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

4  
5

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8

9   **Original investigation**

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43     **Abstract**

44

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

48

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

54

55     **Results:** 50% and 71% of participants perceived improved and reduced fitness respectively,  
56     during specific MC-phases, whereas 42% and 49% perceived improved and reduced  
57     performance, respectively. Most athletes reported their worst fitness (47%) and performance  
58     (30%), and the highest number of side-effects during bleeding ( $p<.01$ ; compared to all other  
59     phases), the phase following bleeding were considered the best phase for perceived fitness  
60     (24%,  $p<.01$ ) and performance (18%,  $p<.01$ ). Only 8% of participants reported to have  
61     sufficient knowledge about the MC in relation to training, and 27% communicated about it  
62     with their coach.

63

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

69

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

72 **Introduction**

73  
74 Differences in physical development between women and men accelerate from the onset of  
75 puberty, mainly due to changes in circulating levels of sex-specific hormones. In women aged  
76 ~13 to ~50 years, ovarian hormones fluctuate with defined phases of varying hormonal profiles  
77 during 21–35-day periods in an individual rhythm called the *menstrual cycle* (MC).<sup>1,2</sup>  
78 Hormonal fluctuations during the MC have been reported to particularly influence ventilation,  
79 thermoregulation, and substrate metabolism<sup>3–6</sup>, as well as causing negative side-effects such as  
80 pain, heavy menstrual bleeding, anemia, and mood changes.<sup>7,8</sup> In theory, such physiological  
81 responses to hormonal fluctuations and their negative side-effects could influence the quality  
82 of training and endurance performance throughout the MC. However, the previous research on  
83 the influence of MC on objectively measured endurance performance are inconsistent.<sup>3,4,9–15</sup>  
84 This is possibly due to methodological differences (e.g., divergent definitions of MC phases),  
85 the low number of available studies using quantified hormonal concentrations to verify MC  
86 phases,<sup>16</sup> and the low number of studies with adequate sample size conducted on this topic.<sup>17</sup>  
87 Furthermore, a substantial proportion of elite athletes are known to be susceptible to menstrual  
88 irregularities,<sup>18,19</sup> which disrupt their hormone profiles and thereby make the interpretation of  
89 research findings challenging.

90  
91 The available research on the athlete's perceived effect of the MC reports that 51% of elite  
92 marathon runners experienced an impact of their MC on training and performance.<sup>8</sup> However,  
93 details on when runners performed best or worst during the cycle were not provided. Moreover,  
94 Martin et al.<sup>7</sup> found that 77% of athletes not using hormonal contraceptives (HCs) reported  
95 negative MC-related symptoms (e.g., abdominal pains or cramps), mostly during the first days  
96 of bleeding. However, their sample included athletes from a range of sports, and they did not  
97 investigate whether the athletes had planned or adjusted their training to accommodate these  
98 negative side-effects. Consequently, specific information about the influence of the MC on  
99 perceived physical fitness and performance and the negative side-effects from a large sample  
100 of elite endurance athletes would provide important information.

101  
102 An estimated 40–70% of female athletes use some type of HCs,<sup>7,18,20</sup> with athletes perceiving  
103 in general more positive than negative effects of HC use.<sup>7</sup> Examples of positive effects are the  
104 ability to predict or manipulate the bleeding period and the reduction of pain, while  
105 negative effects such as weight gain and irregular periods have also been reported.<sup>7</sup>  
106 Women using combined oral contraceptives (OCs) have exhibited higher cortisol levels,<sup>21</sup>  
107 lower maximal aerobic capacity,<sup>22</sup> and less adaptation to sprint-interval training<sup>23</sup> than non-  
108 users, whereas endurance performance seems unaffected.<sup>14,24,25</sup> It is currently unknown  
109 whether the varying doses and routes of administration of sex hormones in different HC  
110 preparations (e.g., OCs, implants, injections, transdermal patches, vaginal rings, and  
111 intrauterine systems) and types of HCs (e.g., estrogen–progestin and progestin-only types) will  
112 influence endurance performance.<sup>26</sup> However, negative side-effects have more often been  
113 reported for progestin-only than estrogen–progestin HCs.<sup>7</sup> In addition, considerable individual  
114 variations in the type and severity of HC-related side-effects, as well as in reasons to start and  
115 stop using HCs, have been reported.<sup>7</sup> Indeed, more specific knowledge about the use of HCs  
116 among competitive endurance athletes could help female athletes to optimize their training  
117 adaptations during the MC. Therefore, the primary aim of the current study was to investigate  
118 changes in self-reported physical fitness, performance, and side-effects during the different  
119 phases of the MC in competitive endurance athletes, and the influence of age (i.e., senior vs.  
120 junior athletes), performance level (i.e., international vs. national), and HC-use.

121

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

132

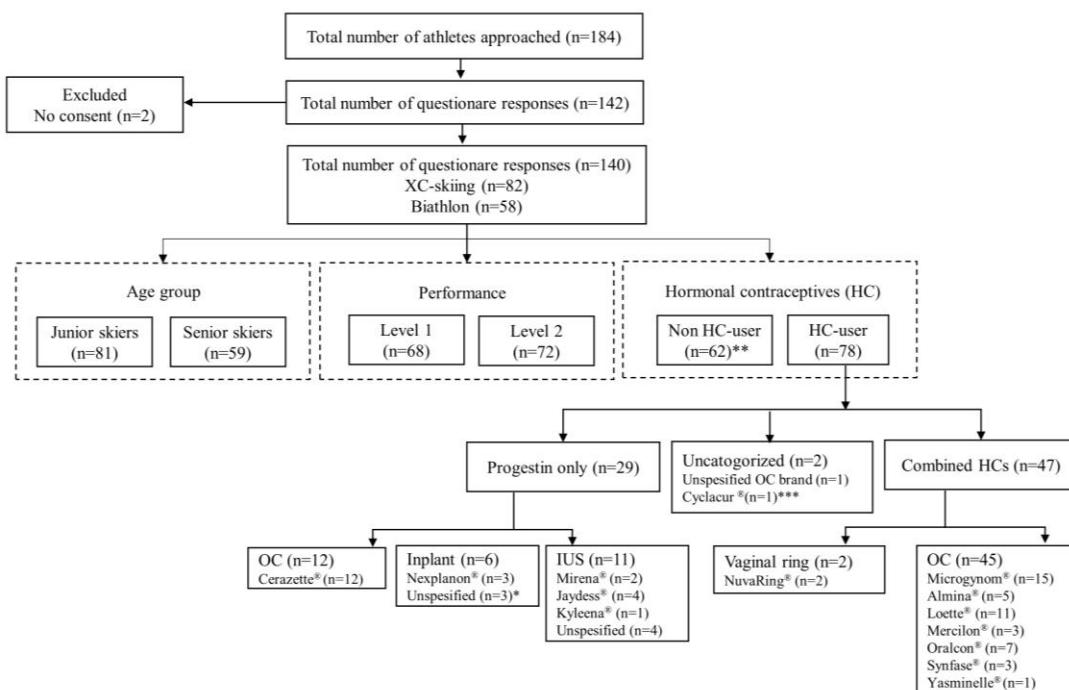
## 133 Methods

134

### 135 Participants

136 As cross-country skiing and biathlon are demanding endurance sports in which approximately  
 137 90% of training consists of aerobic endurance exercises,<sup>30,31</sup> 184 elite female athletes from  
 138 these sports were recruited between May and September 2018. All participants had to be >18  
 139 years old and competing at the national or international level. Ultimately, 140 elite endurance  
 140 athletes completed the questionnaire, and their data were included in the final analysis (Figure  
 141 1). Of them, 59% (n=82) were cross-country skiers, and 41% (n=58) biathletes. The study was  
 142 evaluated by the Regional Committee for Medical and Health Research Ethics (2018/50/REK-  
 143 midt) and approved by the Norwegian Social Science Data Services. All participants were  
 144 informed about the content and nature of the questions, and that they by agreeing to the terms  
 145 and completing the questionnaire, had provided written informed consent for their information  
 146 to be used in this study.

147



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

148

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

151

152      **Questionnaire**

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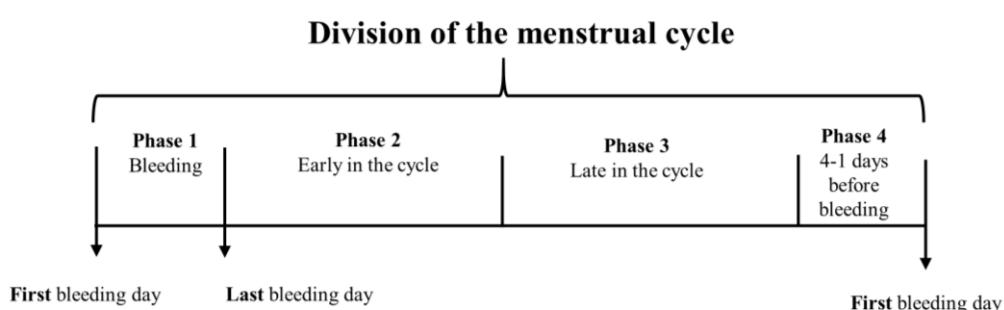
154      Data were collected via an online questionnaire (Questback, 2017) designed according to the  
155      study's aim and developed by an expert panel of former athletes, coaches, a physiologist, and  
156      researchers with experience from similar projects and relevant medical expertise. To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

159

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

182

183



184

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

187

188

189    **Statistics**

190  
191    Questionnaire responses were summarized in numerical values to facilitate statistical analyses.  
192    To categorize free-text questions, two researchers performed independent content, frequency,  
193    and consistency analyses until consensus was reached. Direct verbatim quotations were used  
194    to inform interpretation. Descriptive data for continuous variables were recorded as means (*SD*)  
195    and for categorical variables as totals and percentages. For continuous variables, the Shapiro–  
196    Wilk test and standard visual inspection were used to examine the assumption of normality.  
197

198    A binary group categorization was performed to assess potential differences in subgroups by  
199    age, including junior (i.e., 17–20 years old) versus senior athletes (i.e., 21–33 years old);  
200    performance level, including Level 1 (i.e., at least one ranking of 1–30 in international  
201    competitions or an overall ranking of 1–10 in the Norwegian National Cup) versus Level 2  
202    (i.e., overall ranking of 11–50 in the Norwegian National Cup); and HC use status, including  
203    current HC users versus current non-HC users. Pairwise differences in sample characteristics  
204    between subgroups were assessed with independent samples *t*-tests and differences in  
205    proportions assessed with Pearson’s chi-squared tests.  
206

207    The total score of side-effects was calculated as the sum of reported symptoms during each  
208    phase of the MC. Global differences in the number of side-effects across the phases were  
209    assessed with linear mixed-effects models involving MC-phase as a fixed factor and participant  
210    as a random factor. When significant *F*-values emerged, pairwise post hoc tests with Tukey’s  
211    adjustment were used. Model fit was examined with normal Q–Q plots of studentized residuals.  
212    Interactions of phase with age, performance level, and HC-use were examined to assess  
213    differences between subgroups.  
214

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

219    **Results**

220  
221  
222    The sample’s characteristics appear in Table 1 and summarized questionnaire responses in  
223    Supplementary Tables 1–5. The average age of menarche for all athletes was  $13.9 \pm 2.0$  years;  
224    15% were more than 16 years old at menarche, and one 19-year-old athlete reported primary  
225    amenorrhea. Few athletes (4%) reported no bleeding periods during the previous year, 13%  
226    reported fewer than five periods, 17% reported 5–9, and 56% reported 10–15. Moreover, 30%  
227    experienced loss of menstrual bleeding in connection with high volumes of training and 23%  
228    in connection with large amounts of high-intensity training.  
229  
230

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

	<b>Total</b> (n=140)	<b>Age group</b>			<b>Performance</b>			<b>Current HC-user</b>		
		<b>Junior</b> (n=81)	<b>Senior</b> (n=59)	<i>P</i> -value	<b>Level 1</b> (n=68)	<b>Level 2</b> (n=72)	<i>P</i> -value	<b>No</b> (n=61)	<b>Yes</b> (n=78)	<i>P</i> -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

232 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;  
233 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.

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

235

236 Figure 3 illustrates the athletes' self-reported physical fitness and performance during the MC.  
 237 Fifty and 71% of the athletes reported improved or reduced physical fitness during specific  
 238 phases of the MC, respectively, whereas 42% and 49% reported improved or reduced  
 239 performance, respectively. Global comparisons revealed that physical fitness and performance  
 240 differed significantly by phase (both  $p<.001$ ) and that the greatest proportion of athletes  
 241 experience their worst fitness (47%) and performance (30%) during Phase 1 ( $p<.01$  compared  
 242 to all other groups). By contrast, the best physical fitness was reported most frequently during  
 243 Phases 2 and 3 (24% and 14%, respectively; both  $p<.01$  compared to Phases 1 or 4), as was  
 244 best performance (18% and 18%, respectively; both  $p<.01$  compared to Phases 1 or 4).  
 245 Subgroup analyses revealed no significant differences between age groups, performance levels,  
 246 or use of HCs (all  $p>.05$ ). A large proportion of athletes indicated not to perceive improvement  
 247 (50%) or reduction (29%) in physical fitness, or improvement (58%) or reduction (51%) in  
 248 performance across the different phases of the MC (Figure 3).

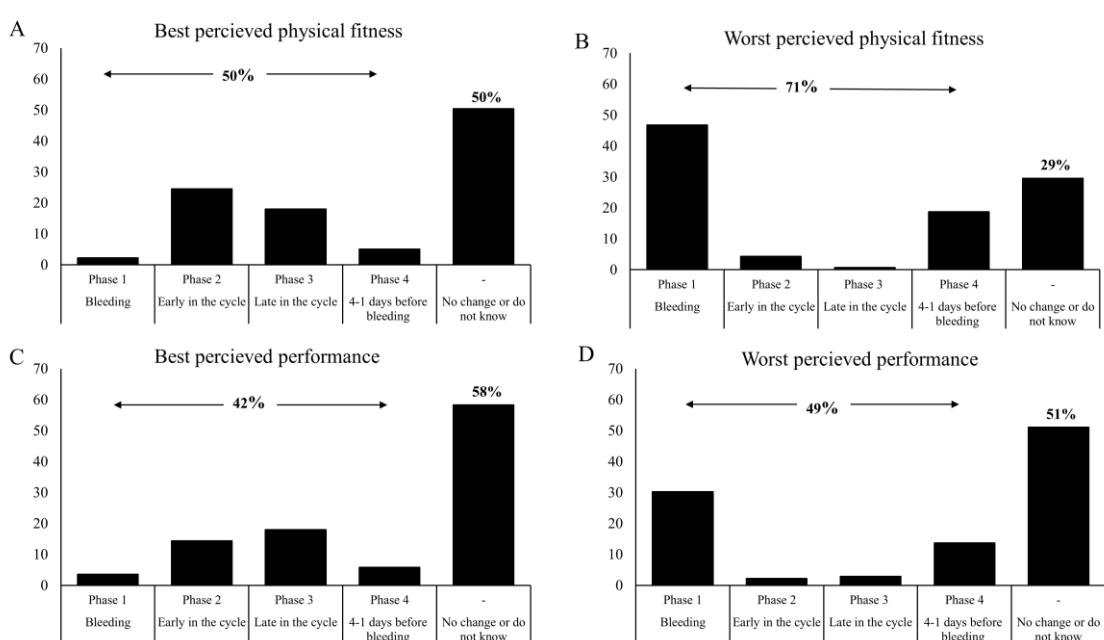
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250 The most frequently reported side-effects were stomach pain (83%) and bloating (63%, Figure  
 251 4), while 8% of the athletes had not experienced any MC-related side-effects in the last year.  
 252 The number of side-effects differed significantly by phase ( $p<.001$ ), with the highest number  
 253 being reported in Phase 1 ( $3.6\pm2.4$ ), followed by Phases 4 ( $2.1\pm2.1$ ), 2 ( $0.5\pm1.3$ ), and 3  
 254 ( $0.3\pm0.7$ ,  $p<.05$  for all pairwise comparisons). Subgroup analyses revealed no significant  
 255 interactions by age group, performance level, or use of HCs (all  $p>.05$ ).

256

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

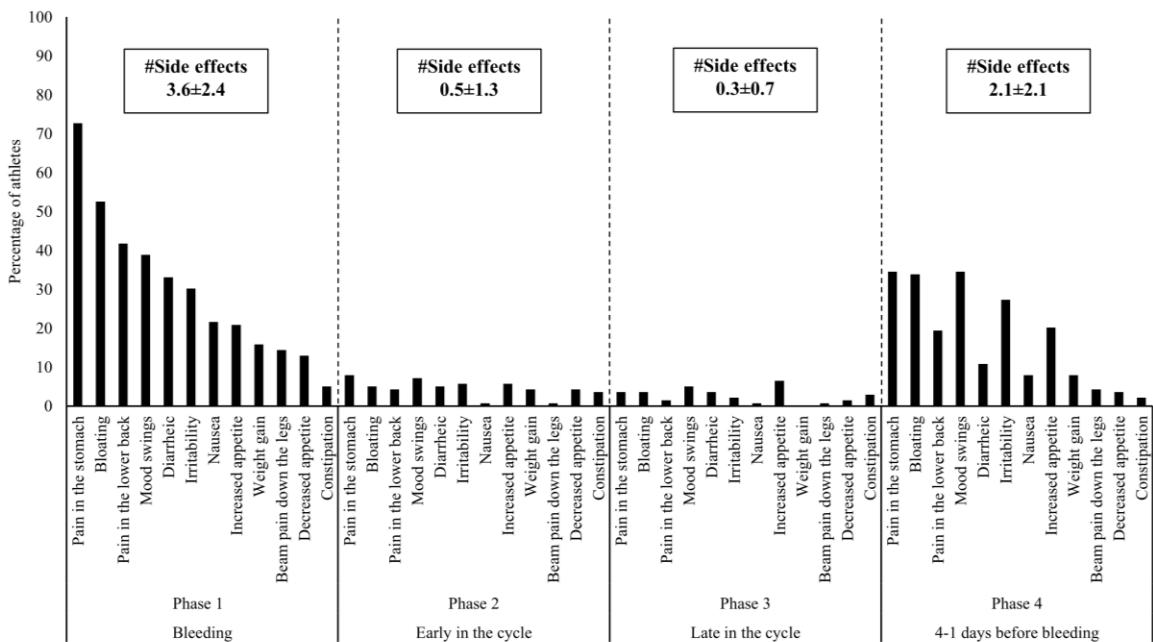
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263

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

267



268

269 Figure 4 – The athletes' self-reported side-effects across the phases of the menstrual cycle.  
270271 **Use of HCs**

272

273 As shown in Figure 1, 56% of the athletes were using HCs at the time of data collection. HC-  
274 users were significantly older than non-users (22.4 vs. 20.5 years;  $p<.01$ ), and 61% used  
275 estrogen–progestin HCs, 38% used progestin-only HCs, and 1% used an unspecified type of  
276 OCs (Figure 1). OCs were the most widely used HCs, followed by intrauterine systems (15%),  
277 implants (9%), and vaginal rings (3%).  
278

279

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

285

286 **Knowledge and communication about the MC**

287

288 Overall, 8% of the athletes reported having sufficient knowledge about the MC in relation to  
289 athletic training and performance. Most athletes had communicated about training and the MC  
290 with other athletes (79%), friends (66%), and family members (56%), while only 27% had  
291 communicated with their coaches about the topic. Notably, 81% of the athletes' coaches were  
292 men, and 19% were women; however, 44% of athletes with female coaches reported discussing  
293 the MC with their coaches, only 22% of ones with male coaches reported doing so. Among  
294 athletes who had not talked to their coaches about the MC and training, 63% did not want to  
295 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**

<b>How have you changed your training according to MC-related side effects?</b> <sup>1)</sup>	
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)	
<b>What would you like to learn in relation to the MC and training?</b> <sup>2)</sup>	
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)	
<b>Why do you find it difficult to talk to your coach about the MC?</b> <sup>3)</sup>	
Private, taboo, uncomfortable or embarrassing (n=11)	"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."
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)	
<b>What knowledge about the MC and training do you think your coach lacks?</b> <sup>4)</sup>	
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)	
<b>How has the use of HCs affected your performance at training or competitions?</b> <sup>5)</sup>	
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)	
<b>Can you describe why you stopped using this type of HC?</b> <sup>6)</sup>	
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 <sup>1)</sup> that they had changed their training because of MC-related side effects <sup>2)</sup>"No" at the question: "Do you think you have enough knowledge about how the MC can affect training and performance?", <sup>3)</sup>"Yes" at the question: "Do you find it difficult to talk to your coach about the MC in relation to training and performance?" <sup>4)</sup>"No" at the question: "Do you think your coach has enough knowledge about the MC in relation to training and performance? <sup>5)</sup>"Yes" at the question: Have you experienced that the HC affects your performance on training or competition? <sup>6)</sup>"Yes" at the question: "Have you ever stopped using a HC, because you experienced it affected your physical fitness or performance?"

303 **Discussion**

304  
305 We investigated changes in self-reported physical fitness, performance, and negative side-  
306 effects during the different phases of the MC among competitive endurance athletes, as well as  
307 the athletes' knowledge and communication with their coaches about this topic. The main  
308 findings of the current study were: 1) 50% and 71% of the athletes perceived improved or  
309 reduced physical fitness, respectively, during specific phases of the MC, whereas 42% and 49%  
310 reported improved and reduced performance, respectively; 2) a large proportion of athletes  
311 perceived no changes in physical fitness or performance across the MC; and 3) no differences  
312 in fitness, performance or negative side-effects by age, performance level, or HC-use emerged.  
313 Moreover, 4) only 8% of the athletes indicated having sufficient knowledge about the MC's  
314 effects on athletic training and performance, and 5) only 27% reported to communicate with  
315 their coaches about the topic.

316  
317 **Physical fitness, performance, and side-effects during the different phases of the MC**

318  
319 The result that approximately 50% of the athletes reported distinct changes in physical fitness  
320 and performance during the MC-phases is comparable to what Bruinvels et al.<sup>8</sup> observed  
321 among marathon runners. Of the athletes who reported that the MC had affected their fitness  
322 or performance, significantly more reported reduced physical fitness or performance in Phase  
323 1 (i.e., bleeding) than during the other three phases. Reduced physical fitness or performance  
324 during the MC has been associated with premenstrual symptoms or dysmenorrhea (i.e.,  
325 menstrual cramps caused by uterine contractions).<sup>2</sup> Likewise, our athletes reported that  
326 negative side-effects of the MC most often occurred during Phase 1, followed by Phase 4 (i.e.,  
327 1–4 days before bleeding). The most common symptoms were stomach pain, bloating, and  
328 mood swings. Such findings align those of Martin et al.<sup>7</sup>, who reported the highest prevalence  
329 of side-effects during days 1 and 2 of Phase 1. Other researchers have observed higher training  
330 monotony and strain during the early stages of the MC than during the ovulatory phase, which  
331 they attributed to the increased prevalence of MC-related symptoms in the first half of the MC  
332 (i.e., follicular phase) compared to the second half (i.e., luteal phase).<sup>33</sup> Most likely due to the  
333 high incidence of side-effects in Phases 1 and 4, athletes in our sample reported the best  
334 physical fitness and performance during Phases 2 and 3. However, experimental research on  
335 endurance performance during the phases of the MC has produced mixed results; some  
336 researchers have observed better performance during the follicular phase<sup>11,15</sup> or increased  
337 performance during the luteal phase,<sup>9,12</sup> although most have reported no fluctuation in  
338 performance during the MC.<sup>3,4,10,13,14</sup> Such inconsistent findings may stem from  
339 methodological differences,<sup>16</sup> particularly in different definitions of the MC's phases.  
340 However, the substantial number of athletes in our study who reported distinct changes in  
341 performance during the MC highlights the need for additional research on the topic.

342  
343 Despite the high incidence of symptoms of stomach pain (83%), only 22% of the athletes  
344 reported to repeatedly (i.e., >3 times/year) alter their training due to MC-related side-effects.  
345 By comparison, Martin et al.<sup>7</sup> found that only 4% of athletes in different sports reported needing  
346 to refrain from exercise at certain points of their MC.<sup>7</sup> In our study, the most frequent types of  
347 MC-related training adjustments were reduced intensity or duration, cancelled sessions and  
348 postponed high-intensity training sessions. To reduce the severity of negative side-effects, 52%  
349 of the athletes reported having used painkillers, which suggests that many athletes experience  
350 some degree of pain during the MC that can affect their physical fitness, performance, and  
351 training quality. However, it remains uncertain whether athletes take those medications to  
352 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 The mean age at menarche ( $13.9 \pm 2.0$ ) was roughly the same as that previously reported by  
358 endurance athletes ( $13.8 \pm 1.5$ ),<sup>18</sup> slightly higher than that of athletes from various sports  
359 ( $13.6 \pm 1.4$ )<sup>7</sup>, and higher than that observed in non-athlete controls ( $13.0 \pm 1.3$ ).<sup>18</sup> Whereas 15%  
360 of the athletes in our study reported primary amenorrhea (i.e., menarche at 16 years of age or  
361 older), only 11% of endurance athletes reported the same in an earlier study.<sup>18</sup> Although it  
362 remains unclear whether delayed menarche derives from genetic factors, high volumes of  
363 training, or a focus on leanness,<sup>18</sup> most non-HC users (56%) reported a prevalence of MCs  
364 within the normal range of 10–15 cycles per year. Notably, 35% of non-HC users reported  
365 fewer than nine periods in the previous year, which could indicate menstrual dysfunction.<sup>34</sup>  
366 Elite female athletes, particularly endurance athletes, are known to be susceptible to menstrual  
367 irregularities, often due to relative energy deficiencies associated with high volumes of  
368 training.<sup>35</sup> In line with that trend, 30% of the athletes in our study indicated the loss of periods  
369 in connection with high volumes of training and 23% with large amounts of high-intensity  
370 training. Although we did not assess energy intake or energy expenditure, high volumes of  
371 training and high amounts of high-intensity endurance training are associated with high energy  
372 expenditure and can prompt relative energy deficiencies. Elite endurance athletes and their  
373 coaches should therefore be aware of the risk of MC irregularities induced by high volumes of  
374 training and high amounts of high-intensity training. The prevention of MC irregularities  
375 should also be pursued, because primary and secondary amenorrhea can result in adverse health  
376 conditions, including reduced bone health.<sup>35</sup>

377  
378 The prevalence of HC use in our study (56%) exceeded that reported for the female population  
379 in Nordic countries (35–45%)<sup>36</sup> but fell within the 40–70% prevalence reported by elite  
380 athletes.<sup>7,18,20</sup> Martin et al.<sup>7</sup> observed that a higher proportion of athletes used estrogen–  
381 progestin HCs (61%) than progestin-only HCs (38%). This was also the case in our study, and  
382 may be explained by the lower proportion of negative side-effects reported with the use of  
383 estrogen–progestin versus progestin-only HCs.<sup>7</sup> Martin et al.<sup>7</sup> additionally reported that HC  
384 users were more likely to indicate positive than negative side-effects, which we also observed  
385 in our study. However, 26% of HC users reported previously discontinuing their use of other  
386 contraceptives because they had compromised their performance. Other researchers have  
387 highlighted a large individual response to HCs,<sup>7</sup> possibly due to limited knowledge and  
388 communication about this topic.

### 389 390 **Knowledge and communication about the MC**

391 Only 8% of the athletes indicated having sufficient knowledge about how the MC affects  
392 athletic training and performance. Most coaches in women's sports are men,<sup>27,28</sup> none of whom  
393 has personal experience with the MC, which may reduce the transfer of knowledge and  
394 communication about the MC and its possible effect on training and performance. In our study,  
395 27% of the athletes reported that they had communicated about the MC with their coach during  
396 the previous year, with the percentage being higher when the coach was a woman (44%) instead  
397 of a man (22%). In line with those findings, a previous study reported that male coaches  
398 believed it was less important to ask athletes about menstrual irregularities, had less knowledge  
399 about the health risk associated with menstrual irregularities, and were less comfortable with  
400 communicating about menstrual irregularity than female coaches.<sup>29</sup> Furthermore, our data also  
401  
402

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

## 412 413 **Limitations**

414  
415 Several limitations of the current study should be highlighted: 1) The data of athletes using  
416 different HCs were combined into one group, while the hormonal concentrations and perceived  
417 side-effects might differ between types of HC; 2) The statistical power was too low to make  
418 comparisons between the different types of HC 3) Recall bias is a limitation of retrospective  
419 questionnaires; 4) Headaches or heavy menstrual bleeding, both of which are frequently  
420 reported side-effects of the MC,<sup>7,8</sup> were not included as side-effects in the questionnaire; 5)  
421 The four-phase definition of the MC (Figure 2) has not been used in previous research, which  
422 makes comparisons to literature difficult, and; 6) The relationships between the changes in  
423 perceived physical fitness, performance and side-effects, and the concentration of hormones  
424 cannot be established. Therefore, we can not provide any recommendations regarding training  
425 and performance optimization during the specific phases of the MC.

## 426 427 **Practical applications**

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

448 **Conclusions**

449

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

458

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460

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464

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466

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