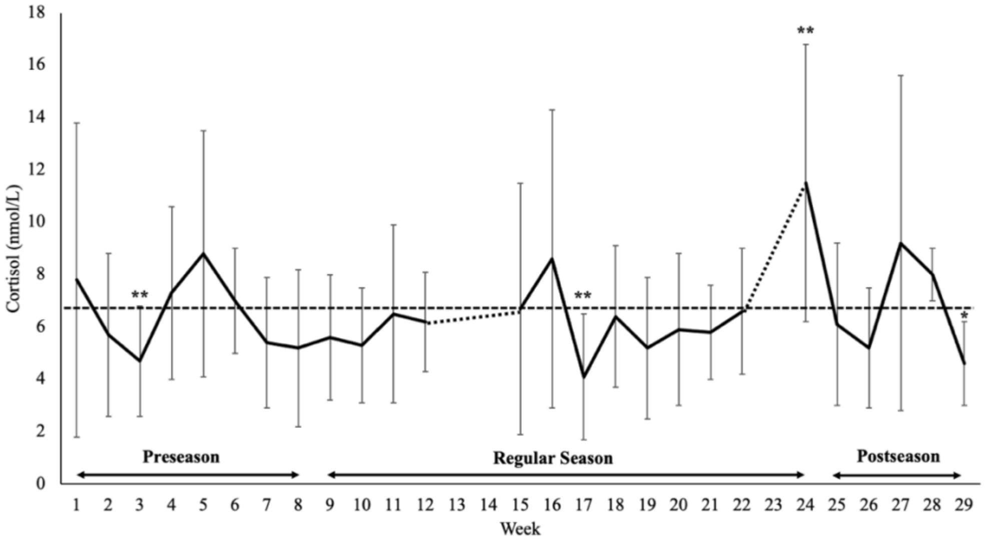

Figure 3. *Cortisol concentrations (x̄±SD). Dashed line represents season average for the team. Note: *p < .05; **p < .01.*

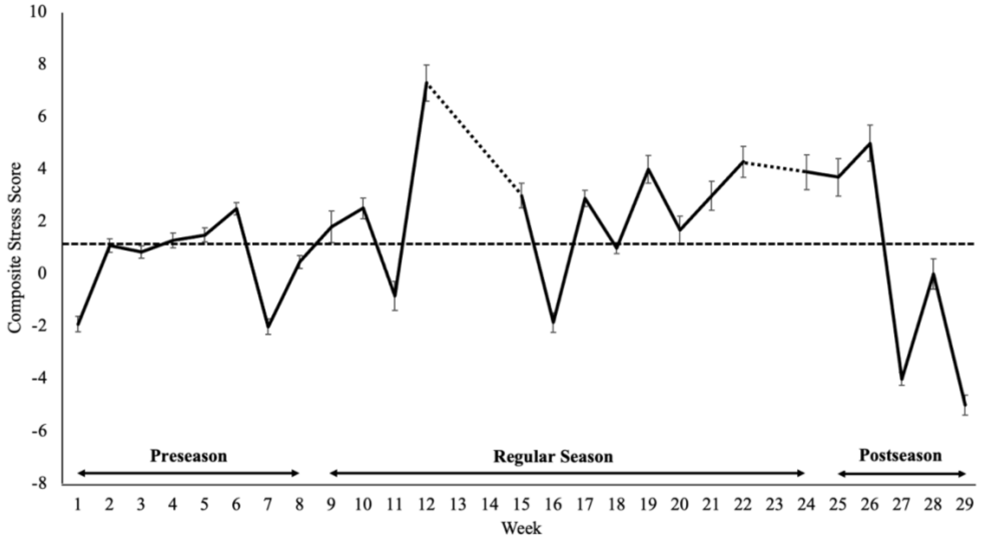

Figure 4. *Composite scores (x̄±SD). Dashed line represents season average for the team.*

DISCUSSION

The results of this study demonstrate that this was an appropriate method for monitoring fatigue management of elite female NCAA Division-I basketball athletes. Several interesting phenomena were observed. First, the return of T/C to the season average values by Week 7, the first week of exhibition play, demonstrated that the athletes were recovered from a stressful preseason training and prepared to start the competition period, beginning the following week. Identical findings were observed in male basketball athletes as significant increase in T/C was observed before the onset of regular competitive season [19]. During Week 6, there was an increase in COMP as a final effort to peak the athletes before the taper used to transition from preseason to the competition period. Specifically, the components of COMP that caused its significant decrease during Week 7 were resistance training volume and practice minutes, which were decreased below the season average; this may have led to the increase in T/C. This is consistent with studies observing male athletes [11,36] which saw T/C return to baseline or beyond after a taper. This is important because if off-season or preseason training is too stressful, then the athletes may not recover in time for competition or may simply not reap the benefits of the program.

The present study observed opposite results of Hoffman et al. [14] in that C was not elevated by the stressful preseason training camp while T dropped from a preseason high back to the season average during camp. Also, T/C significantly decreased during the training camp, while Hoffman et al. [14] observed changes in C, but not T or T/C. In contrast to the results of Schelling et al. [16] the athletes in the present study did not see an increase in T after a taper despite a return to the season average values for T/C. However, Schelling et al. [16] measured total T, while the present study measured free T. Therefore, it is possible that the difference may have been due to total versus free T, suggesting that they may respond differently to a taper in basketball athletes. It is also possible that the results obtained in the present study differed due to the biological sex of the athletes, timing of the taper, athlete type (professional vs. collegiate), or another factor.

During Week 16, which was collected the week after a holiday break, T/C was below the season average values despite a decrease in COMP. While the increase in C during Week 16 was not statistically significant due to team variation, the team average for C during that week was greater than one standard deviation above the season's mean, which may have caused the depressed ratio. While it may be assumed that student-athletes would be refreshed and recovered after a holiday break, it is also possible that the holidays caused more stress for the athletes. For example, one study [37] demonstrated that salivary C is impacted by perceived social standing and friendship networks, suggesting that an increase in C may occur during a period of time where student-athletes feel less connected or more socially pressured, depending on individual personality characteristics. While the current study did not evaluate these characteristics in our student-athletes, it is still possible that these characteristics were impacted by the holiday break and thus influenced C. Therefore, social stress should be taken into consideration when planning training and breaks for athletes. Use of the team psychologist or other stress-reduction and recovery methods during or immediately after the break may potentially benefit the student-athletes.

During Week 24, T/C dropped below the season average and corresponded with an increase in COMP due to increased competitions. This occurred during a three-game losing streak amid a string of important conference matchups, suggesting that important conference play may reduce T/C in elite female basketball athletes. Interestingly, while going through an identical three-game losing streak, no significant alterations in T/C were observed in male collegiate basketball players [19]. The discrepancy in the findings may be attributed to the time point when the losing streak occurred (mid-season vs. end of the season) as prolonged competitive demands could have caused greater physiological responses. During Week 27, which was collected immediately before the team's first match of the NCAA tournament, T/C was below the season average despite a decrease in COMP, suggesting an anticipatory effect. However, the athletes returned to the season average values during the tournament and remained at that level up to and beyond their fourth-round elimination, suggesting that they were physiologically prepared for postseason play. This is similar to the results of Schelling et al. [16], who found that T levels and T/C were significantly lower at the later collection dates, while C remained the same throughout the season. However, in the present study, C varied significantly throughout the season, although it did decrease below the season average within one week of the end of the postseason competition, suggesting that, while the competitive efforts of female NCAA Division-I basketball athletes may be stressful, they may recover quickly from the season. Additionally, the present study may have differed from Schelling and colleagues [16] because of the professional status of their athletes versus the student-athlete status of the athletes in the present study, suggesting that student-athletes may experience more variability in C than professional athletes.

While some may propose that a large decrease in T/C indicates a state of overtraining syndrome, Fry and colleagues [38] have demonstrated that T/C is not necessarily impacted despite onset of overtraining syndrome. Therefore, while changes in T/C may reflect acute fatigue-management, we cannot make statements about overtraining syndrome with this population by simply monitoring T/C. Still, it is advisable to monitor T/C, as it may reflect the health, recovery, preparedness, and physiological status of the athletes, independent from potential diagnoses of overtraining syndrome. Therefore, the potential for overtraining syndrome is not the only reason to perform a biomarker monitoring study, as coaches and scientists can use this information to evaluate the effectiveness of recovery strategies and fatigue management. Additionally, the general population may consider the effects of combined life stressors on hormonal status and attempt to reduce lifestyle stress for the purpose of improving the ratio of anabolic to catabolic hormones, thereby potentially improving health.

The methods of the present study, specifically the frequency of athlete monitoring, may explain some of the differences between this study and others [14,16] which observed hormones in elite basketball athletes. The present study observed T, C, and T/C weekly, from preseason to after postseason, while the other studies [14,16] observed only a few time-points. Hoffman and colleagues [14] observed hormonal levels four times during a four-week off-season training camp. While this was similar to the present study in that it was weekly observations, it only accounted for off-season training and not the stressors of the regular season or postseason play [14]. Schelling et al. [16] observed eight time-points throughout an eight-month period, stating that collections were taken every 4-6 weeks. Had they [16] monitored their athletes weekly, they may have seen more variation in C. Therefore, studies attempting to monitor hormonal changes in elite basketball players should plan to use weekly collections to get a broader view of variation across a season.

Another important aspect of the present study was the COMP. This is not a currently validated measure for assessing student-athlete stress. Rather, it is a novel approach used to attempt to identify changes in cumulative stress throughout an entire season in elite female NCAA Division-I basketball athletes. Previous research has found that academic anxiety was one of the main predictors for student-athlete stress, especially for students with lower academic grades as a threat for loss of eligibility to compete based on NCAA regulations [39]. Also, fatigue resulting from high athletic and academic demands and scheduling issues were additional stressors reported in a student-athlete population [40]. Thus, this measure appears to be appropriate, as changes in COMP appeared to correspond to changes in T/C. Future research could use the measure described in the present study to monitor elite basketball players throughout an entire season span.

Last but not least, other interesting phenomenon involved monitoring the menstrual cycle. A non-significant negative correlation was observed between T and the presence of menses, suggesting the possibility that during weeks where more players were menstruating, T was at its lowest, and vice-versa. Had the correlation achieved statistical significance, it would have been consistent with research demonstrating that T will typically drop to its lowest point during menstruation in healthy non-athlete females [28]. It is possible that this correlation would have been different if each individual's menstrual cycle had been more closely monitored by a physician who was trained to interpret and diagnose irregular cycles, as this may have affected the data with this population. Future studies should attempt to address this component in more detail, as well as consider the implications of fluctuations in T during the menstrual cycle for both athletes and the general population. Additionally, while the use of oral contraceptives was unknown and presented one of the limitations of this investigation, Edwards and O'Neal [41] suggested that salivary T responses to soccer, volleyball, and softball competition were not statistically different between athletes using oral contraception and those who were not. Similar findings emerge from one of the recently published studies indicating that physiological responses to strength exercise, including steroid hormones, were not affected by oral contraceptive usage [42]. Another limitation of the present investigation involves inability of the authors to monitor illness and/or medication consumption that could potentially alter the salivary hormonal concentrations. Future studies should attempt to collect basic performance data (i.e., vertical jump height) after each specimen collection, to see if changes in performance variables relate to changes in salivary hormones, in addition to more detailed professional monitoring of the menstrual cycle.

Conclusion

The findings of the present study indicate that monitoring T, C, and T/C throughout an entire season demonstrated as an appropriate method for monitoring fatigue management of elite female NCAA Division-I basketball athletes. Strength and conditioning practitioners and sport specific coaches should be aware of the in-season and postseason stressors of elite collegiate basketball and should adjust training to allow for optimal recovery. The methods of this study can be used for monitoring fatigue management by assessing how athletes adapt to stressful preseason training and whether or not they recover in time for regular season play, in addition to how the athletes handle the stressors of the competitive season. For example, strength and conditioning practitioners working with elite basketball athletes and the team basketball coaches should consider working together to increase resistance training volume and practice minutes during the preseason, but also leave enough time for reduced resistance training volume and practice minutes to effectively create a taper into the competitive period. Using data to determine the correct length and volume of the peak-taper may be valuable for different teams. Attempting to monitor fatigue management is worthwhile, as changes in T/C may not only affect/reflect performance but may also affect/reflect athlete health and student-athlete academic performance.

Conflict Of Interest

The authors declare no conflict of interests.

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