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Sleep and Physical Performance: A Case Study of Collegiate Women's Division 1 Basketball Players

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Abstract— **In this work, we present a case study to evaluate the connections between sleep, training load, and the perceptions of physical/emotional state of a collegiate, division 1 Women's basketball team. The study took place during the off- (3 weeks) and pre-season (6 weeks) while sleep was tracked using WHOOP wearable straps. Training load was recorded by the strength coach and athletes. Short Recovery and Short Stress (SRSS) questionnaire was used to evaluate the perceptions of athletes on their own emotional and physical states. Our results showed that heart rate measurements are associated with stress levels and recovery perception. We also discovered that the training load was not linked to the sleep variables without the considerations of athletic performance. However, training load may alter perceived stress and recovery which requires further exploration.**

I. Introduction

Sleep is an essential component in the daily performance and quality of human activity [1]. It has been shown that there is a positive correlation between sleep efficiency and mental/physical health or performance [2] [3]. Specifically, daily performance components such as physical exertion, cognitive alertness, and memorization are heavily influenced by sleep quality [4]. Physiological factors such as heart rate (HR) and heart rate variability (HRV) have been used to establish a numerical measure to further understand how sleep influences performance [5]. The length of the Rapid Eye Movement (REM) sleep stage and the resting heart rate during REM have been connected to improved performance [6].

Increased cultural concern for maximizing physical health and performance has cultivated an abundance of technology and studies that measure sleep variables in relation to physical performance [7]. Wearable devices such as the Fitbit, Apple Watch, WHOOP strap and "Moov Now" measure sleep variables and positively influence sleeping behaviors in individuals [8]. These devices have been utilized to investigate ways to optimize health and performance levels [9]. For example, in 2020, a research team at Columbia University utilized the WHOOP strap to measure the HRV and recovery of collegiate athletes with concussions, where a correlation between HRV and the recovery of concussed players was established [10].

During an athlete's training, searching for a balance between recovery and exercise cycles has revealed that sleep and recovery have a strong impact on strength, aerobic power, joint-flexibility, and overall performance (i.e., cognitive, emotional, and physical) [1] [2]. Furthermore, it was found that recovery is the key component in being able to maximize physical performance and prevent overtraining [11]. Recovery techniques such as massages, sleep, and contrast water therapy are effective ways to decrease risk of peripheral and central fatigue [12] [13]. In the case of collegiate athletes, researchers focused on understanding various lifestyle determinants such as school load, sleep schedule, social tendencies, and physical requirements and how they impact physical health and performance as well as overall life quality [14] [15].

In our study, division 1 Women's basketball (WBB) players were analyzed for their sleep, training load, and subjective recovery/stress scores. Studies have found that aerobic exertion, elevation abilities (jumping and leg strength), explosive strength, and stamina are the most reflective measures of the prime physical characteristics in basketball players [16] [17]. Adaptations to athletics training protocols are multifactorial due to many inputs from both training stress, outside stressors, individual genetic factors, and recovery abilities. Because of this complex relationship, coaches are searching for a balance between training stress and recovery. Therefore, the purpose of this study was to examine the associations between sleep, training load, and subjective perception of stress and recovery in female basketball players.

II. Methodology & Protocol

A. Subjects

16 division-1 WBB players (Age: 20.5±1.2yrs, Height:

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172.4±4.4cm, Body Mass: 74.4±0.6kg) from Sacred Heart University were recruited to participate in this study. A longitudinal repeated measures design was employed for nine collection weeks. Prior to collection, informed consent was obtained based on the approved IRB (Institutional Review Board) approval number 170720A.

B. *Sleep Monitoring*

WHOOP straps (WHOOP, Boston, MA, USA) were utilized to track the athletes' sleep and recovery patterns, which have been validated by third parties as a sleep and activity monitoring device based on heart rate [7]. The digital platform WHOOP divides these measurements into three main categories: (1) Strain: A quantified scale number between 0 and 21 based on cardiovascular strain and exertion measurements through heart rate [18], (2) Sleep: Sleep score is generated by using RHR, HRV (via the root mean square of successive differences between heartbeats, RMSSD), and other sleep quantification measurements detailed in [18], (3) Recovery: A percentage value that is calculated from four main physiological markers; HRV, HR, sleep, and respiratory rate. This category combines all the data received from exercise and sleep tracking to determine an athlete's recovery.

C. *Short Recovery and Short Stress Questionnaire (SRSS survey)*

Twice a week, the SRSS questionnaire was administered to the athletes via TeamBuildr (an online strength and conditioning software, Landover, MD). This survey obtains subjective data on physical, mental, emotional, and overall recovery. The survey consists of eight questions (4 stress & 4 recovery) where athletes rank their current recovery and stress on a Likert scale from 0 to 6. The stress questions evaluate: Muscular Stress (MS); Lack of Activation (LA); Negative Emotional State (NES); and Overall Stress (OS). The recovery questions are: Physical Performance Capabilities (PPC); Mental Performance Capabilities (MPC); Emotional Balance (EB); and Overall Recovery (OR).

D. *Quantification of Training Load*

Training load was monitored by obtaining the time and intensity of sport specific training, metabolic conditioning, and resistance training. For each session completed by the athletes a calculation of session rating of perceived exertion was collected by multiplying time in practice by the subjective rating of perceived effort. The total score of each individual session was combined weekly to form a Total Training Load (TTL) score that is a traditional training load quantification metric.

E. *Data Collection Period*

The data collection period began during the final three weeks of offseason training and continued through a six-week preseason training schedule. During this time the athletes wore the WHOOP straps continuously during the collection period allowing for consistent monitoring of data throughout the day.

F. *Statistical Analysis*

The analysis was carried out using the following Python libraries: Pandas, scipy, and numpy (data manipulation), statsmodels (statistical tests), and Seaborn (visualization). Data was collected from two data sources: a daily WHOOP strap data and a bi-weekly SRSS questionnaire, during the nine weeks. We calculated the average of all variables per week of both data sources.

III. RESULTS AND DISCUSSION

The variables that represent the data are summarized in Table 1. While subjective recovery is in the higher band of the spectrum indicating better recovery (3.92 out of 6.0; higher the more recovery perception), subjective stress is relatively high (2.32 out of 6.0; lower the less stress perception). We must also note that the standard deviation for both SRSS averages is quite wide, hinting diverse emotional and perceived recovery states. WHOOP strap data exhibits close RHR values but a significantly wide HRV variation (HRV = 83.37 ms, σ = 36.34 ms) among athletes, suggesting diverse recovery conditions, which can also be seen from the recovery data and amount of sleep they got on average. Individual TTL data, which is the indication of their training load, aligns more closely with team averages. This is due to the fact that strength coaches do not truly adjust the training based on the recovery of the athletes.

TABLE I. THE MEAN AND STANDARD DEVIATION OF THE SURVEY AND SLEEEP FOR THE WBB TEAM.

	Variables	$\bar{x}$	σ
Demographics	Age	20.5	1.20
	Height (cm)	174.2	4.49
	Body Mass (kg)	74.43	0.61
SRSS data	Overall Recovery	3.92	1.20
	Overall Stress	2.32	1.43
WHOOP strap data	RHR (bpm)	59.64	8.26
	HRV (ms)	83.87	36.34
	Recovery	57.8	15.20
	Hours of Sleep (hrs)	6.68	0.92
Training data	TTL	2364.51	152.01

Although average values in Table 1 give an overall view of the athletes' physical conditioning, each week provides a different perspective. Therefore, we provided weekly values of TTL, hours of sleep, and recovery in Table 2. TTL values increased significantly in week 3, which represents the transition from off- to pre-season where the training hours doubled. Although TTL was increasing in week 4, there was a setback in week 5 due to COVID regulations and coaches were more conservative once the team came back from a 1-week hiatus. Overall, hours of sleep did not significantly change but the standard deviation in weeks 6-8 (like week 2) were much higher perhaps due to the difference in coming back to practices from shutdown. Recovery values increased towards the end of the pre-season due to competitive game preparation, hence tapering the training as can be observed in TTL.

Fig. 1 shows the overall Stress (Short Stress OS) and Recovery (Short Rec OR) scores from the questionnaire for each week as the team average. This data represents the athletes' stress level and physical recovery from their perspective. Lower stress values indicate less perceived stress whereas lower recovery values are connected with inadequate recovery perception. There was no data collection in week 5 due to COVID-19 quarantine requirements. We can notice that students are in general reporting being more stressed and overall struggling with the physical recovery in the following two weeks of the quarantine week. Getting closer to the end of the pre-season, athletes reported being less stressed and have high physical recovery overall. Stress and recovery values have quite a wide distribution in week 2, which can be associated with different start dates of joining the team and adjusting periods to off-season practices.

TABLE II. WEEKLY MEAN AND STANDARD DEVIATION VALUES FOR MAIN PARAMETERS: TTL, HOURS OF SLEEP AND RECOVERY FOR THE WBB TEAM.

	TTL ($\bar{x}, \sigma$)	**Hours of Sleep ($\bar{x}, \sigma$)**	**Recovery ($\bar{x}, \sigma$)**
Week 1	754, 253	6.8, 0.7	57, 22
Week 2	711, 254	6.8, 1.3	59, 13
Week 3	2228, 277	6.4, 0.7	60, 16
Week 4	4192, 209	6.7, 0.8	53, 14
Week 5	N/A	6.4, 0.7	65, 13
Week 6	3431, 107	6.6, 1.3	56, 15
Week 7	3828, 104	6.4, 1.0	55, 15
Week 8	3362, 85	6.9, 1.0	58, 14
Week 9	2774, 78	6.9, 0.7	70, 15

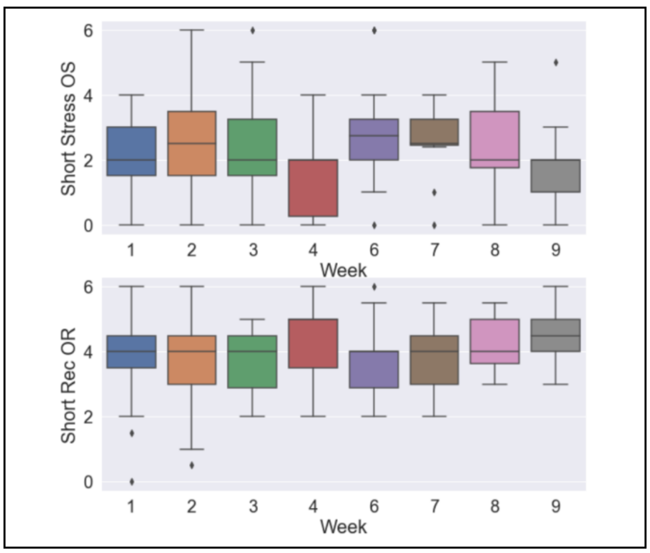

Figure 1. Short Recovery Short Stress survey was averaged for the team per week (2 surveys/athlete). Scores for the overall short recovery and short stress were combined to give a general overview.

Fig. 2 shows the weekly progression in terms of athlete recovery (obtained from WHOOP straps) and training loads. TTL data was added as the blue bar-plot in the background for each WHOOP parameter to visually investigate how these trainings in general affected the athletes' sleep pattern and their biometric measurements. Overall, sleep need was higher when more training resistance and volume training are done during the week while HRV are lower.

When examining the correlation matrix (Fig. 3), there is a moderate negative correlation between RHR and HRV measurements. Furthermore, there is a positive moderate association between perceived stress and increases in heart rate. Because heart rate is used in the HRV calculation, this association is to be expected [19]. Interestingly, when the RHR increases, the overall stress scores, muscular stress, lack of activation, and the negative emotional state increase while the physical performance capability, the mental performance capability and the emotional balance decrease. It is possible that outside stressors such as academic pressure or perceived stress of training may alter this relationship.

Overall, as the hours of sleep increase, the stress level reported by the athletes decreased and the recovery increased. This is reflective of previous studies, which showed sleep strategies that increased sleep duration improved performance [20]. Comparing the WHOOP strap data to the training measurements, we can notice that the sleep need increased with higher training while the HRV decrease. Previous investigations have shown similar decreases in HRV in response to both training volumes and intensities [21] [22]. As training stresses the athletes, variations in both the sympathetic and parasympathetic systems may manifest themselves in changes in RHR and HRV.

When examined together, athlete's weekly surveys and TTL scores show that as training volume increases recovery measurement tend to stay consistent on average whereas stress values show more variation. While team average data is valuable, there is a large spread of responses around the mean as observed in Fig. 1. It is important to consider individual responses to training and recovery. For example, in weeks two and eight, recovery measurements are clustered compared to stress measurements which showed greater variability.

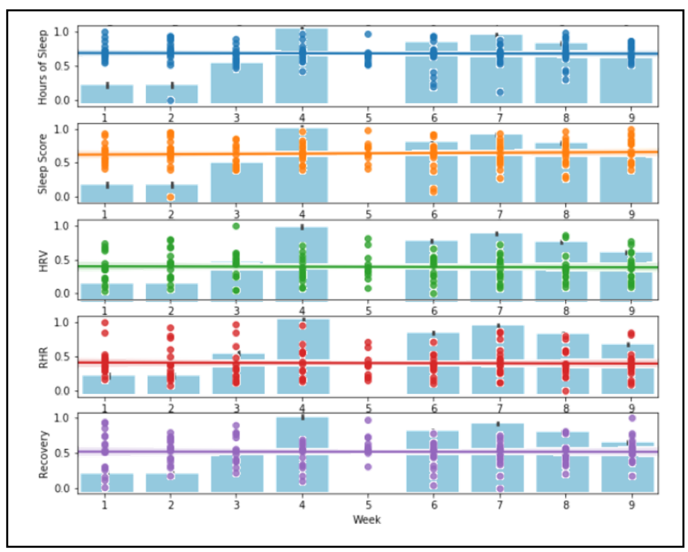

Figure 2. WHOOP strap data was averaged for the entire team for each week. The straight line in each subplot shows the average values over the entire 9 weeks. The blue bar-plot in the background is a representation of the TTL training measurement in average per week.

IV. CONCLUSION

This study examined the interactions of sleep, stress, and training in division 1 female basketball players. The major findings from this study are that: (1) RHR is negatively associated with HRV and moderately associated with perceived stress levels; (2) HRV is moderately associated with recovery; (3) the sleep score was positively associated with hours of sleep and negatively associated with sleep need; and (4) TTL scores were not associated with sleep variables in this study and had weak associations with whoop recovery metric. However, total training volume may alter perceived stress and recovery which should be explored further to elucidate this relationship.

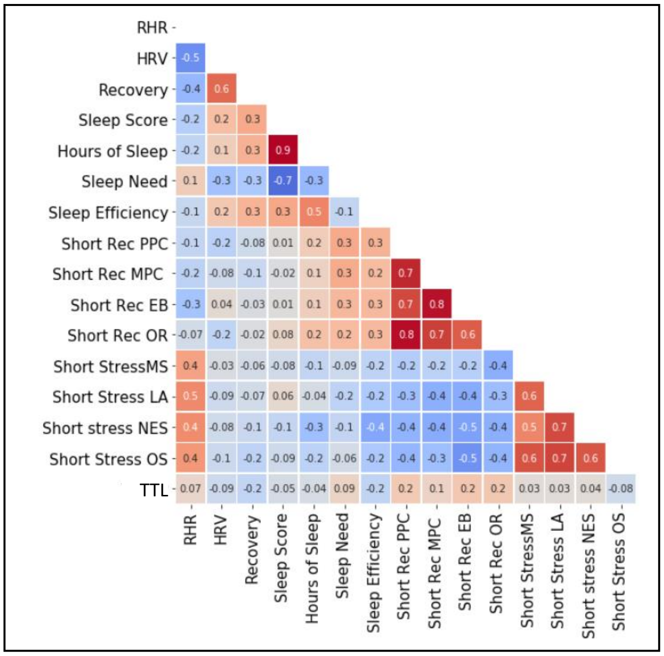

Figure 3. Heat map correlation matrix of all parameters from the WHOOP, training data, and the SRSS for 9 weeks.

Emphasis should be placed on education of sleep practices during times of increased training to help promote recovery. Future research should attempt to further quantify the complex relationship between training, stress, and sleep performance in athletes with the hopes of ultimately linking the training protocol to athletic and academic performance.

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