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Influence of menstrual- and hormonal contraceptive cycle on self-reported symptom severity and recovery measures across an annual season in female endurance athletes: The FENDURA project

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ABSTRACT

This longitudinal study investigated 1) differences in self-reported cycle-related symptom severity and recovery measures (sleep quality, readiness to train, resting heart rate) between pre-bleeding, bleeding, and non-bleeding days in athletes using/not using hormonal contraception (HC); 2) associations between symptom severity and recovery measures. Fifty-eight female endurance athletes recorded recovery measures, perceived symptom severity, and menstruation/withdrawal (bleeding) days for one year. Athletes were grouped as: intrauterine system (IUS)-, implant-, progestin-only oral contraceptive (POC)-, combined oral contraceptive (COC)- and non-HC users. All groups reported higher symptom severity during bleeding compared to pre-bleeding and non-bleeding days (both $p < .001$), while implant users reported less severe symptoms than IUS ($p < .001$) and non-HC users ($p = .008$). Perceived sleep quality was lower during pre-bleeding compared to bleeding days ($p < .001$) for all groups. However, IUS users reported higher sleep quality ($p = .039$) and physical readiness-to-train ($p = .010$) than non-HC users. Symptom severity was negatively associated with sleep quality and physical readiness-to-train (both $p < .050$). Pre-bleeding days and cycle-related symptom severity were found to negatively influence self-reported recovery measures in both HC- and non-HC users. Therefore, athletes and their support staff are advised to prioritize symptom management and the adjustment of recovery strategies on an individual basis throughout the athletes' cycles.

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Menstruation; withdrawal bleeding; premenstrual; sleep quality; readiness to train; resting heart rate

Introduction

Female athletes train and compete with fluctuating endogenous hormone levels according to the different phases of the menstrual cycle (MC) (i.e., follicular, ovulatory, luteal), or various levels of exogenous hormones due to the use of hormonal contraception (HC) (Elliott-Sale et al., 2021). The two types of HC, progestin-only and combined (containing both synthetic oestrogen and progestin), are available in various delivery methods (combined: vaginal ring, transdermal patch, oral contraception; progestin-only: oral contraception, intrauterine system [IUS], implant and injection) and formulations (Elliott-Sale et al., 2021). The synthetic hormones in HC, which are used by around ~ 50–70% of athletes in Europe (Ekenros et al., 2022; Engseth et al., 2022; Martin et al., 2018; Nolan et al., 2022; Oxfeldt et al., 2020), suppress the endogenous hormones and can lead to changes in bleeding patterns or even cessation of bleeding (McGawley et al., 2023). Changes in endogenous sex hormones across the MC and the presence of exogenous sex hormones in HC might influence self-reported cycle-related symptoms and markers of recovery in female athletes.

The impact of the MC and HC cycle on objective measures of athletic performance and recovery is currently uncertain (Elliott-Sale et al., 2020; Hackney et al., 2019; McNulty et al., 2020; Romero-Parra et al., 2021). Nevertheless, research reports that a high proportion of athletes perceive their MC or HC usage to interfere with their recovery, training or performance (Antero et al., 2023; De Martin Topranin et al., 2023; Ekenros et al., 2022; McNulty et al., 2023; Prado et al., 2022; Sims et al., 2021; Solli et al., 2020; Taim et al., 2023). For instance, the pre-bleeding and/or the bleeding days (i.e., menstruation/withdrawal bleeding) have been indicated by women to negatively interfere with several self-perceived recovery measures, such as sleep quality, physical readiness to train, as well as objectively measured resting heart rate (HR) in both HC and non HC users (Antero et al., 2023; Bruinvels, Hackney, et al., 2022; Carmichael et al., 2021; De Martin Topranin et al., 2023; Dorsey et al., 2021; Ekenros et al., 2022; Hrozanova et al., 2021; McNulty et al., 2023; Oxfeldt et al., 2020; Paludo et al., 2022; Prado et al., 2022; Sims et al., 2021; Solli et al., 2020). However, most studies that have included HC users in their sample focused on combined oral contraception (COC) users (Martin & Elliott-Sale, 2016).

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Interestingly, a study by Martin et al. (2018) showed that progestin-only HC users experienced more symptoms than combined HC users. As the usage rates of progestin-only HC among Scandinavian athletes appear to be increasing (Ekenros et al., 2022; Engseth et al., 2022; Solli et al., 2020), there is a growing need to also investigate athletes' experiences with different types of HC on self-reported recovery measures.

The perceived negative influence on recovery measures during the pre-bleeding and bleeding days might be related to the occurrence of cycle-related symptoms experienced by both HC- and non-HC users (Ekenros et al., 2022; Engseth et al., 2022; McNulty et al., 2023; Oxfeldt et al., 2020; Prado et al., 2022; Solli et al., 2020), as the highest symptom prevalence is observed during these days (McNamara et al., 2022; McNulty et al., 2023; Oxfeldt et al., 2020; Prado et al., 2022; Solli et al., 2020). Furthermore, athletes who report more severe symptoms appear to be the most affected (Bruinvels, Hackney, et al., 2022; Ekenros et al., 2022; McNamara et al., 2022; Prado et al., 2022). Notably, the majority of studies investigating athletes' self-reported experiences with MC or HC use, as well as associations with cycle-related symptom severity are based on retrospective questionnaires (Clarke et al., 2021; Ekenros et al., 2022; Engseth et al., 2022; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020) or prospective data collections over a relatively short timeframe and/or small samples (Antero et al., 2023; De Martin Topranin et al., 2023; Paludo et al., 2022) which might limit the generalizability. To our knowledge, only the recent study by Dupuit et al. (2023) provided 6 months of longitudinal data related to menstrual status and cycle-related symptoms in elite athletes, but also in a relatively small sample. Additional long-term prospective studies are required to provide a more nuanced insight into how pre-bleeding and bleeding days, as well as the severity of cycle-related symptoms may influence athletes' self-reported recovery measures.

Therefore, the current longitudinal prospective study, including a sample of highly trained cross-country skiers and biathletes, aimed to investigate the 1) differences in self-reported cycle-related symptom severity and recovery measures (sleep quality, readiness to train, resting HR) between pre-bleeding, bleeding, and non-bleeding days in HC and non-HC users; and 2) associations between symptom severity and recovery measures.

Materials and methods

The current study is part of The Female endurance Athlete (FENDURA) project, which was previously described by Engseth et al. (2022).

Participants

Between May 2020 and September 2020, athletes were recruited for a one-year follow-up study through information meetings, emails to sports clubs and schools, and *via* social media. The recruitment process was performed in collaboration with the Norwegian Ski Federation and the Norwegian Biathlon Federation. The inclusion criteria were: 1) currently competing at a national or international level in cross-country skiing or biathlon (tier 3–5 based on McKay et al. (2022)); 2) ≥ 18 years of age; 3) training systematically in their sport for at least three years. A total of 89 cross-country skiers and biathletes volunteered to participate. Nine athletes were unable to complete a minimum of three months of diary logging and 22 athletes changed, stopped, or started to use HC throughout the study and thus were excluded from analyses. Hence, 58 athletes were included in the final analysis and grouped into five categories: IUS-, implant-, progestin-only oral contraception (POC)-, COC- and non-HC users, based on Elliott-Sale et al. (2021) (Figure 1). For non-HC users, a normal MC length was defined as 21–35 days (Elliott-Sale et al., 2021), and abnormal cycle length was defined as any cycle <21 days or >35

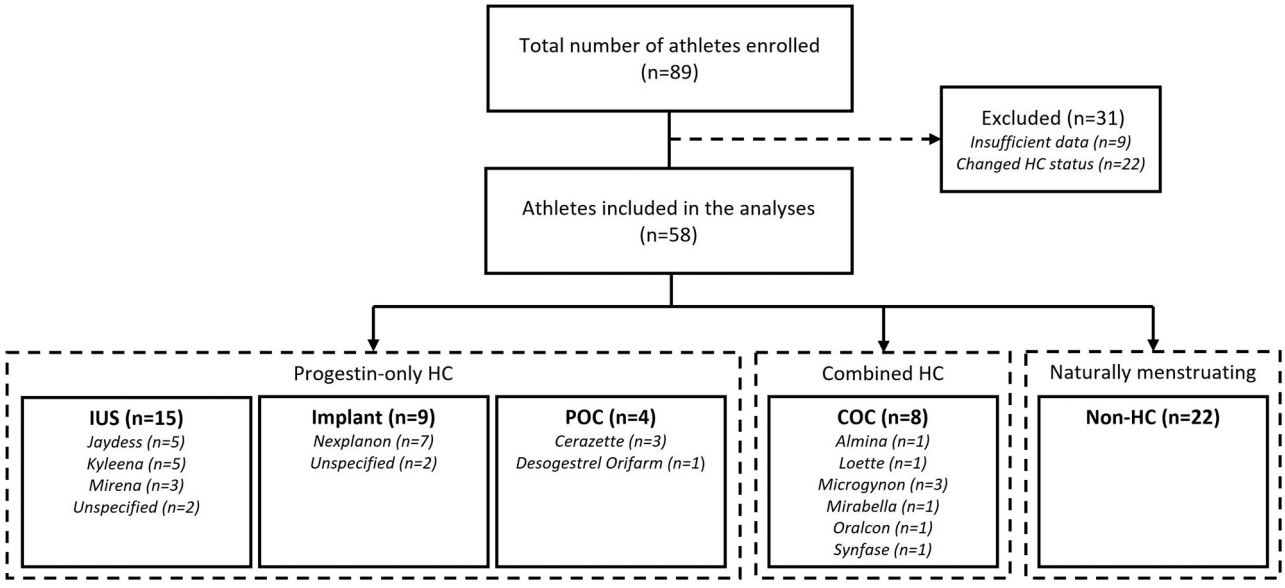

Figure 1. Overview of the athletes included in the study grouped by hormonal contraception (HC) status. Intrauterine system (IUS); progestin-only oral contraception (POC); combined oral contraception (COC). All COC are monophasic except from synfase which is biphasic.

Table 1. Athletes' demographic information (mean and SD) grouped by hormonal contraception (HC) status.

	IUS (n = 15)	Implant (n = 9)	POC (n = 4)	COC (n = 8)	Non-HC (n = 22)
Anthropometric information					
Age (y)	22.5 (3.5)	20.1 (2.2)	22.3 (3.1)	21.1 (2.2)	20.1 (2.3)
Height (cm)	167.9 (5.3)	169.9 (3.5)	169.3 (6.7)	169.4 (2.8)	170.9 (7.2)
Body mass (kg)	61.3 (5.3)	64.0 (4.1)	62.3 (4.1)	61.5 (1.8)	64.1 (5.0)
BMI (kg/m^2)	21.7 (1.1)	22.2 (1.5)	21.8 (1.0)	21.5 (0.7)	22.0 (1.9)
Training					
Annual training volume (hr/year 2019–2020)	653.1 (140.9)	602.0 (130.9)	628.0 (66.8)	630.9 (102.7)	636.0 (112.9)
Annual training volume (hr/year 2020–2021)	669.5 (169.3)	636.7 (95.4)	721.8 (52.9)	718.0 (79.4)	683.2 (157.2)
Recorded bleeding					
Number of weeks involved in the study	50.5 (10.6)	52.3 (1.4)	37.8 (16.7)	46.4 (12.1)	49.5 (6.0)
Number of bleeding periods (periods/year)	8.4 (4.2)	4.9 (5.9)**	8.1 (5.8)	9.6 (2.2)	11.7 (3.7)
Total number of bleeding days (days/year)	45.3 (31.8)	26.7 (35.9)	35.1 (24.7)	42.5 (17.0)	53.7 (15.0)

IUS, intrauterine system; POC, progestin-only oral contraception; COC, combined oral contraception; HC, hormonal contraception; BMI, Body mass index

** Significant less bleeding periods in Implant users compared to non-HC users (p = .002).
Number of bleeding periods and days are estimated based on 52 weeks of diary logging.

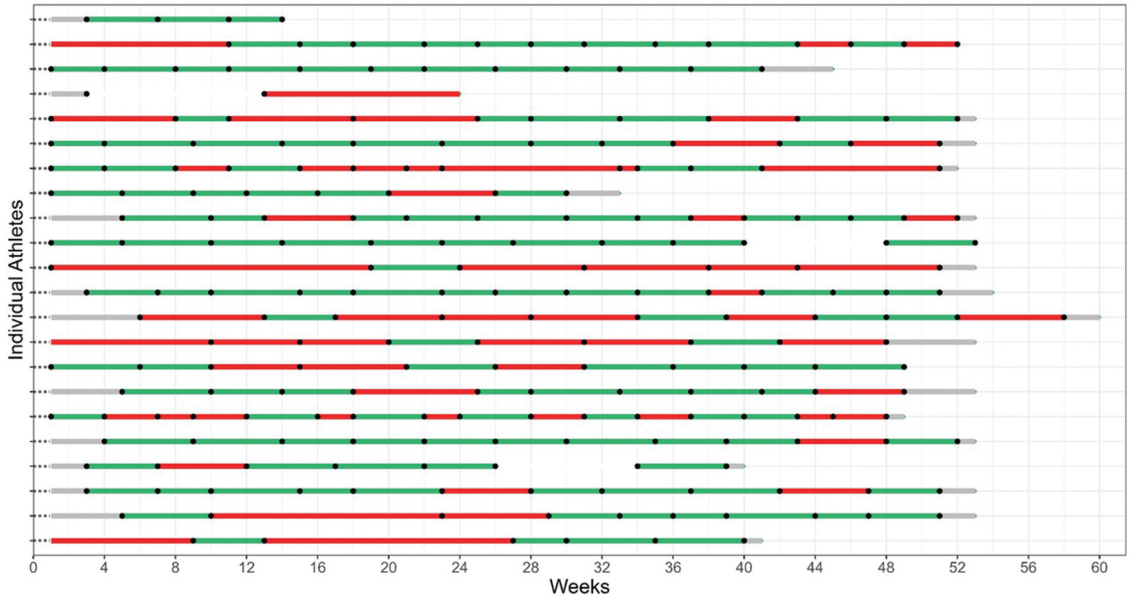

Figure 2. Overview of the non-hormonal contraception (HC) users individual bleeding pattern during the project. Black dots represent bleeding days. Green lines indicate a cycle length within the 21–35 days criteria. Red lines indicate a cycle length shorter/longer than 21–35 days. Grey lines indicate unknown cycle length due to study period. White lines indicate missing data. A total number of 207 cycles were recorded in which 61 being shorter/longer than 21–35 days.

days (Taim et al., 2023). Detailed information about the athletes' anthropometrical, training and bleeding characteristics is presented in Table 1. The information about athletes' individual withdrawal/menstruation bleeding pattern during the study period is presented in Figure 2 (non-HC users) and Figure 3 (HC users). All athletes received information regarding the study in written and oral form before they provided their written informed consent. Athletes were made aware that they could withdraw from the study at any time and without reason. This study was approved by the Norwegian Agency for Shared Services in Education and Research (Sikt) (409326) and evaluated by the Regional Committees for Medical and Health Research Ethics (REK) (135555).

Study design

All athletes used an online training diary to record daily cycle-related symptom severity and recovery measures (perceived sleep quality, physical and mental readiness to train, resting HR) for up to 12 months. Over the year, athletes completed three questionnaires (upon commencement, after 6-, and after 12 months) to collect information about their age, body mass and height, as well as to detect potential changes in (non-) HC use.

Training diaries

The athletes reported cycle-related symptom severity and recovery measures in one of two digital training diaries, developed by either the Norwegian Top Sport Centre (Olympiatoppen) or Bestr (Oslo, Norway). All parameters included in this study were identically presented, with the same descriptions and scales, in both training diaries (see supplementary Figure S1).

The athletes reported "yes/no" to indicate the presence of menstruation/withdrawal bleeding. Furthermore, athletes were asked to rate their severity of cycle-related symptoms, sleep

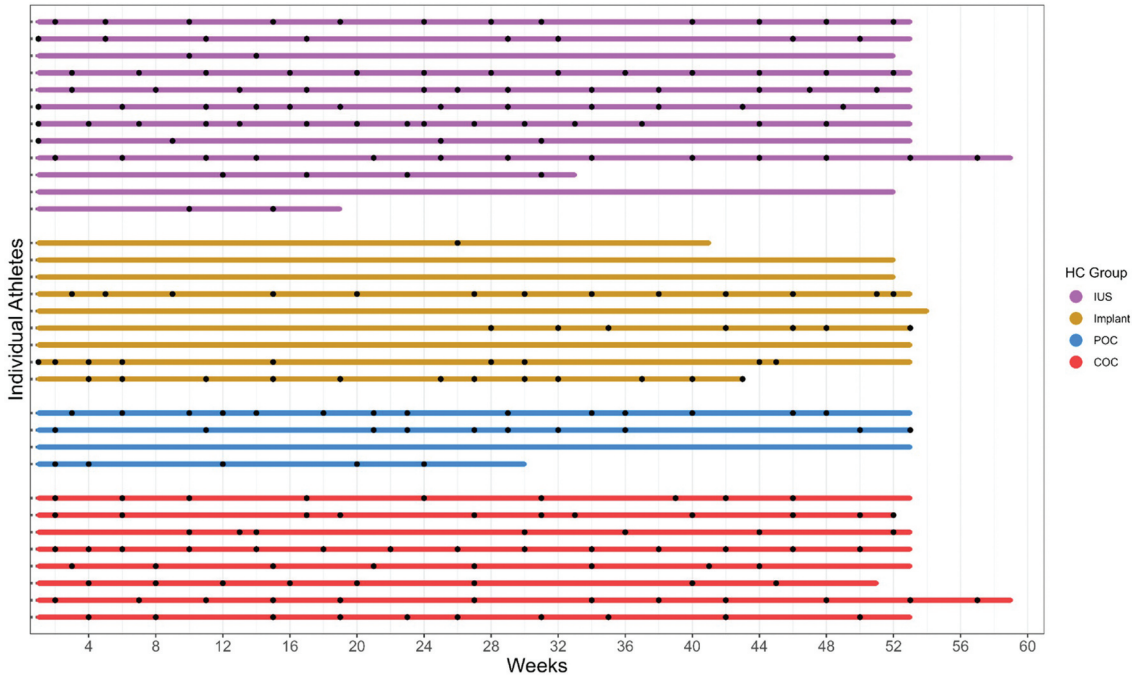

Figure 3. Overview of the bleeding pattern for athletes using hormonal contraception (HC). Black dots represent bleeding days. Intrauterine system (IUS); progestin-only oral contraception (POC), combined oral contraception (COC).

quality, physical readiness to train and mental readiness to train using a visual analogue scale (VAS) with integer options from 1 to 10. For cycle-related symptom severity, 1 was defined as [translated] "no symptoms" and 10 as "severe symptoms". For sleep quality, 1 was defined as "low sleep quality" and 10 as "high sleep quality". For both physical and mental readiness to train, 1 was defined as "not ready" and 10 as "very ready". The scale was presented with different anchors in Norwegian for each measure. Additionally, the athletes reported resting HR using a standardized procedure upon awakening (i.e., passive rest for 5 minutes while supine in bed, and recording HR during the last minute) or using an overnight-monitoring watch and were instructed to use the same method throughout the project. Athletes were asked to log all variables daily at approximately the same time each day. Further, they were explicitly instructed to refrain from modifying any previously recorded entries in their diary. The athletes' diaries were inspected twice a week by the same investigator to ensure compliance.

Conceptualization of pre-bleeding, bleeding and non-bleeding days

Cycle-related symptoms appear to be prevalent in athletes (HC and non-HC users) both in the days before, as well as during bleeding (McNamara et al., 2022; McNulty et al., 2023; Oxfeldt et al., 2020; Prado et al., 2022; Solli et al., 2020). However, these days are not well studied in sport science research (Bruinvels, Hackney, et al., 2022) and the methodology used varies; while Prado et al. (2022) included the last ten days before menstruation as the pre-bleeding phase, Solli et al. (2020) included the last four days. As Solli et al. (2020) investigated a similar sample of endurance athletes, both using and not using HC and found a high prevalence of cycle-related symptoms in the four days prior to bleeding, a similar timeframe (i.e., four days preceding bleeding) was used in this present study. The HC and non-HC users' cycles were divided into: 1) pre-bleeding (the last four days before the onset of menstruation/withdrawal bleeding according to Solli et al. (2020)); 2) bleeding (all days with menstruation/withdrawal bleeding); 3) non-bleeding (all other days in the cycle).

Data analysis

A manual inspection and interpretation of the data set was carried out to ensure that the coding of the various days (pre-bleeding, bleeding, non-bleeding) was as reliable as possible. One occasion with spotting (i.e., only one day of bleeding that did not occur in connection with the bleeding days) was excluded from the analysis in five IUS users, two POC users, one implant user, and three non-HC users. Short cessations between bleeding days (i.e., up-to six days between two bleedings) were excluded from the analysis in three IUS users and three implant users.

Ordinal dependent variables (i.e., sleep quality, physical readiness to train, mental readiness to train, cycle-related symptom severity) were modelled using cumulative link mixed regression with logit link fitted by Laplace approximation (*clmm* function from the ordinal package (Christensen, 2023)). Resting HR was modelled with linear mixed effects regression (lme4 package). Models included days (levels: pre-bleeding, bleeding, non-bleeding), group (levels: COC, implant,

IUS, POC, non-HC), and their interaction (days by group), as fixed factors. A potential mediating factor, symptom severity, was included in all ordinal models. The association between cycle-related symptom severity and sleep quality, physical readiness, and mental readiness to train were, as described above, adjusted for potential confounding factors (i.e., days, group, and days by group). For this analysis, the severity of cycle-related symptoms was aggregated into four distinct ordinal categories: 1 was defined as "no symptoms", 2–4 as "mild symptoms", 5–7 as "moderate symptoms", and 8–10 as "severe symptoms". All models included a random intercept, with days nested within athlete. Models were checked for convergence, and residuals checked using the *DHARMa* package (Hartig, 2022). Post-hoc testing was completed using the *emmeans* package (Lenth et al., 2020), with "multivariate t" correction for multiple comparisons. Statistical significance was assumed to be $\alpha = 5\%$. For ordinal data modelled using cumulative link mixed regression, a rating of "7" was identified as a common breakpoint, and therefore the cumulative probability of a rating ≤ 7 was used for between-group comparisons. Data are provided as modelled marginal means and cumulative probability estimates, unless otherwise noted. All analyses were performed using R (R Core Team 2021).

Results

Differences in self-reported cycle-related symptom severity and recovery measures during pre-bleeding, bleeding and non-bleeding days

An overview of how self-reported cycle-related symptom severity, sleep quality, physical- and mental readiness to train differ between pre-bleeding, bleeding, and non-bleeding days within and between groups is presented in Figure 4.

Cycle-related symptoms severity

There was a significant main effect of *days* (i.e., pre-bleeding, bleeding, and non-bleeding) ($p < .001$), with cycle-related symptom severity being higher during bleeding compared to pre-bleeding ($p < .001$) and non-bleeding days ($p < .001$), as well as during pre-bleeding compared to non-bleeding days ($p < .001$). The probability of symptom occurrence (i.e., rating > 1) for the different days was: pre-bleeding = 7.7%; bleeding = 39.5%; and non-bleeding = 2.0%. A significant main effect was found for *group* ($p = .022$), with implant users reporting significantly lower symptom ratings (i.e., less severe symptoms) than both IUS ($p < .001$) and non-HC users

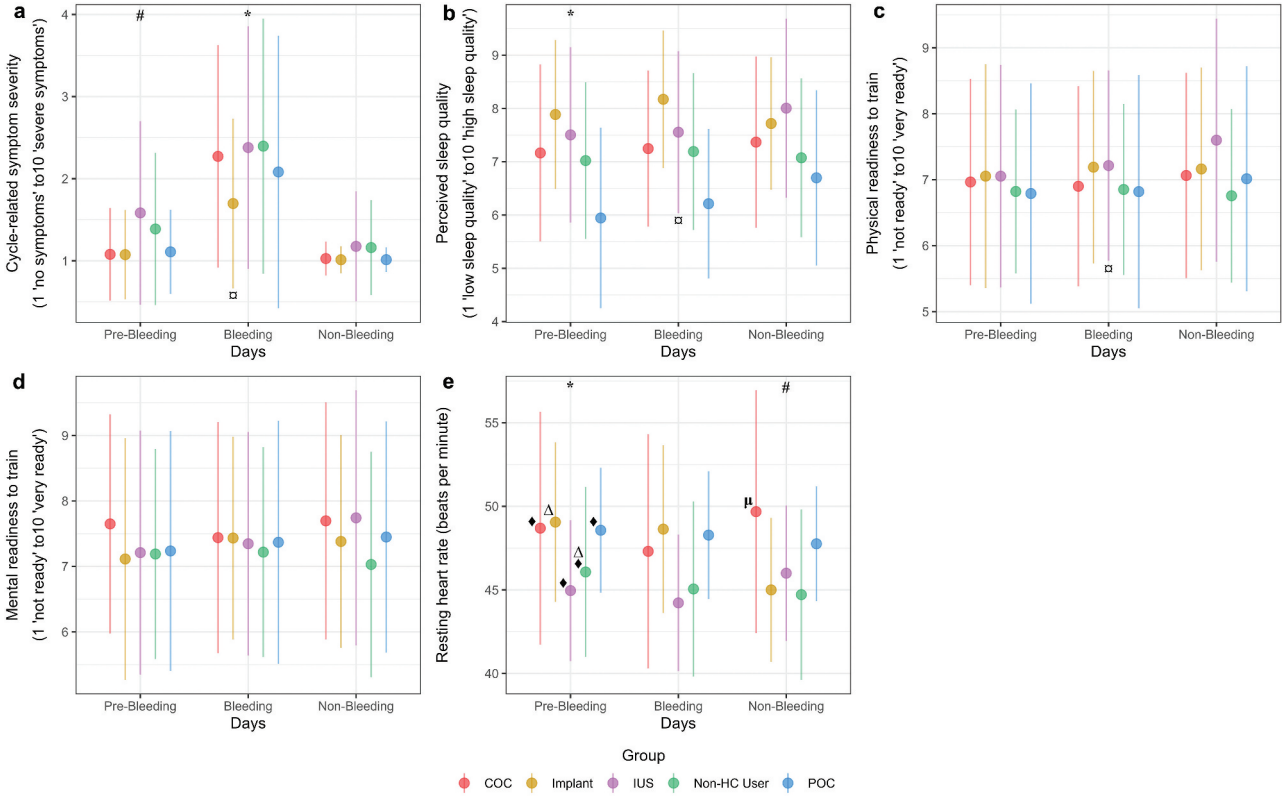

Figure 4. Days and group differences in recovery measures. Data are presented as means and standard deviations. Combined oral contraception (COC); intrauterine system (IUS); hormonal contraception (HC); progestin-only oral contraception (POC). a) * significant more severe symptoms compared to pre-bleeding and non-bleeding days. # significant more severe symptoms compared to non-bleeding. ¤ significant lower symptom ratings for implant users compared to IUS and non-hc users. b) * significant worse sleep quality compared to bleeding. ¤ significant better sleep quality for IUS users compared to POC users and non-hc users. c) ¤ significant higher ratings of physical readiness to train during pre-bleeding, bleeding and non-bleeding days for IUS users compared to non-hc users. e) * significant higher resting heart rate (HR) compared to bleeding and non-bleeding. # significant higher resting HR compared to bleeding. ♦ significant higher resting HR compared to bleeding for POC-, IUS-, COC- and non-hc users. Δ significant higher resting HR compared to non-bleeding for implant and non-hc users. μ significant higher resting HR compared to bleeding for COC users. All $p < .05$.

($p = .008$). The probability of a symptom rating > 1 was 9.3% for the implant, compared to 31.1% for IUS and 26.7% for non-HC users. No significant *days by group* interaction ($p = .578$) was found for cycle-related symptom severity.

Perceived sleep quality

A significant main effect of *days* ($p < .001$) was found on sleep quality, with lower rated (i.e., worse) sleep quality during pre-bleeding (mean rating = 7.0 units) compared to bleeding days (7.3 units; $p < .001$). There was no significant difference between non-bleeding and bleeding ($p = .077$) or pre-bleeding ($p = .062$) on sleep quality. A significant main effect was found for *group* ($p = .022$), with IUS users reporting significantly higher sleep quality (7.9 units) than POC (6.1 units; $p = .040$) and non-HC users (6.9 units; $p = .039$). The probability of a sleep quality rating ≤ 7 was only 31.0% for IUS, while the probability for POC and non-HC users was 85.1% and 65.1%, respectively. No significant *days by group* interaction was found for sleep quality ($p = .578$).

Physical and mental readiness to train

No significant main effect of *days* (=.055) was found for physical readiness to train. A significant main effect of *group* ($p < .001$) was found, with IUS users reporting a higher physical readiness to train (7.4 units) compared to non-HC users (6.4 units; $p = .010$). There was a significant *days by group* interaction ($p < .001$), where IUS users reported higher ratings (i.e., more ready) of physical readiness to train (7.44, 7.49, and 7.38 units) compared to non-HC users (6.34, 6.37, and 6.34 units) during all days (pre-bleeding: $p = .008$; bleeding: $p = .012$; non-bleeding: $p = .020$). The probability of IUS users reporting a physical readiness to train rating ≤ 7 was 44.3%, 45.7% and 49.0% (for pre-bleeding, bleeding, and non-bleeding), while non-HC users were more likely to provide a rating that was ≤ 7 (80.6%, 80.3%, and 80.9%, respectively). No significant effects of *days* ($p = .638$), *group* ($p = .638$), or a *days by group* interaction ($p = .638$) were found for mental readiness to train.

Resting heart rate

A significant main effect of *days* ($p < .001$) was found for resting HR, with higher resting HR during pre-bleeding compared to bleeding (+1.0 beats·min^{-1}; $p < .001$), and non-bleeding (+0.5 beats·min^{-1}; $p = .010$), while non-bleeding was also significantly higher than bleeding (+0.5 beats·min^{-1}; $p = .019$). No significant main effect of *group* was found for resting HR. There was a significant *days by group* interaction, with a significantly higher resting HR during pre-bleeding compared to bleeding for all groups (+1 to + 1.6 beats·min^{-1}; $p < .001$ to $p = .036$) apart from implant users ($p = .440$). For implant users and non-HC users, pre-bleeding resting HR was higher than non-bleeding resting HR (+1.5 beats·min^{-1}; $p = .006$ and + 1.1 beats·min^{-1}; $p < .001$, respectively), and for COC users, resting HR was higher

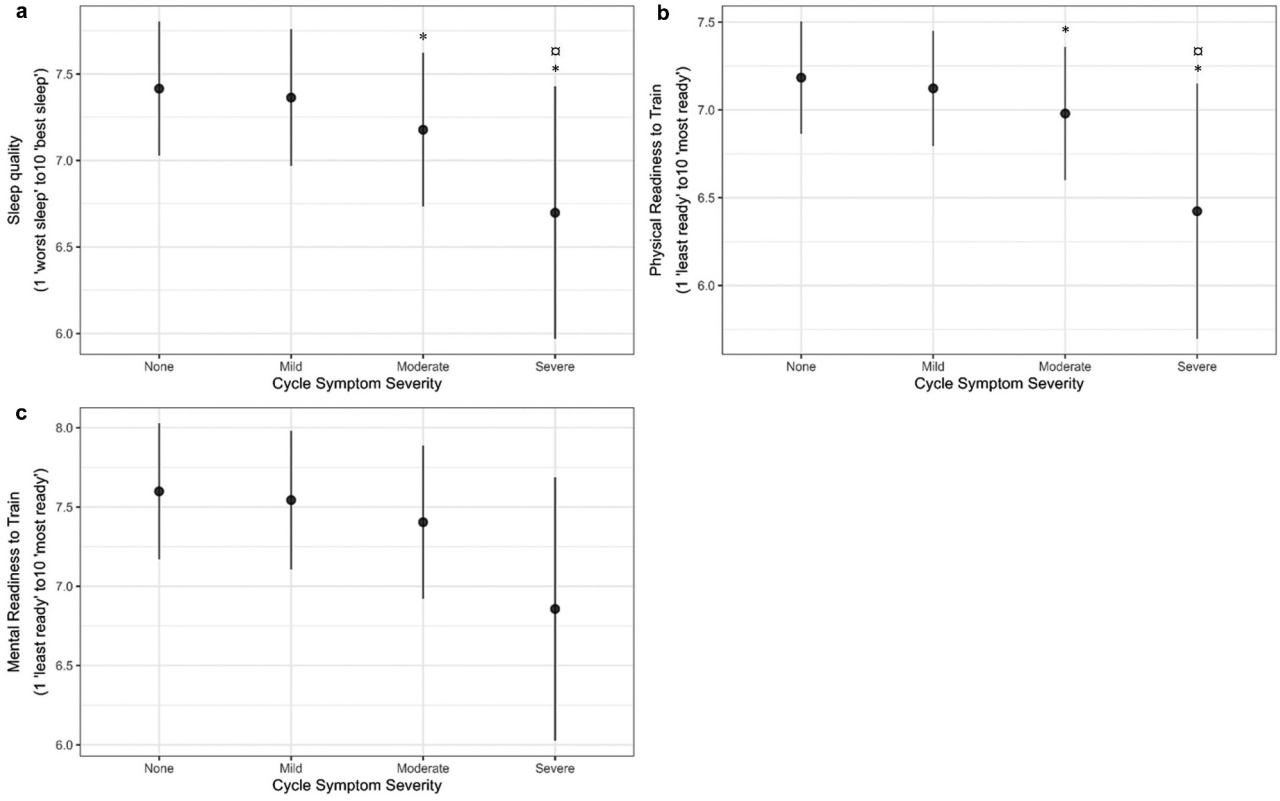

Figure 5. Figure 5: overview of the association between severity of cycle-related symptoms (none, mild, moderate, severe) and; a) sleep quality; b) physical readiness to train; and c) mental readiness to train. Data are estimated marginal means (black circles) and 95% CI (black lines). Symbols indicate * significantly different ($p < .05$) to symptom severity of "none"; ¤ significantly different ($p < .05$) to symptom severity of "mild".

during non-bleeding compared to bleeding (+2 beats·min^{-1}; $p < .001$).

The association between cycle-related symptom severity and recovery measures

An overview of how cycle-related symptom severity is associated with self-reported sleep quality, physical and mental readiness to train is presented in Figure 5.

Discussion

This longitudinal observational study, featuring a large cohort of highly trained endurance athletes, compared self-reported symptom severity and recovery measures across pre-bleeding, bleeding, and non-bleeding days in HC- and non-HC users. Furthermore, the association between the symptom severity and recovery measures was investigated. The main findings were: 1) All groups reported higher cycle-related symptom severity during bleeding compared to pre-bleeding and non-bleeding days; 2) Perceived sleep quality was lower during pre-bleeding days compared to bleeding days in all groups, while no change was found for physical and mental readiness to train; 3) Implant users reported lower cycle-related symptom severity than IUS and non-HC users, while IUS users reported higher sleep quality than POC and non-HC users; 4) Cycle-related symptom severity was negatively associated with sleep quality and physical readiness to train. As such, pre-bleeding and bleeding days, as well as the severity of cycle-related symptoms might influence self-reported measures of recovery.

Cycle-related symptom severity

For all groups, the severity of cycle-related symptoms was found to be highest during bleeding days compared to pre-bleeding and non-bleeding days. Additionally, cycle-related symptom severity was also higher during pre-bleeding compared to non-bleeding days for all groups. This aligns with previous studies that reported both HC and non-HC users experiencing cycle-related symptoms during pre-bleeding and bleeding days (Engseth et al., 2022; McNamara et al., 2022; McNulty et al., 2023; Oxfeldt et al., 2020; Solli et al., 2020), with an increase in these symptoms during the bleeding days (McNulty et al., 2023; Solli et al., 2020). These symptoms may arise from changes in the concentration of different reproductive hormones (Bruinvels, Hackney, et al., 2022), as well as the production of prostaglandins, which are associated with menstrual pain (Taim et al., 2023). Hormonal contraceptives may reduce the amount of prostaglandins released (Casper, 2017) and are commonly used to alleviate cycle-related symptoms through suppression of endogenous hormones (McGawley et al., 2023). As the present study did not collect blood samples, the association between the concentration of these hormones and cycle-related symptom severity was not investigated. However, as HC users have been found to report similar symptomology to non-HC users (Clarke et al., 2021; Engseth et al., 2022; McNulty et al., 2023) there appear to be other unknown factors, aside prostaglandins and endogenous sex hormones, that may potentially contribute to these negative symptoms.

Comparable to previous research (Clarke et al., 2021; Engseth et al., 2022; McNulty et al., 2023), all groups in this study reported similar symptom severity, with no significant differences between groups, except for implant users who reported less severe symptoms compared to both IUS users and non-HC users. As no information was collected concerning cycle-related symptom severity prior to the commencement of their current HC, it is possible that HC users experienced more severe symptoms prior to their initiation of HC use. At least, this has been previously suggested as a potential reason for why HC and non-HC users report similar symptomology (Clarke et al., 2021; Engseth et al., 2022; McNulty et al., 2023). With an increase in symptom severity during bleeding days, potential mechanisms related to bleeding and blood loss might play a role in cycle-related symptoms regardless of circulating hormones (McNulty et al., 2023). Therefore, future studies should explore the potential changes in perceived cycle-related symptoms in athletes starting with HC use, to obtain a more nuanced understanding of how HC use influences symptomology.

In the current study, implant users reported lower severity of cycle-related symptoms compared to IUS users. However, when comparing IUS and implants, a recent systematic review concluded that both delivery methods provided similar improvements in pain scores related to dysmenorrhoea and endometriosis (Ambacher et al., 2022). Moreover, the positive and negative side effects of different types of HC can vary greatly between individuals (Burke, 2011; Martin et al., 2018; Shulman, 2011) and, therefore, it remains difficult to interpret why implant users in the current study reported less severe symptoms than IUS users.

Perceived sleep quality

All groups reported significantly worse sleep quality during pre-bleeding compared to the bleeding and non-bleeding days. Additionally, cycle-related symptom severity was negatively associated with sleep quality. Similar findings were reported by Ekenros et al. (2022) and Antero et al. (2023) in naturally menstruating athletes, although no differences were found for HC users. Reduced subjective sleep quality during the pre-bleeding days in non-HC users may be due to the increase in body temperature which is associated with the luteal phase (Dorsey et al., 2021). Further, women with pre-menstrual symptoms are more likely to report awakenings, insomnia, and daytime sleepiness (Dorsey et al., 2021). This is in line with the findings of the current study and, since all groups experienced higher severity of cycle-related symptoms during the pre-bleeding days, this might explain why also HC users in our study reported worse perceived sleep quality.

The between-group comparison showed that IUS users reported better sleep quality than both POC and non-HC users. A previous study reported that HC use might improve overall sleep quality in women with sleep problems (Guida et al., 2020). However, the recent meta-analysis by Bezerra et al. (2022) found no differences in perceived sleep quality between HC and non-HC users. The mechanisms for improved sleep quality in IUS users compared to POC remain unclear, and

more research investigating the impact of different types of HC on both objective and subjective markers for sleep quality in athletes is therefore needed.

Overall, there appears to be a consistent pattern between groups i.e., lower subjective sleep quality during the pre-bleeding days compared to the bleeding- and non-bleeding days, as well as a negative association between sleep quality and cycle-related symptom severity. As sleep quality is an important variable when evaluating athletes' training response (Saw et al., 2016) and recovery (Meeusen et al., 2013) our findings underline the importance of monitoring subjective sleep quality and the severity of cycle-related symptoms.

Physical and mental readiness to train

In this study, physical and mental readiness to train did not differ between pre-bleeding, bleeding and non-bleeding days. This somewhat contrast the findings of a recent study from our research group, where physical readiness to train was reduced in the ovulatory and the mid-luteal phase compared to the early follicular phase (bleeding days) in naturally menstruating athletes (De Martin Topranin et al., 2023). However, a more detailed analysis (e.g., using urinary-ovulation testing) to identify the effect of MC phases was not included in the protocol of the current study, as the aim focused on pre-bleeding and bleeding days. In the current study, late follicular, ovulatory, and mid-luteal phases were all included as "non-bleeding days". Since these MC phases were not explicitly defined in the current study, this might explain why no differences were observed.

When groups were compared, IUS users reported higher rates of physical readiness to train compared to non-HC users, which could be related to the higher perceived sleep quality in IUS users. Just like sleep quality, physical readiness to train was negatively associated with cycle-related symptom severity, i.e., physical readiness to train was lower when symptoms were more severe. As readiness to train, together with a subjective rating of fatigue, has been used to discriminate between acutely fatigued and functionally overreached athletes (Ten Haaf et al., 2017), this observation provides valuable information for athletes. Thus, when interpreting data on physical readiness to train, the possible influence of HC use and cycle-related symptom severity should be considered on an individual basis.

Resting heart rate

Resting HR was higher during pre-bleeding compared to bleeding days for all groups except for implant users. The increase in resting HR during pre-bleeding days may reflect the higher metabolic rate reported in the late-luteal phase (i.e., pre-bleeding days) (Benton et al., 2020). Similar patterns have been found in previous studies investigating resting HR in non-athletic (Altini & Plews, 2021; Tenan et al., 2014) and exercising (Sims et al., 2021) women, as well as in naturally menstruating endurance trained athletes (De Martin Topranin et al., 2023). Sims et al. (2021) found that progestin-only HC users and naturally menstruating women followed the same pattern, with resting HR being lowest in the follicular phase (i.e., corresponding to the inactive pill/withdrawal week and first active pill week) and highest in the luteal phase (i.e., corresponding to the 2nd and 3rd active pill week). Resting HR rose rapidly after the bleeding days in COC users and then gradually decreased throughout the active pill weeks (Sims et al., 2021). This aligns with the findings of the current study, where COC users were the only group with higher resting HR during the non-bleeding compared to bleeding days. The higher resting HR during the non-bleeding days may be related to the consistent delivery of exogenous hormones that are highly potent at the receptor level (Hirschberg, 2022) which may play a role in the upregulation of ventilatory rate and thereby the resting HR (Sims et al., 2021). In the current study, the largest difference in resting HR was 2 beats·min^{-1} (2.2–4.5%) between pre-bleeding, bleeding and non-bleeding days across groups. In comparison, a + 1.3% and + 3.4% change in resting HR during the luteal phase compared to follicular phase has been reported in exercising women (Altini & Plews, 2021) and in endurance trained athletes (De Martin Topranin et al., 2023), respectively. However, since the day-to-day variations in resting HR has been reported to be as large as 13% (Plews et al., 2013) the observed changes in resting HR found in the current study are arguably negligible and may therefore simply be the result of daily variation. However, as resting HR is commonly used to monitor and evaluate adaptation to training, such minimal changes may still have some practical relevance for athletes who regularly track their resting HR.

Methodological considerations

This study is one of the first to provide longitudinal day-to-day data over an annual season, exploring changes in recovery measures during the MC and HC cycles in a sample of highly trained endurance athletes. However, some limitations should be acknowledged. Firstly, we did not collect the athletes' HC history, and it is possible that some of the athletes had stopped or started using HC or changed delivery method immediately prior to participating in the study, which might have affected the athletes' hormonal profiles for a period (Elliott-Sale et al., 2021). Besides, athletes were only asked to record symptom severity. It might be that although symptom severity was lower in implant users compared to both IUS and non-HC users, that symptom frequency was lower in for example IUS users. Additionally, it is important to acknowledge that symptoms experienced during the menstrual-/HC cycle might be influenced by other lifestyle factors as well (Mitsuhashi et al., 2023). Future studies should therefore not only include cycle-related symptom severity, but also symptom frequency.

In the present study, we used calendar-based counting, which is the first step of the three-step method suggested for MC phase verification (Schaumberg et al., 2017). Based on the research question we had specific interest in the influence of pre-bleeding and bleeding days versus non-bleeding days, and since these days can be reliably observed through calendar-based counting, advanced testing methods (i.e., ovulation testing and serum blood samples) were not necessary for this design (Noordhof et al., 2024). Additionally, this design is inclusive to all athletes (regardless of HC use and MC function) which

provides valuable real-world knowledge that applies to a broad range of the female athletic population. It is important, however, to highlight that the majority of the non-HC users (19 out of 22) showed abnormal MC lengths (Figure 2), which might have influenced the observed changes in the recovery measures. Therefore, the present findings may not be reflective of eumenorrheic athletes. However, we believe that including all athletes (HC and non-HC users; eumenorrheic or not) in the analysis was important to achieve a representative sample and strengthen external validity.

The pre-bleeding days have almost been ignored within sport science, although pre-bleeding days, together with the bleeding days, are when athletes report most adverse symptoms and negative influences on recovery, training and performance (Bruinvels, Hackney, et al., 2022). Moreover, the use of the athletes' tracking tool to collect data provided high ecological validity and made it possible to collect longitudinal data from a large sample of highly trained athletes using different types of HC. Using the athletes' own tracking tool to collect data without interfering their daily routines may have, however, led to some inconsistency in the timing of recording, which might have influenced the athletes' perception of different measures. In addition, some of the groups were relatively small (i.e., the POC group) and our findings should therefore be replicated in studies with larger sample sizes.

Finally, it is important to acknowledge that the data was collected during the COVID-19 pandemic (May 2020–September 2021). This may have influenced our results as the potential lifestyle changes, as well as the vaccines and COVID-19 sickness, have been reported to potentially impact both the MC, bleeding, and cycle-related symptoms (Bruinvels, Blagrove, et al., 2022; Nazir et al., 2022; Quejada et al., 2022). Unfortunately, we did not record the athletes' medical history of vaccinations/COVID-19 sickness, nor were athletes asked if they experienced any MC or bleeding abnormalities in association with COVID-19. Therefore, it is not possible to estimate the impact of this on the results.

Conclusion

This long-term, observational study of highly trained endurance athletes found pre-bleeding days, as well as the severity of cycle-related symptoms, to detrimentally influence recovery measures in both HC- and non-HC users. Collectively, lower perceived sleep quality and readiness to train, as well as higher resting HR could indicate a less favourable recovery state and thereby negatively influence training adaptations and performance. Therefore, athletes and their support staff are advised to systematically monitor recovery measures, as well as the MC/HC cycle and related symptoms. Furthermore, symptom management and adjustment of recovery strategies should be prioritized on an individual basis throughout the athletes' cycles to optimize the training process.

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Author contributions

TE, GSS, BM, DN, ØS, EA and BW designed the study. TE and GSS recruited subjects and collected data together with MT and VMT. TE, JO, and BW analysed the data. TE wrote the first draft of the manuscript. All the authors have contributed to the revision of the manuscript and have read and approved the final version.

Consent to participate

The participants provided their written informed consent to participate in this study.

Data availability statement

The datasets generated during and/or analysed during the current study are not publicly available due to privacy concerns, but are available from the corresponding author on reasonable request

Ethics approval

This project was reviewed and approved by Sikt, Norwegian Agency for Shared Services in Education and Research (Project ID: 409326) and evaluated by REK, Committees for Medical and Health Research Ethics (Project ID: 135555).

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