Monitoring Heart Rate Variability and Its Association with High-Intensity Running, Psychometric Status, and Training Load in Elite Female Soccer Players during Match Weeks

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Abstract: In order to maximize adaptations to reach high performance, sports coaches must regularly monitor the healing process following competitions or important training sessions and maintain psychometric status. As a result, the objective of this study was to track heart rate variability (HRV) in elite Spanish female soccer players during match weeks and examine its connection to high-intensity running, psychometric status, and training load. Changes in the nocturnal HRV measured along the square root of differences between adjacent RR intervals of 4 h (rMSSD 4 h) during the first phase of slow wave sleep (rMSSD 5 min), resting heart rate (RHR 4 h and RHR 5 min) were recorded with Firstbeat Bodyguard 2 (Firstbeat Technologies, Jyvaskyla, Finland). Training and match loads were recorded with rating perceived exertion and high-intensity running data by using a global positioning system (GPS) device (SPI-Pro X, GPSports). Ultimately, the psychometric test was recorded by a 5-item questionnaire, and all data were analyzed across three weeks of a competitive season. The day of the match found the lowest HRV, while the day following the match found a substantial (p < 0.01) rise in rMSSD 4 h and rMSSD 5 min. Similarly, these variables showed significant differences two days after the match. Furthermore, significant differences were found between the RHR 4 h and RHR 5 min (p < 0.01) and rMSSD 4 h and rMSSD 5 min (p < 0.05) and variables after two days with a higher training load. The results gathered from the psychometric tests, and the various HR markers showed significant associations. As a result, HRV, RHR, and psychometric assessments are probably sensitive to changes in load within a microcycle, providing a straightforward and non-invasive technique to assess changes in the recovery/fatigue status of top-level female soccer players.

Keywords: GPS; heart rate; high-speed running; physical stressors; parasympathetic nervous system; recovery; sleep

1. Introduction

The introduction of micro-technology into the team sports setting, such as wearable inertial measurement units and electronic performance tracking systems, has increased the number of ways that practitioners can monitor and analyze training load using various external load metrics such as total distance covered, distance covered in different speed zones, accelerations, decelerations, or as well as internal load such as heart rate variability (HRV) [1]. In this decade, the use of various match/training analysis techniques has increased following their association with fatigue management and rapid recovery strategies [2]. This knowledge is very important in team sports such as soccer, which are
Changes in the HRV are of considerable interest to researchers studying the influence of competition load on athletes [6,7], who note the predominance of the sympathetic nervous system immediately following [6] and up to two days after competition [7]. Accordingly, D’Ascenzi et al. [8] have shown that the HRV decreases prior to a major competition within a sample of elite volleyball players. Additionally, Ayuso-Moreno et al. [11] recently found that HRV differed significantly between the HRV traits of the lost and winning matches. These results demonstrate the significance and usefulness of evaluating HRV as a gauge of post-competitive fatigue in semiprofessional female soccer players [11].

However, of the studies cited above, only the report by Bricout et al. [6] conducted nocturnal heart rate (HR) recordings. Thus, it will be of interest to further investigate heart activity during this time. Sleep is likely the most suitable condition for recording the characteristics of the HRV due to the lack of external stimuli, which may alter the results [6,12,13]. On the other hand, the high-intensity running (HIR) distance variable has been shown to be a possible indicator of accumulated fatigue over several matches [14]. Furthermore, this variable has been shown to correlate with psychometric tests and HRV data in male soccer players [15]. Therefore, the different values of this index recorded during competitive games could be related to changes in the autonomous nervous system (ANS) or the results of the psychometric tests conducted after competitions as indicators of accumulated fatigue.

HRV represents the change in the time interval between successive heartbeats and has become a strong focus of sports science research. This is due to the fact that HRV provides an index of the parasympathetic nervous system. Among the variables in determining HRV, it is very important for studies and interesting that assess the root of the mean square of successive differences (rMSSD) because it shows reflects vagal tone. High frequency and low frequency are frequently used to measure HRV, and they have inverse functional relationships with each other [16]. The fraction of consecutive normal sinus RR intervals longer than 50 ms (pNN50) is connected with rMSSD and high-frequency power and is thus thought to reflect vagal tone. As a result, there are two variables that are capable of detecting changes. However, rMSSD usually provides a better assessment of vagal tone and is usually recommended over the pNN50. Finally, the most generally used time domain measure of HRV is the standard deviation of all normal to normal R-R (NN) intervals (SDNN), which is the standard deviation of all normal RR (NN) intervals over a 24 h period. The change in NN intervals between day and night accounts for a significant portion of the SDNN magnitude (about 30–40%) [17].

To our knowledge, there is a lack of research in relation to the changes in the ANS over several weeks of competition in elite female soccer players by considering the variables listed above. Additionally, most of the aforementioned studies cited only analyzed a single week or isolated days and were thus possibly too decontextualized. Therefore, the objectives of this study were to (i) analyze changes in the nocturnal HR-derived indices during three microcycles of competition and (ii) observe the relationship with other variables (e.g., HIR, psychometric tests, and training load) to study the value of these measures in interpreting the recovery condition of athletes.

2. Materials and Methods
2.1. Participants

A total of 8 female soccer players (23.8 ± 4.5 years, 56.9 ± 6.8 kg, 1.6 ± 0.4 m, 21.2 ± 3.7 body fat %) belonging to the same team in the Spanish First Division soc-
cer league composed this part of the study. Among them, one was unable to complete the study due to injuries. All players underwent a physical examination by the club’s medical team and were free of any illness that could alter results or interfere with exercise. Based on previous studies highlighted large to very large correlations between HRV and its association with high-intensity running and wellness status in athletes [18–21]. Therefore, we followed a priori correlation (point biserial model) analysis to calculate sample size power with the following information: $\alpha$ err prob = 0.05, power ($\beta$ err prob) = 0.80. The result was that seven participants would be required to achieve 82.2% actual power. For the calculation of sample power, G*Power software was used (University of Düsseldorf, Düsseldorf, Germany). Recommendations and controls were performed in the following order [22]: (i) players were advised to have a normal night’s sleep before the tests; (ii) players were advised not to exercise vigorously the day before the test days; (iii) players were advised not to eat and drink coffee or caffeinated drinks such as energizing drinks at least 2 h before the assessments; (iv) players were advised not to drink alcohol or smoke at least 24 h before the assessments. While the study players did not have habitual behavior in this case; (v) participants were told to refrain from consuming depressants or oral contraceptive intake during the study. The time when data were collected was maintained constant at the same time of the day [22]. In addition, all of the participants provided informed written consent forms and participated in this study voluntarily. This study was completed according to the Declaration of Helsinki and adhered to the proposed ethical guidelines of the International Journal of Sport Management. This study was approved by the ethical committee of Castilla-La Mancha University.

### 2.2. Study Design

Three independent microcycles were analyzed with a similar previously estimated training load. The training microcycle is visible in Table 1. In each microcycle, the monitoring steps were as follows, always at the same time: (i) the tonic HRV was analyzed over five nights in the time domain [22], including the night of the match (Sunday), the following day (Post 1-Monday), two days after (Post 2-Tuesday), four days after (Post 4-Thursday), and the day before (Pre 1-Saturday) the next match. Recordings were performed with Firstbeat Bodyguard 2 (Firstbeat Technologies, Jyvaskyla, Finland technology); (ii) in all training sessions of the match weeks, HIR external load monitoring was performed by SPI-Pro X, GPSports (Canberra, Australia); (iii) internal load monitoring was performed by Borg questionnaire 0–10 points and thirty minutes after each training session or match, and (iv) players’ well-being status or psychometric test was monitored by the 5-point, the questionnaire rated their fatigue, sleep quality, general muscle soreness, stress levels, and mood every morning after measuring HRV.

#### Table 1. Structure of the three microcycles.

<table>
<thead>
<tr>
<th>Sunday</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rec. T</td>
<td>F. Games (L. I)</td>
<td>F. Games</td>
<td>R. Games</td>
<td>R. Strg</td>
<td>Exp. Strg</td>
<td>F. Games</td>
<td>Flex</td>
</tr>
<tr>
<td>Match</td>
<td>Prop</td>
<td>×</td>
<td>Tra</td>
<td>DB</td>
<td>C</td>
<td>Tra. M.</td>
<td>Match</td>
</tr>
<tr>
<td>Flex</td>
<td>Drills</td>
<td></td>
<td></td>
<td>Transitions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prop = Proprioception, F. Games = F. Games, R. Games = Reduced Games, R. Strg = Resistance Strength, Exp. Strg = Explosive Strength, Rec. T = Recovery Training, Tra = Training, × = the day without training (rest day), Flex = Flexibility, C = Completion, DB = Dead ball, Tra. M. = Training match, L. I = Low intensity.

For the data collection, we have followed the advice from Berna et al. [23]. So, the training sessions were performed at 20:00 h, and the matches were performed at 12:00 h. A total of 27 data points were collected after competitive games, with 27 data points per day and for a total of 135 recordings. Although the relationship between the menstrual cycle and the ANS is not clear [24–26], this was controlled menstrual stage was controlled in this study by completing a written form [8]. We had scheduled to perform all of the research...
tests at the beginning or mid-follicular phase based on the information from completing the above form [27]. Therefore, we could not include all the players in the study.

2.3. Instruments and Outcomes

2.3.1. Heart Rate Variability Measurements

Recordings HRV parameters were performed with Firstbeat Bodyguard 2 (Firstbeat Technologies, Jyvaskyla, Finland). When the participants were to sleep, they placed the device in the chest, which was connected through two electrodes that guaranteed the correct recording of the data. Firstly, the skin was carefully cleaned before attaching the electrodes. Subsequently, we attached the disposable electrodes to the Bodyguard device. One of the electrodes was placed on the right side of the body, just below the collarbone, as well as the main part of the Bodyguard. The wire was attached at the end of the Bodyguard to the left side of the body below the heart (on the rib cage), where was placed the other electrode. The reliability of the Firstbeat Bodyguard 2 has been previously tested by other studies [28,29], reporting accurate data for HRV analysis during rest and exercise. We considered more than 100 ms for the length of the data segment. The measurement accuracy for heart rate recording is 1 ms (1000 Hz). Then, the data were downloaded to the Firstbeat Sports Team (v. 4.4) software and exported to Kubios HRV v 2.2 software (University of Eastern Finland, Kuopio, Finland) for analysis, which allows removing ectopic beats between RR indexes. Later, Visual inspection was used to select the channel with better ECG RAW signal quality for every subject. An automatic R-peak detection algorithm contained in the HRV tool was applied to the selected channel. This approach reduces the quantization error caused by a low ECG sampling rate [30]. Arrhythmias (ectopic beats) were identified by using an algorithm for heart timing signals and excluded from the final statistical evaluation and comparison.

The data were analyzed according to two different methodologies. The first consisted of an analysis lasting four hours, which started half an hour after the athletes went to sleep [18,31,32]. The second method included the analysis of the first stable five-minute period (i.e., tonic or baseline HRV, and is when HRV is taken at one time point) within the first phase of slow wave sleep (SWS) over a segment with a duration of at least 15 min [19,33–35]. Recordings were analyzed only when the measurement error was ≤3% [13]. The spectral analysis technique was used to extract the high-frequency power (0.15–0.40 Hz) that reflects the modulation of the vagal tone. Finally, we extracted the data from the Excel database for their inclusion in SPSS software.

To detect this phase of sleep, the method proposed by Brandenberger, Buchheit, Ehrhart, Simon, and Piquard [33] was applied. Subsequently, the data were analyzed according to previously described methods [36]. To interpret the results, the root mean square of the successive differences of RR intervals (rMSSD) was analyzed. The resting heart rate (RHR) was calculated as the mean of the time period analyzed.

Regarding preprocessing, according to Aranda [31], the filter system provided by the Kubios software to remove artifacts is suitable for analyzing HRV index values. However, we have considered several considerations for this process in this study. We removed artifacts, including aberrant beats and arrhythmic events, by manually checking aberrant beats. In addition, slow changes in mean HR during recording can have adverse effects on some parameters of HRV analysis. For this reason, we removed non-stationary slow trends from the HRV time series before analysis.

2.3.2. High-Intensity Running Measurement

The data for distance covered at the velocity of HIR (>15 km·h⁻¹) [14,37] was recorded using a 15 Hz global positioning system (GPS) device (76 g; 48 mm × 20 mm × 87 mm; SPI-Pro X, GPSports, Canberra, Australia). The validity of these devices has been tested previously [38–40] due to the use of these instruments [41]. The subjects carried the same GPS device during different recordings. The data recorded by each of the GPS units were analyzed using software from the same company (Team AMS; GPSports, R1 2014.3). The players were familiar with the use of this technology because they had previously used it.
2.3.3. Training Load

The training load of sessions was estimated using the Borg CR-10 rating of perceived exertion (RPE) scale [20,42,43]. This was calculated by applying RPE at approximately 30 min after each training session or match and multiplying the result obtained by the training time to reach an RPE session (sRPE) [40]. Players were previously familiarized with the scale during two years at the club. This instrument includes values from 0 (no effort perceived) to 10 (maximum effort perceived). The accuracy of this procedure to the purpose described has been proved in soccer tasks [44].

2.3.4. Psychometric Test

Each day upon waking and after measuring the HR, players completed a psychometric 5-item questionnaire designed by McLean et al. [4], questioning player fatigue, sleep quality, general muscle soreness, stress level, and mood using a 1–5 Likert style scale. A lower response indicated a worse state (i.e., greater fatigue, poorer sleep quality, greater muscle soreness, increased stress level, or decreased mood). The overall well-being score was calculated by adding the values of each of the five boxes [4].

2.3.5. Body Fat Assessment

Body fat percentage was analyzed by bioimpedance (Inbody 230, Biospace Co. Ltd., Seoul, South Korea). Participants were previously warned not to eat or drink anything for 2 h before the measurement, which occurred on the Wednesday morning of the week before microcycle analysis.

2.4. Statistical Analysis

All analyses were performed using SPSS (v. 21 for Mac) software. The normal distribution of the data was verified using the Shapiro–Wilk test. To analyze the differences between each day, a repeated measures ANOVA test was used, along with a Bonferroni adjustment for pairwise comparisons. The significance level was set at \( p < 0.05 \). The thresholds for the values found were defined as [45] 0 to 0.30, small; 0.31 to 0.49, moderate; 0.50 to 0.69, large; 0.70 to 0.89, very large; and 0.90 to 1.00, almost perfect. Pearson correlation analysis has performed between HRV parameters with HIR, TL, and psychometric status with a confidence interval at 95% level (CI 95%). The data are presented as means ± standard deviations.

3. Results

The combined three-week analysis of the HRV, RHR, psychometric tests, and physical load are shown in Table 2 and Figure 1.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Match</th>
<th>Post 1</th>
<th>Post 2</th>
<th>Post 4</th>
<th>Pre 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHR 4 h (bpm)</td>
<td>60.51 ± 5.39</td>
<td>56.45 ± 4.54 **</td>
<td>55.74 ± 4.97 **</td>
<td>59.16 ± 7.35</td>
<td>57.05 ± 5.18</td>
</tr>
<tr>
<td>RHR 5 min (bpm)</td>
<td>62.45 ± 6.30</td>
<td>55.92 ± 5.20 **</td>
<td>56.56 ± 5.420 **</td>
<td>60.57 ± 9.36</td>
<td>58.23 ± 7.46</td>
</tr>
<tr>
<td>rMSSD 4 h (ms)</td>
<td>64.74 ± 20.64</td>
<td>82.11 ± 24.19 **</td>
<td>83.49 ± 31.37 *</td>
<td>65.56 ± 20.12</td>
<td>77.88 ± 29.22</td>
</tr>
<tr>
<td>rMSSD 5 min (ms)</td>
<td>41.51 ± 17.83</td>
<td>59.92 ± 20.79 **</td>
<td>53.77 ± 16.22 *</td>
<td>43.75 ± 15.29</td>
<td>56.28 ± 27.95</td>
</tr>
</tbody>
</table>

Note. ** \( p < 0.01 \) compared to the match. * \( p < 0.05 \) compared to the match.

The changes in the physical load and the results of the psychometric test, as well as the variables rMSSD 5 min and rMSSD 4 h for each week, are shown in Figure 2. The RHR indices (4 h and 5 min) during the three weeks are shown in Figure 3.
Figure 1. Changes in the results of psychometric tests and the physical load recorded across three microcycles ** difference (p < 0.01) with the other days; # difference (p < 0.05) with Post 2. a Difference (p < 0.01) with the other days. b Difference (p < 0.05) with the other days except with "b". AU: arbitrary units.

Figure 2. Changes in the load, psychometric test, rMSSD 5 min, and rMSSD 4 h across the three weeks studied. The circles represent the match days. * p < 0.05 or ** p < 0.01 compared to the previous day. a p < 0.05 or b p < 0.01 compared to the two previous days; AU: arbitrary units.
Figure 2. Changes in the load, psychometric test, rMSSD 5 min, and rMSSD 4 h across the three weeks studied. The circles represent the match days. * \(p < 0.05\) or ** \(p < 0.01\) compared to the previous day. \(^a\) \(p < 0.05\) or \(^b\) \(p < 0.01\) compared to the two previous days; AU: arbitrary units.

Figure 3. Changes in the RHR during the three weeks of the study. The circles represent the match days. * \(p < 0.05\) or ** \(p < 0.01\) compared to the previous day. \(^a\) \(p < 0.05\) or \(^b\) \(p < 0.01\) compared to the two previous days; BPM: beats per minute.

The distance covered at HIR for the first match was 1169.3 ± 303.5 m, followed by 899.2 ± 24.3 m, and 1422.7 ± 95.4 m for the last match.

In the correlations between HRV parameters with HIR, TL, and psychometric status presented in Table 3, the most important correlation between parameters was: rMSSD in 4 h (r = 0.93; CI 95% [0.65 to 0.99]; \(p \leq 0.001\)) is largely related to RHR in 4 h. In addition, rMSSD in 5 min (r = 0.86; CI 95% [0.40 to 0.98]; \(p = 0.01\)) is largely related to RHR in 5 min. Additionally, SDNN is largely related to RHR in 5 min (r = 0.85; CI 95% [0.38 to 0.97]; \(p = 0.01\)) and rMSSD in 5 min (r = 0.87 large; CI 95% [0.44 to 0.98]; \(p \leq 0.001\)).

Table 3. Correlation analysis between HRV parameters with high-intensity running, psychometric status, and training load in elite female soccer players.

<table>
<thead>
<tr>
<th>Variables (r)</th>
<th>(\beta_0)</th>
<th>(p)</th>
<th>(\beta_1)</th>
<th>(p)</th>
<th>(\beta_2)</th>
<th>(p)</th>
<th>(\beta_3)</th>
<th>(p)</th>
<th>(\beta_4)</th>
<th>(p)</th>
<th>(\beta_5)</th>
<th>(p)</th>
<th>(\beta_6)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHR 4 h ((\beta_0))</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RHR 5 min ((\beta_1))</td>
<td>−0.03</td>
<td>0.95</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rMSSD 4 h ((\beta_2))</td>
<td>0.93</td>
<td>(\leq 0.001^*)</td>
<td>−0.03</td>
<td>0.95</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rMSSD 5 min ((\beta_3))</td>
<td>−0.34</td>
<td>0.41</td>
<td>0.86</td>
<td>0.01^*</td>
<td>−0.37</td>
<td>0.37</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SDNN ((\beta_4))</td>
<td>−0.04</td>
<td>0.92</td>
<td>0.85</td>
<td>0.01^*</td>
<td>0.05</td>
<td>0.91</td>
<td>0.87</td>
<td>(\leq 0.001^*)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIR ((\beta_5))</td>
<td>0.40</td>
<td>0.33</td>
<td>0.21</td>
<td>0.62</td>
<td>0.32</td>
<td>0.43</td>
<td>−0.22</td>
<td>0.60</td>
<td>−0.18</td>
<td>0.67</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TL ((\beta_6))</td>
<td>−0.42</td>
<td>0.30</td>
<td>0.07</td>
<td>0.88</td>
<td>−0.30</td>
<td>0.47</td>
<td>0.43</td>
<td>0.29</td>
<td>0.44</td>
<td>0.28</td>
<td>(−0.75)</td>
<td>(0.03^*)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Psychometric ((\beta_7))</td>
<td>−0.75</td>
<td>0.03^*</td>
<td>0.04</td>
<td>0.93</td>
<td>(−0.74)</td>
<td>0.03^*</td>
<td>0.46</td>
<td>0.25</td>
<td>0.20</td>
<td>0.64</td>
<td>(−0.74)</td>
<td>0.04^*</td>
<td>0.53</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Abbreviations: rMSSD: the square root of differences between adjacent RR intervals; RHR: resting heart rate; SDNN: standard deviation of all normal to normal R-R (NN) intervals; HIR: high-intensity running; TL: training load; significant differences are highlighted in bold with \(^*\) at \(p \leq 0.05\) level.

Psychometric status is largely related to RHR in 4 h (r = −0.75; CI 95% [−0.96 to −0.01]; \(p = 0.03\)), rMSSD in 4 h (r = −0.75; CI 95% [−0.95 to −0.08]; \(p = 0.03\)) and HIR (r = −0.74; CI 95% [−0.95 to −0.07]; \(p = 0.04\)), respectively. TL was largely related to HIR (r = −0.75 large; CI 95% [−0.95 to −0.09]; \(p = 0.03\)).

4. Discussion

To our knowledge, this is the first study that analyzes the changes in the ANS among elite female soccer players over several weeks of competition using GPS data and other variables to investigate the athlete’s fitness. The main findings of this study are the decreased
values of the nocturnal HRV on the night of the competition and after two days with increased training load, accompanied by an increase in the RHR, producing a reduction in parasympathetic activity in elite female soccer players. In addition, the correlations show that the HRV, RHR, and psychometric tests may be sensitive to changes in the physical state of elite soccer players. The psychometric status showed a large correlation with RHR 4 h, rMSSD 4 h, HIR, and training load.

After exercise, parasympathetic activity can decrease [6,7,18,46,47] compared to a day of rest [6], recovering to baseline levels over the following days [7]. This may indicate the ideal time to initiate training [48] and may explain the significantly high RHR values after a match. Additionally, taking into consideration the existing relationship between the rMSSD indices and the parasympathetic nervous system [13], the lower values observed after competition than those found after the process of recovery can be explained. The fact that this increase in HRV was accompanied by a significant increase in the score of the psychometric test might indicate the recovery of the athletes after matches. In line with these results, it has been reported that HRV and rMSSD (they are often regulated by cardiac vagal tone) have emerged as a useful measure for assessing recovery condition, as it provides an indirect assessment of the balance between the sympathetic and parasympathetic neural systems [11,21]. On the other hand, cardiac vagal tone, which represents the parasympathetic nervous system’s contribution to cardiac control performance (i.e., SDNN and rMSSD), has been connected to a variety of psychometric statuses, including mood, sleep, and stress [22].

Changes in the ANS are directly related to the intensity of physical exercise [48]. In sports such as soccer, with a high number of matches, it may be interesting to study the influence of different matches with distinct loads on the physical state of the athletes. Edmonds, Sinclair, and Leicht [7] observed that competition significantly reduces the HRV (high frequency) values for a time period of up to two days. The individualized analysis conducted during each week suggests that recovery of the ANS after a soccer game can vary from week to week, demonstrating the need to analyze these variables continuously during the season. This will allow the adjustment of loads within each microcycle from the outset according to the individuals’ conditions.

Similarly, upon analyzing the three weeks of training and competition together, this study has shown a significant decline in the HRV and an increase in the RHR indices after two days of training compared to a day of rest. Although it has been previously shown [6] that a training load would not be sufficient to significantly change the HRV levels, it has been suggested [48] that after low loads, recovery of the ANS could occur within the first 24 h. Given this information and observing that the greatest training load corresponded to Wednesday and Thursday, these two sessions together, and perhaps an inadequate recovery between them [35], could have caused the decline in the HRV and increase in the RHR.

Likewise, the day before the match, we expected the HRV to decrease as a result of precompetitive stress [8,9]. The failure to find this result could have occurred because this was a day of rest, which may permit restoration of the HRV levels [6] and compensated for the effect of precompetitive stress. Thus, it is essential to consider the context of measurements when interpreting changes.

As previously demonstrated, psychometric tests could be sensitive to changes in daily training load [5] and HIR distance [15]. Therefore, the correlations between the test and the HR-derived indices recorded in this study could indicate the utility of these two measurements. When analyzed together, these measures could serve as a tool with great potential for sports technicians. In this study, after two high-load games (measured both by the distance covered at HIR and the sRPE method), significant changes were found in the ANS, with the greatest increase in HRV during recovery days. This may show the utility of these two variables in terms of predicting possible changes in parasympathetic activity during the days following matches. Nevertheless, fatigue throughout the matches is not only dependent on the distance covered but also influenced by factors such as mental fatigue, the field, winning or losing, and the level of the opponent [49]. The data reported
here may reflect this and could explain the fact that significant correlations with the HIR variable were not found.

Finally, although analysis of the HR during SWS has been proposed as the most stable index for the analysis of HRV [6,19,33], variables in this study were sensitive to changes during the week, which may be due to adequate sleep patterns [50] or the quality of sleep [51]. Perhaps the combined analysis of the HR during 4 h and SWS can provide more complete information, thus warning technicians of changes in the sleep patterns of athletes in cases in which the ratios derived from a four-hour analysis begin to differ from those analyzed during the first phase of SWS.

The study contained some limitations that are mentioned here in order. One of the limitations of the present study was the small number of participants. We recommend that researchers conduct such a study with more participants in the future. When the number of participants is more, we recommend that the researchers consider the differences between the positions of the players as well as the effect of the results of the matches on the study variables. Another limitation of the present study was the short duration of the monitoring period of the participants, which we recommend researchers conduct in the future during one season of competition. We recommended to use of more variables; the cardiac effort is important but not sufficient in this type of study. It would be better in this context to analyze more physical effort parameters such as respiratory rate or muscle fatigue; therefore, we strongly suggest that researchers consider this point as well for future studies.

Conclusions

We can conclude that analysis of the nocturnal HRV is sensitive to changes produced during different weeks of competition in elite women soccer players, demonstrating recovery of the HRV and RHR values for at least two days following matches. However, it is necessary to conduct an individualized and contextualized analysis after each match because the demands of each match could affect the extent of changes observed in the ANS. Furthermore, the correlations of the HRV and RHR with data obtained from psychometric tests indicate that the analysis of the nocturnal HR (four-hour and SWS) together with a simple psychometric test can be a combined tool with great potential for analyzing the physical state of athletes. Therefore, HRV, RHR, and psychometric tests are likely sensitive to load changes within a microcycle showing a simple and non-invasive tool to analyze changes in the recovery/fatigue status of elite female soccer players.

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