Effect of the Menstrual Cycle on Athletic Performance in NCAA Division III Collegiate Athletes

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ABSTRACT

Background: Gender-specific aspects of physiology influence multiple systems including the cardiovascular, respiratory, neuromuscular, and musculoskeletal systems. Studies have shown that female athletes are 2 to 10 times more susceptible to ligamentous injury than men. Studies contributed these findings to varying anatomical structure between men and women, hormonal changes throughout the menstrual cycle, and some athletes taking oral contraceptives. A female athlete may be just as fit as her male counterpart, yet it is recognized that the menstrual cycle has unique physiological and psychological effects on athletic performance. Fluctuations in sex hormones and symptoms of the menstrual cycle may impact one's ability to train and compete.

Objectives: To analyze the effect of the menstrual cycle on athletic performance in NCAA Division III collegiate athletes.

Study Design: Prospective, nonexperimental, descriptive study.

Methods: Participants were recruited from NCAA Division III universities in Pennsylvania. Data were collected on participants' demographics, menstrual cycle history, use of birth control, premenstrual symptoms, and athletic performance. Athletic performance was examined and compared during the follicular and luteal phases and during nonmenstruating and menstruating days.

Results: Eight athletes were included in the analysis. No trends were observed when comparing athletic performance during the follicular and luteal phases. When examining nonmenstruating and menstruating days, most average race times slowed or increased.

Conclusion: Incorporating menstrual cycle tracking into a plan of care can help therapists determine best exercises based on phase of cycle. Therapists can also educate patients at risk of injury, modifying training plans and expectations on performance.

Key Words: female athlete, premenstrual symptoms, sex hormones

INTRODUCTION

In 1972, only 1% of college athletic budgets funded female sports and for every 1 female athlete, there were 12.5 male athletes.[1] Today male student athletes total approximately 278 614 or 56% of the population in the NCAA, while women total 216 378 or 44%. Women's NCAA teams make up 54% of the total as compared with 46% for men.[2] As the number of women in sports rises, so do the number of injuries related to training and competing. In fact, female athletes may be at a higher risk for injury than their male counterparts. Multiple studies have shown that women participating in the same sports activities as men are 2 to 10 times more susceptible to ligamentous injury.[3–6] Sallis et al[3] compared the pattern of injury between men and women, aged 18 to 22 years, in 7 collegiate sports over a 15-year period. The researchers found that overall, 47 of 100 men playing sports were expected to injure some part of their body. Of 100 women playing sports, it was expected that 52 of them will end up with a sports injury. The NCAA analyzed basketball injuries from 2009 to 2015 and found statistically significant results that women tended to sustain more lower extremity injuries during both practices (67% vs 62% for men) and games (59% vs 54% for men).[4] The NCAA also analyzed gender differences in volleyball injuries during the 2013 and 2014 academic years. Again, they found that women had a higher rate of injury, discovering 7 injuries for every 1000 female athletes compared with 4 for every 1000 male

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athletes.[5] Studies contributed these findings to varying anatomical structure between men and women, hormonal changes throughout the menstrual cycle, and some athletes taking oral contraceptives.[3–6]

The menstrual cycle can be broken down into phases, the follicular and luteal phases. The follicular phase can be broken down further into follicular and late follicular phases. Days 1 to 7 are the follicular phase of the menstrual cycle, where estrogen and progesterone concentrations are low, and ovarian follicles begin to mature.[7] In the late follicular phase, days 9 to 14, estrogen levels reach their peak. On days 14 to 15 of the cycle, the estrogen surge ends and progesterone levels start to rise as ovulation begins. The corpus luteum secretes both estrogen and progesterone. Estrogen stimulates the growth of epithelial cells of the endometrium to increase its thickness, and progesterone differentiates cells in the endometrial lining to prepare the uterus for implantation of a fertilized ovum. Estrogen levels rise during the mid-follicular phase and then drop precipitously after ovulation.[7] Following ovulation, the luteal phase begins, with days 20 to 25 defined as the mid-luteal phase. During the mid-luteal phase, estrogen is low and there is a surge of progesterone. Progesterone helps thicken the lining of the uterus and prepare for pregnancy. If pregnancy does not occur, progesterone levels drop and menstruation begins. It is important to keep in mind that the exact number of days in the cycle can vary between women. However, no matter the length of the cycle, sex hormone concentrations change throughout the phases of the cycle.

Relaxin is another hormone secreted by the corpus luteum and commonly recognized as a hormone related to pregnancy. It plays a role in increasing joint laxity to accommodate changes in anatomy as the body prepares for childbirth.[7,8] During a normal menstrual cycle, relaxin regulates muscle activity in the wall of the uterus to prevent contraction and prepares lining of the uterus for pregnancy. The levels are highest during the mid-luteal phase until menstruation begins. Therefore, there are certain points during the menstrual cycle that women may be at a higher risk for injury due to the effect relaxin has on connective tissue. Relaxin creates a general laxity in a woman's ligaments and may impact the incidence of sports-related injuries.[3–6,9]

It is also worth noting the physiological symptoms of the premenstrual and menstrual phases can affect athletic performance in some individuals. Therefore, symptoms of the various phases of the menstrual cycle should also be considered. Premenstrual and menstrual symptoms can negatively impact an individual physically and emotionally, which could potentially affect quality of life and reduce work capacity. In some, severe symptoms may make it difficult to perform acts of daily living. For the athlete, peak performance during training or competition may also be affected.[10] Symptoms of premenstrual syndrome may include water retention, sore breasts, headaches, fatigue, irritability, change in sleep patterns, anxiety, and/or depression. Increased body weight and generalized edema are also observed in the premenstrual and menstrual periods and are another consideration of the cycle's impact on athletic performance.[10] Women also commonly report swollen and tender breasts and abdominal bloating; however, edema related to water retention affects the entire body including the lower extremities. A less common premenstrual symptom is reduction in sleep quality and quantity; however, it could result in fatigue. Lack of sleep can lead to a decreased cognitive performance that may limit a woman's ability to perform in her sports.[11]

Symptoms of the menstrual phase, including uterine cramps and potentially heavy bleeding, are also a consideration when examining sports performance at various phases of the menstrual cycle. Experiencing pain is the body's means of signaling that something is wrong and that one should modify activity. Furthermore, heavy menstrual bleeding can decrease red blood cell levels, which, in turn, decrease a woman's oxygen levels due to the lack of available hemoglobin.[12] Decreased oxygen supply may limit the ability of the muscles to perform, leading to muscle fatigue and an overall feeling of being tired. Both of these symptoms may lead to a decreased level of sports performance.

Few research studies have examined the effects of the menstrual cycle on a woman's athletic performance. A female athlete may be just as fit as her male counterpart, yet it is recognized the menstrual cycle has unique physiological and psychological effects on athletic performance. Fluctuations in sex hormones and symptoms of the menstrual cycle may impact one's ability to train and compete. The purpose of this study was to examine the effect of the menstrual cycle on athletic performance in NCAA Division III collegiate athletes. A second purpose was to examine how the symptoms of and physiological process of menstruation can affect performance in these athletes.

STUDY DESIGN

The research study was a prospective, nonexperimental, descriptive study to determine whether a relationship exists between phase of menstrual cycle and athletic performance in female collegiate athletes.

METHODS

Participants

Participants were recruited from NCAA Division III universities in Pennsylvania. The sample was obtained by contacting coaches of female track and field teams at 3 schools to ask for time to speak with their athletes

to request voluntary participation in the research. Eligible women were 18 to 30 years old with regular menstrual cycles. Exclusion criteria for this study included amenorrhea or highly irregular menstrual cycles, current pregnancy or pregnancy within the last 3 months, or individuals currently breastfeeding. In the weeks prior to the start of the season, potential subjects were screened with a scripted invitation to participate at their respective institutions. Interested participants were then provided a written informed consent. Misericordia University Institutional Review Board (IRB) approved the study protocol (#IRB 49-18-T2). Seventeen women were enrolled in the study.

Procedure

After participants signed an informed consent, they were asked to fill out a questionnaire. It collected information on the participants' demographics, menstrual cycle history, use of birth control, and experiences with premenstrual symptoms. Participants were also provided with instructions on how to use a mobile device application (app) called Clue[13] that tracks one's menstrual cycle and common premenstrual symptoms such as pain, change in sleep patterns, and fatigue. After downloading the app, participants connected their Clue accounts to that of the researchers' account. When linked, app users share the details of their menstrual cycle and any additional information entered about premenstrual symptoms. Premenstrual symptoms were defined as abdominal cramping, bloating, fatigue, headaches, mood swings, breast tenderness, food cravings, and muscle aches. Participants were asked to update the data collected on the app at least weekly. When using the app, one accesses a calendar where one is prompted to report on premenstrual symptoms, menstrual bleeding, and level of energy. After adding the data, the researchers were immediately able to see the report. All participants received a $5 gift card to a local cafe prior to and at completion of the research study as an incentive to participate regularly.

Data on athletic performance were collected by accessing NCAA athletic Web sites. Individual participants' times were recorded for races completed at track and field meets during one season. The number of data points recorded for each individual varied on the basis of the number of events in which they participated in at any given track meet. For this study, the menstrual cycle was divided into the follicular phase and the luteal phase. The luteal phase was defined as beginning 14 days prior to the start of menstruation. The follicular phase was defined as any day leading up to the start of the luteal phase, since menstrual cycles vary in length for any individual. Each data point was coded as occurring during either the follicular phase or the luteal phase. Subjects were included as a case if they had data for at least 2 cycles. Data points were also coded as nonmenstruating and menstruating days.

Data Analysis

Descriptive statistics were performed on the subjects' demographics. All data on average times per event are presented as means and percent differences. Participants' athletic performance during the follicular and luteal phases and nonmenstruating and menstruating days was compared. Cases were eliminated from the analysis if none of their data spanned 2 cycles.

RESULTS

Of the 17 participants, 8 athletes were included in the analysis. Four subjects were excluded because of noncompliance with consistently entering menstrual cycle data into the Clue app, and 5 were excluded because of lack of data for any given event that spanned 2 cycles. Because of the researchers using track and field data with multiple events per participant, not all data spanned 2 cycles. For example, a participant may have competed in one event for the span of 1 month, then not repeated that event the following month but instead competed in a different distance event.

Table 1 summarizes the demographic makeup of the participants. The composition of ages, body

Table 1. Subject Characteristics

Participant #	Height, in	Weight, lb	BMI	Age, y	BC	Length on BC	Premenstrual Symptoms	Rate Symptoms	Length of Period
1	67	130	20.4	19	No	n/a	Yes	Mild	4-7 d
2	63	120	21.3	20	No	n/a	No	Mild	4-7 d
3	64	127	21.8	20	Oral	<3 mo	Yes	Moderate	4-7 d
4	68	128	19.5	20	Oral	4 mo to a year	Yes	Mild	4-7 d
5	66	141	22.8	19	No	n/a	Yes	Moderate	4-7 d
6	65	130	21.6	18	Oral	4 mo to a year	Yes	Mild	4-7 d
7	68	116	17.6	20	No	n/a	Yes	Mild	4-7 d
8	59	105	21.2	22	No	n/a	Yes	Moderate	4-7 d

Abbreviations: BC, birth control; BMI, body mass index; n/a, not applicable.

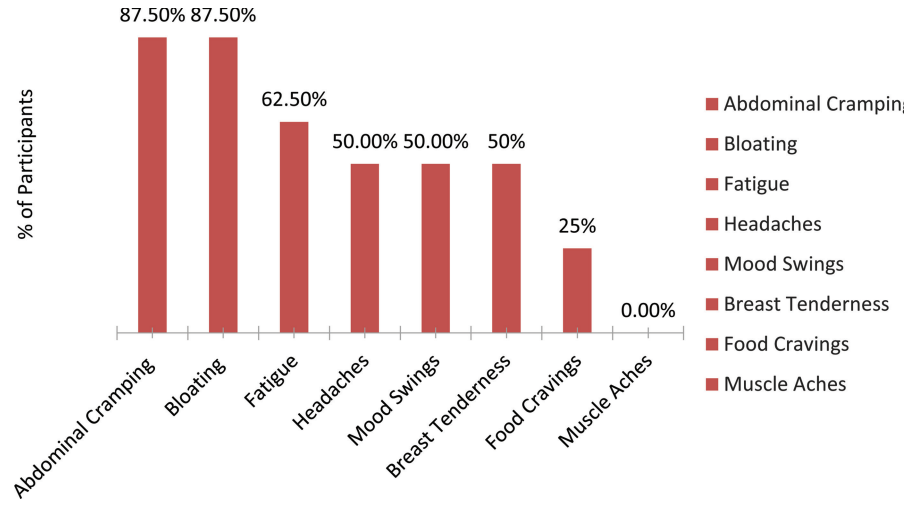

Figure. Prevalence of menstrual symptoms. This figure is available in color online (https://journals.lww.com/jwhpt).

mass index, and birth control history is typical of the female collegiate athlete and broadly represents women who participate in other sports that require aerobic endurance. All of the participants reported regular menstrual cycles with mild to moderate symptoms of menstruation (Figure).

Participants' athletic performance was examined and compared during the follicular and luteal phases and during nonmenstruating and menstruating days (Table 2). No trends were observed when comparing the average race times per event during the follicular and luteal phases. Looking at percent change between the follicular and luteal phases, individual times varied from an improvement or faster race time of −5.7% to a slower or longer race time of +3.7%. In the individual who experienced a −5.7% change, it meant a reduction in her 800-m event of 9 seconds. In the participant who experienced a slower race time of +3.7%, her 5000 m was 41 seconds longer. During the follicular phase, her average time (minutes:seconds) was 18:28 and during the luteal phase her average time was 19:09.

Table 2. Average Race Times by Event (Minutes:Seconds) and Percent Change by Phase of Cycle

Participant	Event	Follicular	Luteal	% Change	Nonmenstruating	Menstruating	% Change
1	800 m	2:38	2:29	−5.7%	2:34	2:43	+5.84%
	1500 m	5:06	5:07	+.33%	5:05	5:10	+1.64%
	1 mile				5:36	5:52	+4.76%
2	800 m	2:45	2:45	0%	2:44	2:47	+1.83%
	1500 m	5:35	5:30	−1.49%	5:33	5:31	−0.6%
3	1500 m	4:57	5:04	+2.36			
	3000 m				10:54	10:59	+0.76%
	5000 m	18:56	19:14	+1.58%			
4	400 m	1:05	1:03	−3.08%	1:03	1:05	+3.17%
	800 m	2:30	2:27	−2.0%	2:29	2:28	−0.67%
5	800 m				2:38	2:44	+3.8%
	1500 m				5:22	5:26	+1.24%
	5000 m	21:00	20:31	−2.3%			
6	5000 m	20:27	20:22	−0.41%	20:25	20:28	+.24%
7	1500 m	5:09	5:01	−2.59%			
	5000 m	18:28	19:09	+3.7%			
8	1 mile	5:59	5:55	−1.11%	5:55	6:03	+2.25%

When examining nonmenstruating and menstruating athletic performance, most average race times slowed or increased. The range in percent change between race times when participants were in a nonmenstruating phase and comparing with their race times during menstruation was an improvement in or faster race time of −0.67 % to a slower or longer race time of +5.84%. Participant 1 overall had longer races when menstruating. For this participant, this meant that during her 800-m event, her average time increased by 9 seconds and her 1 mile increased by 16 seconds. For participant 5, her average 800 m slowed by 7 seconds. Participant 4 had an increase in time of +3.17% on average for her 400 m; however, for this event, it translated to a change of only 2 seconds on average.

DISCUSSION

The aim of this study was to determine whether a relationship exists between phase of menstrual cycle and athletic performance in female collegiate athletes. The current study used a prospective, nonexperimental, descriptive design. We found no trends in changes in athletic performance between the follicular and luteal phases for any event whether it be more of an endurance or sprinting event. This is both supported and refuted in the literature.[14–19] Julian et al[14] studied soccer players' performance in both an endurance test and a sprint test. Athletes' scores on the endurance test were significantly lower during the luteal phase than during the follicular phase. During the luteal phase, subjects were not able to continue the protocol of the endurance test for the same duration. However, when the same study examined sprint performance, there was no significant difference between phases.

Pallavi et al[15] also reported a difference during the follicular and luteal phases when examining muscle function using handheld dynamometers. They found that phase of the menstrual cycle affected one's strength and endurance. Muscle contractions were significantly higher, more forceful, and less fatigable during the follicular phase than during the luteal phase. It is considered that the estrogen levels during the follicular phase may explain the difference in performance. Estrogen is critical to the physiological and metabolic regulations of muscle. Estrogen is comparatively lower in the luteal phase and may alter muscle function.[20]

Sprinting performance over phases of the menstrual cycle has been studied by other researchers with similar findings to the absence of trends observed in the current study. Tsampoukos et al[16] concluded that sprinting is unaffected by the phase of the menstrual cycle. The research examined women at 3 points over the course of a menstrual cycle. The females sprinted at self-regulated velocity after being instructed to "sprint as fast as possible." They found no difference in peak speed between the follicular and luteal phases. Our findings are also consistent with Janse De Jonge et al,[17] who found no changes in prolonged exercise performance over the menstrual cycle. The researchers examined women in temperate conditions exercising at 60% of V_{O_2}max for 60 minutes. No difference was found between the menstrual cycle phases in the amount of time it took to exhaust the participants. Furthermore, Sunderland and Nevill[18] found no difference between the follicular and luteal phases in distance running and high-intensity shuttle running in hot conditions. Environmental conditions were considered in these studies as a compounding factor affecting sports performance. In the luteal phase, body temperature rises. The combined effects of those factors may have an impact as it has been recognized that increased core temperature may limit exercise performance.[19]

When examining athletic performance during nonmenstruating and menstruating phases in the current study, most average race times increased, indicating a decline in performance. Although they were minimal, with the exception of participant 1, other studies have found that during menstruation, muscle function and sports performance may decline.[15,21] Bruinvels et al[21] studied the impact of heavy menstrual bleeding in female runners. The researchers found that when examining 5000-m race times, participants who experience heavy menstrual bleeding had slower average race times than women who have typical menstrual bleeding. The study also reported that those with heavy menstrual bleeding were more likely to report that the menstrual cycle disrupts their training and performance. They found an association with heavy menstrual bleeding, self-reported anemia, and use of iron supplementation in addition to the perceived negative impact on performance. Iron-deficiency anemia related to heavy menstrual bleeding potentially compromises athletic performance due to its effect on oxygen transport.

When looking at muscle function during menstruation, it has been found that muscles show the highest fatigue rate during the menstrual phase as compared with both the follicular and luteal phases. This phenomenon may have been observed because of the blood loss and concomitant compromise of iron stores and therefore altered oxidative metabolism. Researchers have also hypothesized that dysmenorrhea and psychological factors may play a role in hampering athletic performance.[11]

An additional symptom of the premenstrual and menstrual phases of the cycle to recognize is fluid retention. Estrogen and progesterone affect fluid regulation and increase plasma volume.[22] Although the increase in total body water varies by individual, it may affect athletic performance. The current study did not have enough data to compare the differences

in performance between the combined premenstrual and menstrual period with other phases of the cycle; however, research has found that fluid retention in the legs may affect physical performance. Sawai et al[10] examined athletic agility using a side-step test over the phases of the menstrual cycle. Side-step ability showed a significant decrease during the menstrual phase and had a negative correlation with fluid retention measured using magnetic resonance imaging. Agility declined as edema increased.

Based on the findings of the study and literature review, menstrual cycle tracking can help one prescribe training activities best suited for phase of cycle. For example, during the early part of the luteal phase, intense training activities might be appropriate. However, in the mid- to late luteal phase, a woman is at a higher risk for injury. Significant increases in mileage and speed may be better suited for the follicular phase due to an increase in relaxin, creating a general laxity in a woman's ligaments during the luteal phase.[3–6,9] The follicular phase may be a more appropriate time to focus on certain training approaches such as high-intensity interval training and plyometrics. Cycle-related fluid retention is another reason to modify training during the luteal phase and initial days of menses. Agility during this time may be affected and therefore also put one at a higher risk for injury.[10]

The same training principles may be applied during menses for those who experience heavy menstrual bleeding and those with intense symptoms of menstruation such as cramping. This may be a better time to employ complementary training techniques such as yoga, Pilates, and light strength training and stretching, with estrogen and progesterone returning to relatively low levels. Although injury risk is not as high as compared with the mid- to late luteal phase, it should be recognized that blood loss, concomitant compromise of iron stores, and therefore altered oxidative metabolism may lead to overall fatigue.[12]

Carefully planned scheduling of an athletic event may also be a consideration. For collegiate track and field, this may be challenging as events are typically weekly and follow a predetermined calendar. However, if we expand our knowledge of the physiological changes related to the menstrual cycle to women who are participating in sports outside the NCAA, scheduling may be controlled. For example, if an athlete is attempting to qualify for future events, such as a marathon or triathlon, one may choose the qualifying race based on phase of cycle. Not only may this assist in performance but also help in avoiding injury while competing at one's highest level.

The small sample size due to attrition and multiple events in the sports of track and field limited the findings of the study. There were not enough participants competing in the same event during the same phase of the menstrual cycle to pool the times to compare them statistically. The study could have been continued into another season to increase the number of participants; however, all data collection was suspended because of the pandemic. In addition, among those who did participate, 3 of the 8 were on oral forms of birth control. Birth control suppresses sex hormones such as estrogen and progesterone and decreases levels of relaxin.[23,24] Finally, accurate tracking of the menstrual cycle and symptoms of the menstrual cycle requires consistent use of the app. For those subjects who were included in the data analysis, it was assumed that the start and duration of menstrual bleeding were accurate. If the start date was not recorded properly, the calculation of phase of cycle and menstruating and nonmenstruating days may not be valid.

CONCLUSION

Gender-specific aspects of physiology, specifically the menstrual cycle, influence multiple systems including the cardiovascular, respiratory, neuromuscular, and musculoskeletal systems. There are limited studies on how the phases of the menstrual cycle impact exercise physiology and thus athletic performance. Future research is indicated with a larger sample size. The original design of this study is being examined to eliminate face-to-face contact in light of the current pandemic. Furthermore, one of the researchers is looking at adding a qualitative piece to better understand the effect of symptoms of the menstrual cycle on athletic performance. Collecting data on nutrition may also complement the design of the study as it is recognized that nutrition has an impact on athletic performance as well.

In addition to suggesting that more research is indicated, the researchers suggest that health care practitioners can educate themselves on physiological changes across the menstrual cycle. Physical therapists should apply this knowledge in their practice of treating female athletes. Incorporating menstrual cycle tracking into a plan of care can help therapists determine best exercises based on phase of cycle and how to modify progression of training based on a known increased risk for injury during some points in the cycle. Therapists can also educate patients on risk of injury, modifying training plans and expectations on performance based on phase of cycle.

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