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Influence of Menstrual Phase and Symptoms on Match Running in Professional Footballers

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ABSTRACT

This study examined the effects of menstrual cycle phases and symptoms on match running performance in football (soccer) players. Twenty-one nonhormonal contraceptive using football players from four professional teams were monitored for up to four menstrual cycles during a domestic league season. Menstrual phases, classified as early-follicular phase (EFP), mid-late follicular phase (MFP), and luteal phase (LP), were determined by self-reporting of menstruation and urinary hormone tests (luteinizing hormone and pregnanediol-3-glucuronide). On match day, players completed a menstrual symptom severity questionnaire. In repeated matches, players wore 10 Hz Global Positioning Satellite (GPS) devices to measure relative (/min) total distance, high-speed running distance, very high-speed distance, peak speed, acceleration count, and deceleration count. Linear mixed models were performed for each GPS measure to determine the relationship with phase or symptoms. Data for 7 and 10 players were included for menstrual phase and menstrual symptoms analyses, respectively. A significantly higher total distance was reported during MFP compared to EFP (Δ 5.1 m min^{-1}; $p = 0.04$) and LP (Δ 5.8 m min^{-1}; $p = 0.007$). Significantly greater high-speed running was reported during MFP compared to EFP (Δ 1.2 m min^{-1}; $p = 0.012$) and LP (Δ 1.1 m min^{-1}; $p = 0.007$). No significant effect of menstrual phase was found for any other GPS measures ($p > 0.05$). Accelerations declined with increasing symptom severity ($p = 0.021$, estimate = −0.01count.min^{-1}). Menstrual symptom severity did not affect any other GPS measures ($p > 0.05$). In conclusion, greater total distance and high-speed running occurred during the MFP. Additionally, accelerations minimally decreased with increasing menstrual symptom severity. Large intra- and inter-variability existed, suggesting individualized monitoring and management of menstrual effects on performance would be beneficial.

1 | Introduction

The menstrual cycle (MC) is suggested to affect athletic performance, primarily due to the influence of phase-related fluctuations of estrogen and progesterone concentrations on physiological functions [1]. Further, the proposed influence of menstrual symptoms (e.g., abdominal cramps) on athletic performance has received increasing attention. In football (soccer), many professional players perceive a negative effect of the MC on their match performance [2, 3]. Yet despite this, little research exists on the influence of the MC on football match running performance. Match running is one part of overall football performance [4], though remains of critical focus for coaching and support staff for professional players. Understanding how the MC affects match running performance of female footballers may aid training prescription, periodization, and match preparation.

The primary roles of the female sex hormones estrogen and progesterone are to control the MC and reproductive function; however, they have also been shown to influence other physiological functions, including skeletal muscle physiology, cardiovascular responses, and exercise metabolism [1]. Research on how these effects translate to athletic performance across menstrual phases remains inconclusive [5]. Systematic reviews and a meta-analysis found exercise performance may be trivially reduced during the early-follicular phase (EFP) (menstruation) compared to all other phases, though large variation existed between studies and the majority of studies were rated as "poor quality" [5, 6]. In terms of physical capacities specific to football performance, one study reported improved YoYo test performance during the early follicular compared to mid-luteal phase [7], though another found no difference in footballers of similar playing level [8]. Inconsistencies in the literature make it difficult to ascertain the effect of menstrual phase on physical performance or football match running performance.

Limited field-based studies exist exploring menstrual phase effects on football match running performance. While lab-based studies provide a highly controlled environment, comparing running performance during matches can provide ecologically valid insights. Julian et al. [9] reported more very high-intensity running per minute (individualized threshold ~17–20 $km\,h^{-1}$) in the luteal than follicular phase for elite football players when comparing the two phases. However, large individual and match variation existed, and comparing two menstrual phases may have masked sub-phase effects (e.g., mid-late follicular phase consists of low hormone (early) and high estrogen (late) phases). Comparing three menstrual phases, Igonin et al. [10] found less distance covered at moderate (7–14 $km\,h^{-1}$) and high velocities (14–19 $km\,h^{-1}$) in the EFP compared to late follicular and mid-luteal phases. These studies demonstrate potential changes in match running performance between menstrual phases. However, during match data collection both studies [9, 10] estimated menstrual phases via calendar-based counting, a method unable to detect subtle menstrual disturbances such as anovulation and luteal phase deficiency (LPD), which display altered hormonal profiles [11] and are common in exercising women [12]. Thus, research exploring the effect of menstrual phase on football match running is limited and to date has relied on less accurate menstrual phase classification methods [11].

Athletes with three or more menstrual symptoms are twice as likely to report being negatively affected by their MC [13]. Although up to 93% of athletes report experiencing menstrual symptoms [13], research on symptoms effect on athletic performance is scarce [14], with no studies related to football match running. Given menstrual symptoms may be monitored more easily than and regardless of a "normal" hormonal profile, this may be useful to professional football populations. For example, 50% of exercising women may experience subtle menstrual disturbances, like anovulation and LPD, which affect hormone levels [12] and preclude them from the phase-based comparisons [15]. Hence, assessing whether menstrual symptoms affect match running may complement phase-based monitoring to provide a deeper understanding of MC effects on performance, alongside more feasible methods of monitoring and managing menstrual-related effects on performance.

To support the physical performance of female football players, it is essential to understand the influence of the MC on match running performance. Therefore, the aims of the study were to examine (1) the effects of MC phases (early follicular, mid-late follicular, and luteal) on match running performance and (2) the effects of menstrual symptoms on match running performance. We hypothesized that match running would be reduced during the EFP and with increasing menstrual symptom severity.

2 | Methods

2.1 | Participants

Professional female football players from a national first tier league were invited to participate in the study following stipulation of the inclusion criteria: (1) not pregnant, (2) not using hormonal contraceptives or used in the previous 3 months, (3) average MC in the previous 3 months was 21–35 days, and (4) not diagnosed with any illness or disease which disrupts the MC (e.g., polycystic ovary syndrome) [15]. Following description of all testing procedures, 32 players consented to participating in the study and completed an online eligibility questionnaire to ensure they met the inclusion criteria. Eleven players were excluded or withdrew prior to study commencement (goalkeepers [$n = 4$], highly irregular cycles and/or cycle lengths > 35 days [$n = 3$], personal reasons [$n = 3$], and season long injury [$n = 1$]), resulting in 21 players participating in the study. Following strict inclusion criteria (explained throughout the methods), 11 players data were analyzed: 7 players (27.7 ± 6.0years, 166.7 ± 5.3 cm, 63.3 ± 5.0 kg) in the menstrual phase analysis and 10 players (25.6 ± 6.2years, 164.9 ± 5.9 cm, 62.8 ± 5.4 kg) in the menstrual symptoms analysis. A typical training week for these professional clubs included four to five field sessions, one to two gym sessions, and one match. A multi-club, repeated measures design was used to maximize participant numbers and observations given the sample size limitations associated with elite athlete populations [16], menstrual phase research and the high prevalence of abnormal cycles in exercising women [12], and the field-based nature of the study. Though a small sample size transpired, which should be considered when interpreting the results, we believe this study positively contributes to the emerging body of research. Given the wide geographical spread of clubs involved, communication between the players and lead researchers was via WhatsApp (Facebook, Inc).

2.2 | Study Overview

To assess changes in football match running in relation to MC phase and symptoms, players were monitored for up to four MCs during the 2022/2023 season. Players monitored their MC via self-reporting of menstruation and urinary hormonal testing. Players were also asked to complete a menstrual symptom severity questionnaire on the evening after matches and wear their club's Global Positioning Satellite (GPS) devices during matches. Ethical approval was provided by the Institutional Human Research Ethics Committee (ETH22-7106) and written informed consent provided by all players, and parents for players aged 16–17 years.

2.3 | Menstrual Status

Menstrual status was assessed via cycle length and urinary hormonal testing. Prior to commencing hormonal testing, to confirm a normal cycle length (21–35day), the lead researcher contacted players twice a week regarding onset of menses for a minimum of one MC. Players were then setup on an online platform, Smartabase (Fusion Sport, Brisbane, Australia), to self-report days of menstruation.

To accurately predict ovulation, players were provided urinary ovulation tests (Clearblue Ovulation Digital Test kits, Geneva, Switzerland) [17, 18]. The tests are 99% effective at detecting a surge in luteinizing hormone (LH > 40 mLU mL^{-1}) [19], which predicts ovulation within 24–48 h of a positive test [20]. The LH test start date was calculated by the researcher according to the manufacturers' instruction and communicated to players each MC. Players were instructed to test daily at approximately the same time, until a positive test was obtained. If players did not receive a positive test after 10 days, the researcher contacted the player to determine whether additional testing days would be beneficial (e.g., in the case of longer cycles or cycles with more variation), or to instruct the player to stop testing. When a positive test was not detected, the player was deemed to have an anovulatory cycle and only data during their EFP was retained.

Players who obtained a positive LH test were asked to complete urinary progesterone tests (Confirm Kit, Proov, USA). The at-home tests detect an increase in pregnanediol-3-glucoronide (PdG > 5 μg/mL), the urinary metabolite of progesterone, which has been shown to correlate to serum progesterone levels ($r = 0.81$) [21]. Players were instructed to test from 7 days following a positive LH test, and reminders were sent by the lead researcher. If a positive test was not obtained, only the EFP data was retained. Players were provided with written and video test instructions for both at home urinary hormone tests and asked to upload a photograph of each test result to Smartabase for visual confirmation by the researcher [15]. The most accurate method of verifying menstrual phase requires confirmation of hormone concentrations via blood samples; however, players trained and played at multiple club locations, therefore serum testing was not possible.

2.4 | Menstrual Phase Classification

The MC can be classified in up to seven phases [15] though in the absence of analyzing bloods this is not possible to accurately achieve, thus a three-phase model was used [14]. (1) Early-follicular phase (EFP)—days of menstruation or until Day 5 of each cycle (whichever was longer), where > 2 days of bleeding occurred. (2) Mid-late follicular phase (MFP)—from the day after EFP until 1 day after a positive LH test. (3) Luteal phase (LP)—from the day after MFP until the day prior to the next cycle starting, when a positive PdG test was detected, and the LP was ≥ 10 days [11]. If a player did not obtain a positive LH or PdG test, only their EFP data were retained for that cycle as this continues to be a "low hormone" phase. The three-phase model represents low sex hormones (EFP), high estrogen (MFP), and high estrogen and progesterone (LP) [14].

2.5 | Menstrual Symptoms Severity

Players completed a menstrual symptoms severity questionnaire on the night of match days. The questionnaire was adapted from the Menstrual Symptoms Index [22], which is an online survey to assesses symptom presence and frequency. It is recognized this questionnaire is not psychometrically validated as yet. The questionnaire consisted of 18 physical and psychological menstrual-related symptoms (see [22]), which players were asked to rate on a Likert scale; 0—none, 1—mild, 2—moderate, and 3—severe. Players' daily ratings were summed from 0 (no symptoms) to 54 (maximal number and severity of symptoms) to provide a single Symptom Severity score.

2.6 | Match Running

Match running was measured using 10 Hz GPS devices, and given the multi-club, multi-city methodology, GPS brands differed between teams (STATSports Apex, Catapult Playertek and Catapult One), though players used the same GPS unit for the entirety of the research period to allow intra-subject comparison. Good inter-unit reliability for distances and maximum speed (coefficient of variance range and 90% confidence limits: 0.2% ± 1.5% – 1.5% ± 1.6%) have been reported for 10 Hz STATSports and other Catapult devices using manufacturer software [23], though reliability of accelerometery counts is unknown. Players and team sport scientists turned on devices under clear sky prior to each match to allow time for satellite connectivity and players wore vests which hold the GPS devices securely between their scapulae. Following each match, data was downloaded and processed by each team's sport scientist using the manufacturer GPS analysis software (Sonra for STATSports, Catapult PlayerTek Online and Catapult One Online). The following measures and thresholds were standardized across teams based on previous research [24, 25]: minutes played, peak speed ($km\,h^{-1}$), total distance (TD), high-speed running (HSR) distance (18–25 $km\,h^{-1}$), and very high-speed running (VHSR) distance (> 25 $km\,h^{-1}$) [24], number of acceleration (ACC) and decelerations (DEC) (> 2 $m\,s^2$) [25]. To account for differences in minutes played we calculated TD, HSR, VHSR, ACC, and DEC relative to minutes played (i.e., $m\,min^{-1}$ and count min^{-1}). Given positional differences exist for match running, playing position for each player was provided by the team's sport scientist as central defense, wide defense, central midfield, wing, and forward for each match [4]. Excel data files were shared by the team's sport scientist with the researchers via password protected OneDrive folders.

While repeated match observations in all phases across multiple cycles is desirable [15], due to field-base nature of the study this was not possible. However, to reduce intra-participant variability and increase power, the following criteria were set (1) to be included in the menstrual phase analyses, a minimum of two menstrual phases and two matches per phase per player were required, in addition to the aforementioned MC status and phase classification criteria; (2) to be included in the menstrual symptoms analyses, a minimum of two Symptom Severity scores aligned with matches per player were required, regardless of MC status.

2.7 | Statistical Analysis

Data (player ID, date, team, GPS, menstrual phase, and menstrual symptoms) which met the above inclusion criteria were merged to one excel spreadsheet and imported into R Statistical Software (R Core Team 2020) for analysis. To determine the minimum minutes played required for inclusion in the final dataset, the effect of minutes played on match running (TD, HSR, VHSR, peak speed, ACC, and DEC) in this dataset was assessed using linear mixed models (lme4 package) with minutes played specified as the fixed effect, player ID and position as random effects, while controlling for GPS brand. Player ID was included to account for repeated measures and non-independence, position was included to account for its effect on match running [4] and GPS brand was included as a covariate (fixed effect) due to different GPS systems used. Starting with a minimum of 60 min playing time, 5 min increments were used until the effect of minutes played had no effect on any match running variable ($p > 0.05$). Hence ≥ 70 min was used as the minimum inclusion criteria for the final dataset as no effect existed on any relative match running outputs.

To determine the effect of *menstrual phase* and *symptoms*, linear mixed models were performed for GPS measures (TD, HSR, VHSR, peak speed, ACC, and DEC) with player ID and position as random effects, while controlling for GPS brand. Separate models were performed for menstrual phase and menstrual symptoms as the fixed effect due to differing datasets (see Table 1). Homogeneity and normality of residuals were assessed using residuals vs. fitted plots and qq plots, respectively. To examine within-participant differences between menstrual phases, post hoc pairwise comparisons were performed using estimated marginal means (emmeans package) and Tukey's adjustment, with significance set at $p < 0.05$. Numerical estimates and their 95% confidence intervals (CI) are reported for significant pairwise effects. Standard deviation (SD) of the random effects on the same scale as the outcome variable are reported for each model (see Table 1). R^2 are reported for each model to explain the proportion of variance explained by phase or symptoms, plus total model (fixed and random effects; see Table 1). Of note, position provided zero variance for TD, so the model was re-run without *position*, which did not improve model fit nor change the interpretation of significance of results, thus the initial models was retained. Heteroscedasticity was detected for the VHSR models, consequently data were transformed using $\log(x+1)$ due to the presence of zeros. No improvement to the VHSR model fits were observed, thus the initial models were retained which should be considered when interpreting results.

3 | Results

The number of MCs monitored was 2.8 ± 0.8/player (range 1–4). Cycle length was 29.3 ± 4.8 days (with 40% coefficient of variation (CV)) for the cycles analyzed. Among the cycles which met

TABLE 1 | Model outputs for main effect of menstrual phase and symptoms on match performance variables.

	Menstrual phase models					Menstrual symptoms models					
	Fixed effect	Random effects		R^2		Fixed effect		Random effects		R^2	
	Phase (p)	Player (SD)	Position (SD)	Phase	Total model	Symptoms (p)	Symptoms (estimate)	Player (SD)	Position (SD)	Symptoms	Total model
TD ($m\,min^{-1}$)	0.005*	6.9	0.0	0.10	0.71	0.52	−0.10	8.1	3.4	0.002	0.79
HSR ($m\,min^{-1}$)	0.002*	1.7	0.7	0.08	0.81	0.79	−0.01	0.25	0.0	< 0.001	0.87
VHSR ($m\,min^{-1}$)	0.67	3.4	< 0.1	0.004	0.83	0.38	−0.005	0.3	< 0.1	0.01	0.73
Peak speed ($km\,h^{-1}$)	0.11	0.9	1.3	0.02	0.54	0.16	−0.06	0.9	0.7	0.02	0.40
ACC ($count\,min^{-1}$)	0.09	0.4	< 0.1	0.01	0.89	0.03*	−0.01	0.5	0.0	0.01	0.91
DEC ($count\,min^{-1}$)	0.27	0.3	0.2	0.05	0.8	0.12	−0.01	0.6	0.1	0.02	0.90

Abbreviations: ACC = accelerations, DEC = decelerations, HSR = high-speed running, SD = standard deviation, TD = total distance, VHSR = very high-speed running.
*Denotes a significant effect.

the menstrual phase criteria, MFP length was 12.3 ± 4.9 days (CV = 37%), and LP length was 10.7 ± 4.0 days (CV = 16%). Two players experienced one or more cycle lengths of 37–38 days, which did not meet the initial stipulated criteria, though reported positive LH and PdG tests for all cycles and meets the International Federation of Gynecology and Obstetrics for regular menstrual bleeding [26], therefore their data were included in analyses. Match player position and GPS was obtained for 134 individual observations. Included in the final datasets were 54 menstrual phase versus GPS observations (8 ± 3/player; EFP = 14, MFP = 17, LP = 23) and 57 menstrual symptom versus GPS observations (6 ± 3/player).

3.1 | Menstrual Phase

The effects of menstrual phase on match running are reported in Figure 1, while the main effect, random effect SD and R^2 for all menstrual phase models are reported in Table 1. A significantly higher TD was reported during MFP compared to EFP ($p = 0.045$, Δ 5.0 m min^{-1}, CI 0.1–10.0) and LP ($p = 0.007$, Δ 5.7 m min^{-1}, CI 1.4–9.9). Similarly, a significantly higher HSR was reported during MFP compared to EFP ($p = 0.009$, Δ 1.2 m min^{-1}, CI 0.3–2.1) and LP ($p = 0.006$, Δ 1.1 m min^{-1}, CI 0.3–1.9). No significant difference in VHSR, peak speed, ACC or DEC were observed between any menstrual phases ($p > 0.05$). Figure 2 shows box plots representing the individual variability in TD and HSR across phases, noting raw data points have been used, thus position has not been accounted for. As reference, Player 1 played CM, WM, and FW; Player 2 played CM; Player 3 played CB, Player 4 played FB, Player 5 played CM, WM, and one match at CB; Player 6 played FW; and Player 7 played CB and FB.

3.2 | Menstrual Symptom Severity

The effects of menstrual symptom severity on match running are reported in Figure 3, while the main effects, random effects standard deviation, and R^2 for menstrual symptom severity models are reported in Table 1. Median menstrual symptoms

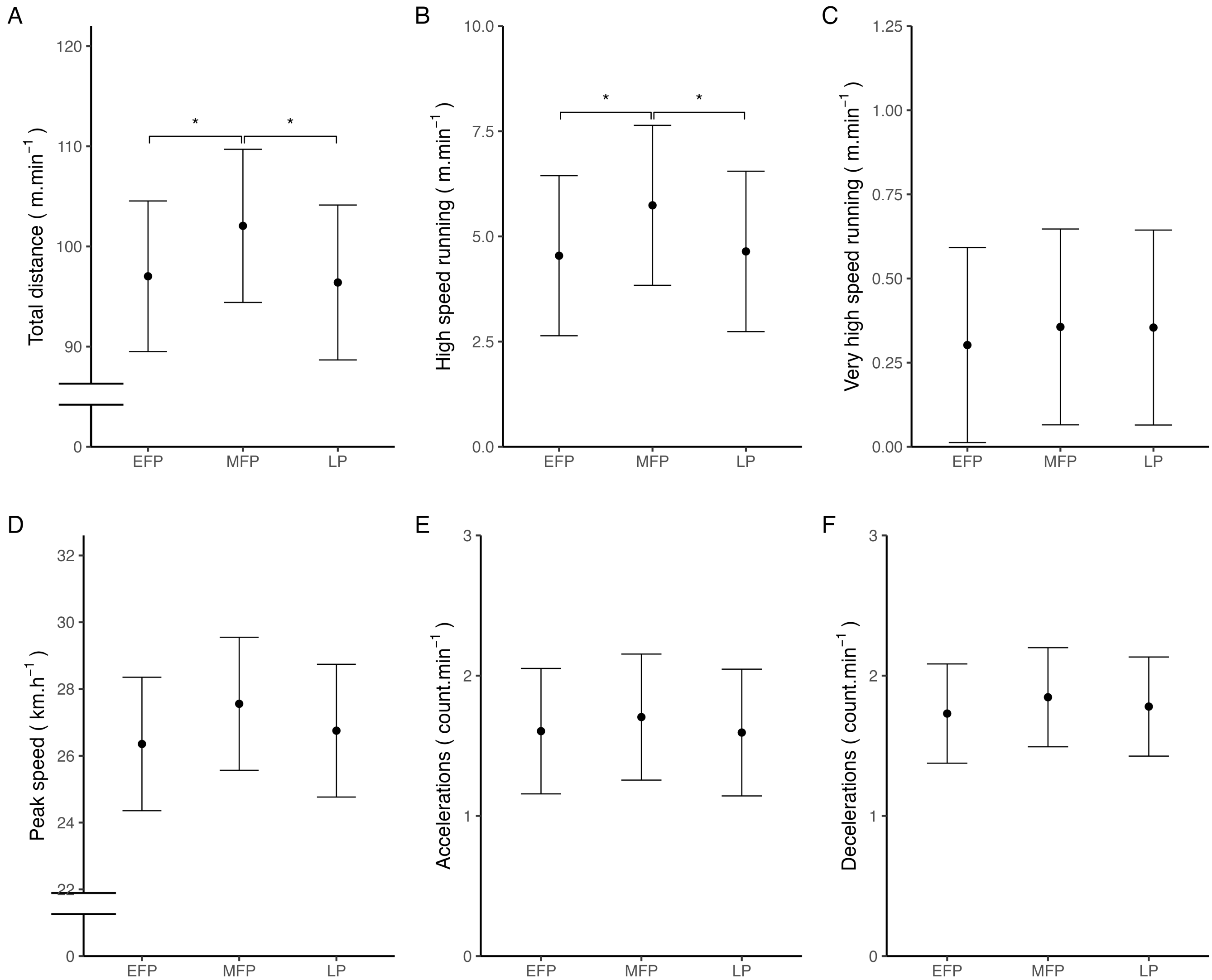

FIGURE 1 | Relative match running across the menstrual phases for (A) total distance, (B) high speed running, (C) very high-speed running, (D) peak speed, (E) accelerations, and (F) decelerations. Results are reported as estimated marginal means and 95% confidence intervals. * indicates a significant difference ($p < 0.05$). Number of match observations per phase: Early-follicular phase (EFP) = 14, mid-late follicular phase (MFP) = 17, and luteal phase (LP) = 23. Number of players per phase: EFP = 6, MFP = 5, and LP = 7.

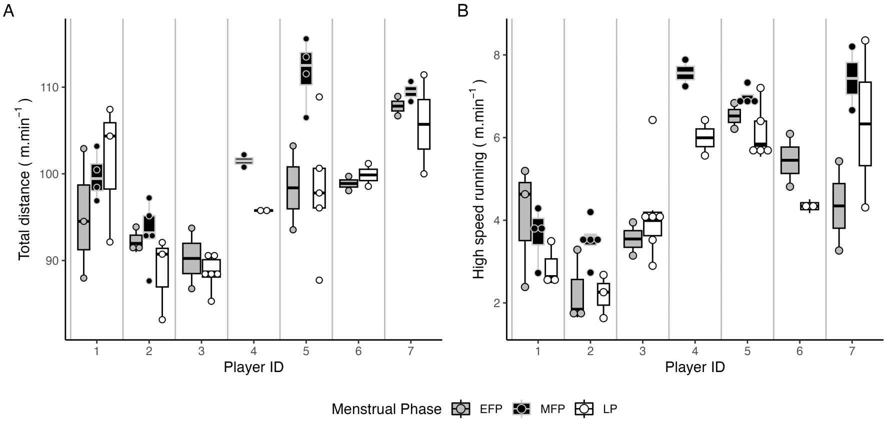

FIGURE 2 | Variability in match running across the menstrual phases for relative (A) total distance and (B) high-speed running as represented by box plots. Each dot represents a single match observation. EFP, early-follicular phase; LP, luteal phase; MFP, mid-late follicular phase.

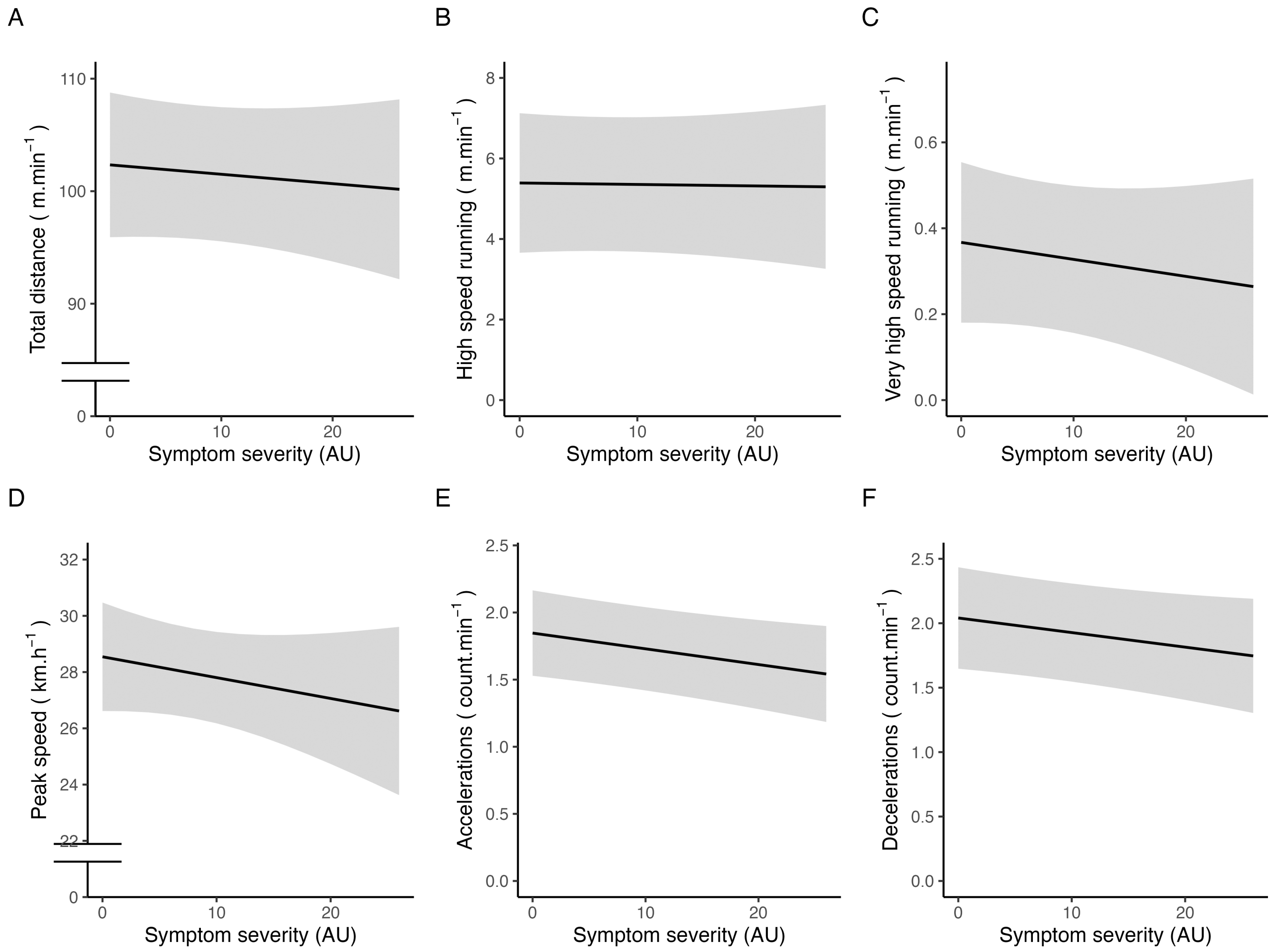

FIGURE 3 | Relative match running in response to menstrual symptom severity for relative (A) total distance, (B) high speed running, (C) very high-speed running, (D) peak speed, (E) accelerations, and (F) decelerations. Results are reports as estimated marginal means and 95% confidence intervals as shaded area.

severity was 6 (interquartile range 2–8, range 0–25). Menstrual symptom severity had a significant effect on ACC ($p=0.03$), where ACC increased by 0.01 count min^{-1} per 1 unit increase in menstrual symptom severity. Menstrual symptom severity did not affect TD ($p=0.52$), HSR ($p=0.79$), VHSR ($p=0.38$), peak speed ($p=0.16$), or DEC ($p=0.12$).

4 | Discussion

This novel study investigated the effects of menstrual phase and symptoms on match running in professional footballers. The main findings were a greater TD and HSR during the MFP compared to EFP and LP, though large variability existed in GPS measures based on phase and player. Additionally, increasing menstrual symptom severity resulted in lower ACC. Given the small sample size and variability of results, an individualized approach to the management of menstrual phase and symptoms effects on football performance seem appropriate.

Menstrual phase had a significant effect on TD, with increased TD during the MFP than EFP and LP. Previously, Igonin et al. [10] also reported greater TD in the late FP than EFP, though without differences to LP possibly due to the shorter windows used to classify phases (late FP days 10–13 and mid-LP days 20–23) [10]. Julian et al. [9] found no difference in TD between the FP and LP, though did not distinguish EFP from MFP, perhaps masking any effect. In the current study, the estimated difference in TD across 90 min correlates to ~460 m (EFP vs. FP) and ~520 m (MFP vs. LP), which is greater than the typical within-player standard deviation for elite female footballers match (259 m, 90% CI = 239–277 m [27]). Hence, these findings support the frequently self-reported perceived reduction in athletic performance during the EFP and/or premenstrual phase [3], though the premenstrual phase was included within the LP due to the small number of observations. While menstrual phase had a significant effect on TD, the standard deviation of player (5.6 $m\,min^{-1}$) was similar to the estimated TD difference between phases (5.1–5.8 $m\,min^{-1}$), highlighting the effect of phase on TD varies greatly between and within players. This is supported by Figure 2 where TD and HSR for Player 4 (FB in all matches) is distinctly higher in MFP than LP, whereas Player 1 (CM and WM) demonstrates generally higher TD in LP and HSR in MFP with large overlap between phases. The evidently large within and between player variability highlights individualized monitoring and management of menstrual phase effects is required.

Greater HSR (18–25 $km\,h^{-1}$) was evident during the MFP compared to EFP and LP, though phase had no effect on VHSR (> 25 $km\,h^{-1}$). This contrasts to Julian et al. [9] who reported more running at ~17–20 $km\,h^{-1}$ in the LP than FP, no difference in running > 20 $km\,h^{-1}$ and Igonin et al. [10] who found no difference in running > 19 $km\,h^{-1}$. Differing speed thresholds make direct comparisons between studies difficult. Further, these studies used calendar-based phase estimations which increase the risk of including anovulatory and LPD cycles, resulting in sampling heterogeneity [15]. Across a 90 min match, our results extrapolate to ~100 m greater HSR in the MFP than EFP and LP. Within-player match variability for running distances in speed thresholds 16–20 $km\,h^{-1}$ and > 20 $km\,h^{-1}$ have been reported as 160 m (90% CI 148–171 m) and 73 m (68–78 m) respectively [27]. Therefore, whether a reduction of 100 m HSR is of concern to practitioners may be player dependant and interpreted within the context of normal match-to-match variations, such as those cause by situational factors (e.g., opposition quality and match outcome) [28]. While speculative, menstrual phase influence on substrate metabolism [29] may contribute to differences in match running; however, research using high-intensity intermittent exercise research is scarce, with one study showing significantly greater muscle glycogen utilization in the late- compared to early-follicular phase [30]. No significant differences in VHSR were reported (< 7 m difference between phases across 90 min) and the large overlap of 95% CI's with very low variance (marginal $R^2 = 0.01$) explained by menstrual phase for VHSR may be attributed to the higher match-to-match variability that exists with increasing speed thresholds [27]. Such variability may be greater than that observed between phases, highlighting the importance of ecological studies, and the need for larger sample sizes due to individual variability and confounders.

Accelerations and decelerations occur frequently during matches, particularly given most sprints are < 10 m [4]. These actions, alongside maximal effort sprints, are important to goal scoring opportunities in women's football [31]. Menstrual phase did not significantly affect ACC, DEC, or peak speed. Julian et al. [7] reported no difference in 30 m sprint performance across menstrual phases for football players; however, a basketball study found a greater magnitude of accelerations and decelerations during the ovulatory phase (late FP) than EFP, mid FP, or LP [32]. Regardless, the low variance of ACC, DEC, and peak speed explained by menstrual phase (R^2 0.01–0.05) further highlights the lack of menstrual phase effect. Given this is the first study to assess accelerations, decelerations and peak speed during football matches, further research is required to support these findings.

Menstrual symptoms are associated with a perceived negative effect of the MC on athletic performance [33], though observational studies exploring their effect on athletic performance are lacking. Increasing menstrual symptom severity significantly reduced ACC, albeit large individual variability exists, and menstrual symptom severity did not affect any other match running measures. In support of this, a study of recreationally active females found reduced lower-body power, measured by jump height and Wingate test, coincided with higher levels of self-reported physical pain; while improved performance was positively correlated with motivation, arousal and pleasure without effect of menstrual phase [34]. Though not explicitly stated in our questionnaire, a “negative” focus of symptoms is implied, and few psychological symptoms were assessed, which could have limited our findings. Indeed, the symptom severity questionnaire is yet to be validated and remains to be explored in future research on menstrual symptomology. Another factor that may explain the lack of symptoms effect is that athletes appear more likely to report a negative MC effect during training compared to competition [13]. Selective attention or expectations to perform during competition may supersede symptom distraction and effects on performance [35]. Further, median symptom severity appeared low being 6 (interquartile range 2–8) out of a possible 54, though limited longitudinal studies exist for comparison. Given the ecological nature of the study, it is possible we did not capture players with, or matches when, players were experiencing higher symptom severity. Overall symptom severity explained < 2% of the variance (R^2) in each model, highlighting the limited predictability of menstrual symptoms for match running. While we found limited influence of menstrual symptoms on match running, other performance aspects such as tactical and technical factors remain to be investigated.

Several limitations exist within the study. While this is the first study to measure LH and PdG urine concurrent to football match GPS measures, the gold standard blood hormone analysis was not performed, preventing further sub-phase classification and increasing the possibility of including players with anovulatory or LPD cycles. Clubs used different manufacturers GPS units and processing software, though previous research shows good inter-unit reliability between the brands used [23], we controlled for GPS brand in the models, and the models explore within-subject effects. Contextual factors may influence match running and while match outcome, opposition quality and possession show trivial effects [36], we acknowledge not controlling for environmental conditions is a limitation. Lastly, the sample size for each analysis was relatively small ($n = 7$–10 players). Initially, 32 players were recruited but many players or menstrual phases were excluded due to menstrual status, with further observations limited by injuries, match scheduling, and player selection for matches—which are common concerns in such research contexts.

5 | Perspective

This novel study reports some match running variables for professional football players were affected by menstrual phase, while symptoms minimally affected match running. Specifically, greater TD and HSR occurred during the MFP, compared to EFP and LP. Additionally, ACC decreased with increasing menstrual symptom severity. Given the small sample size and variability presented, an individualized approach to management of the MC's effects on football performance is recommended and further research is required to inform these findings.

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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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