The exploration of how hormonal changes throughout the menstrual cycle impact women's perception of running performance

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Abstract

The menstrual cycle causes women's hormones, estrogen and progesterone, to fluctuate. These hormonal changes influence physiological and psychological factors that may impact women's perceived running performance. This 7-week study explored the relationship between the menstrual cycle and performance, perceived performance, and moods in eumenorrheic recreationally active runners. Six participants recorded their running distance, speed, pain, a moods survey, and the Modified Perceived Performance in Team Sports Questionnaire (PPTSQ) after performing at an RPE (Rate of Perceived Exertion) of 14-17. Participants ran 30 minutes, 3 times per week for 5 weeks. The data was analyzed using Welch's unpaired t-tests and paired t-tests for running metrics (distance and speed). There were no significant differences seen in running distance, speed, or pain perception between follicular and luteal phases. The moods survey analysis revealed no statistically significant differences, besides a trend toward increased sadness during the luteal phase compared to the follicular ($p = 0.0995$). Perceived performance, exercise potential, exercise quality, and personal expectations increased significantly in the follicular phase compared to the luteal phase ($p<0.05$). These findings suggest that although no change was seen in objective markers of performance, perceived performance decreased during the luteal phase, and there was a trend toward increased sadness during the luteal phase. This exploration highlights the need for further research with larger sample sizes and more diverse populations to study how women's exercise performance is impacted by their menstrual cycle.

Table of Contents

Introduction

The menstrual cycle is a fundamental part of female physiology that affects many aspects of daily life. The typical menstrual cycle is 28 days but can fluctuate between 21 to 35 days. The menstrual cycle consists of four phases: the follicular phase, ovulation, the luteal phase, and menstruation. Each phase of the menstrual cycle consists of specific hormonal changes and physiological processes.[1] The first phase of the menstrual cycle is the follicular phase. At the beginning of the follicular phase estrogen and progesterone levels are low. The body releases follicle-stimulating hormone (FSH) and luteinizing hormone (LH) which causes growth of follicles in the ovaries and estrogen levels to rise. In the late follicular phase, estrogen levels are high while progesterone levels remain low. Ovulation occurs when estrogen levels peak and LH surge which triggers the mature follicle to rupture and release an egg. After ovulation, the luteal phase begins.[2] In the luteal phase, the follicle turns into the corpus luteum which releases progesterone and small amounts of estrogen. In the early luteal phase progesterone is low and peaks in the mid-luteal phase. Estrogen levels also peak in the mid-luteal phase. At the end of the luteal phase progesterone and estrogen decrease rapidly as the body prepares for menstruation.[3] During menstruation the estrogen, FSH, and progesterone levels decrease and the uterine lining sheds in the absence of pregnancy. The average length of menstruation is 4-6 days, but the normal range is 2 to 8 days.[4]

Estrogen and progesterone are hormones that play a primary role of regulating functions of the uterus. Estrogen has important roles outside of the menstrual cycle such as maintaining bone mass, influencing cognitive function, heart function, and regulating body temperature and mood.[5] In turn, low estrogen can cause adverse health outcomes such as depression, obesity, and osteoporosis.[6] The main role of progesterone is thickening the uterine lining. Progesterone also helps regulate bleeding during menstruation, enhances mood, and supports thyroid function.[7] In the early to mid-follicular phase serum estrogen levels range from 20 and 80 pg/mL, then in the late follicular phase rise to 200-500 pg/mL. In the mid-luteal phase levels decrease back to 200 pg/mL.[8] In the follicular phase serum progesterone levels range from 0.1 to 0.7 ng/mL and in the luteal phase range from 2 to 25 ng/mL.[9]

Muscular fitness is made up of muscular strength, endurance, and power.[10] Muscle strength is a vital building block that assists in all aspects of movement from tasks in daily life to athletic performance. Muscle strength is the amount of force that the muscle can create in a specific pattern of movement.[11] Muscular endurance is the capacity of the muscle to generate force prior to muscular fatigue.[12] Together muscular strength and muscular endurance supply power to perform a wide range of tasks from carrying in groceries to sprinting in an athletic game. Aerobic exercise uses large muscle groups and can be maintained without interruption in a rhythmic nature.[13] Examples of aerobic exercise are walking, running, swimming, and cycling. Aerobic exercise has health benefits due to sustaining an elevated heart rate and the ability to increase aerobic capacity and oxygen consumption. Improving these physiological attributes holds value as they not only increase exercise and athletic performance but can improve quality of life by increasing ability to move with ease, enhance balance and stability, and reduce injury risk. A more comprehensive understanding of the connection between the menstrual cycle and exercise is not only relevant from a physiological perspective but also holds practical significance in sport and athletic training, as well as in clinical settings. Thus, a women's rehabilitation or training program could then accommodate for their physiological variations across the menstrual cycle.

The objective of this study is to explore how the menstrual cycle impacts female perceived running performance, energy, mood, and motivation. This research will contribute to important insights in how changes in the female body may affect athletic performance. This research will benefit a wide variety of women including those who enjoy fitness, those recovering from injury, and those who are professional athletes to maximize their training. This research may also help professionals make more attuned training plans based on clients' menstrual phases.

Literature Review

Perceived Impact of the Menstrual Cycle

The luteal phase is the phase before menstruation begins. The luteal phase is often accompanied by symptoms including irritability, fatigue, and mood changes.[14] Premenstrual Syndrome (PMS) has both mental and physical manifestations, and commonly occurs during the luteal phase then ends shortly after the onset of menstration.[15] Symptoms of PMS include social withdrawal, depressed mood, poor sleep, poor concentration, headache, fatigue, fluid retention, and breast tenderness.[16] A majority of females regardless of fitness level or type of activity face menstrual-related symptoms impacting performance.[17]

Ekenros et al. evaluated the perceived impact of the menstrual cycle and hormonal birth control on physical exercise.[18] One thousand eighty-six female athletes were surveyed on training and performance. Of the non-hormonal birth control users, 78% reported premenstrual symptoms, which negatively affected aerobic fitness, strength, cognition, and recovery. Of the hormonal birth control users, 40% reported side effects impacting performance, specifically in inactive pill phases when menstruation occurs. Despite decreased performance in the luteal phase, only 18% of the athletes considered their menstrual cycle when planning their training or competitions. Overall, the women perceived a negative impact during their late luteal phase, with the optimal time for training beginning in their late- follicular phase. The women's symptoms and decreased perceived performance around their late-luteal phase are most likely due to the drop in estrogen and luteinizing hormone (LH) and rise of progesterone. These results indicate that greater focus is needed to identify and effectively treat different menstrual cycles and hormonal contraceptive-related symptoms on an individual level.

Findlay et al. explored athletes' experiences and perceptions of the menstrual cycle's impact on sports performance.[19] The participants were 15 female rugby players aged 24.5±6.2 years who were interviewed on their past and current experiences and perceptions of the menstrual cycle in relation to sports performance. Ninety-three percent of the women reported menstrual cycle-related symptoms, and 67% said their symptoms impaired their performance. Based on thematic review of the interviews, it was found that physiological and psychological menstrual cycle-related symptoms included reduced energy levels, worry, fluctuating emotions, and reduced motivation. As for the perceived impact of menstruation on daily life and performance, women had negative and neutral responses. Thus, menstrual-related symptoms are prevalent with almost all athletes perceiving that their menstrual cycle negatively impacted their performance. Although variable on the individual, further awareness and education of how the menstrual cycle impacts exercise is important for best supporting female health and performance.

In a study by Antero et al., researchers evaluated the menstrual cycle's impact on training, performance, and wellness in elite rowers. The study included 12 Olympic and Paralympic elite rowers.[20] Of the women, 6 rowers had a regular menstrual cycle, 1 had amenorrhea, and 5 were on hormonal birth control. The women self-reported perceived exertion, self-assessment of performance, mood, injury, and other external factors that could impact performance. The coaches of the athletes also completed evaluation of athletic performance. The researchers used chi-square test and Bayesian ordinal logistic regression to analyze performance metrics. Data showed that women peaked in both performance and wellness at ovulation (mid-cycle). The premenstrual (late luteal) and menstrual phases resulted in lower performance and wellness. For athletes on hormonal contraceptives, performance was higher while on the pill and lower during menstruation when off the pill. Overall, other coaches' evaluations and self-reported data aligned to support that menstrual phase impacted performance.

In Pinel et al. the impact and persevered barriers of menstruation was evaluated in female soccer players.[21] Data was collected through online surveys and researchers looked at the impact of different phases of the menstrual cycle on performance and exercise ability. Responses were gathered from 127 amateur female athletes with a regular menstrual cycle. Of the participants, 73% of women reported menstruation causes one or more barrier to performance, and 83% reported PMS to limit play to some extent. The most common symptoms respondents "always" experienced were reported: 45% stomach cramps, 31% bloating, 28% breast tenderness. Respondents answered "often" or "sometimes" for the following: 70% tiredness, 68% low energy, 68% low mood. Notably, 67% of players reported menstruation caused suffering while playing 1-3 days a month, and 12% suffered 4-8 days a month. The results of this survey show that women feel impacted by their menstrual cycle and its symptoms in their athletic performance.

In another study, Armour et al. assessed the challenges of training and competing associated with menstrual symptoms.[22] The study included 124 Australian female athletes who completed a 36-question questionnaire on their menstrual cycle and related symptoms. The questionnaire included contraceptive use and menstrual bleeding characteristics, prevalence and severity of symptoms, fatigue, and perceived performance. The data was analyzed by chi-square tests and descriptive statistics. Data found that 82% of athletes reported menstrual pain, 50% reported fatigue and reduced performance during practices or training. Despite perceived lower performance and fatigue, 75% of athletes reported no changes or conditions were made to their training by themselves or coaches. Additionally, 76% of athletes did not talk to their coaches about menstruation or related symptoms.

In addition, Solli et al. explored the changes in physical fitness and performance throughout the menstrual cycle in competitive endurance athletes.[23] The study included 140 female participants competing in biathlon or cross-country skiing. The participants completed an online questionnaire with questions asking about training volume, menstrual cycle history, physical fitness, performance during the menstrual cycle, and menstrual cycle side effects. Of the women, 50% of participants reported increased fitness and 71% of participants reported decreased fitness in specific menstrual cycle phases. In addition, 42% reported improved performance and 49% reduced performance, in specific menstrual cycle phases. Although the phases that were increased and decreased when perceiving fitness and performance were not stated, there are clear variations of changes throughout the cycle. During bleeding, 47% reported their worst fitness and 30% reported their worst performance. The follicular phase was rated as the best phase for perceived fitness by 24% and performance by 18%. Additionally, 52% of participants had changed their training at least once due to menstrual-related symptoms. Solli et al. concluded that most athletes experienced specific and noticeable changes in fitness, performance, and symptoms throughout the menstrual cycle.

Menstrual Cycle's effect on Muscle Strength

In Pallavi et al., researchers looked at variations in muscle strength and fatigue in different phases of the menstrual cycle.[24] Participants included 100 healthy females between the ages of 18 and 24 with a regular cycle between 26 and 32 days. Fatigue was measured by the Mosso's ergograph, and work done was measured by the handgrip dynamometer to find muscle strength. Data showed an average handgrip strength of 33.04±3.7 kg during the follicular phase and 27.3±3.4 during the luteal phase. In the follicular phase handgrip strength was significantly higher ($p<0.001$). Work done measured at 26±2.8J in the follicular phase and at 19.6±2.2J in the luteal phase. Fatigue was reported to be 51.6±4% in the follicular phase and 56±4% in the luteal phase. According to the data, work done, and handgrip strength were significantly higher in the follicular phase, while fatigue rates were lower ($p<0.001$). This supports an increase in muscle strength in the follicular phase as compared to the luteal phase.

Sung et al., assessed how hormonal variations throughout the menstrual cycle impacted strength trainability, specifically in the follicular and the luteal phase.[25] The study included 20 eumenorrheic women. Participants completed follicular phase-based training (FP) and luteal phase-based training (LP) on the leg press for three menstrual cycles. For follicular phase-based training, women trained the leg press 8 times in the follicular phase and 2 times in the luteal. For luteal phase-based training, women trained the leg press 8 times in the luteal phase and 2 times in the follicular. Participants trained one leg using follicular phase-based training and the other with using luteal phase-based training. In the follicular phase, maximum isometric muscle strength was increased at 267 ± 101 N compared to 188 ± 98 N in the luteal phase. Muscle diameter was measured at 0.57 ± 0.54 cm in the follicular phase and 0.39±0.38 cm in the luteal phase ($p<0.05$), showing increased muscle growth in the follicular phase. Additionally, maximum isometric force was higher in the follicular phase than in the luteal phase ($p<0.05$). As a result, researchers found that follicular phase-based training had improved outcomes for muscle strength compared to luteal phase-based training. Pallavi et al. and Sung et al. found strength was significantly higher in the follicular phase than in the luteal phase.

Menstrual Cycle's effect on Power and Performance

A study by Romero-Moraleda et al., evaluated the menstrual cycle effect on muscle strength and power in eumenorrheic women.[26] The study included 13 triathletes who performed Smith machine half squats during the three phases of their menstrual cycle. The phases were divided into the early follicular phase (EFP), late follicular phase (LFP), and mid-luteal phase (MLP), and squats were performed at 20%, 40%, 60%, and 80% of their one-repetition maximum (1RM). The researchers measured power output, force, and velocity during and compared them in the three phases but found no significant differences across the three menstrual cycle phases.

In a study by Dam et al., researchers evaluated muscle performance and power, menstrual hormones, and psychological well-being during the menstrual cycle.[27] The study included 30 eumenorrheic women (non-HBC) and 10 on oral contraception, all aged 18-35 years old. Researchers tested isometric handgrip strength, elbow flexor strength, countermovement jump (CMJ) height, and a 10-second Wingate bike test for power. To measure psychological state and sex hormones women completed self-report questionnaires and blood sampling. CMJ height was 6% lower in the late luteal (LL) phase compared to the midluteal (ML) phase ($p = 0.04$). Wingate peak power was 3% lower in the early follicular (EF) phase than in ML, but average power was 2–5% lower during late luteal compared to the other menstrual phases ($p = 0.04$). The self-report questionnaires showed women had higher pain in the early follicular and late luteal phases which aligned with lower muscular performance. The decrease in performance and increase in pain did not align with sex hormone changes found in the blood sampling. There was no significant difference in the results in the eumenorrheic and oral contraceptive groups. Therefore, psychological and physical well-being parameters throughout the menstrual cycle affected performance parameters while changes in sex hormones did not.

In another study, Dasa et al. assessed the menstrual cycle's impact on female strength and power.[28] The study included 29 female athletes from elite sport teams including soccer, volleyball, and handball. Of the women, 21 athletes were on hormonal contraceptives (HC) and 8 athletes were not on hormonal contraceptives. The women participated in 6 weeks of an exercise intervention including isometric grip strength, 20-meter sprint times, CMJ height, and leg press performance. The menstrual cycle was divided into the follicular and luteal phase to compare performance. Results found no significant differences between the follicular and luteal phases or hormonal contraceptives (HC) and non-hormonal contraceptive users.

Menstrual Cycle's effect on Fatigue and Recovery

Exercise can be affected by numerous factors including muscle fatigue, contractility, and recovery. Hackney et al. evaluated muscle damage and inflammation during exercise recovery in female runners.[29] The study included 8 trained female runners who exercised at least 4 to 5 days a week with aerobic training and had a regular menstrual cycle. The study aimed to investigate exercise recovery in the mid-follicular and mid-luteal phases of the menstrual cycle using Creatine Kinase (CK) to assess muscle damage and IL-6 as a marker of inflammation. The exercise intervention consisted of running in the mid-follicular and mid-luteal phases as researchers examined exercise recovery. Participants completed 90 minutes of running at 70% VO2max on a treadmill. CK and IL-6 were monitored immediate-post exercise (IP), at 24-hour, and at 72-hour after exercise comparing to the mid-follicular phase to the mid-luteal phase. At rest, CK and IL-6 in the luteal and follicular phases were not significantly different, but 24-hour, and at 72-hour after exercise CK and IL-6 were greater in the mid-follicular phase compared to the mid-luteal ($p < 0.05$). The decreased CK and IL-6 response in the mid-luteal phase could support the need for extended recovery time during this phase, but overall findings show that different physiological responses to exercise are seen between the mid-follicular mid-luteal phase.

A clinical trial by Peltonen et al., studied the maximal explosive leg press to investigate how fatigue and force production are influenced by the menstrual cycle.[30] The study included 16 women with a regular menstrual cycle. Participants performed 2 × 10 at 60% one-repetition maximum load with two minutes of recovery time between sets. The test was completed during menstruation, the mid-follicular phase, ovulation, and the mid-luteal phase. The loading protocol resulted in similar decreases in power production in all phases of the menstrual cycle ($P<0.001$). Isometric maximum voluntary force (MVC), which is the average force over the first 100 milliseconds, decreased over all phases ($P<0.001$-0.05). Mean power frequency showed increased fatigue during the menstruation ($P<0.05$) and mid-luteal ($P<0.05$) compared to at ovulation. Electromyography decreased due to loading, but there was no significant change between the phases. Overall, fatigue-induced changes were not observed by the study results.

Menstrual Cycle's effect on Running Performance

In a clinical trial by Shakhlina et al., researchers evaluated the performance of female athletes in the 800-meter and 1500-meter events.[31] The study included 13 middle distance runners between the ages of 17 and 24. The menstrual cycle was studied in five different stages: menstrual (Days 1-5), postmenstrual (Days 6-12), ovulatory (Days 13-15), postovulatory (Days 16-24), and premenstrual (Days 25-27). Physical working capacity along with heart rate and blood lactate levels were measured. Performance capacity was highest in the postmenstrual and postovulatory phases ($p<0.05$), and significantly decreased in the other phases of the menstrual cycle. This was supported by faster 4x400m times during the postmenstrual and postovulatory phases ($p<0.05$). Additionally, average heart rate was higher during the 4x400m in the postmenstrual and postovulatory phases ($p<0.05$) while lactate concentration in arterial blood was higher in the menstrual, premenstrual, and ovulatory phases ($p<0.05$). These results support that running performance can be influenced by hormonal changes in the menstrual cycle.

A survey-based study by Greenhall et al. examined the impact of the phase of the menstrual cycle on marathon performance in female runners.[32] The study included 185 recreational female runners with a regular menstrual cycle. The study divided the menstrual cycle into the follicular phase and the luteal phase. Researchers issued a survey to classify the best marathon performance. The survey was completed by 599 women of which 185 were eligible. Of the women, 106 women stated their best marathon performance was in their luteal stage and 79 in follicular.

Dokumac et al. studied the impacts of the menstrual cycle on the energy cost of running, also referred to as running economy.[33] The study included 11 women with a regular menstrual cycle with a mean age of 21.2±3.7 years. Running economy was measured at 75%, 85%, and 95% of the lactate threshold during the follicular and luteal phases. The results of the study found that running economy was more efficient in the luteal phase compared to the follicular phase, as VO2 was significantly lower in the luteal phase compared to the follicular phase ($p > 0.05$).

A study by Goldsmith et al., also assessed running economy in 10 women with a regular menstrual cycle.[34] The participants completed four step tests on the treadmill weekly while measuring running economy, core temperature, and minute ventilation. The phases of the menstrual cycle evaluated in this study were the early follicular, late follicular, and mid-luteal phases. The results found decreased running economy in the mid-luteal phase compared to the early and late follicular phases ($p=0.001$). Additionally results found higher resting core temperature and evaluated minute ventilation in the mid-luteal phase. Results indicate that the impacts of the menstrual cycle on running performance are mixed and assess different factors, but variation in data shows that the phases of the menstrual cycle have an impact on running performance.

Julian et al., assessed performance in elite female soccer players throughout the menstrual cycle.[35] The study included nine female soccer players with a regular menstrual cycle. The menstrual cycle was divided into the two main phases, the early follicular phase and mid luteal phase. The athletes completed the Yo-Yo endurance test and the CMJ test. The study found that performance on the Yo-Yo endurance test was significantly lower in the luteal phase compared to the follicular phase, 2833±896 m and 3288±800 m run, respectively. Results on the CMJ test were inconclusive. The decreased performance on maximal endurance performance during the mid-luteal phase of the menstrual cycle indicates a change in running performance during the menstrual cycle.

Williams et al. evaluated the impact of the menstrual cycle on the running economy.[36] The study included 10 moderately trained female runners with a regular menstrual cycle. The runners maintained a consistent training program over the course of the study. The average weekly mileage for the group was 15.75 miles per week with mileage ranging from 12 to 26 miles per week. The menstrual phases were separated into the early follicular (EF), late follicular (LF), early luteal (EL), mid-luteal (ML), and late luteal (LL). Results found that in the luteal phase, VO2, minute ventilation (VE), and ventilatory drive all increased compared to the follicular phase. Additionally, running economy (RE) speeds at 80% VO2max decreased in the luteal phase compared to the follicular. RE at 55% VO2max did not change. This indicates that the decreased running economy seen in the luteal phase might only be detected at higher outputs approaching the ventilatory threshold.

Lastly, in a study by Tsampoukos et al., researchers investigated how the follicular, ovulation, and luteal phases impact sprinting performance and recovery in females.[37] The study included eight well trained females with a regular menstrual cycle and tracked phase changes through estradiol and progesterone levels. The women completed repeated sprints with 30 seconds on and 2 minutes of rest in the three phases of their menstrual cycle. The study found that peak power output (PPO) and mean power output (MPO) did not have significant change ($p > 0.05$) throughout the menstrual cycle phases. Additionally, performance after recovery or metabolic factors such as blood lactate and plasma ammonia after sprinting remained unchanged ($p > 0.05$).

Hormonal Birth Control versus Non-Hormonal Birth Control

A study by Hooper et al. looked at the effects of perceived exertion and pain during the menstrual cycle.[38] The participants in this study included 117 previously sedentary women and were separated into two subgroups of hormonal birth control (HBC) and no HBC. The women completed a treadmill session at 65% VO2max during their early follicular, late follicular, and luteal phase. At 10, 20, and 30 minutes, RPE was measured by the BORG scale. The results showed that non-HBC women had significantly greater RPE and pain in the follicular and luteal phases compared to HBC women. Women in the early follicular phase who were not using HBCs had significantly greater increases in RPE and increases in pain compared with women using HBC in the late follicular and luteal phases. Therefore, the use of birth control had a positive impact on sedentary women's exercise in the follicular and luteal phases.

Amenorrhea

When studying female running performance, it is important to not overlook that many women, especially athletes including runners, are impacted by amenorrhea. Amenorrhea is the absence of menstruation often linked to low body fat, intense training, and under fueling. Amenorrhea impacts 66 percent of female athletes, compared to 2 to 5 percent of the general female population.[39] Most commonly amenorrhea impacts women in sports that emphasize low body weight such as distance running. De Souza et al. assessed the menstrual phase versus amenorrhea on exercise performance in female runners.[40] The study included 16 women, 8 with a regular menstrual cycle and 8 experiencing amenorrhea. The eumenorrheic participants completed a maximal treadmill run to test endurance limit and a submaximal (40 min at 80% VO2max) test in the early follicular and midluteal phases. The amenorrheic runners performed the same tests, but without timing tied to the menstrual cycle. Overall, results found no significant difference in time to fatigue, heart rate, rate of perceived exertion (RPE), or any other variable collected between the amenorrhea and eumenorrheic women.

In a clinical study by Teixeira et al., female athletes were studied to evaluate their experiences of menstrual function and dysfunction.[41] The study contained both a qualitative with surveys and quantitative approach with interviews. The study found that athletes had a higher rate of menstrual dysfunction and there was stigma and normalization of menstrual disturbances as part of intense training. Menstrual dysfunction may lead to negative physical outcomes such as decreased bone health and fatigue, and negative psychological well-being.

In addition, Dadgostar et al. evaluated amenorrhea and oligomenorrhea in female athletes to better understand the female triad.[42] The study included 788 Iranian female athletes from 34 different sports. The females aged from 13-37 years old, and athletes under the age of menarche were excluded. The athletes completed a self-administered questionnaire on athletic history, history of injuries, and their menstrual cycle. Of the athletes, 71 reported amenorrhea/ oligomenorrhea and underwent further investigation. With 9% of women experiencing amenorrhea/ oligomenorrhea it was supported that the prevalence of amenorrhea/ oligomenorrhea in female athletes is significant and higher than the population.

Hormonal Birth Control's Impact on Performance

In a study by Ekenros et al., the researchers found that oral contraceptives (OC) did not have an effect on muscle strength in women.[43] The cross over study included active women with a regular menstrual cycle and evaluated upper limb, lower limb, and hop performance across three phases of the menstrual cycle in OC and non-OC phases. The results of the study found no significant change in maximal isokinetic muscle strength of knee extensors, isometric handgrip strength, or 1-leg hop test for distance were measured in the women's performance in OC and non-OC phases.

In addition, Elliot et al. examined the effects of oral contraceptives on maximum force production in women.[44] The study included 21 women who were separated into a control (7 women with regular menstrual cycles) and pill users (14 women on oral contraceptives for at least 6 months). The women completed exercises to measure maximum dynamic and isometric leg strength, and maximum isometric strength. The pill users were tested on day 7 and 14 of the pill and day 5 of their menstrual cycle. Non-pill users were tested on day 2 and 21 of their menstrual cycle. The results found no significant differences between dynamic, isometric leg strength, or handgrip strength across the pill phases ($p < 0.05$) or between pill users and the eumenorrheic control group ($p < 0.05$).

Casazza et al. evaluated the influence of oral contraceptives on exercise capacity.[45] The study included six women classified as moderately active, and examined peak oxygen consumption (VO2 peak). The study was a cross over design. Prior to oral contraceptives (OC) the women tested VO2 peak in the follicular and luteal phases. After 4 months of OCs and were tested the week of inactive oral contraceptives (menstruation) and the second week of oral contraceptives. Results showed an increase in body weight and fat mass weight after OC ($p \leq 0.05$), and decreased VO2 peak by 11%.

In another study on exercise capacity, Lebrun et al. evaluated the impact of triphasic oral contraceptives on maximal aerobic capacity in active women.[46] The study included 14 very active women with a regular menstrual cycle and VO2max over 50 $ml \cdot kg^{-1} \cdot min^{-1}$. The women were not on hormonal contraceptives at least 3 months prior to the start of the study. The women were tested during their follicular and mid-luteal phases for baseline then randomized into the triphasic oral contraceptive group or placebo. The results found that in the oral contraceptive group, VO2max decreased by an average of 4.7%, and in the placebo group VO2max increased by an average of 1.5%.

Purpose and Specific Aims

This study aimed to investigate how hormonal changes throughout the menstrual cycle affected women's perceived exercise performance during 30-minute treadmill runs at an RPE of 14-17 on the BORG Scale. Females with a regular menstrual cycle and not on hormonal birth control were recruited for participation in this study. This research sought to understand the effect of the menstrual cycle on women's running performance and expand knowledge of how a women's hormones affect energy and exercise performance to provide women with a more refined and practical understanding of their bodies. This research is important for promoting gender-inclusive practices, optimizing female performance, and increasing understanding of the impact of female body's hormonal fluctuations. The development of this research can be applied to a wide range of specialties and practice such as physical therapies for individuals after accidents, training for female athletes, or for recreational exercisers to better under their body.

This study aimed to focus on women's performance as women have commonly been excluded and underrepresented in scientific research.[47] Low representation of women in research has resulted in decreased understanding of how the female body responds to exercise, relative to men. It is understood that muscles are impacted by numerous physiological responses which can be influenced by biological sex due to differing hormone levels and responses.[48] Therefore this study will focus on women's exercise performance, perceived performance, and moods. This is to gain a deeper understanding of how the female body responds to physical performance throughout the menstrual cycle when hormones, specifically estrogen and progesterone, are fluctuating in the follicular and luteal phases.

Methods

Participants and Recruitment

Prior to participant recruitment, study approval was received from the Institutional Review Board (IRB) at Virginia Tech (IRB #25-144, Appendix A). The IRB deemed this study exempt from human research protocols. Participants were recruited on a voluntary basis via flyers and word of mouth. If interested in the 7-week study, the participants scanned the QR code on the flyer and completed the interest form. After the initial interest, participants were contacted and a meeting was scheduled with the researcher to discuss the study procedure, guidelines, and collect consent. The women participating in the study were screened for eligibility, including confirmation of regular menstrual cycles and to ensure a non-pregnancy status through a self-reported health history questionnaire. Participants were previously active recreational runners who were accustomed to regular running. Prior to the exercise, participants completed a Google Form on demographic and menstrual cycle information including age, ethnicity, exercise frequency, age of first period, period length, period management, period symptoms, and period severity. Participants were provided with a participant ID number to de-identify their information and they self-reported all data via weekly Google Forms. Six women (n=6) successfully completed the study, and their demographics are presented in Table 1. Of the women, the mean age was 24.5 years, and the average age of first period was 12.33 years old. For ethnicity, 66.7% of the participants were White and 33.3% were Black or African American. The average menstrual cycle length was 27.2 days and for period length 4 women reported 3-4 days and 2 reported 5-6 days. On a scale from 1-10, reported cramp severity ranged from 2 to 10 with an average of 6.5. All participants (n=6) reported an exercise frequency of 4+ types a week.

Table 1: Demographic Information

Participant Number	Age	Ethnicity	Exercise frequency	Age of first period	Length of menstrual cycle	Length of period	Cramp severity (scale 1–10)
12	21	White	4+ times per week	11	29 Days	3-4 days	10
88	25	Black or African American	4+ times per week	12	26 Days	5-6 days	8
13	22	White	4+ times per week	14	25 Days	3-4 days	5
22	22	White	4+ times per week	12	28 Days	5-6 days	7
39	26	White	4+ times per week	12	28 Days	3-4 days	7
20	31	Black or African American	4+ times per week	13	26-28 Days	3-4 days	2

Study Design

The study was 7 weeks long, with a lead in week of baseline data collection, five weeks of running data collection, and a week of post-study data collection. In Weeks 1 and 7 participants tracked menstrual cycle data, pain scale, and a survey of moods. In Weeks 2-6, participants completed 30-minute running workouts on the treadmill 3 days a week (Monday, Wednesday, Friday) at an RPE of 14-17 and after completion of the run, completed a Google Form with menstrual cycle data, running data, survey of moods, and the Modified PPTSQ. Participants were sent reminders and forms through the Remind App on days where the Google Forms and runs needed to be completed. The treadmill was used to eliminate confounders from the environment including heat, humidity, elevation, and grade. The participants were provided the instructions written via email and through a recorded video that verbally and visually walked them through the surveys and expectations. The moods survey, RPE, and pain scale were explained via recorded video and a summary was included, written in the notes of the questions on the Google Forms. After consent was signed, the participants were given access to all resources to complete the study and provided with a participant number to de-identify their data.

Menstrual data collection

The data of the women's menstrual cycle was collected via Google Forms 3 days a week for 7 weeks. For severity of menstrual bleeding 66.7% (n=3) reported moderate bleeding, 16.7% (n=1) reported light bleeding, and 16.7% (n=1) reported heavy bleeding. The most common symptoms were bloating (66.7%), Fatigue or low energy (66.7%), Mood swings (66.7%), Acne or skin breakouts (66.7%), and Increased or decreased appetite (66.7%). Premenstrual syndrome (PMS) was reported by 50% of participants, and Headaches and Breast tenderness or swelling were reported by 33.3%. Additionally, symptoms reported were Nausea or upset stomach (16.7%), Joint or muscle pain (16.7%), and Lower back pain (16.7%). All percentages are out of the 6 participants (n=6).

Participants tracked their cycle for 7-weeks, this ensured that the study captured an entire menstrual cycle. Using the data from participants on length of cycle, length of nenstruation, and dates of menstruation, calculations were used to find the follicular, ovulation, luteal, and menstrual phases. The follicular and luteal phases were the compared in data as hormonal changes are greatest during these two phases. The data collected after each exercise intervention was then sorted based on menstrual phase. To estimate menstrual cycle phases, *Thiyagarajan DK, Basit H, Jeanmonod R. "Physiology, Menstrual Cycle."* (StatPearls, updated September 27, 2024) was followed for definitions and timing guidance. Shown below, on the left is the calculated phases of the menstrual cycle. On the right is the dates of running and data collection which were then sorted based on the calculations of the menstrual cycle phases.

Example: *On the top is a sorted data table that shows how the survey data was used to estimate the menstrual phases. On the bottom is a sorted table of survey submissions which was lined up with the estimated cycle phase*

Menstruation Data
First day of period 1: 5/21/2025
First day of period 2: 6/21/2025
First day of period 3: 7/16/2025
Bleeding duration: 5-6 days
Cycle 1 (5/21 – 6/20/2025, 31 days)
Menstrual phase: 5/21 – 5/25
Luteal phase: 6/8 – 6/20
Cycle 2 (6/21 – 7/15/2025, 25 days)
Menstrual phase: 6/21 – 6/25 (5 days)
Follicular phase: 6/21 – 7/1
Luteal phase: 7/3 – 7/15

FOLLICULAR	6/27/2025
FOLLICULAR	6/30/2025
OVULATION	7/2/2025
LUTEAL	6/9/2025
LUTEAL	6/11/2025
LUTEAL	6/13/2025
LUTEAL	6/16/2025
LUTEAL	6/18/2025
LUTEAL	6/20/2025
LUTEAL	7/4/2025
LUTEAL	7/7/2025
LUTEAL	7/9/2025
LUTEAL	7/11/2025
MENSTRUAL	6/23/2025
MENSTRUAL	6/25/2025

Running data collection

Running data was collected after each session during the 5-week study intervention. Participants ran 3 days per week over 5 weeks. For each session sped in miles per hour (MPH) and distance in miles was recorded. The average speed and distance in the follicular and luteal phases were found.

Mood data collection

In each survey participants completed they filled out a survey of moods. The moods evaluated included: Worn Out, Lively, Unhappy, Sad, Active, Energetic, Fatigue, Anxious, Confident, Worthless, and Satisfied. The moods were scored on the Likert Scale of 0 to 4. To calculate the Negative Mood Score for each participant the total of the negative moods were added (Worn Out, Unhappy, Sad, Fatigue, Anxious, Worthless). For the Positive Mood Score all positive moods were added (Lively, Active, Energetic, Confident, Satisfied). To find the Total Mood Score the Positive Mood Score was subtracted from the Negative Mood Score. All scores were then averaged.

Modified PPTSQ collection

This study used the Perceived Performance in Team Sports Questionnaire (PPTSQ) from a study by Gershgoren et al. and modified it for individual performance.46 The modified PPTSQ looks at Exercise Quality, Exercise Potential, Exercise Intensity, Personal Exercise Expectations, Exercise Effort, and Exercise Commitment. The components were scored on a scale from 1 to 5. The 6 items can be organized into two dimensions: Effort Investment and Perceived Outcomes (Quality and Expectations). Effort Investment includes Exercise Intensity, Exercise Effort, and Exercise Commitment. Quality and Expectations includes Exercise Quality, Exercise Potential, and Exercise Expectations. In the two dimensions, the three scores were added (Intensity + Effort + Commitment) and (Quality + Potential + Expectations) and then values were divided by 3 to find the average. For the Total Exercise Score, all 6 components were added and then divided by 6 to find the average.

Perceived Pain data collection

Perceived Pain was collected via the Visual Analogue Scale with values 0 – 10. A value of zero denotes no pain and a value of 10 denotes severe pain.

Statistical Analysis

The program GraphPad Prism (Graph Pad, San Diego, CA), a software for scientific data analysis, graphing, and statistics, was used for statistical analysis. All analysis was done via an unpaired t test except for speed and distance which was analyzed with a paired t test. The t test compared the sample means of the follicular and luteal phases to evaluated if the mean was significantly different in the two-phase groups. For all analysis except speed and distance, each submission was collected and analyzed independently rather than finding the average in each phase which allowed for a bigger n value in each component. A bigger n allowed for more data which increases statistical power and decreases margin of error.

Results

This investigation sought to explore how the female menstrual cycle impacted perceived exercise performance in women.

Menstrual data

The data of the women's menstrual cycle for 7 weeks is shown in Figures 1 and 2. As shown in Figure 1, the most common symptoms were bloating (66.7%), fatigue or low energy (66.7%), mood swings (66.7%), acne or skin breakouts (66.7%), and increased or decreased appetite (66.7%). Premenstrual syndrome (PMS) was reported by 50% of participants, and headaches and breast tenderness or swelling were reported by 33.3%. Additionally, symptoms reported were nausea or upset stomach (16.7%), joint or muscle pain (16.7%), and lower back pain (16.7%). For severity of menstrual bleeding, 66.7% (n=3) reported moderate bleeding, 16.7% (n=1) reported light bleeding, and 16.7% (n=1) reported heavy bleeding (Figure 2). All percentages are out of the 6 participants (n=6).

Figure 1.

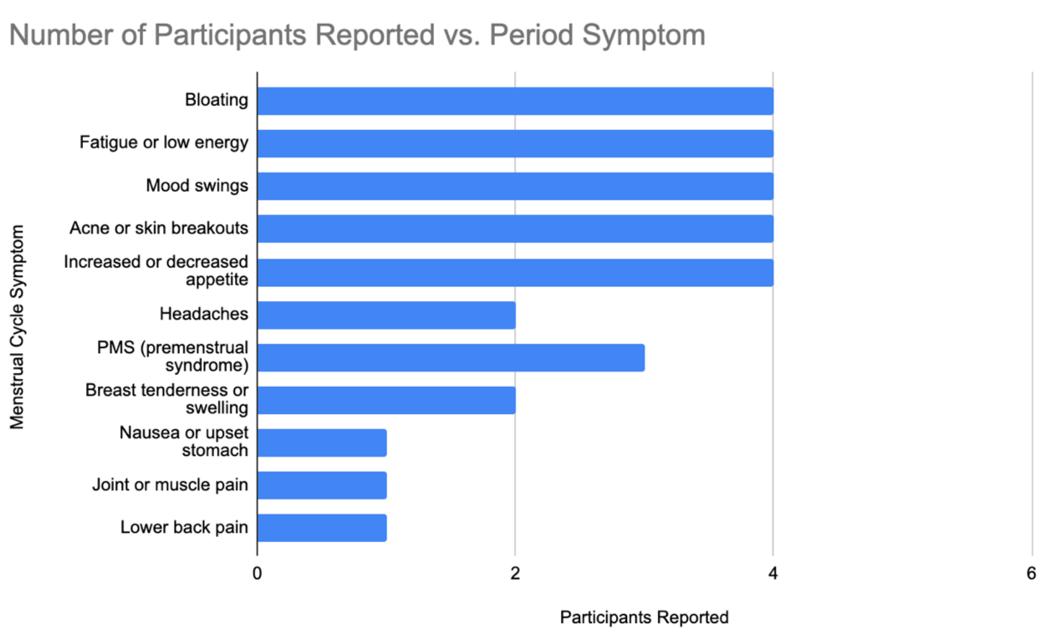

Figure 1. Period Symptoms. List of reported period symptoms in the participants on the y axis and number of participants reporting such symptoms on the x axis.

Figure 2.

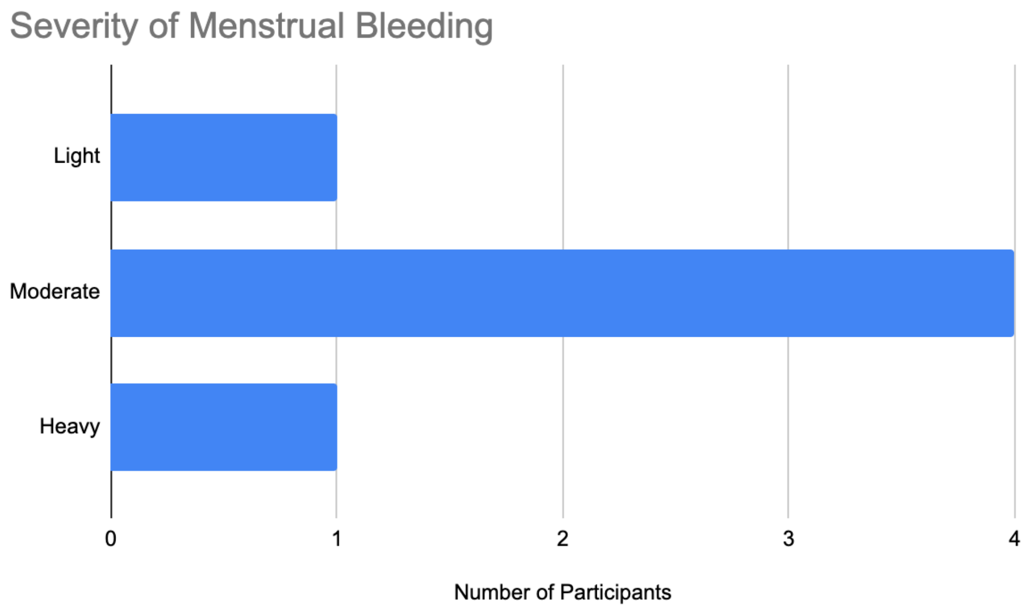

Figure 2. Severity of Menstrual Bleeding. Reported menstrual bleeding severity as light, moderate, or heavy in the participants. Number of participants reporting each bleeding category is on the x axis.

Running data

The average speed in the follicular phase ranged from 4.03 MPH to 7.39 MPH (6.13 ±0.51, average ± SEM), and in the luteal phase ranged from 4.187 MPH to 7.553 MPH (6.13±0.49, average ± SEM). During the follicular phases average running distance ranged from 2.02 miles to 3.695 miles (3.06±0.26, average ± SEM), and in the luteal phase between 2.097 miles to 3.77 miles (3.05±0.25, average ± SEM). There was no significant change in average speed per participant or average distance per participant when comparing the follicular and luteal phases (see Figure 3).

Figure 3.

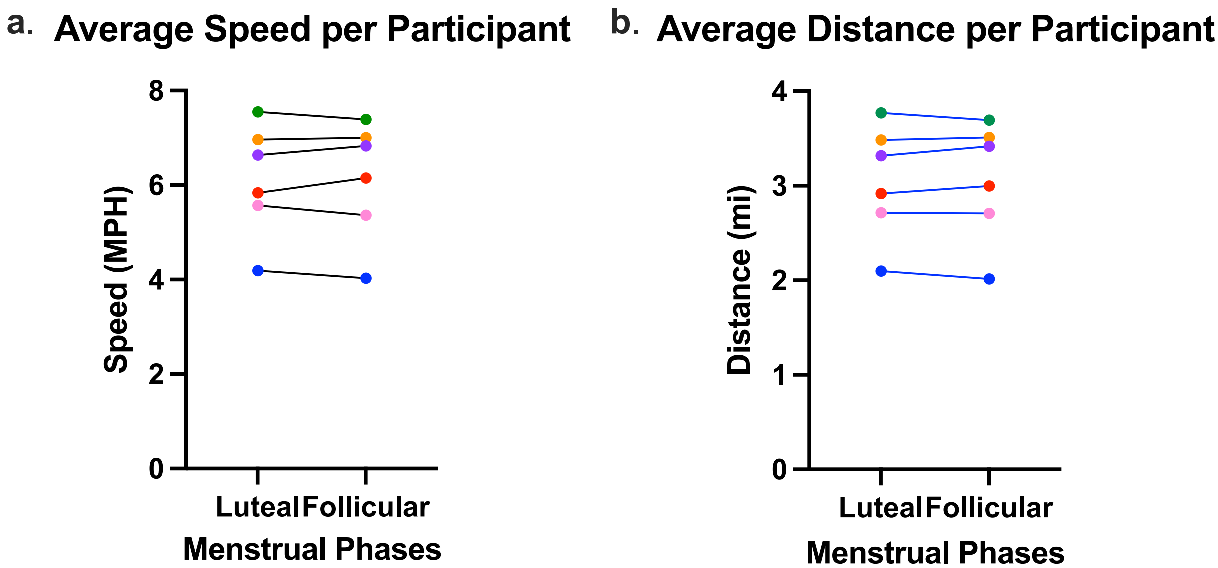

Figure 3. Average Speed and Distance per Participant. a. Average speed (MPH) for each participant in the luteal and follicular phases showed no significant difference between the phases. b. Average distance (miles) ran for each participant in the luteal and follicular phases showed no significant difference between the phases.

Mood scores

As seen in Figure 4a-c, there was no significant difference in the Negative Mood Score, Positive Mood Score, or Total Mood Score when the averages were compared between the follicular and luteal Phases. When looking at the individual moods, there was a trend towards decreased sadness in the follicular phase compared to the luteal phase (p=0.0995) as seen in Figure 4d.

Figure 4.

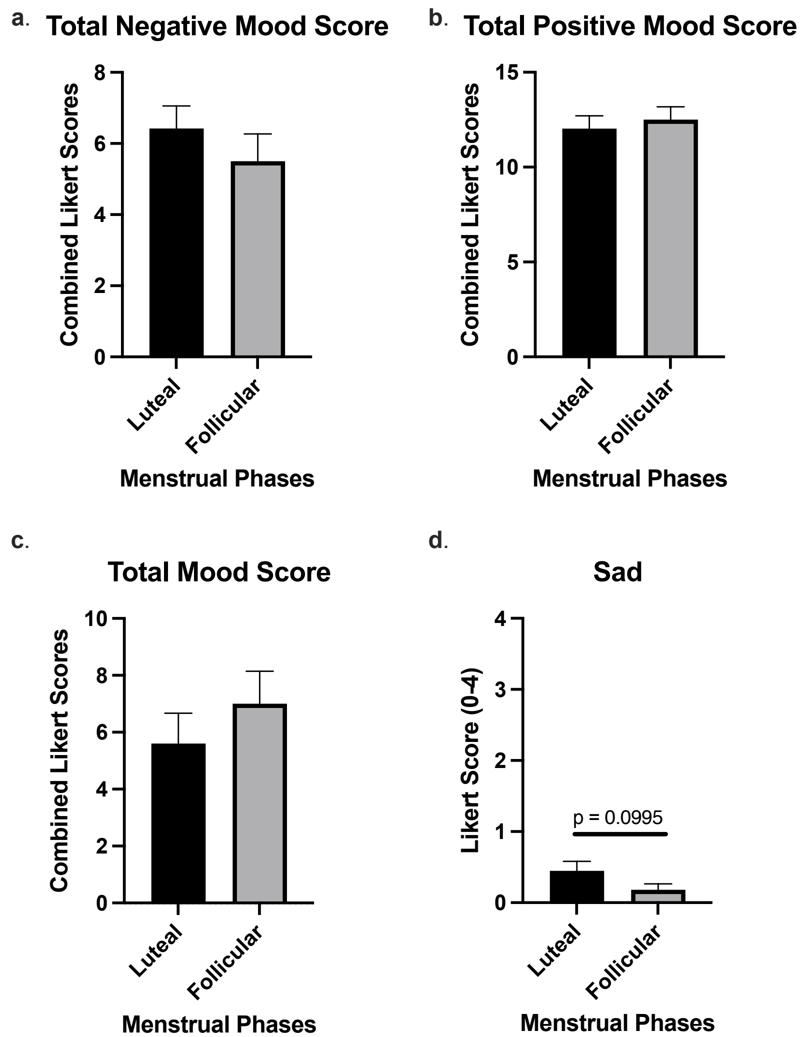

Figure 4. Mood Scores. a. Total negative mood scores were not different between follicular and luteal phases as calculated by the addition of all negative mood states. b. Total positive mood scores were not different between follicular and luteal phases as calculated by the addition of all the positive mood states. c. Total mood scores were not different between the follicular and luteal phases as calculated by the difference between positive and negative mood scores. d. A trend towards decreased sadness was seen in the follicular phase compared to the luteal phase.

Modified PPTSQ scores

The Perceived Performance in Team Sports Questionnaire (PPTSQ) showed that for Exercise Investment there was no significant change (not shown). For Exercise Potential, and Quality and Expectations scores there was a significant difference between the values in the follicular and luteal phases with higher scores in both components in the follicular phase than in the luteal phase (P<0.01) (Figure 5b and d). In addition, there was a significant increase in exercise quality, personal expectations, and total exercise score in the follicular phase compared to the luteal phase (P<0.05) (Figure 5a, c, e).

Figure 5.

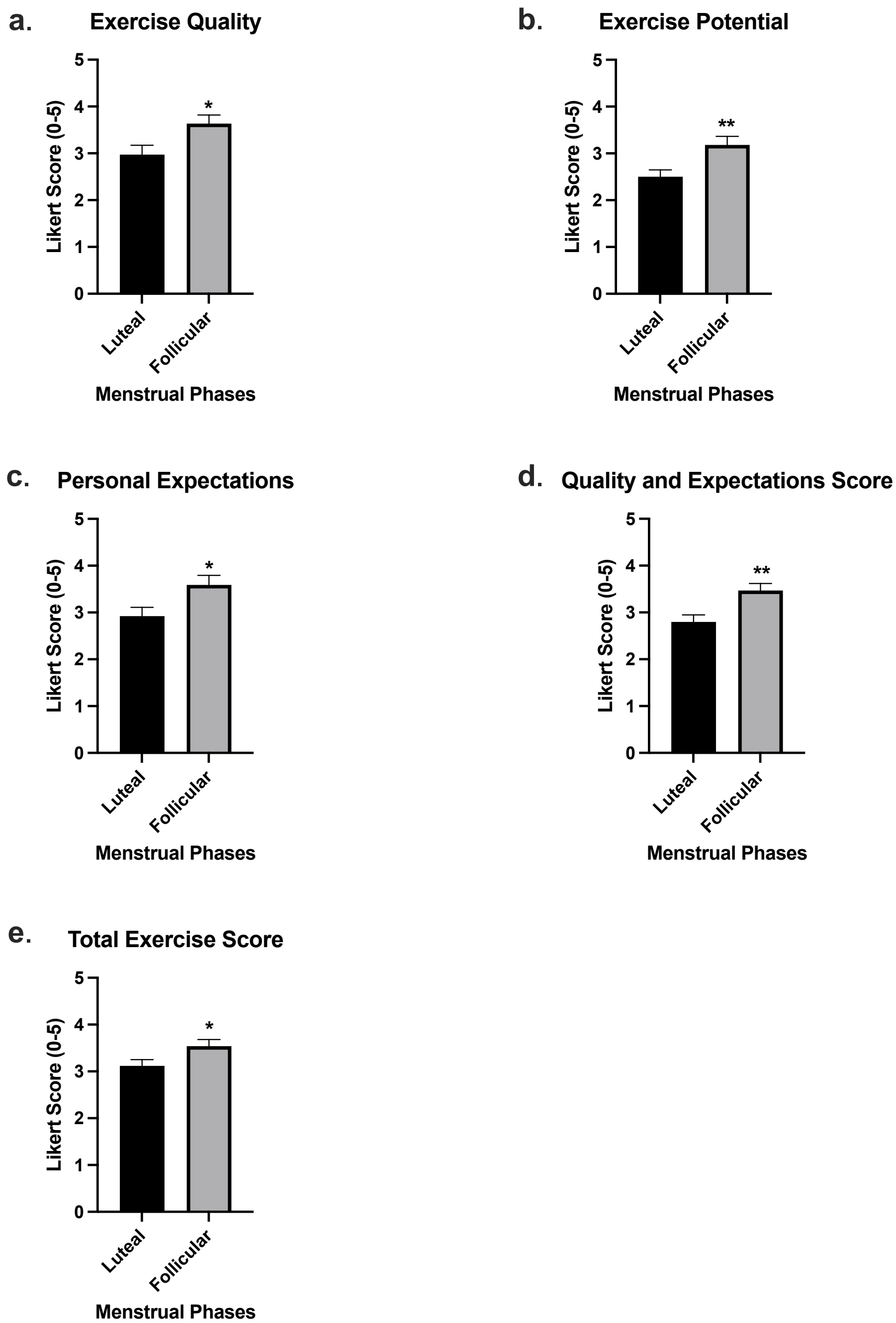

Figure 5. Modified PPTSQ Data. a. Participants perceived significantly increased exercise quality in the follicular phase as compared to the luteal phase. b. Participants perceived significantly increased exercise potential in the

follicular phase as compared to the luteal phase. c. Participants perceived significantly increased personal expectations for exercise in the follicular phase compared to the luteal phase. d. Participant's quality and expectations score was significantly increased in the follicular phase compared to the luteal phase. e. Participant's total exercise score was significantly increased in the follicular phase compared to the luteal phase. *Denotes a P<0.05, ** denotes a P<0.01.

Perceived pain scores

There was no significant change in perceived pain across the menstrual cycle.

Figure 6.

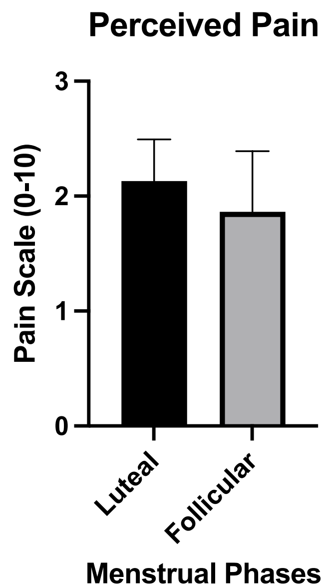

Figure 6. Perceived Pain Data. There was no significant differences in perceived pain as measured on a 0-10 VAS scale between the luteal and follicular phases.

Discussion

This small scale 7-week study shows that there are potential impacts of the female menstrual cycle on perceived running performance. The improvements of perceived performance through components such as exercise potential and quality and expectations in the follicular phase show a correlation between improved perceived performance and the follicular phase. These findings align with some current literature including Ekenros et al. which found a greater negative impact was perceived in the late luteal phase, with the optimal time for training beginning in their late- follicular phase.[18] Pinel et al. and Armour et al. both reported that women had symptoms and felt that their performance was impacted by their menstrual cycle causing reduced performance and fatigue. In Pinel et al. 83% of women admitted Premenstrual Syndrome was reported to have limited their play.[18] In Armour et al. 50% reported fatigue and reduced performance, and yet 76% of athletes did not talk to their coaches about related symptoms.[22] The lack of open discussion about these challenges, whether due to stigma or insufficient understanding, could contribute to feelings of isolation and negatively impact mood. Breaking down these barriers to communication is essential for supporting overall wellbeing and pushing forward research that could help understanding and adaptability.

This exploration found no significant change in performance markers such as distance and speed. The current literature is mixed with some studies seeing performance improvements across different phases. Due to limitations in tracking hormonal changes that identify phase changes, the study broke down the female menstrual cycle into two phases, follicular and luteal. In more comprehensive studies such as Sakhlina et al., researchers evaluated five phases within the menstrual cycle which allowed for a more precise look at fluctuations. [31] Their study found that peak running performance increased in the 4x400m during the postmenstrual, postovulatory, and premenstrual phases, and lower performance while maintaining more physical working capacity in the menstrual, ovulatory, and premenstrual phases. Additionally, studies including Julian et al. found decreased performance on maximal endurance performance during the mid-luteal phase of the menstrual cycle, and Goldsmith et al. found decreased running economy in the mid-luteal phase compared to the early and late follicular phases.[34,35] These studies on running performance across the menstrual cycle show that research is limited with conflicting or inconclusive results. This indicates the importance of further research with specific parameters and similar physiological markers so results can be compared with more accuracy.

Limitations and Future Directions

There are limitations to fully exploring and understanding how the menstrual cycle impacts a female's perceived exercise performance. A major factor is the individuality of women and how their menstrual cycle impacts their bodies. Menstrual symptoms, hormone fluctuations, and general tolerance of individuals impact their feelings and reactions to their menstrual cycle. Each cycle has variations and complexities when it comes to tracking the female menstrual cycle. Additionally, performance can be affected by confounding life factors including sleep, nutrition, and stress. Although the study avoided environmental confounding variables such as elevation, humidity, and weather due to using treadmills for the running intervention, confounding variables limit the ability to evaluate the isolated relationship between the phases of the menstrual cycle and performance. Further, there is a lack of knowledge of the phases of the menstrual cycle and tracking the cycle. Due to most exercise performance being done on men, and studying the menstrual cycle being a relatively new concept, there was limited scientific research and no standardized parameters making it harder to accurately assess the results of the studies and compare them. Additionally, the small sample size of the study was a limitation. The small size decreased statical power and limited generalizability. Due to the study requirements including mandating that participants run on the treadmill recruiting runners was challenging. Data in the study was also self-reported via surveys and rate of perceived exertion to measure running effort.

Future directions in research should prioritize longitudinal studies with larger sample sizes and more diverse age ranges, fitness levels, and ethnicities to provide a more comprehensive look at how the menstrual cycle impacts women. Expanding research will improve generalizability of the findings across populations. Additionally, research should investigate confounding variables such as sleep quality, nutrition, stress management, and body composition to test the true relationship between the menstrual cycle and exercise performance.

Conclusion

The findings of this exploration on how the menstrual cycle impacts perceived performance in female runners aligns with existing research. The research shows that although objective performance metrics such as speed and distance may remain unchanged across menstrual cycle phases, female athletes' perceived performance and feelings about their abilities decrease during the luteal phase compared to the follicular phase. This outcome separating actual and perceived performance highlights the complex relationship between physiological changes and psychological well-being of females in athletic performance.

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Appendix A. IRB Approval and Informed Consent

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE:	May 2, 2025
TO:	Angela Suzanne Anderson, Leah Bohannon
FROM:	Virginia Tech Institutional Review Board (FWA00000572)
PROTOCOL TITLE:	The exploration of how hormonal changes throughout the menstrual cycle impact women’s perception of running performance.
IRB NUMBER:	**25-144**

Effective May 1, 2025, the Virginia Tech Institution Review Board (IRB) approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date:	**April 24, 2025**
Progress Review Date:	**April 24, 2026**

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor

* Date this proposal number was added.

If this protocol is to cover any other grant proposals, please contact the HRPP office (irb@vt.edu).

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Consent to Take Part in a Research Study

25-144 The exploration of how hormonal changes throughout the menstrual cycle impact women's perception of running performance.

Title of research study: 25-144 **The exploration of how hormonal changes throughout the menstrual cycle impact women's perception of running performance.**

Principal Investigator: Angela Anderson, Ph.D.
Department of Human Nutrition, Foods and Exercise, Virginia Tech
256 Wallace Hall, Blacksburg, VA 24061, asphay@vt.edu: 540-231-2487

Other study contact(s): Leah Bohannon Lbohannon@vt.edu

Key Information: The following is a short summary of this study to help you to participate in the study. More detailed information can be found later in the consent form.

This study aims to investigate how hormonal changes throughout the menstrual cycle affect women's perceived exercise performance during a hybrid training program. Female recreationally active runners from Virginia Tech with a regular menstrual cycle will be recruited for participation in this study. Participants must have a regular menstrual cycle and not be pregnant or currently have an IUD. Participants will be between the ages of 18 and 36 years old and be able to commit the time to participate in the study. Over a total of seven weeks, participants will track their menstrual cycles, symptoms, and energy levels while engaging in the running exercise intervention consisting of three days a week of 30-minute runs of the treadmill. The study will last a total of seven weeks, including a one-week baseline tracking period before the intervention, 5 weeks of the exercise intervention, and a one-week follow-up period of tracking after the exercise intervention.

Why am I being invited to take part in a research study?

We invite you to take part in this research as a recreationally active female runners with a regular menstrual cycle who is able to participate in three days a week of 30-minute runs on the treadmill.

What should I know about being in a research study?

- Researchers will explain this research study to you.
- Participation is completely voluntary.
- You can agree to take part and later change your mind and withdrawal from the study.
- Your decision to participate, not participate, or withdrawal will not be held against you.
- You can ask all the questions you want before you decide to take part in the study.

Why is this research being done?

The menstrual cycle is a fundamental part of female physiology that affects many aspects of daily life. This research will help uncover the interaction between the menstrual cycle and perceived exercise performance. Understanding the effect of the menstrual cycle on exercise performance is significant for athletes, fitness enthusiasts, and healthcare professionals. The knowledge of how our hormones affect our energy and strength can provide women with a more refined and practical understanding of their bodies. With this information individuals and professionals can create training regimens, optimize athletic performance, and improve overall well-being.

How long will the research last and what will I need to do?

Over a total of seven weeks, participants will track their menstrual cycles, symptoms, and energy levels while engaging in an exercise intervention consisting of three 30-minute runs on the treadmill at an RPE (Rate of Perceived Exertion) of 16 to 17. The study will last a total of seven weeks, including a one-week baseline tracking period before the intervention and a one-week follow-up period of tracking after the exercise intervention. You will be asked to download the Remind App receive reminders to complete the forms and runs. In Week 1, participants will begin tracking their menstrual cycle, symptoms, and energy levels using the Google Form three days per week (Monday, Wednesday, and Friday). During intervention Week 2 through Week 6, participants will engage in the 30-minute treadmill runs three times per week (Monday, Wednesday, and Friday). Participants will track in the Google Form the day of exercise which includes questions about their cycle, questions about their run, the pain scale, a Modified Physical Perception of Training and Self-Efficacy Questionnaire (PPTSQ), and an abbreviated POMS. In Week 7 of the study, participants will continue tracking their menstrual cycle and complete an abbreviated POMS.

More detailed information about the study procedures can be found under, **"What happens if I say yes, I want to be in this research?"**

Is there any way being in this study could be bad for me?

The risks of this study include the normal risks of exercise including injury. The risk of breach of confidentiality is possible, although precautions and protocols to ensure that participants' information is securely protected are in place.

More detailed information about the risks of this study can be found under **"Is there any way being in this study could be bad for me? (Detailed Risks)."**

Will being in this study help me in any way?

This study cannot ensure benefits to the study participants. However, research has found positive benefits to exercising and participating in exercise. Additionally, the study hopes to provide participants with a better understanding of how their menstrual cycle may impact performance including factors such as mood, perceived performance, and energy levels.

What happens if I do not want to be in this research?

Participation in research is completely voluntary. You can choose to participate or not to participate.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Consent to Take Part in a Research Study

25-144 The exploration of how hormonal changes throughout the menstrual cycle impact women's perception of running performance.

Detailed Information: The following is more detailed information about this study in addition to the information listed above.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at Angela Anderson, asphay@vt.edu, 540-231-2487.

This research has been reviewed and approved by the Virginia Tech Institutional Review Board (IRB). You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your rights as a research subject
- Your questions, concerns, or complaints are not being answered by the research team
- You cannot reach the research team
- You want to talk to someone besides the research team to provide feedback about this research

How many people will be studied?

We plan to include about 12-36 people in this research study.

What happens if I say, yes, I want to be in this research?

If you say yes to participate in research, you will be asked to participate in the exercise intervention which consists of three 30-minute runs on the treadmill at an RPE of 15 to 17. After signing the consent form, you will be given a participant number that will be used to track your data. You will also be asked to download the Remind App to receive reminders about completing the necessary forms and runs. The study will last a total of seven weeks, including a one-week baseline tracking period before the intervention and a one-week follow-up period of tracking after the exercise intervention. In Week 1, participants will begin tracking their menstrual cycle, symptoms, and energy levels using the Google Form three days per week (Monday, Wednesday, and Friday). During intervention Week 2 through Week 6, participants will engage in the 30-minute treadmill runs three times per week (Monday, Wednesday, and Friday). Participants will track in the Google Form the day of exercise which includes questions about their cycle, questions about their run, the pain scale, a Modified Physical Perception of Training and Self-Efficacy Questionnaire (PPTSQ), and an abbreviated POMS. In Week 7 of the study, participants will continue tracking their menstrual cycle and complete an abbreviated POMS. The time requirement of the study includes the 30-minute running workouts on the treadmill 3 days a week (Monday, Wednesday, Friday) over Weeks 2-6 in the study. After completion of the run, they will complete a Google Form with menstrual cycle data, running data, abbreviated POMS, and the Modified PPTSQ. This will take 10-15 minutes 3 days a week. In Week 1 and 7 participates will only be tracking menstrual cycle data and POMS. This will take 5 minutes 3 days a week. If you agree to the study, you will get more information in the form of a recorded video to help you understand the scales and required forms. You will receive messages via the Remind App to remind you to complete your workout and Google Forms.

What are my responsibilities if I take part in this research?

If you take part in this research, you will be responsible to:

- Three days a week (Monday, Wednesday, and Friday) of 30-minute running workouts on the treadmill at an RPE of 15-17
- Complete all workouts honestly and to the best of your ability at the correct RPE and for the correct time
- Fill out Google Forms (Monday, Wednesday, and Friday) accurately and honestly

What happens if I say yes, but I change my mind later?

You can leave the research study at any time, for any reason, and it will not be held against you.

If you decide to leave the research, contact the investigator so that the investigator can note this information for the rest of the study team.

If you stop being in the research, already collected data may not be removed from the study database.

Is there any way being in this study could be bad for me? (Detailed risks)

- In terms of physical risks, there are not any known risks outside of the normal risks associated with running. This can include injury, joint pain, and soreness.
- There are no known psychological, legal, social, or economic risks of this study.

What happens to the information collected for the research?

Research data will be self-reported by participants and submitted directly to researchers via Google Form. All data will be de-identified and Google Form will be completed with participant ID number. All data will be stored on Leah's and Dr. Anderson's computer which are password protected and meets the Virginia Tech security requirements for low-risk data. All data will be de-identified using participants numbers.

Data analysis will occur on Leah's computer, which meets the Virginia Tech security requirements for low-risk data as it has password protected access and has a physical hard drive on which the data will be stored. All data will be de-identified using participants numbers.

If identifiers are removed from your private information or samples that are collected during this research, that information or those samples could be used for future research studies or distributed to another investigator for future research studies without your additional informed consent.

Dr. Anderson and Leah Bohannon will handle all non-de-identified information and be the only people in the study to have access identifying information.

De-identified data will be stored for up to 5 years following publication. Identifying information will be stored in a separate file for the same time period.

The results of this research study may be presented in summary form at conferences, in presentation, reports, academic papers, and as part of a thesis/dissertation.

Can I be removed from the research without my OK?

Researchers can remove you from the research study without your approval. Possible reasons for removal include failure to participate in the study parameters including the workouts and Google Form surveys. Additionally, if a participant becomes pregnant, they will be removed from the study.

What else do I need to know?

If you need medical care because of taking part in this research study, contact the investigator and medical care will be made available. Generally, this care will be billed to you, your insurance, or other third party. Virginia Tech has no program to pay for medical care for research-related injury.

If a participant voluntarily withdraws from the study, we will not use any of the data collected from the Google Forms. This includes information on the Menstrual Cycle (age of first period, day of last period, length of menstrual cycle, menstrual cycle symptoms), Pain Scale, Abbreviated POMS, Modified Perceived Performance in Team Sports Questionnaire (PPTSQ), and Running data (Distance of run (Miles), Rate of Perceived Exertion Scale (RPE), Grade, MPH, Time of run).

Researchers will not be able to share your individual data results with you, but we will share study results in paper form once published in Summer 2025.

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Signature Block for Capable Adult

Your signature documents your permission to take part in this research. We will provide you with a signed copy of this form for your records.

Signature of subject	Date
Printed name of subject	
Signature of person obtaining consent	Date
Printed name of person obtaining consent	