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Changes in self-reported physical fitness, performance, and side-effects across the phases of the menstrual cycle among competitive endurance athletes

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Original investigation

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Abstract

Purpose: To investigate changes in self-reported physical fitness, performance, and side-effects across the menstrual cycle (MC) phases among competitive endurance athletes, and to describe their knowledge and communication with coaches about the MC.

Methods**:** The responses of 140 participants (>18 years), competing in biathlon or cross-country skiing at the (inter)national level were analyzed. Data were collected via an online questionnaire addressing participants' competitive level, training volume, MC history, physical fitness and performance during the MC, MC-related side-effects, and knowledge and communication with coaches about the MC and its effects on training and performance.

Results: 50% and 71% of participants perceived improved and reduced fitness respectively, during specific MC-phases, whereas 42% and 49% perceived improved and reduced performance, respectively. Most athletes reported their worst fitness (47%) and performance (30%), and the highest number of side-effects during bleeding (p<.01; compared to all other phases), the phase following bleeding were considered the best phase for perceived fitness (24%, p<.01) and performance (18%, p<.01). Only 8% of participants reported to have sufficient knowledge about the MC in relation to training, and 27% communicated about it with their coach.

Conclusions**:** A high proportion of athletes perceived distinct changes in fitness, performance, and side-effects across the MC-phases, with their worst perceived fitness and performance during the bleeding phase. Because most athletes indicate a lack of knowledge about the MC's effect on training and performance and few communicate with coaches on the topic, we recommend that more time should be devoted to educating athletes and coaches.

Keywords: coaching, female athlete, hormonal contraceptives, sex hormones, training quality, coach education

Introduction

Differences in physical development between women and men accelerate from the onset of puberty, mainly due to changes in circulating levels of sex-specific hormones. In women aged ~13 to ~50 years, ovarian hormones fluctuate with defined phases of varying hormonal profiles during 21–35-day periods in an individual rhythm called the *menstrual cycle* (MC).[1,2] Hormonal fluctuations during the MC have been reported to particularly influence ventilation, thermoregulation, and substrate metabolism[3-6], as well as causing negative side-effects such as pain, heavy menstrual bleeding, anemia, and mood changes.[7,8] In theory, such physiological responses to hormonal fluctuations and their negative side-effects could influence the quality of training and endurance performance throughout the MC. However, the previous research on the influence of MC on objectively measured endurance performance are inconsistent.[3,4,9-15] This is possibly due to methodological differences (e.g., divergent definitions of MC phases), the low number of available studies using quantified hormonal concentrations to verify MC phases,[16] and the low number of studies with adequate sample size conducted on this topic.[17] Furthermore, a substantial proportion of elite athletes are known to be susceptible to menstrual irregularities,[18,19] which disrupt their hormone profiles and thereby make the interpretation of research findings challenging.

The available research on the athlete's perceived effect of the MC reports that 51% of elite marathon runners experienced an impact of their MC on training and performance.[8] However, details on when runners performed best or worst during the cycle were not provided. Moreover, Martin et al.[7] found that 77% of athletes not using hormonal contraceptives (HCs) reported negative MC-related symptoms (e.g., abdominal pains or cramps), mostly during the first days of bleeding. However, their sample included athletes from a range of sports, and they did not investigate whether the athletes had planned or adjusted their training to accommodate these negative side-effects. Consequently, specific information about the influence of the MC on perceived physical fitness and performance and the negative side-effects from a large sample of elite endurance athletes would provide important information.

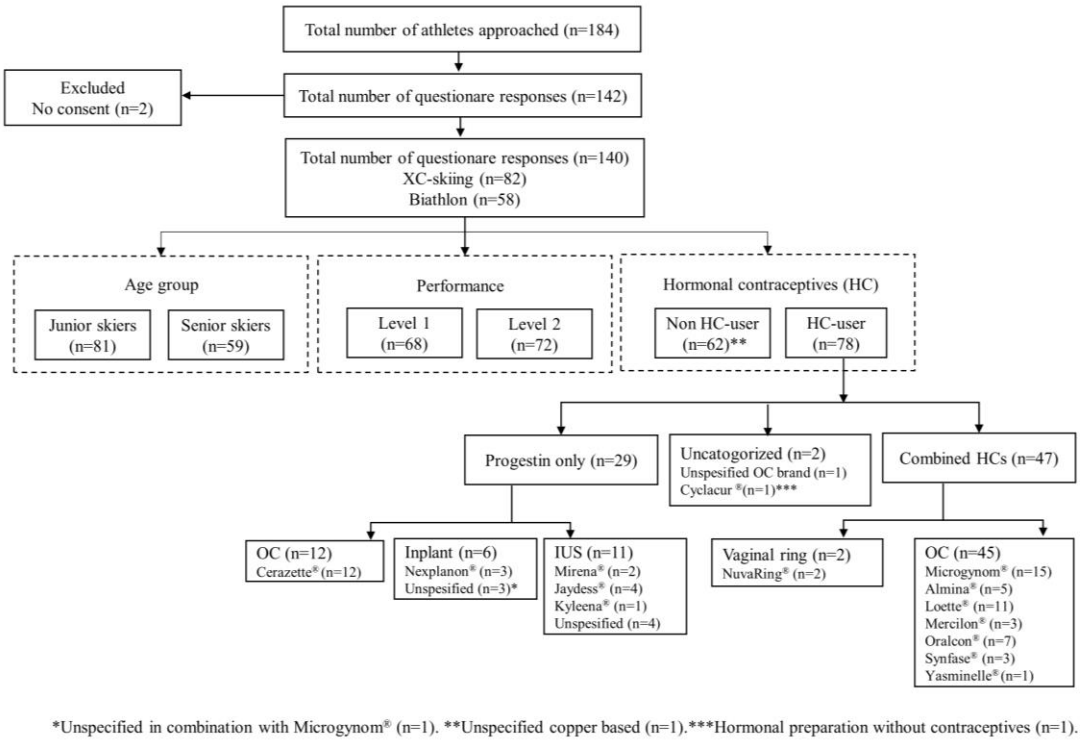
An estimated 40–70% of female athletes use some type of HCs,[7,18,20] with athletes perceiving in general more positive than negative effects of HC use.[7] Examples of positive effects are the ability to predict or manipulate the bleeding period and the reduction of pain, while negative effects such as weight gain and irregular periods have also been reported.[7] Women using combined oral contraceptives (OCs) have exhibited higher cortisol levels,[21] lower maximal aerobic capacity,[22] and less adaptation to sprint-interval training[23] than non-users, whereas endurance performance seems unaffected.[14,24,25] It is currently unknown whether the varying doses and routes of administration of sex hormones in different HC preparations (e.g., OCs, implants, injections, transdermal patches, vaginal rings, and intrauterine systems) and types of HCs (e.g., estrogen–progestin and progestin-only types) will influence endurance performance.[26] However, negative side-effects have more often been reported for progestin-only than estrogen–progestin HCs.[7] In addition, considerable individual variations in the type and severity of HC-related side-effects, as well as in reasons to start and stop using HCs, have been reported.[7] Indeed, more specific knowledge about the use of HCs among competitive endurance athletes could help female athletes to optimize their training adaptations during the MC. Therefore, the primary aim of the current study was to investigate changes in self-reported physical fitness, performance, and side-effects during the different phases of the MC in competitive endurance athletes, and the influence of age (i.e., senior vs. junior athletes), performance level (i.e., international vs. national), and HC-use.

Another unclear factor is how much endurance athletes know about the MC and its possible effects on their training and performance. Furthermore, a large proportion of female athletes are coached by men,[27,28] who, according to a previous study, are less knowledgeable about, and less comfortable with talking about MC irregularities than female coaches.[29] However, this has only been examined in a sample of high-school coaches whose knowledge and communication behaviors might differ from coaches of elite athletes. Moreover, the main topic of their questionnaire was the female athlete triad, not the MC. Consequently, research on how much endurance athletes and their coaches know and communicate about the MC remains necessary. Therefore, the secondary aim of the current study was to describe athletes' knowledge and communication with their coaches about the MC.

Methods

Participants

As cross-country skiing and biathlon are demanding endurance sports in which approximately 90% of training consists of aerobic endurance exercises,[30,31] 184 elite female athletes from these sports were recruited between May and September 2018. All participants had to be >18 years old and competing at the national or international level. Ultimately, 140 elite endurance athletes completed the questionnaire, and their data were included in the final analysis (Figure 1). Of them, 59% (n=82) were cross-country skiers, and 41% (n=58) biathletes. The study was evaluated by the Regional Committee for Medical and Health Research Ethics (2018/50/REK-midt) and approved by the Norwegian Social Science Data Services. All participants were informed about the content and nature of the questions, and that they by agreeing to the terms and completing the questionnaire, had provided written informed consent for their information to be used in this study.



*Unspecified in combination with Microgynom® (n=1). **Unspecified copper based (n=1).***Hormonal preparation without contraceptives (n=1).

Figure 1 – Sample characteristics and the prevalence of type, delivery method, and preparation of HCs used; HC, hormonal contraceptives; IUS, intrauterine system; OC, oral contraceptive.

Questionnaire

Data were collected via an online questionnaire (Questback, 2017) designed according to the study's aim and developed by an expert panel of former athletes, coaches, a physiologist, and researchers with experience from similar projects and relevant medical expertise.To ensure that participants understood the questions, a pilot study with eight participants was conducted before data collection commenced.

Designed to take 15–20 min to complete, the questionnaire contained 54 questions: 25 closed-ended questions, 11 questions asking for a numeric value, seven yes-or-no questions, three multiple-choice questions, and 11 open-ended questions. Participants reported their demographic information, aspects of training, competition level, menstrual history, physical fitness (perceived training quality), and performance (results on tests or competitions) during the MC, as well as MC-related negative side-effects. To ensure a uniform understanding of the MC's different phases, a simple four-phase definition of the MC was provided prior to questions regarding the different phases (Figure 2). The questionnaire also contained questions about the athletes' perceptions of their own and their coaches' knowledge of the MC in relation to training and how they communicated about the topic. All athletes answered the questions related to communication and knowledge about the MC (n=140), while all athletes who reported to have had their menarche answered the questions regarding physical fitness, performance and menstrual-related side effects across the different phases of the MC (n=139). Current HC users (n=78, 56%) were instructed to complete an additional set of in-depth questions about their experience with using HCs. Because the questionnaire was in Norwegian, a translating process was performed to ensure validity when interpreting the questions in English. First, the questionnaire was translated by one person that was fluent in English and had a good understanding of Norwegian. Thereafter, this version was back-translated independently by two persons who were fluent in Norwegian and had a good understanding of English. Thereafter, all three translators compared the original questionnaire with the one translated back and assessed if a word or several words reflected the same in both the original and the English version of the questionnaire.[32]

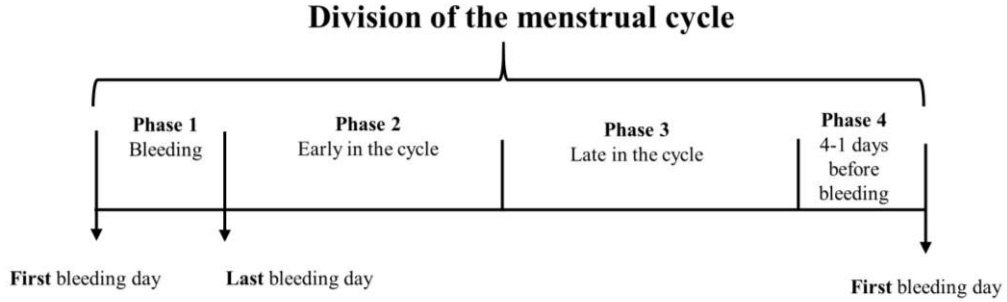


Figure 2 – Definition of the menstrual cycle in connection to questions related to phases of the cycle.

Statistics

Questionnaire responses were summarized in numerical values to facilitate statistical analyses. To categorize free-text questions, two researchers performed independent content, frequency, and consistency analyses until consensus was reached. Direct verbatim quotations were used to inform interpretation. Descriptive data for continuous variables were recorded as means (*SD*) and for categorical variables as totals and percentages. For continuous variables, the Shapiro–Wilk test and standard visual inspection were used to examine the assumption of normality.

A binary group categorization was performed to assess potential differences in subgroups by age, including junior (i.e., 17–20 years old) versus senior athletes (i.e., 21–33 years old); performance level, including Level 1 (i.e., at least one ranking of 1–30 in international competitions or an overall ranking of 1–10 in the Norwegian National Cup) versus Level 2 (i.e., overall ranking of 11–50 in the Norwegian National Cup); and HC use status, including current HC users versus current non-HC users. Pairwise differences in sample characteristics between subgroups were assessed with independent samples *t*-tests and differences in proportions assessed with Pearson's chi-squared tests.

The total score of side-effects was calculated as the sum of reported symptoms during each phase of the MC. Global differences in the number of side-effects across the phases were assessed with linear mixed-effects models involving MC-phase as a fixed factor and participant as a random factor. When significant *F*-values emerged, pairwise post hoc tests with Tukey's adjustment were used. Model fit was examined with normal Q–Q plots of studentized residuals. Interactions of phase with age, performance level, and HC-use were examined to assess differences between subgroups.

All statistical tests were two-sided, and p values $<.05$ were considered statistically significant. Statistical analyses were conducted using the Statistical Package for the Social Sciences version 24.0 (SPSS Inc., Chicago, IL, USA) and Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

Results

The sample's characteristics appear in Table 1 and summarized questionnaire responses in Supplementary Tables 1–5. The average age of menarche for all athletes was 13.9±2.0 years; 15% were more than 16 years old at menarche, and one 19-year-old athlete reported primary amenorrhea. Few athletes (4%) reported no bleeding periods during the previous year, 13% reported fewer than five periods, 17% reported 5–9, and 56% reported 10–15. Moreover, 30% experienced loss of menstrual bleeding in connection with high volumes of training and 23% in connection with large amounts of high-intensity training.

Table 1 Age and training data (Mean±SD) for the 140 elite female cross-country skiers and biathletes included in this study.

	Total	Age group			Performance			Current HC-user		
	(n=140)	Junior (n=81)	Senior (n=59)	*P-value*	Level 1 (n=68)	Level 2 (n=72)	*P-value*	No (n=61)	Yes (n=78)	*P-value*
Age (years)	21.6±3.1	19.4±0.9	24.4±2.8	*.000*	22.4±3.5	20.8±2.5	*.009*	20.5 ± 2.3	22.4 ± 3.4	*.000*
Training volume (h/year)	575±148	523±109	620±163	*.000*	640±130	513±138	*.000*	570±130	579±162	*.633*
Weekly volume GP (h/wk)	13.6±3.9	12.7±3.5	14.5±4.1	*.000*	15.4±3.4	12.0±3.5	*.000*	13.4±3.7	13.9±4.0	*.373*
Weekly sessions GP (h/wk)	9.9±2.6	9.5±2.8	10.3±2.4	*.013*	10.4±2.0	9.0±2.7	*.000*	9.8±2.4	10.1±2.8	*.481*
Weekly HIT GP (h/wk)	2.4±0.8	2.3±0.8	2.4±0.8	*.035*	2.5±0.7	2.2±0.9	*.014*	2.2±0.8	2.4±0.9	*.045*
Weekly volume CP (h/wk)	10.1±3.0	9.6±2.4	10.7±3.3	*.013*	11.4±2.5	9.1±2.9	*.000*	10.0±3.0	10.4±2.9	*.264*
Weekly sessions CP (h/wk)	8.5±2.6	8.3±2.7	8.9±2.4	*.014*	9.5±2.5	7.8±2.4	*.000*	8.5±2.7	8.7±2.4	*.247*
Weekly HIT CP (h/wk)	2.6±0.8	2.6±0.8	2.7±0.8	*.169*	2.8±0.6	2.5±0.9	*.008*	2.6±0.7	2.7±0.9	*.304*

HC; hormonal contraceptives, Level 1; at least one ranking between 1-30 in world cup races and/or an overall ranking between 1-10 in the Norwegian National Cup, Level 2; at least and/or an overall ranking between 11-50 in the Norwegian National Cup, HIT; high-intensity training, GP; general preparation phase, CP; Competition phase.

Physical fitness, performance, and MC-related side-effects during the MC

Figure 3 illustrates the athletes' self-reported physical fitness and performance during the MC. Fifty and 71% of the athletes reported improved or reduced physical fitness during specific phases of the MC, respectively, whereas 42% and 49% reported improved or reduced performance, respectively. Global comparisons revealed that physical fitness and performance differed significantly by phase (both $p<.001$) and that the greatest proportion of athletes experience their worst fitness (47%) and performance (30%) during Phase 1 ($p<.01$ compared to all other groups). By contrast, the best physical fitness was reported most frequently during Phases 2 and 3 (24% and 14%, respectively; both $p<.01$ compared to Phases 1 or 4), as was best performance (18% and 18%, respectively; both $p<.01$ compared to Phases 1 or 4). Subgroup analyses revealed no significant differences between age groups, performance levels, or use of HCs (all $p>.05$). A large proportion of athletes indicated not to perceive improvement (50%) or reduction (29%) in physical fitness, or improvement (58%) or reduction (51%) in performance across the different phases of the MC (Figure 3).

The most frequently reported side-effects were stomach pain (83%) and bloating (63%, Figure 4), while 8% of the athletes had not experienced any MC-related side-effects in the last year. The number of side-effects differed significantly by phase ($p<.001$), with the highest number being reported in Phase 1 (3.6±2.4), followed by Phases 4 (2.1±2.1), 2 (0.5±1.3), and 3 (0.3±0.7, $p<.05$ for all pairwise comparisons). Subgroup analyses revealed no significant interactions by age group, performance level, or use of HCs (all $p>.05$).

Fifty-two and 22% of the athletes altered their training at least once or more than 3 times, respectively, due to MC-related side-effects during the previous year. Only 7% of athletes planned their training according to their MC ($p<.001$). The most frequent reasons for altering training were stomach pain (40%) and lower-back pain (20%) (detailed information presented in Table 2).

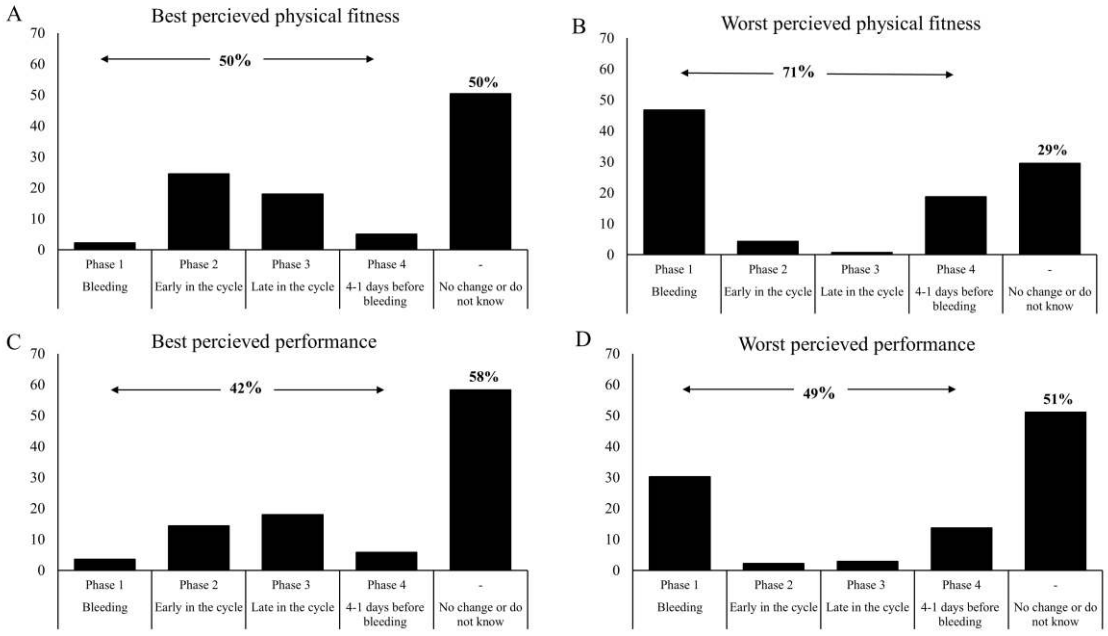


Figure 3 A–D – The athletes' self-reported best (A) and worst (B) physical fitness, and the athletes' self-reported best (C) and worst (D) performance across the phases of the menstrual cycle.

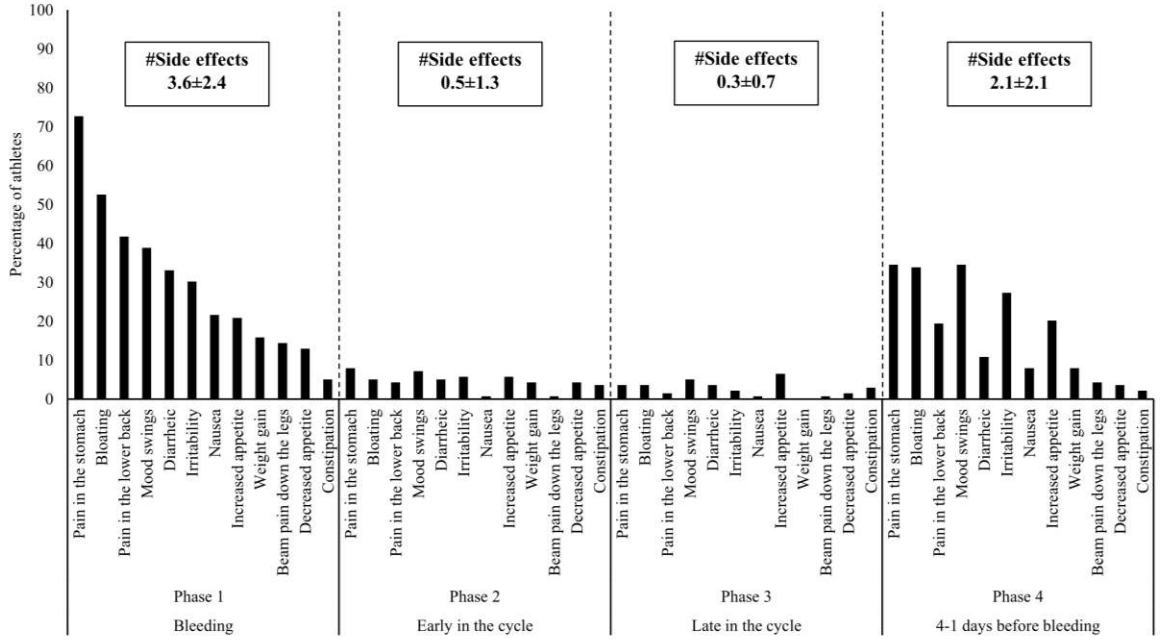


Figure 4 – The athletes' self-reported side-effects across the phases of the menstrual cycle.

Use of HCs

As shown in Figure 1, 56% of the athletes were using HCs at the time of data collection. HC-users were significantly older than non-users (22.4 vs. 20.5 years; $p<.01$), and 61% used estrogen–progestin HCs, 38% used progestin-only HCs, and 1% used an unspecified type of OC (Figure 1). OCs were the most widely used HCs, followed by intrauterine systems (15%), implants (9%), and vaginal rings (3%).

In response to follow-up questions, nearly all HC users (98%) used HCs throughout the entire year, and 33% used HCs to manipulate their timing of the MC. 17% of HC-users stated that HCs had positively affected their performance or physical fitness, 5% reported negative experiences, and 26% reported previously discontinuing their use of another type of HC that had compromised their performance (detailed information presented in Table 2).

Knowledge and communication about the MC

Overall, 8% of the athletes reported having sufficient knowledge about the MC in relation to athletic training and performance. Most athletes had communicated about training and the MC with other athletes (79%), friends (66%), and family members (56%), while only 27% had communicated with their coaches about the topic. Notably, 81% of the athletes' coaches were men, and 19% were women; however, 44% of athletes with female coaches reported discussing the MC with their coaches, only 22% of ones with male coaches reported doing so. Among athletes who had not talked to their coaches about the MC and training, 63% did not want to do so, and 27% found broaching the subject difficult (reasons presented in Table 2).

Table 2 Overview of the analysis of open-end follow up questions about menstrual cycle-related adjustments of training, knowledge and communication about the menstrual cycle and the experiences of hormonal contraceptives

How have you changed your training according to MC-related side effects?[1)]	
Reduced the intensity (n=22)	*"I did not train due to a bad physical shape or feeling miserable. I sometimes performed an easier type of session, and often missed a good training session."*
Cancelled/postponed session or taken a rest day (n=21)	
Reduced the duration (n=17)	
Postponed high-intensity sessions (n=10)	*"I just get very tired and have poor physical shape on the first day of the bleeding phase. If it is an interval session or test, I try to postpone it because it always goes bad on these days."*
Interrupted sessions (n=4)	
Changed exercise mode (n=4)	
What would you like to learn in relation to the MC and training?[2)]	
General information about how the MC can affect training (n=41)	*"If and to what extent the MC can affect exercise. For example, if I can benefit from exercising in a specific way, like more emphasis on high-intensity or strength sessions in a particular phase of the cycle. The same applies recovery after sessions; how does the MC affects this, and to what extent would the use of oral contraceptives affect training and recovery."*
If it's possible to periodize training sessions after the MC to get more effect of the training (n=33)	
If the MC affects performance (n=30)	
If the MC can affect training adaptations (n=19)	
If/how HCs affect training and performance (n=9)	*"I have lost my period completely, so it would be nice to know if this is normal and whether it will be possible to have children in the future."*
If it is dangerous if the menstrual bleeding phase disappears (n=6)	
If there are menstrual phases during which you are more vulnerable for injuries (n=2)	
If there is something you can do to reduce pain (n=2)	
Why do you find it difficult to talk to your coach about the MC?[3)]	*"Feels like it's a taboo. I am afraid that the coach won't take it seriously and thinks I'm using it as an excuse.*
Private, taboo, uncomfortable or embarrassing (n=11)	
My coach is a man (n=10)	*"I think I have more competence and knowledge about this topic than he."*
Don't know (n=7)	
Don't know the coach well enough (n=4)	*"Because he is a man."*
The coach lacks knowledge on this topic (n=3)	
What knowledge about the MC and training do you think your coach lacks?[4)]	
General information about how the MC can affect training (n=22)	*"The difference between female and male athletes. I think there may be differences due to the MC that he is not aware of."*
Don't know since we have not talked about this (n=16)	
If the MC can affect training adaptations or performance (n=13)	
That it leads to pain (n=3)	*"General lack of knowledge about the menstrual cycle"*
How it affects the risk for injuries (n=1)	
How has the use of HCs affected your performance at training or competitions?[5)]	
Less pain (n=9)	*"Decreases pain and shortens the bleeding phase."*
More tired (n=4)	
Don't need to worry about the bleedings (n=2)	*"Positive: can skip my period in the competition season."*
Gain of weight (n=2)	
Less bleeding (n=1)	*"Gained 3 kg! When I quit using the pill, I lost weight and could run much easier uphill."*
Mood swings (n=1)	
Can you describe why you stopped using this type of HC?[6)]	
Weight gain (n=7)	*"Gained weight. It negatively affected my performance."*
Irregular MC(n=6)	
Increased pain (n=5)	*"Mostly because I felt out of balance, both physically and mentally."*
Mood swings (n=5)	
Lack of performance progress (n=2)	*"Experienced discomfort during the bleeding period. Got irregular bleeding, weight gain and mood swings."*
Unsure if it could affect my training adaptations (n=1)	
Thrombosis (n=1)	
Stressful to remember to take the pill (n=1)	

MC; menstrual cycle, HC; hormonal contraceptives. The questions in the table were follow-up questions asked to all athletes answering [1)] that they had changed their training because of MC-related side effects [2)] *"No"* at the question*: "Do you think you have enough knowledge about how the MC can affect training and performance?",* [3)] *"Yes"* at the *question: "Do you find it difficult to talk to your coach about the MC in relation to training and performance?"* [4)] *"No" at* the question: *"Do you think your coach has enough knowledge about the MC in relation to training and performance?* [5)] *"Yes"* at the question: *Have you experienced that the HC affects your performance on training or competition?* [6)] *"Yes"* at the question: *"Have you ever stopped using a HC, because you experienced it affected your physical fitness or performance?"*

Discussion

We investigated changes in self-reported physical fitness, performance, and negative side-effects during the different phases of the MC among competitive endurance athletes, as well as the athletes' knowledge and communication with their coaches about this topic. The main findings of the current study were: 1) 50% and 71% of the athletes perceived improved or reduced physical fitness, respectively, during specific phases of the MC, whereas 42% and 49% reported improved and reduced performance, respectively; 2) a large proportion of athletes perceived no changes in physical fitness or performance across the MC; and 3) no differences in fitness, performance or negative side-effects by age, performance level, or HC-use emerged. Moreover, 4) only 8% of the athletes indicated having sufficient knowledge about the MC's effects on athletic training and performance, and 5) only 27% reported to communicate with their coaches about the topic.

Physical fitness, performance, and side-effects during the different phases of the MC

The result that approximately 50% of the athletes reported distinct changes in physical fitness and performance during the MC-phases is comparable to what Bruinvels et al.[8] observed among marathon runners. Of the athletes who reported that the MC had affected their fitness or performance, significantly more reported reduced physical fitness or performance in Phase 1 (i.e., bleeding) than during the other three phases. Reduced physical fitness or performance during the MC has been associated with premenstrual symptoms or dysmenorrhea (i.e., menstrual cramps caused by uterine contractions).[2] Likewise, our athletes reported that negative side-effects of the MC most often occurred during Phase 1, followed by Phase 4 (i.e., 1–4 days before bleeding). The most common symptoms were stomach pain, bloating, and mood swings. Such findings align those of Martin et al.[7], who reported the highest prevalence of side-effects during days 1 and 2 of Phase 1. Other researchers have observed higher training monotony and strain during the early stages of the MC than during the ovulatory phase, which they attributed to the increased prevalence of MC-related symptoms in the first half of the MC (i.e., follicular phase) compared to the second half (i.e., luteal phase).[33] Most likely due to the high incidence of side-effects in Phases 1 and 4, athletes in our sample reported the best physical fitness and performance during Phases 2 and 3. However, experimental research on endurance performance during the phases of the MC has produced mixed results; some researchers have observed better performance during the follicular phase[11,15] or increased performance during the luteal phase,[9,12] although most have reported no fluctuation in performance during the MC.[3,4,10,13,14] Such inconsistent findings may stem from methodological differences,[16] particularly in different definitions of the MC's phases. However, the substantial number of athletes in our study who reported distinct changes in performance during the MC highlights the need for additional research on the topic.

Despite the high incidence of symptoms of stomach pain (83%), only 22% of the athletes reported to repeatedly (i.e., >3 times/year) alter their training due to MC-related side-effects. By comparison, Martin et al.[7] found that only 4% of athletes in different sports reported needing to refrain from exercise at certain points of their MC.[7] In our study, the most frequent types of MC-related training adjustments were reduced intensity or duration, cancelled sessions and postponed high-intensity training sessions. To reduce the severity of negative side-effects, 52% of the athletes reported having used painkillers, which suggests that many athletes experience some degree of pain during the MC that can affect their physical fitness, performance, and training quality. However, it remains uncertain whether athletes take those medications to become able to perform planned training sessions and whether doing so affects subsequent

353 training adaptations. In response, monitoring the MC could likely provide information to guide
354 the development of training schedules and optimize performance.
355
356 **Period prevalence and HC use**
357
358 The mean age at menarche (13.9±2.0) was roughly the same as that previously reported by
359 endurance athletes (13.8±1.5),[18] slightly higher than that of athletes from various sports
360 (13.6±1.4)[7], and higher than that observed in non-athlete controls (13.0±1.3).[18] Whereas 15%
361 of the athletes in our study reported primary amenorrhea (i.e., menarche at 16 years of age or
362 older), only 11% of endurance athletes reported the same in an earlier study.[18] Although it
363 remains unclear whether delayed menarche derives from genetic factors, high volumes of
364 training, or a focus on leanness,[18] most non-HC users (56%) reported a prevalence of MCs
365 within the normal range of 10–15 cycles per year. Notably, 35% of non-HC users reported
366 fewer than nine periods in the previous year, which could indicate menstrual dysfunction.[34]
367 Elite female athletes, particularly endurance athletes, are known to be susceptible to menstrual
368 irregularities, often due to relative energy deficiencies associated with high volumes of
369 training.[35] In line with that trend, 30% of the athletes in our study indicated the loss of periods
370 in connection with high volumes of training and 23% with large amounts of high-intensity
371 training. Although we did not assess energy intake or energy expenditure, high volumes of
372 training and high amounts of high-intensity endurance training are associated with high energy
373 expenditure and can prompt relative energy deficiencies. Elite endurance athletes and their
374 coaches should therefore be aware of the risk of MC irregularities induced by high volumes of
375 training and high amounts of high-intensity training. The prevention of MC irregularities
376 should also be pursued, because primary and secondary amenorrhea can result in adverse health
377 conditions, including reduced bone health.[35]
378
379 The prevalence of HC use in our study (56%) exceeded that reported for the female population
380 in Nordic countries (35–45%)[36] but fell within the 40–70% prevalence reported by elite
381 athletes.[7,18,20] Martin et al.[7] observed that a higher proportion of athletes used estrogen–
382 progestin HCs (61%) than progestin-only HCs (38%). This was also the case in our study, and
383 may be explained by the lower proportion of negative side-effects reported with the use of
384 estrogen–progestin versus progestin-only HCs.[7] Martin et al.[7] additionally reported that HC
385 users were more likely to indicate positive than negative side-effects, which we also observed
386 in our study. However, 26% of HC users reported previously discontinuing their use of other
387 contraceptives because they had compromised their performance. Other researchers have
388 highlighted a large individual response to HCs,[7] possibly due to limited knowledge and
389 communication about this topic.
390
391 **Knowledge and communication about the MC**
392
393 Only 8% of the athletes indicated having sufficient knowledge about how the MC affects
394 athletic training and performance. Most coaches in women's sports are men,[27,28] none of whom
395 has personal experience with the MC, which may reduce the transfer of knowledge and
396 communication about the MC and its possible effect on training and performance. In our study,
397 27% of the athletes reported that they had communicated about the MC with their coach during
398 the previous year, with the percentage being higher when the coach was a woman (44%) instead
399 of a man (22%). In line with those findings, a previous study reported that male coaches
400 believed it was less important to ask athletes about menstrual irregularities, had less knowledge
401 about the health risk associated with menstrual irregularities, and were less comfortable with
402 communicating about menstrual irregularity than female coaches.[29] Furthermore, our data also

revealed that most of the athletes (63%) did not want to talk to their coaches about their MCs, which indicates that the topic continues to be regarded as taboo. Since menstrual dysfunctions are an important marker for relative energy deficit, a syndrome affecting many aspects of physiological functioning, health, and athletic performance,[35] it is important that athletes feel comfortable to discuss this topic with their coach. Furthermore, because of the high inter-individual variability in performance and side effects experienced by athletes during the MC, coach-athlete communication is important to safeguard the athlete's health as well as optimize training adaptations and performance. In response, increased attention should be paid to educating female athletes and their support teams about the MC and athletic training.

Limitations

Several limitations of the current study should be highlighted: 1) The data of athletes using different HCs were combined into one group, while the hormonal concentrations and perceived side-effects might differ between types of HC; 2) The statistical power was too low to make comparisons between the different types of HC 3) Recall bias is a limitation of retrospective questionnaires; 4) Headaches or heavy menstrual bleeding, both of which are frequently reported side-effects of the MC,[7,8] were not included as side-effects in the questionnaire; 5) The four-phase definition of the MC (Figure 2) has not been used in previous research, which makes comparisons to literature difficult, and; 6) The relationships between the changes in perceived physical fitness, performance and side-effects, and the concentration of hormones cannot be established. Therefore, we can not provide any recommendations regarding training and performance optimization during the specific phases of the MC.

Practical applications

- *Systematic monitoring of the MC:* Coaches should motivate their athletes to track their MC and MC-related symptoms and actively use this information in the evaluation of training quality, training adaptations and performance.
- *Conscious use of HC:* Coaches should make the athletes aware that HCs could affect their training response, both positively and negatively, and ensure that the athletes communicate about this with the medical doctor, so the preparations prescribed are optimal for their individual situation. Athletes should also systematically monitor their training response when starting with a (new) HC.
- *More communication:* Because of the high inter-individual variability in performance and side effects experienced by athletes during the MC, coach-athlete communication is important to safeguard the athlete's health as well as to optimize training adaptations and performance. The same applies for the use of HC.
- *Increased knowledge about the MC and HC:* Coaches should consult experts to ensure that they have enough knowledge to have an evidence-based dialogue about this topic with their athletes.
- *Education of athletes:* Increased attention should be paid to educating female athletes and their support teams about the MC, HC and athletic training.

Conclusions

A high proportion of athletes experienced distinct changes in fitness, performance, and side-effects across the MC-phases, with their worst perceived physical fitness, performance and most reported MC-related side-effects during bleeding. However, no differences by age, performance level, or HC use emerged, indicating these findings to be generalizable for the endurance athlete population. Because most athletes indicated a lack of knowledge about the MC's effect on athletic training and performance and few to communicate with their coaches about the topic, we recommend that more time should be devoted to educating athletes and coaches.

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References

1. Diaz A, Laufer MR, Breech LL. Menstruation in girls and adolescents: Using the menstrual cycle as a vital sign. *Pediatrics.* 2006;118(5):2245-2250.
2. Constantini NW, Dubnov G, Lebrun CM. The menstrual cycle and sport performance. *Clin Sports Med.* 2005;24(2):51-82.
3. Dombovy ML, Bonekat HW, Williams TJ, Staats BA. Exercise performance and ventilatory response in the menstrual cycle. *Med Sci Sports Exerc.* 1987;19(2):111-117.
4. Bemben DA, Salm PC, Salm AJ. Ventilatory and blood lactate responses to maximal treadmill exercise during the menstrual cycle. *J Sports Med Phys Fitness.* 1995;35(4):257-262.
5. Oosthuyse T, Bosch AN. The effect of the menstrual cycle on exercise metabolism: Implications for exercise performance in eumenorrhoeic women. *Sports Med.* 2010;40(3):207-227.
6. Pivarnik JM, Marichal CJ, Spillman T, Morrow JR, Jr. Menstrual cycle phase affects temperature regulation during endurance exercise. *J Appl Physiol (1985).* 1992;72(2):543-548.
7. Martin D, Sale C, Cooper SB, Elliott-Sale KJ. Period prevalence and perceived side effects of hormonal contraceptive use and the menstrual cycle in elite athletes. *Int J Sports Physiol Perform.* 2018;13(7):926-932.
8. Bruinvels G, Burden R, Brown N, Richards T, Pedlar C. The prevalence and impact of heavy menstrual bleeding (menorrhagia) in elite and non-elite athletes. *PLoS One.* 2016;11(2):e0149881.
9. Jurkowski JE, Jones NL, Toews CJ, Sutton JR. Effects of menstrual cycle on blood lactate, o2 delivery, and performance during exercise. *J Appl Physiol Respir Environ Exerc Physiol.* 1981;51(6):1493-1499.
10. De Souza MJ, Maguire MS, Rubin KR, Maresh CM. Effects of menstrual phase and amenorrhea on exercise performance in runners. *Med Sci Sports Exerc.* 1990;22(5):575-580.
11. Campbell SE, Angus DJ, Febbraio MA. Glucose kinetics and exercise performance during phases of the menstrual cycle: Effect of glucose ingestion. *Am J Physiol Endocrinol Metab.* 2001;281(4):E817-825.

12. Oosthuyse T, Bosch AN, Jackson S. Cycling time trial performance during different phases of the menstrual cycle. *Eur J Appl Physiol.* 2005;94(3):268-276.
13. Shaharudin S, Ghosh AK, Ismail AA. Anaerobic capacity of physically active eumenorrheic females at mid-luteal and mid-follicular phases of ovarian cycle. *J Sports Med Phys Fitness.* 2011;51(4):576-582.
14. Vaiksaar S, Jurimae J, Maestu J, et al. No effect of menstrual cycle phase and oral contraceptive use on endurance performance in rowers. *J Strength Cond Res.* 2011;25(6):1571-1578.
15. Julian R, Hecksteden A, Fullagar HH, Meyer T. The effects of menstrual cycle phase on physical performance in female soccer players. *PLoS One.* 2017;12(3):e0173951.
16. de Jonge X, Thompson B, Han A. Methodological recommendations for menstrual cycle research in sports and exercise. *Med Sci Sports Exerc.* 2019.
17. Bruinvels G, Burden RJ, McGregor AJ, et al. Sport, exercise and the menstrual cycle: Where is the research? *Br J Sports Med.* 2017;51(6):487-488.
18. Torstveit MK, Sundgot-Borgen J. Participation in leanness sports but not training volume is associated with menstrual dysfunction: A national survey of 1276 elite athletes and controls. *Br J Sports Med.* 2005;39(3):141.
19. De Souza MJ, Toombs RJ, Scheid JL, O'Donnell E, West SL, Williams NI. High prevalence of subtle and severe menstrual disturbances in exercising women: Confirmation using daily hormone measures. *Hum Reprod.* 2010;25(2):491-503.
20. Brynhildsen J, Lennartsson H, Klemetz M, Dahlquist P, Hedin B, Hammar M. Oral contraceptive use among female elite athletes and age-matched controls and its relation to low back pain. *Acta Obstet Gynecol Scand.* 1997;76(9):873-878.
21. Wikström-Frisén L, Nordström A, Mincheva-Nilsson L, Larsén K. Impact of season and oral contraceptive use on cortisol levelsin physically active women. . *J Exerc Sports Orthop.* 2016;3.
22. Lebrun CM, Petit MA, McKenzie DC, Taunton JE, Prior JC. Decreased maximal aerobic capacity with use of a triphasic oral contraceptive in highly active women: A randomised controlled trial. *Br J Sports Med.* 2003;37(4):315-320.
23. Schaumberg MA, Jenkins DG, Janse DEJXA, Emmerton LM, Skinner TL. Oral contraceptive use dampens physiological adaptations to sprint interval training. *Med Sci Sports Exerc.* 2017;49(4):717-727.
24. Rechichi C, Dawson B, Goodman C. Oral contraceptive phase has no effect on endurance test. *Int J Sports Med.* 2008;29(4):277-281.
25. Myllyaho MM, Ihalainen JK, Hackney AC, et al. Hormonal contraceptive use does not affect strength, endurance, or body composition adaptations to combined strength and endurance training in women. *J Strength Cond Res.* 2018.
26. Elliott-Sale KJ, Hicks M. Hormonal-based contraception and the excercising female. In: Forsyth J, Roberts C, eds. *The exercising female: Science and its application.* Routledge; 2018:30-44.
27. Reade I, Rodgers W, Norman L. The under-representation of women in coaching: A comparison of male and female canadian coaches at low and high levels of coaching. *Int J Sports Sci Coach.* 2009;4(4).
28. Fasting K, Sisjord MK, Sand TS. Norwegian elite-level coaches: Who are they? *Scandinavian Sport Studies Forum.* 2017;8:29-47.
29. Kroshus E, Sherman RT, Thompson RA, Sossin K, Austin SB. Gender differences in high school coaches' knowledge, attitudes, and communication about the female athlete triad. *Eat Disord.* 2014;22(3):193-208.
30. Solli GS, Tønnessen E, Sandbakk Ø. The training characteristics of the world's most successful female cross-country skier. *Front Physiol.* 2017;8:1069.

31. Luchsinger H, Kocbach J, Ettema G, Sandbakk Ø. Comparison of the effects of performance level and sex on sprint performance in the biathlon world cup. *Int J Sports Physiol Perform.* 2018;13(3):360-366.
32. Gjersing L, Caplehorn JRM, Clausen T. Cross-cultural adaptation of research instruments: Language, setting, time and statistical considerations. *BMC med res methodol.* 2010;10:13-13.
33. Cristina-Souza G, Santos-Mariano AC, Souza-Rodrigues CC, et al. Menstrual cycle alters training strain, monotony, and technical training length in young. *J Sports Sci.* 2019:1-7.
34. Tenforde AS, Carlson JL, Chang A, et al. Association of the female athlete triad risk assessment stratification to the development of bone stress injuries in collegiate athletes. *Am J Sports Med.* 2017;45(2):302-310.
35. Mountjoy M, Sundgot-Borgen J, Burke L, et al. The ioc consensus statement: Beyond the female athlete triad-relative energy deficiency in sport (red-s). *Br J Sports Med.* 2014;48(7):491-497.
36. Lindh I, Skjeldestad FE, Gemzell-Danielsson K, et al. Contraceptive use in the nordic countries. *Acta Obstet Gynecol Scand.* 2017;96(1):19-28.