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Graduate thesis in Medicine
Supervisor: Øyvind Sandbakk
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Abstract

Purpose

The present study investigated the training routines during the menstrual cycle (MC) of female cross-country skiers. The primary objective was to investigate whether self-chosen training load and the amount of high intensity training differed between the different phases of the MC among female junior cross-country skiers.

Methodology

Thirteen 17-19 years old female cross-country skiers participated. Inclusion criteria were regularly menstruation and logging of exercise data during the eight consecutive weeks, while exclusion criteria included use of hormonal contraceptives. Data were collected through a menstruation form and a training diary. Days with menstrual bleeding was used to define the phases of the MC. Daily training was recorded using the Norwegian Olympic Federation´s training diary and included self-reported total training time distributed across intensity zones.

Results

No significant difference in the distribution of neither HIT ($p = 0.94$, $\eta_{p2} = 0.008$) nor total training load, i.e. TRIMP, ($p = 0.92$, $\eta_{p2} = 0.010$) was found between the four phases of the MC.

Conclusion

These findings indicate that female athletes do not adjust their self-chosen training load or alter their training intensity to their MC. However, future studies need to elucidate further if training periodized according to the MC would be beneficial.

Sammendrag

Bakgrunn

Den aktuelle studien undersøkte treningsrutiner gjennom menstruasjonssyklusen (MS) for kvinnelige langrennsløpere. Det primære målet var å undersøke om selvvalgt treningsbelastning og mengden høy intensitetstrening var ulik mellom de forskjellige fasene i MS blant kvinnelige junior langrennsløpere.

Metode

Tretten 17-19 år gamle kvinnelige skiløpere deltok i studien. Inklusjonskriterier var regelmessig menstruasjon og loggføring av treningsdata i åtte påfølgende uker. Eksklusjonskriterier var bruk av hormonell prevensjon. Data ble samlet inn gjennom et menstruasjonsskjema og treningsdagbok. Blødningsdager ble bruk til å definere de ulike fasene i MS. Daglig trening ble loggført via Olympiatoppens treningsdagbok og inkluderte selv-rapportert total treningstid fordelt over ulike intensitetssoner.

Resultater

Det ble ikke funnet noen signifikante forskjeller i fordelingen av hverken HIT ($p = 0.94$, $\eta_{p2} = 0.008$), eller total treningsbelastning, dvs. TRIMP, ($p = 0.92$, $\eta_{p2} = 0.010$) mellom de fire fasene i MS.

Konklusjon

Funnen indikerer at kvinnelige idrettsutøvere ikke tilpasser selvvalgt treningsbelastning eller intensitet til menstruasjonssyklusen. Videre studier bør belyse om trening periodisert til MS vil være fordelaktig eller ikke.

Introduction

Our current understanding of exercise physiology is mainly driven by research on male athletes. Hence, there is a lack of understanding regarding female physiology, especially research taking the hormonal fluctuations during the menstrual cycle (MC**)** into account. Disruptions in hormonal balance throughout the MC have been reported to particularly influence thermoregulation and substrate metabolism (1-4), as well as causing negative side-effects such as pain, dysmenorrhea and mood changes (4-6). In a previous study among female marathon runners, 30% reported that their MC seemed to have negative impact on training and performance (5). More specifically, Martin et al. (7) found that 77% of athletes reported negative MC-related symptoms during the first days of bleeding, and despite the high incidence of symptoms, only 4% of the athletes reported to refrain from training due to MC-related side-effects (7). Other research (6) found that 22% of the athletes altered their training to the MC, and the most frequent training adjustments were reduced intensity or duration, cancelled sessions and postponed high-intensity training sessions. These findings indicate that female body respond differently to training load depending on where in the MC the woman is. However, previous studies have not investigated if female athlete, consciously or unconsciously, adapt self-chosen training load and intensity to the MC.

Training load and training intensity

While entering puberty, the differences in men and women physical development accelerate, mainly driven by higher concentrations of sexual hormones (8). While men have a steady level of testosterone circulating in their body (9), women have a monthly fluctuating level of female sex hormones called the MC (4, 8, 10). In endurance performance, gender differences are ascribed to inherent biological inequity such as higher levels of testosterone and hemoglobin, more muscle mass and relatively less fat among men compared to women (9, 11). However, common for both sexes are the body´s ability to adapt to training load, which primarily depends on the intensity, duration and frequency of the training (12), and secondary on biological inequities (11). Research has found a high proportion of female international cross-country skiers reported changes in fitness and performance across the MC, with their worst perceived fitness and performance during the bleeding phase (6). More specifically, Cristina-Souza et al. (13) 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. Others have found improved performance of high intensity exercise and decreased lactate production in the luteal phase (14), while some have found a reduction in maximal endurance performance during the luteal phase (15). Despite these findings, most studies have reported no change of endurance performance parameters in female athletes across the MC (1, 16, 17).

The menstrual cycle

The MC is part of women's sexual maturation, consisting of a monthly fluctuating level of female sex hormones distributed over a period averaging 25-35 days (18). The cycle is manifested throughout the reproductive years, commencing with menarche at 11-13 years and terminating at menopause at about 50 years (4, 10). The MC can be divided in two halves with ovulation splitting the cycle at the halfway point (2, 4, 10, 15, 18). Each phase is dominated by different hormones, which stimulate the anatomical changes in the endometrium (4). The first half of the cycle is called the follicular phase (FP), which is predominated by follicle-stimulating hormone (FSH), released from the anterior pituitary gland. FSH stimulates the follicles in the ovaries to mature and then produce and secrete estradiol (18). Towards day 14, estradiol concentration builds up and stimulate a peak in luteinizing hormone (LH), and lesser FSH peak, which initiate ovulation and thus the luteal phase (8). The ovulation is signified by an elevation of about 0,5 °C in body temperature (3, 4, 15). The increased thermoregulatory set point is due to high progesterone secretion (3, 4). The hormonal fluctuations have not only reproductive function, but also physically and physiologically function, which might effect athlete's performance (4).

The follicular phase

During the FP, women can experience increased body weight as well as subjective ailments related to menstruation which both can affect performance in different intensity zones (4, 6). In the FP, estrogen is the dominating female hormone (10). Like testosterone, estrogen accounts for differences in female and male performance level. While testosterone has a powerful anabolic effect, increasing protein deposition in the muscles (9), estrogen increases fat deposition in woman, especially around the hips, breast and subcutaneous tissue (18). This increased body fat composition is a detriment to the highest levels of athletic performance in events in which performance depends on speed, or on the ratio of total body muscle strength to body weight (19). Estrogen also increases body weight due to sodium and water retention. The fluid retention is caused by the chemical similarity between estrogen and adrenocortical hormones, which causes higher concentration of aldosteron in the kidneys (10). The extra weight could be a disadvantage in sports events where gravity matters (4). Besides increased body weight, the subjective symptoms such as mood, dysmenorrhea, heavy bleeding, bloating and anemia may be present during the early stages of MC (5, 20). Reiley et al. (4) found mood to change consistently with the MC. Positive mood was pronounced late in the FP and early in the luteal phase (LP), whereas more negative mood was dominating late in the LP and during menstruation. In relation to this, athletes have reported reduced fitness during the pre-menstrual days and bleeding days due to menstrual side-effects (4, 6, 8, 21). However, research have not investigated whether athletes have planned or adjusted their training to accommodate self-reported changes in fitness and performance across the MC.

The luteal phase

In the LP, both estrogen and progesterone concentration are high (1, 4, 18). Previous research has found that during the ovulation and the LP, the glycogen stores in the liver and muscles are higher because estrogen tend to spare glycogen stores by shifting metabolism toward free fatty acids by increasing lipolysis (4, 8, 16, 22). This is favorable for endurance athletes because fat utilization make it possible to keep high speed also during low- and middle intensity training sessions (23). Additionally, estrogen and progesterone together facilitate carbohydrate sparing and contribute to a greater reliance on fat oxidation during prolonged exercise (24). In support of this, studies of more prolonged exercise have indicated females to preferentially utilize fat as a fuel source during the LP (18, 24-26). These findings indicate that women can benefit from adjusting their training to the MC. Consequently, information regarding whether self-chosen training load and intensity are adapted to the MC is of significant interest.

Aim of the study

Today, most studies focusing on exercise in female athletes are done without taking the MC into account. As a consequence, training and implementation are tailored to male athletes, without considering that training adaptations and performance in female athletes may be affected by hormonal fluctuations throughout the MC. Therefore, the aim of the current study is to examine if self-chosen training load and the amount of high intensity training differ between the different phases of the MC among female cross-country skiers with regular menses and without using hormonal contraceptives.

Methodology

This study was done as part of a larger study focusing on sleep in junior elite athletes, including a PhD project named "Long-term monitoring of sleep in junior elite athletes: roles of cognitive and physical stress". The methodology is therefore based on this project.

Subjects

Female junior athletes between the ages of 17-19 were recruited from high schools specialized in sports in Trøndelag. Athletes that used hormonal contraceptives were excluded. Initially, 18 participants were included. Among these, two were excluded due to use of hormonal contraceptives, and one was excluded due to missing data. Additionally, two were excluded due to zero training days. Results are therefore based on 13 female athletes having normal menstruation and existing training data. The study lasted eight consecutive weeks. The study was evaluated by the Regional Committees for Medical and Health Science Ethics (REC) and approved by the Norwegian Social Science Data Service. All athletes signed a consent form prior the commencement of the study.

Instruments

Two instruments were used: a menstruation form and a training diary. The menstruation form registered when the subjects had menstruation. The menstrual bleeding was then used to define the MC: for individuals having two or more bleeding periods during the 8-weeks, the MC was calculated by counting the days from the first day of bleeding, to the last day before the next bleeding. The MC was then divided into four phases where the follicular and luteal phase make up the first and second half of the cycle respectively (4, 6). For unequal number of days between phases, the LP was given the extra day. The pre-menstrual phase was defined by the three days prior to menstrual bleeding and were included in the luteal phase. The bleeding days were included in the FP.

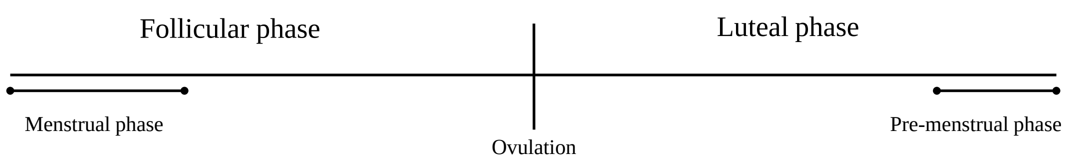

Figure 1: Defined phases of the menstrual cycle.

Olympic Federations Training Diary

The participants recorded day-to-day training in digital diaries developed by the Norwegian Olympic Federations (27). The training recorded for each session included self-reported total training time distributed across intensity zones. Training intensity was determined with the use of the Norwegian Olympic Federations 5-zone intensity scale, which is based on athletes self-determined lactate and heart rate ranges. In this study, intensity zone 1 and 2 are low-intensity zone (LIT), intensity zone 3 is middle intensity zone (MIT) and intensity zone 4 and 5 are high intensity zone (HIT).

Based on athletes self-reported training load and minutes in each intensity zone, the two main variables were calculated. HIT was calculated by adding all registered minutes in HIT for each participant in every phase of the MC. To quantify total training load, training impulse (TRIMP) was calculated by multiplying the total number of minutes in each endurance intensity zone by a particular constant (28): LIT zones 1 and 2 were multiplied by a constant of 1, MIT zone 3 was multiplied by a constant of 2, and HIT zones 4 and 5 were multiplied by a constant of 3 (29, 30). The respective TRIMP scores were then added to obtain total TRIMP for each training day in the different phases of the MC (31). Both variables were then normalized for number of days in each phase by dividing total HIT and TRIMP in each phase by total days in each phase.

Statistics

All data is presented as mean (standard deviation). For measuring the difference between groups, one-way ANOVA was used. To localize the differences, post-hoc Tukey HSD was used. For measuring the effect size, UNIVARIATE and Partial Eta Squared were used. Statistical significance was accepted with an α -level <0.05, and p-values were presented. All statistical analyses were carried out by using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, N.Y., USA).

Results

The sample

The sample consisted of 13 women with mean age 17.5 (0.5). In total 779 training sessions were analyzed during the 8 consecutive weeks. The MC descriptive characteristics appear in Table 1.

Table 1 Profile of mean values (SD) for all participants during the MC. The mean duration, sum, minimum and maximum for the four phases are calculated as average of one cycle per participant, altogether 13 cycles.

	Mean	**Sum**	**Min**	**Max**
Menstrual cycle	26.8 (3.9)	349.0	20.0	33.0
Bleeding days	4.5 (1.5)	59.0	2.0	7.0
Follicular phase	13.1 (1.8)	171.0	10.0	16.0
Luteal phase	13.6 (2.1)	178.0	10.0	17.0
Pre-menstrual days	3.0 (0)	39.0	3.0	3.0

Distribution of HIT and total training load during the MC phases

There were no overall effects of MC phase on the amount of HIT ($p = 0.94$, $\eta_{p2} = 0.008$) nor on total training load ($p = 0.92$, $\eta_{p2} = 0.010$). Post-hoc testing revealed no significant differences between the four phases of MC (see detailed results in Table 2 and Table 3).

Table 2 Mean values (SD) for the amount of HIT (high intensity training) in minutes across the four phases of the MC (menstrual cycle) among the 13 normally menstruating female cross-country skiers (who did not use hormonal contraception), as well as p-values for the comparisons of HIT amounts between all phases of MC.

HIT means (SD)		**HIT means differences for the four phases of MC**	
			p-value
BD	5.8 (4.1)	BD vs. FP	0.991
FP	5.3 (3.3)	BD vs. LP	0.991
LP	6.2 (2.2)	BD vs. PMD	0.998
PMD	5.5 (4.6)	FP vs. LP	0.933
		FP vs. PMD	0.999
		PMD vs. LP	0.968

BD = bleeding days, FP = follicular phase, LP = luteal phase, PMD = pre-menstrual days.

Table 3 Mean values (SD) for the amount of total training load (i.e. training impulse (TRIMP)) across the four phases of the MC (menstrual cycle) among the 13 normally menstruating female cross-country skiers (who did not use hormonal contraception), as well as p-values for the comparisons of total training load (i.e TRIMP) between all phases of MC.

TRIMP means (SD)		**TRIMP means differences for the four phases of MC**	
			p-value
BD	95.2 (38.5)	BD vs. FP	1.0
FP	94.2 (24.8)	BD vs. LP	0.993
LP	98.6 (20.5)	BD vs. PMD	0.951
PMD	102.1 (40.2)	FP vs. LP	0.984
		FP vs. PMD	0.925
		PMD vs. LP	0.993

BD = bleeding days, FP = follicular phase, LP = luteal phase, PMD = pre-menstrual days.

Discussion

The present study investigated the training routines across the MC among female cross-country skiers. The primary objective was to investigate whether self-chosen training load and the amount of high intensity training differed between the different phases of the MC among female junior cross-country skiers with regular menses and without the use of hormonal contraceptive. Following a period of eight consecutive weeks and two MCs, the main findings was that we found no significant difference in the distribution of neither HIT nor total training load (i.e. TRIMP) between the four phases of the MC.

The current findings which consist of no difference in self-chosen distribution of HIT or total training load across the MC corresponds with a previous study which have reported that only 22% of the athletes altered their training due to MC-related side-effects (6). In addition, most studies have reported no change of endurance performance parameters in female athletes across the MC (1, 16, 17). More specifically, Dombovy et al. (1) found no differences in cardiovascular response, including heart rate, cardiac output and oxygen delivery during maximal exercise performance testing between the follicular and luteal phase. The same research also found no differences in self-chosen total training load between the phases. However, the existing research is inconsistent. While Cristina-Souza et al. (13) found higher amount of training monotony and strain in the FP, but no difference in total training load across the MC, other studies have reported variations in self-reported fitness and performance during the bleeding phase (4, 6-8, 21). Jurkowski et al. (14) found improved performance of HIT-sessions accompanied with lower lactate levels in LP at the end of exhaustive exercise compared to same exercise in the FP. Such inconsistent findings may stem from methodological differences such as division and measuring of intensity zones in different exercise tests. For example, results obtained from an exercise test evaluating maximal performance (13) are not necessarily directly related to results obtained from an endurance test (1). This highlights the need for additional research on the topic.

Considering the literature with several studies reporting significant variations in endurance performance across the MC (1, 6, 13, 14, 16, 17, 32), it is surprising that we did not find any differences in distribution of HIT and total training load across the MC. A possible explanation could be a lack of knowledge about MC and its possible effects on athletes training and performance. Solli et al. (6) state that only 8% of the athletes reported having sufficient knowledge about the MC in relation to athletic training and performance which can correlate with only 22% of the athletes in the same study reported to alter their training due to MC-related side-effects. These current findings by Solli et al. (6) can explain our findings: The present study had a small sample size with only 13 subjects. When considering the high inter-individual variability in performance and side-effects experienced by athletes during the MC, the sample size is too small to generalize the findings. When interpreting the results, this could be an explanation to why we do not find any differences between the four phases of the MC. Further research should therefore have a bigger sample size.

A limitation to the current study was the division of the MC, which was based on the menstrual bleeding and the fact that it constitutes of two halves with ovulation splitting the cycle at the halfway point (2, 4, 10, 18). We did not detect the ovulation based on other measures e.g. body temperature or hormonal concentrations. The division of MC by using bleeding days are imprecisely because menstrual and pre-menstrual days span luteal and follicular phases, each with very different hormones. Definitive determination of follicular, ovulatory, and luteal phases of the MC requires the assessment of serum estradiol and progesterone levels. Concentrations of these hormones in the saliva or urine appear to correlate with serum levels (8), and therefore collection of these fluids may be used as noninvasive methods. Further studies should therefore measure the female sex-hormones to accordingly differentiate the MC into its phases.

A second limitation is lack measuring self-reported wellness. The quality of training depends on motivation, mood and behaviour (33). Mood changes are related to MC side-effects. More positive mood is pronounced late in the FP and early in the LP, and more negative mood was pronounced pre-menstrual and during the bleeding days (4). A study measuring perceived exertion found that these psychophysiological alterations led to higher ratings of perceived exertion for a given exercise intensity during the bleeding days (34). Further studies should therefore consider the interaction between mood and distribution of training load and intensities across the MC.

The study also has strengths. The well-defined group of participants with females ranging from 17 to 19 years and who are having the same type of exercises and training load, is a strength in this study. We also managed to exclude the ones using hormonal contraceptives, which are important in terms of minimizing hormonal bias. However, the number of total participants was only 13, which is too small a number to say that the findings are significant and general.

Conclusion

This investigation demonstrated that there are no differences in distribution of self-chosen HIT or total training load (i.e. TRIMP) between the different phases of the MC. This indicates that female athletes do not adjust their self-chosen training load or alter their training intensity to their MC. However, future studies need to elucidate further if training periodized according to the MC would be beneficial. Todays, the variety of research methodologies used, and contradictory findings does not allow us to create a clear picture of how the MC affect female athletes training. Further investigations should have more sophisticated methodology, by measuring hormones, physiological tests and performance, include a bigger sample and monitor several MC.

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