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Influence of Menstrual Phase and Symptoms on Sleep Before and After Matches for Professional Footballers

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ABSTRACT

This study investigated the association of menstrual cycle phase and symptoms with objective and subjective sleep measures from professional footballers before and after matches. Twenty-three non-hormonal contraceptive-using professional footballers (from four clubs) were monitored for up to four menstrual cycles during a domestic league season. Menstrual phases (menstruation, mid-late follicular, luteal) were determined using calendar counting and urinary hormone tests (luteinizing hormone and pregnandiol-3-glucuronide). Players rated the severity of 18 symptoms on the evenings of matches and the following two evenings. Individual daily summed menstrual symptom severity (MSS) scores were calculated. Subjective sleep quality was rated the morning of matches and the following two mornings. Objective sleep (bedtime, waketime, total sleep time [TST], sleep onset latency, wake after sleep onset, sleep efficiency) obtained from actigraphy was measured the night prior to (MN−1), of (MN), and following (MN+1) matches. Linear mixed models were performed for each sleep measure to examine the effects of menstrual phase and symptoms. Bedtime was significantly later for MN ($p < 0.001$), waketime was significantly earlier for MN+1 ($p < 0.001$), and TST was significantly longer for MN−1 ($p < 0.001$). Menstrual phase did not have a significant effect on any sleep variable ($p > 0.05$). Increased MSS score was associated with increased TST ($p = 0.03$) and increased waketime ($p = 0.03$). Increased lower back pain severity and mood changes/anxiety severity were associated with increased waketime ($p = 0.048$) and TST ($p = 0.009$), respectively. Overall, bedtime and waketime were affected by the night related to matches, with increased TST the night before a match. Menstrual phase was not related to any objective or subjective sleep variables, whilst increasing menstrual symptom severity was related to later waketime and longer TST.

1 | Introduction

To optimize football performance, sufficient volume and quality of sleep is considered an important part of preparation and recovery for training and competition [1]. As such, understanding factors influencing players' sleep duration, quality, and behavior is essential, particularly around matches where athlete sleep is disrupted [2]. However, compared to male athlete sleep research, female athlete research is scarce, with only 25% of studies reporting female-specific sleep data [3]. As such, understanding the influence of female-specific factors, such as the menstrual cycle (MC), which may negatively impact sleep, is limited [3]. Indeed, the MC, which involves endogenous sex hormone fluctuations that primarily control reproductive function [4], may affect sleep patterns, behaviors, and perceptions [3], though this is yet to be explored in football players as related to match days. The influence of the MC on sleep may be related to phase-based hormonal fluctuations [5], as well as the presence of menstrual symptoms, like headaches and abdominal cramps [5]. Given disrupted sleep can affect performance [1], understanding whether menstrual phase and symptoms affect footballers' sleep may assist in the implementation of sleep monitoring and player management strategies to optimize performance and post-match recovery.

The effect of menstrual phase on sleep in relation to hormonal variations is complex. Theoretically, estrogen and progesterone fluctuations may influence sleep due to the locations of their receptors throughout the central nervous system in areas of sleep modulation [5]. Evidence of objective sleep responses across menstrual phases shows conflicting results [5], though subjective sleep quality is frequently reported to be disturbed during and prior to menstruation [5]. In athlete-specific studies, objective sleep measures, total sleep time, and sleep efficiency are demonstrated to vary between menstrual phases [6, 7]. Additionally, professional footballers subjective sleep quality was unaffected by menstrual phase on match day and the following three days [8]. Of note, these studies [6–8] used calendar-based counting to estimate menstrual phase, which cannot accurately determine phase and increases the likelihood of including participants with subtle menstrual disturbances and heterogenous hormonal profiles [9]. Research with more robust menstrual phase measures is required to better understand the association between menstrual phase and sleep for footballers, particularly around matches where optimizing sleep is critical to performance and recovery.

Sleep disturbance is common amongst women with menstrual symptoms, particularly women with menstrual dysfunction such as premenstrual syndrome [5]. Between 24% and 100% of athletes are reported to experience negative menstrual symptoms [10]; however, little is known about their effect on athlete sleep. Amongst professional footballers, sleep duration and wake after sleep onset increased with increasing number of symptoms, though the number of symptoms had no relationship with subjective sleep [11]. In contrast, a cross-sectional study of athletes trained to international level found increasing menstrual symptom frequency was associated with decreased subjective sleep quality and unfavorable sleep behavior [12]. Whilst these studies demonstrate variable effects of menstrual symptoms on athlete sleep, the effect of menstrual symptoms on athlete sleep around competition has not been examined, which is arguably the most important time for sleep given the likelihood for impaired sleep is highest due to match loads and schedules [1, 2]. Given the high prevalence of menstrual symptoms and the importance of sleep to athletic performance and recovery, further studies are required to confirm these findings.

The aims of this study were to explore whether there is an association between football players' objective and subjective sleep around matches and (i) menstrual phase and (ii) menstrual symptoms. A secondary aim was to examine the influence of each night (night before, of, and following matches) to understand changes in footballers' sleep around matches.

2 | Methods

2.1 | Participants

Female footballers from four clubs in a professional national domestic league were invited to participate in the study. Initial stipulation of the exclusion criteria involved pregnancy, using hormonal contraceptives or having used hormonal contraceptives in the previous 3 months, average MC in the previous 3 months < 21 or > 35 days, and being diagnosed with any illness or disease that disrupts the MC (e.g., polycystic ovary syndrome) [9]. Following this, 32 players consented to participate and completed an online questionnaire regarding the exclusion criteria to confirm eligibility. Nine players were excluded or withdrew prior to commencing any sleep measures (irregular cycles and/or cycle lengths > 35 days [n = 3], season-long injuries [n = 2], personal reasons [n = 4]), resulting in 23 players data being included in the study (23.9 ± 6.0 y, 167.9 ± 6.5 cm, 65.1 ± 8.9 kg). Ethical approval was provided by the Institutional Human Research Ethics Committee (ETH22-7106), and written informed consent was provided by all players, including parents for those aged 16 and 17 years.

2.2 | Overview

Menstrual cycle and sleep data were collected from 23 professional football players during their 2022/23 season. Participants were asked to track their MC via urinary hormonal testing and self-reporting menses, monitor menstrual symptoms via a questionnaire, and record objective sleep via actigraphy. This study was part of a larger study that monitored participants for up to four MCs, measuring several performance and recovery-related factors on match day and the following 2 days, including subjective sleep quality. Of note, mean kick-off time was 3:30 pm ± 1 h 15 min, range 1:00–7:00 pm. To minimize participant burden and maximize compliance, participants were asked to track their objective sleep concurrent to MC monitoring for up to two MCs.

2.3 | Menstrual Phase Classification

Following completion of the exclusion criteria questionnaire and confirmation of a 21–35 day MC, participants were set up on Smartabase (Fusion Sport, Brisbane, Australia) to report days of menstruation. To estimate menstrual phase and reduce the risk of including anovulatory cycles/heterogeneous hormonal profiles, participants were provided with urinary luteinizing hormone (LH) and pregnanediol-3-glucorinide (PdG) test kits, with written and video instructions. The lead researcher calculated all LH and PdG test start dates as per the manufacturer's instructions and communicated dates to participants via WhatsApp (Facebook Inc). The LH (Clearblue Ovulation Digital Test kits, Geneva, Switzerland) tests are 99% effective at detecting a surge in LH (> 40 mLU mL^{-1}) [13], which predicts ovulation within 24–48 h of a positive test [14]. Participants were instructed to test daily at approximately the same time until a positive test was obtained or until 10 consecutive days without a positive test. If participants did not receive a positive test after 10 days, the researcher assessed whether additional testing days were beneficial (e.g., for longer cycles) or instructed participants to stop testing. Participants with a positive LH test were asked to complete PdG tests (Confirm Kit, Proov, USA) to confirm an increase in PdG > 5 Ug/mL, which correlates to serum progesterone [15]. Participants were instructed to start testing 7 days after a positive LH surge for four consecutive mornings. The MC was classified into three phases [16]:

- Menstruation phase (MP): days of menstruation or until day 5 of each cycle (whichever was longer), when > 2 days of bleeding occurred, regardless of LH and PdG test results as this represents the low hormone phase.
- Mid-late follicular phase (FP): from the day after MP until 1 day after a positive LH test, only if a positive LH test was received.
- Luteal phase (LP): from the day after FP until the day prior to the next cycle starting, when positive LH and PdG tests were detected, and the LP was ≥ 10 day [17].

Verification and further subclassification of menstrual phases require confirmation of hormone concentrations via blood samples [9], however, this was not possible in the current study due to participants training and competing across multiple states and countries.

2.4 | Menstrual Symptoms Severity

On the evening of match days and the following two evenings, participants completed a daily menstrual symptoms severity questionnaire. The questionnaire consisted of 18 menstrual- related symptoms rated on a Likert scale; 0—none, 1—mild, 2—moderate, 3—severe. A daily menstrual symptom severity score was calculated by summing the severity of all symptoms, resulting in a score between 0 (no symptoms) and 54 (maximal daily presence and severity of symptoms). The daily summed score was used in the analysis as the summed *Menstrual Symptom Severity score* (*MSS score*). The questionnaire was adapted from the Menstrual Symptoms Index [18], which assesses symptom frequency and has previously been used with exercising women, though as yet it is not psychometrically validated. Additionally, the six most reported symptoms from this study were then used for analysis of individual symptom severity effects within mixed model analyses.

2.5 | Sleep

Objective sleep parameters were measured through actigraphy using the Actigraph GT9X Link. The Actigraph GT9X Link is a valid alternative to polysomnography, which is the gold standard sleep measurement, with a demonstrated accuracy of 89% and sensitivity of 94%, although a lower specificity of 57%, when using the Cole-Kripke algorithm for analysis [19]. Actigraphy is a practical sleep measurement that detects movement and uses an algorithm to determine sleep/wake schedules [20]. The actigraphs were set up with the following participant details: height (cm), body mass (kg), date of birth, and non-dominant wrist. The sampling frequency and epochs were set at 60 Hz and 60 s, respectively. Participants were instructed to wear the watch on their non-dominant wrist, from approximately 1 h prior to bedtime to after waking in the morning for three consecutive nights starting from the night prior to their team's match. Participants also had one night of familiarization prior to the first night of monitoring. To assist in determining sleep onset and waketimes, concurrent to wearing the actigraph, participants were asked the following based on the Consensus Sleep Diary [21], which accurately assesses sleep timings [22]:

1. What time did you try to go to sleep?
2. How long did it take you to fall asleep?
3. What time was your final awakening?

Team travel dates were obtained from club staff members to account for time-zone differences when calculating bedtime and wakeup time, as the actigraphs do not account for this. Additionally, subjective sleep quality was measured by a single question, "How was your sleep last night?" rated on a 7-point Likert scale from 1 “Outstanding sleep” to 7 "Horrible, virtually no sleep" based on the Hooper Index questionnaire [23], which participants were completing as part of the larger study. Participants answered these on Smartabase as part of their morning monitoring questionnaire on match day and the following two mornings.

Actigraph data was analyzed using ActiLife (Florida, USA). The following sleep variables were obtained from the actigraphs and sleep questions [19, 24]:

- Bedtime (hh:mm): the self-reported clock time at which a participant went to bed to attempt to sleep.
- Waketime (hh:mm): the self-reported clock time at which a participant woke up and stopped attempting to sleep.
- Sleep onset latency (SOL; min): the period between bedtime and sleep onset time.
- Total sleep time (TST; h min): the total amount of sleep obtained during a sleep period.
- Sleep efficiency (SE; %): the percentage of time in bed that was spent asleep.
- WAKE after sleep onset (WASO; min): the total amount of time spent awake during a sleep period.

2.6 | Squad Selection

Each team invited to participate in the study consisted of a minimum of 23 players; however, only 16 players were selected in each match day squad. Therefore, participants were categorized as “in squad” or "not in squad" for each match. This was recorded due to known effects of match and training schedules on sleep [25, 26].

2.7 | Data Management

Sleep data exported from ActiLife was aligned with the MC and sleep quality data in an Excel spreadsheet. Nighttime sleep was aligned with the following morning's sleep quality data and evening menstrual symptoms data and labeled as match night (MN), i.e., MN−1 (sleep the night before matches), MN (sleep the night of matches), and MN+1 (sleep the night after match day). A minimum of one recorded sleep in at least two menstrual phases (MP, FP, LP) for two or more of the nights (MN−1, MN, MN+1) was required to be included in the menstrual phase models. A minimum of two recorded sleeps aligned with menstrual symptoms data for two or more of the nights (MN−1, MN, MN+1) was required to be included in the menstrual symptom models.

2.8 | Statistical Analysis

All analyses were completed in R Statistical Software (R Core Team 2020). Respective linear mixed-effect models were performed to determine the association of *menstrual phase* (MP, FP, LP) and *MSS score* with the sleep variables. Linear mixed models are unable to handle missing predictor variable data; thus, separate models were created for *menstrual phase* and *MSS score* as the fixed effect due to final dataset differences. Additionally, analyses for the six most prevalent individual symptom severities - tiredness/fatigue, mood changes/anxiety, cravings/increased appetite, lower back pain, bloating/increased gas, and joint pain - in association with the sleep variables were performed (symptom severities as fixed effects), separate from the *menstrual phase* and *MSS score* models. To examine the influence of *night* (MN−1, MN, MN+1) on sleep variables, it was included as a fixed effect in all models whilst *participant ID* was included as a random effect due to repeated within-participant observations [27]. To control for the effect of *squad selection*, it was included in each model. The interaction effect of *squad selection***night* was of interest; however, due to the limited number of observations, this interaction effect was not possible. The Bonferroni Holm correction was applied to the *p*-values obtained for the main effect of *night* on all sleep variables to control for multiple testing (*night* included in both menstrual phase and menstrual symptom models). For the phase models, posthoc pairwise comparisons were performed using estimated marginal means (emmeans package) and Tukey's adjustment for *menstrual phase* and *night*, with the difference in estimated marginal means between pairs reported, e.g., MP—FP (reported as delta differenceΔ). To avoid repeated testing of *night*, post hoc pairwise comparisons were not performed for the symptom models. The assumptions of homogeneity and normality of residuals were assessed using residuals vs. fitted plots and QQ plots respectively. Of note, SOL demonstrated heteroskedasticity and was log-transformed to improve model fit, with estimates back-transformed. Significance was set at $p < 0.05$. Marginal and conditional R^2 were calculated to explain the proportion of variance explained by the fixed effects and the whole model, respectively.

3 | Results

A total of 210 from a possible 379 sleep periods (55%) were recorded via actigraphy from 21 participants. After aligning data that met the inclusion criteria, included in the final objective sleep parameters analyses were 107 menstrual phase observations (MP = 20, FP = 47, LP = 40) from 9 participants and 145 menstrual symptoms observations from 20 participants. The subjective sleep quality data from the larger scale study resulted in 318 menstrual phase observations (MP = 78, FP = 131, LP = 109) from 15 participants and 379 menstrual symptoms observations from 23 participants. Of note, two participants reported 37–38 day cycles, though they reported positive LH and PdG tests for all cycles; therefore, their data were retained.

3.1 | Menstrual Phase Models

The main effects from the menstrual phase models are reported in Table 1, Figure 1, and Table S1. Sleep variables did not significantly differ between menstrual phases ($p > 0.05$). Bedtime, waketime, and TST significantly differed between nights ($p < 0.001$). Pairwise comparisons for menstrual phase and night for all sleep variables are reported in Table 2. Bedtime was significantly later for MN compared to MN−1 (Δ 01:27; $p < 0.001$) and MN+1 (Δ = 01:17; $p < 0.001$). Waketime was significantly earlier for MN+1 compared to MN− 1 (Δ = 00:56; $p < 0.001$) and MN (Δ = 00:58; $p < 0.001$). Significantly longer TST was reported for MN−1 compared to MN (Δ = 01:21; $p < 0.001$) and MN+1 (Δ = 00:57; $p < 0.001$).

3.2 | Menstrual Symptoms

From the 379 menstrual symptoms observations from 23 participants, a total of 1479 symptoms were reported, of which 69% were rated as 1 (mild), 26% as 2 (moderate), and 5% as 3 (severe). The median number of symptoms per player per day was 3 out of 18 (interquartile range [IQR] 1–6), and the median MSS score was 4 out of 54 (IQR 1–7). The main effects for the menstrual symptom models are reported in Table 3 and Figure 2. For every 1 unit increase in MSS score, TST increased by 3.1 min ($p = 0.03$), representing longer sleep duration, and waketime increased by 3.2 min ($p = 0.03$), representing a later waketime. Bedtime ($p < 0.0001$), waketime ($p = 0.0002$), and

TABLE 1 | Model outputs for objective and subjective measures of sleep as related to menstrual phase and night.

Sleep measures	Menstrual phase (*p*)	Night (*p*)	R^2m; R^2c
Bedtime (hh:mm)	0.71	< 0.0001*	0.29; 0.30
Waketime (hh:mm)	0.49	< 0.0001*	0.17; 0.22
Total sleep time (hh:mm)	0.35	< 0.0001*	0.24; 0.43
Sleep onset latency (min)	0.47	0.34	0.05; 0.24
Wake after sleep onset (min)	0.52	0.48	0.03; 0.49
Sleep efficiency (%)	0.29	0.34	0.03; 0.63
Sleep quality (au)	0.55	0.37	0.01; 0.19

Abbreviations: au, arbitrary units; R^2c, conditional R^2; R^2m, marginal R^2.
*Indicates significant association ($p < 0.05$) between menstrual phase or night and the sleep measure.

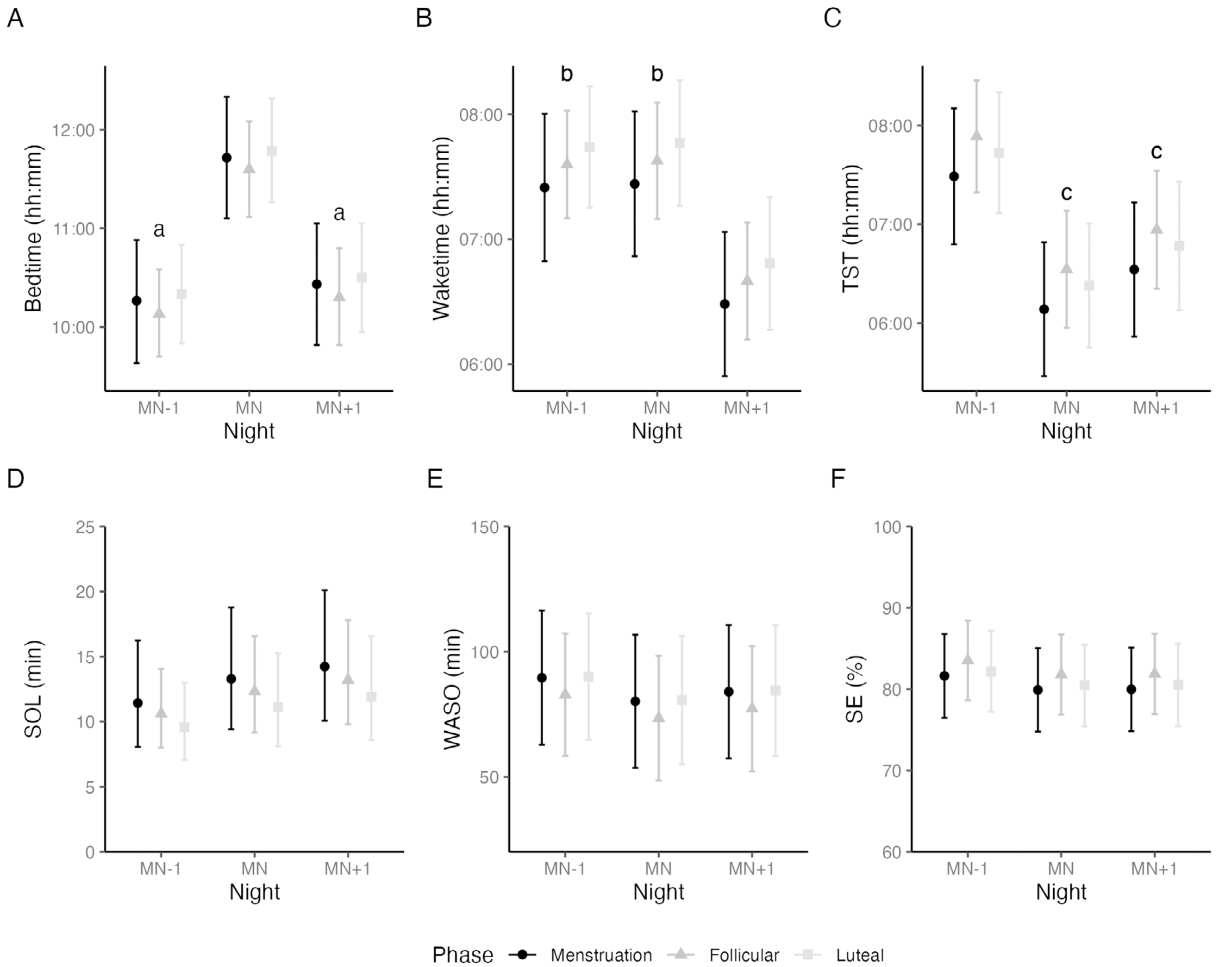

FIGURE 1 | Objective sleep measures as determined by menstrual phase and night for (A) bedtime, (B) waketime, (C) TST, (D) SOL, (E) WASO, and (F) SE. Results are estimated marginal effects and 95% confidence intervals. TST, total sleep time; SOL, sleep onset latency; WASO, wake after sleep onset; SE, sleep efficiency. [a]significantly different from MN; [b]significantly different from MN+1; [c]significantly different from MN−1.

TST ($p=0.001$) significantly differed between nights. The six most prevalent menstrual symptoms reported were (1) tiredness/fatigue, (2) mood changes/anxiety, (3) cravings/increased appetite, (4) lower back pain, (5) bloating/increased gas, and (6) joint pain. Holding other individual symptom severity variables constant, waketime was increased with increased lower back pain severity ($p=0.048$, coefficient = 21.1 min). Additionally, TST was increased with increased mood changes/anxiety severity ($p=0.009$, coefficient = 32.8 min). Bedtime, SOL, WASO, SE, and sleep quality were not significantly associated with symptom severities ($p>0.05$).

4 | Discussion

This study examined the relationship between menstrual phase and symptoms with the objective and subjective sleep of professional footballers on nights around matches. As expected, the night related to the match had a significant effect on bedtime, waketime, and TST, resulting in longer TST the night before a match (MN−1). Menstrual phase (MP, FP, LP) was not related to any objective sleep variables or subjective sleep quality the nights prior (MN−1), of (MN), or the following (MN+1) the match. Increasing MSS score and lower back pain severity was associated with later waketime, whilst increasing MSS score and mood/anxiety changes severity was associated with longer sleep durations (TST). Overall, this study highlights that female footballers' sleep is influenced by matches more so than menstrual phase, though monitoring menstrual symptoms may improve understanding of players' sleep.

To provide initial context, and as supported by the current literature [2, 25, 26], the night of sleep related to matches had a significant effect on the timings of sleep (bedtime and waketime) and sleep duration (TST), though no relationship was evident with other objective sleep measures or subjective sleep quality. Bedtime was ~1 h 20 min later for MN than MN−1 and MN+1. This was likely an effect of evening matches as well as the high physical and cognitive loads encountered during matches [26, 28], though it's acknowledged match kickoff times and measures of load were not included in the models. That said, not all players were part of the match day squad, and previous research shows they may also have reduced sleep quality and volume on match nights [29]. Waketime was ~1 h earlier for MN+1 than

TABLE 2 | Results of pairwise comparisons between nights and menstrual phases.

Sleep measures	Δ EMM (95% CI)	*p*
Bedtime (min)		
MN−1—MN	−87 (−122, −53)	< 0.0001*
MN−1—MN+1	−10 (−46, 26)	0.78
MN—MN+1	77 (39, 115)	< 0.0001*
Menstruation—follicular	7 (−36, 51)	0.95
Menstruation—luteal	−4 (−48, 40)	0.97
Follicular—luteal	−12 (−46, 23)	0.73
Waketime (min)		
MN−1—MN	−2 (−34, 30)	0.99
MN−1—MN+1	56 (23, 79)	0.0003*
MN—MN+1	58 (23, 93)	0.0004*
Menstruation—follicular	−11 (−51, 29)	0.79
Menstruation—luteal	−20 (−60, 21)	0.49
Follicular—luteal	−8 (−40, 23)	0.80
Total sleep time (min)		
MN−1—MN	81 (49, 113)	< 0.0001*
MN−1—MN+1	57 (23, 90)	0.0003*
MN—MN+1	−24 (59, 11)	0.23
Menstruation—follicular	−24 (−64, 16)	0.34
Menstruation—luteal	−14 (−56, 27)	0.69
Follicular—luteal	10 (−22, 42)	0.74
Sleep onset latency (min)		
MN−1—MN	−2 (−5, 2)	0.44
MN−1—MN+1	−3 (−6, 1)	0.23
MN—MN+1	−1 (−5, 3)	0.86
Menstruation—follicular	1 (−4, 6)	0.88
Menstruation—luteal	2 (−3, 7)	0.52
Follicular—luteal	1 (−2, 5)	0.67
Wake after sleep onset (min)		
MN−1—MN	9 (−7, 26)	0.36
MN−1—MN+1	6 (−11, 23)	0.71
MN—MN+1	−4 (−22, 14)	0.86
Menstruation—follicular	7 (−14, 28)	0.72
Menstruation—luteal	−0.5 (−22, 21)	1.0
Follicular—luteal	−7 (−24, 9)	0.54
Sleep efficiency (%)		
MN−1—MN	2 (−1, 4)	0.25
MN−1—MN+1	2 (−1, 4)	0.31
MN—MN+1	−0.1 (−3, 3)	1.0
Menstruation—follicular	−2 (−5, 1)	0.36
Menstruation—luteal	−1 (−4, 3)	0.92
Follicular—luteal	1 (−1, 4)	0.43
Sleep quality (au)		
MN−1—MN	−0.2 (−0.5, 0.1)	0.36
MN−1—MN+1	−0.2 (−0.6, 0.1)	0.28
MN—MN+1	−0.02 (−0.4, 0.3)	0.98
Menstruation—follicular	0.01 (−0.4, 0.4)	1.0
Menstruation—luteal	−0.1 (−0.5, 0.3)	0.7
Follicular—luteal	−0.1 (−0.5, 0.2)	0.6

(Continues)

TABLE 2 | (Continued)

Abbreviations: ΔEMM, difference in estimated marginal means between pairs; au, arbitrary units; CI, confidence interval; MN+1, night following a match; MN, night of match; MN−1, night prior to match.
*Indicates significant difference ($p < 0.05$) between pairs.

MN−1 and MN, which likely demonstrates an effect of morning training schedules [25] reported by clubs, although they were not specifically recorded or included in the models. Finally, TST was highest for MN−1, being 1 h 21 min and 57 min greater than MN and MN+1, respectively, highlighting the effect that later bedtimes after a match (MN) and earlier waketimes for training (MN+1) have on TST. Similar results are reported in other football codes [26] and may reflect players' attempting to maximize sleep on nights prior to matches to enhance performance. The match-imposed sleep disruptions resulted in less than the recommended sleep duration (< 7 h) on match nights, which is commonly reported the night after competition [26], due to late matches, physical arousal and mental stimulation from match play, post-match press, and social commitments [2] and may negatively affect recovery [28].

In the present study, objective and subjective sleep did not differ between menstrual phases (MP, FP, LP) the night prior to, the night of, and the night following matches. Research on the influence of menstrual phase on sleep has primarily been conducted with the general population, whereby conflicting changes in objective sleep are reported, though subjective sleep quality is reportedly worse around menstruation [5]. Our results concur with those of an English professional football club

TABLE 3 | Model outputs for objective and subjective measures of sleep as related to menstrual symptoms and night.

	Menstrual symptoms		Night	
Sleep measures	***p***	**Coefficient (95% CI)**	***p***	**R^2m; R^2c**
Bedtime (hh:mm)	0.44	−1.11 (−3.93, 1.68)	<0.0001*	0.17; 0.30
Waketime (hh:mm)	0.03*	3.19 (0.48, 5.89)	0.0002*	0.15; 0.30
Total sleep time (hh:mm)	0.03*	3.10 (0.4, 5.8)	0.001*	0.13; 0.19
Sleep onset latency (min)	0.87	−0.002 (−0.02, 0.02)[a]	0.99	0.001; 0.20
Wake after sleep onset (min)	0.51	0.46 (−0.89, 1.81)	0.83	0.01; 0.33
Sleep efficiency (%)	0.91	−0.02 (−0.27, 0.25)	0.40	0.01; 0.40
Sleep quality (au)	0.26	−0.02 (−0.04, 0.01)	0.40	0.01; 0.29

Abbreviations: Au, arbitrary units; CI, confidence interval; R^2c, conditional R^2; R^2m, marginal R^2.
[a]Estimates are on the log scale.
*Indicates significant association ($p<0.05$) between menstrual symptoms or night and the sleep measure.

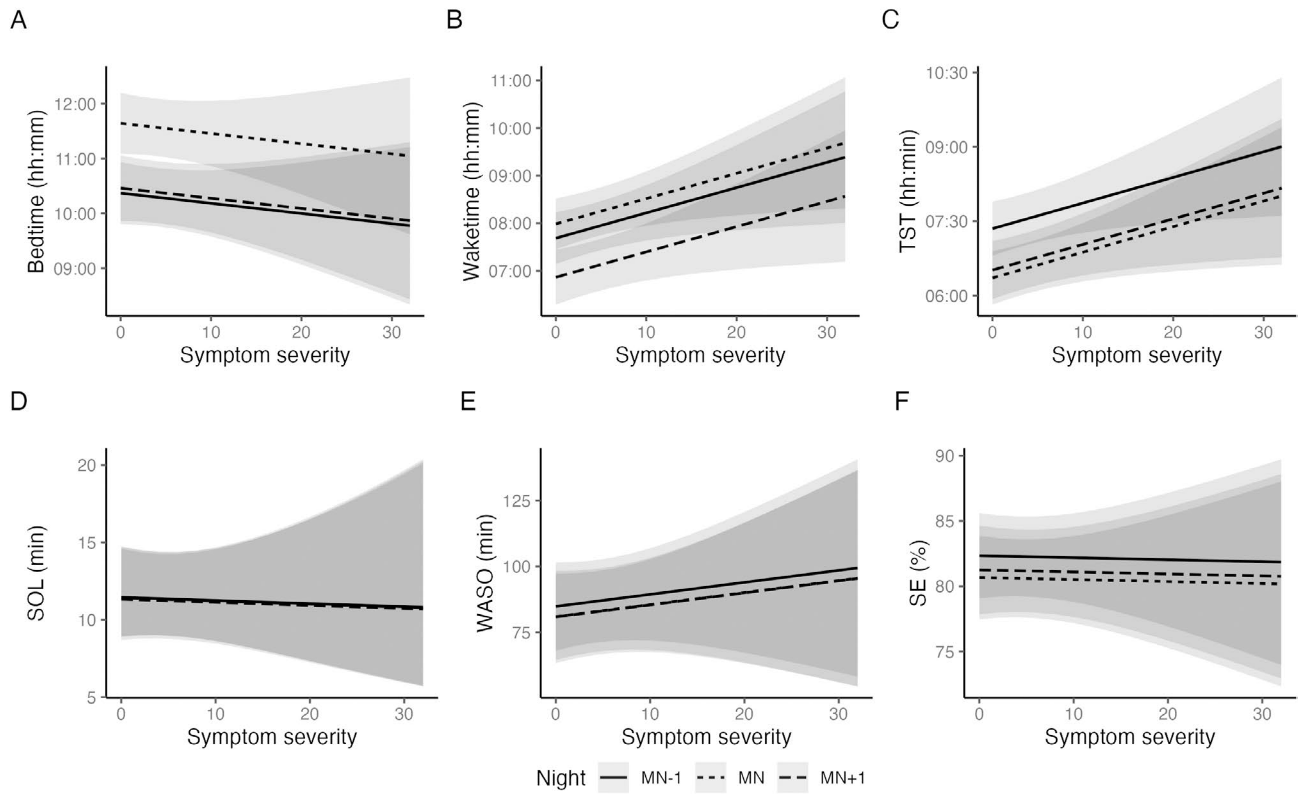

FIGURE 2 | Objective sleep measures as determined by menstrual symptoms severity score and night for (A) bedtime, (B) waketime, (C) TST, (D) SOL, (E) WASO, and (F) SE. Results are marginal effects (lines) and 95% confidence intervals (shaded areas). Higher symptom severity scores represent a high number and/or severity of symptoms. SE, sleep efficiency; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset.

where subjective sleep quality on match day and the following 3 days (including both matches and training) was unaffected by menstrual phase [8]. However, this differs from the findings of Koikawa et al. [7], who reported lower TST, increased SOL, and lower SE during the first two nights of menstruation, compared with the mid-FP for college athletes from various sports, as recorded by at-home EEG during one MC, though not related to training or match days. Additionally, Australian Rules Football athletes reported worse subjective sleep quality during the LP than FP [30], however, the sample size was low ($n=5$), and sleep was only assessed prior to training sessions. Perhaps in the current study, the influence of matches and the larger influence of schedules, travel, and cognitive and physical load due to match demands concealed menstrual phase-related changes in sleep suggested in the aforementioned studies. Thus, our findings suggest there is a limited association between menstrual phase and sleep outcomes for professional footballers the night before, the night of, and the night following matches.

For menstrual symptoms experienced, most were rated as mild (69%), though the number of symptoms experienced per player and day ranged from 0 to 18. While a significant relationship between menstrual symptoms and objective sleep was reported, there was no association between symptoms and subjective sleep quality. Specifically, around match days, increased MSS score and lower back pain severity were associated with a later waketime, whilst increased MSS score and mood changes/anxiety severity were associated with a longer TST. Interestingly, tiredness/fatigue severity was not associated with any sleep variables. The findings suggest participants woke later and slept longer, which could be inferred as a self-management strategy to help cope with increased symptom severities, despite potential sleep restrictions imposed by the matches. Of note, the practical impact was likely low for most players, given the median MSS score was 3, equating to +9 min waketime and TST. Similar findings were reported in a professional English football club, with increased sleep duration (+21 min) associated with increased number of symptoms assessed across one MC [11]. Therefore, where longer sleep durations are inhibited, e.g., early morning post-match travel or trainings, recommending alternate sleep strategies to players with high symptom severity may be beneficial. In comparison, previous research reported menstrual symptoms did not affect college athletes' TST, though only a single-item symptom question was used and sleep was not assessed in relation to match or training nights [7]. In German athletes, decreased subjective sleep quality was associated with increased menstrual symptom frequency [12], an association that is supported by general population studies [5, 31]. Our study did not show these findings, possibly due to a lack of sensitivity of the single-item sleep quality question used, as opposed to the validated Pittsburgh Sleep Quality Index used within the German athlete study [12]. Overall, footballers' sleep does not appear to be negatively impacted by menstrual symptoms on nights around matches, though players appear to self-manage menstrual symptoms with sleep extension strategies.

The study is not without limitations, which should be taken into consideration when interpreting the results. Firstly, serum estrogen and progesterone hormone analysis to confirm menstrual phase was not possible due to the widespread geographical location of training sessions and matches. This could have resulted in the inclusion of players with heterogeneous hormonal profiles; however, the methods used within the current study balance the practicality of researching with professional athletes whilst implementing some hormonal testing to reduce menstrual status and phase estimation errors. The lack of validity surrounding the sleep quality measure is acknowledged; however, to minimize participant burden, it was decided not to ask participants to complete a separate sleep quality questionnaire, and single-item questions are common in elite sport [32]. It should also be recognized that the symptoms questionnaire is yet to be validated, though it provides practitioners valuable insights. Further, several factors that could have affected participant sleep, such as travel, home vs. away matches, and physical match load [2] were not controlled for within the study. While these variables were recorded, small sample sizes transpired (particularly objective sleep vs. menstrual phase [$n=9$]), which may have resulted in an underpowered sample size; thus the inclusion of the variables as fixed effect covariates would have resulted in overfitting; therefore simplified models were used.

5 | Perspective

The present study found no association between menstrual phase and objective or subjective sleep, no association between menstrual symptoms and subjective sleep, and small associations between menstrual symptoms and objective sleep during the nights before and after matches for footballers. Whilst acknowledging the limited sample size, this multi-club study highlights matches affect female players' sleep more so than menstrual phase during the nights before and after matches. However, increased menstrual symptom severities were associated with longer sleep durations and later waketimes, which may suggest players utilize sleep to manage menstrual symptoms. Monitoring menstrual symptoms and implementing sleep extension or menstrual symptom management strategies to assist increased sleep could be of practical benefit to promote player recovery and performance.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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