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A Comparison Between Physiological and Perceived Exertion During Maximal and Submaximal Treadmill Exercise at Three Menstrual Cycle Phases

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A COMPARISON BETWEEN PHYSIOLOGICAL AND PERCEIVED
EXERTION DURING MAXIMAL AND SUBMAXIMAL TREADMILL
EXERCISE AT THREE MENSTRUAL CYCLE PHASES

(TITLE)

BY

KATHLEEN M. McCUNE

THESIS

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ABSTRACT

The purpose of this study was to investigate the differences in physiological and subjective perceived exertion levels at maximal and submaximal treadmill exercise between three phases of the menstrual cycle in eumennorheic women.

Nine females of varying fitness levels were subjects in the study. None of the subjects were using oral contraception or hormone altering medications at the time of the study.

The subjects performed three separate maximal graded exercise tests (GXT) using the Balke protocol. During each GXT, oxygen uptake (VO_2), heart rate (HR), blood pressure (BP), respiratory quotient (RQ), rate of perceived exertion, and total time to exhaustion were recorded. During an eight minute recovery period, RQ, HR, and BP were recorded. These GXTs were performed beginning with either onset of menses, at ovulation, (as determined by oral temperature), or at cycle end chosen in random order.

Group mean values for each menstrual cycle phase were calculated for VO_2, HR, RQ, and time to exhaustion. Means were compared between the three phases using a multivariate analysis of variance for repeated measures with an alpha of 0.05. It was found that at 75% maximal exertion and at maximal exertion, the ovulation phase means tended to be highest for the parameters of VO_2 (75% mean =26.662 $\pm$ 6.281 $ml \cdot kg^{-1} \cdot min^{-1}$, maximal mean = 35.32$\pm$ 6.711 $ml \cdot kg^{-1} \cdot min^{-1}$), HR (75% mean - 153.25$\pm$ 7.146 bpm, maximal mean =

175.75 ± 13.573 bpm), and time to exhaustion (15.205± 3.902 minutes). The lowest mean values for these same parameters were found at the menses phase at the 75% and maximal exertion levels of intensity (mean $\dot{V}O_2$ 75% = 26.109 ± 5.063 $ml \cdot kg^{-1} \cdot min^{-1}$, mean $\dot{V}O_2$ max = 34.826 ± 6.799 $ml \cdot kg^{-1} \cdot min^{-1}$; mean HR at 75% = 152.625 ± 16.928 bpm, mean HR at maximal =171.25± 14.23 bpm; mean time to exhaustion = 14.845 ± 3.125 minutes). However, these differences were found not to be satistically significant (p=<0.05) between any of the menstrual phases.

It was concluded that the physiological responses which occur during submaximal and maximal exercise do not differ between menstrual cycle phases. However, trends were evident to indicate that ovulation produced the highest mean values for those parameters, and the menses phase produced the lowest. Further investigation of these trends is recommended.

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Dedication

This project is dedicated to my dearest friend and colleague without whose encouragement to "Get up and go the distance", success would not have been realized. It is also dedicated to the song "Learning to Fly" by Tom Petty and the Heartbreakers, and to the unknown author of the words "There's room at the top for those who choose to climb."

Acknowledgements

The author wishes to express her heart felt gratitude to Dr. John Emmett, Dr. Thomas Woodall, and Dr. Jeff McClung for their guidance and encouragement throughout this thesis project.

A special thanks to the graduate students who assisted with data collection and to all the subjects.

CHAPTER 1

INTRODUCTION

With an increasing number of women participating in a wide variety of competitive sport, fitness training, and recreational activities comes an interest in the performance capabilities of females. However, the amount of scientific study involving women has been fairly small. One significant reason for this is that the female menstrual cycle, and the individual's response to it, is highly variable among women and is very difficult to control for in experimental situations. There is little information available as to the degree of variability that actually exists between the menstrual cycle phases and how crucial it would be to control for this in female experimental studies.

Because each phase of the menstrual cycle is caused by hormonal fluctuations, it is possible that perceptual, as well as physiological, responses to physical exertion are affected. Particularly, because subjective rating of intensity can vary daily with emotional state and general feeling of good health in all individuals, perceived exertion may alter with hormonal fluctuations in females. These fluctuations in hormones and perception, therefore, may improve or impair performance in females at various stages during the menstrual cycle, regardless if physiological responses are affected.

Statement of the Problem

There are times throughout the menstrual cycle when a female can expect not to "feel well" generally due to normal hormonal changes that can cause cramping, irritability, aggressiveness, fatigue, water retention, etc. These common symptoms may cause exercise to be perceived as more difficult and may cause physiological factors such as heart rate (HR), oxygen uptake ($\dot{V}O_2$), and respiratory quotient (RQ) during exercise and recovery HR to respond differently among the various phases of the menstrual cycle. This may be especially inconvenient and discouraging for women involved in competition, physical training, and recreation. An understanding of the possible points in the cycle when exercise is likely to be perceived as more intense, as well as physiologically more stressful, (thus impairing performance), would be possible and beneficial for scheduling events and training sessions so that peak performance could be achieved.

Purpose of the Study

The purpose of the study was to determine if a difference in physiological and subjective perceived exertion levels at submaximal and maximal exercise exists between three phases of the menstrual cycle in eumennorheic women.

Limitations

1) Hormone levels were not measured to precisely determine menstrual cycle phase.

2) Eumennorheic subjects not using oral contraception were of limited availability.

3) Oral basal body temperature method was used to determine ovulation.

4) Menstrual cycles among the subjects were not an equal number of days.

5) Subjects were responsible for measuring and recording daily oral basal body temperature changes.

Hypothesis

There will be a difference between physiological and perceived exertion levels at submaximal, maximal, and recovery from treadmill exercise between three phases of the menstrual cycle. Those three phases will be identified as the onset of menses, ovulation, and cycle end.

Definition of Terms

For the purposes of this study the following key terms have been defined as follows:

Basal Body Temperature: Oral body temperature taken before rising in the morning.

Cycle End: Two to three days prior to expected onset of menses.

Eumennorheic: Normal monthly menstruation.

Follicular Phase: That phase of the menstrual cycle occurring between the end of menses and ovulation.

Heart Rate (HR): The number of ventricular beats per minute (bpm).

Luteal Phase: That phase of the menstrual cycle occurring between ovulation and menses.

Menses: That phase of the menstrual cycle occurring on the first day of menstruation.

Ovulation: That day of the menstrual cycle when basal body temperature sharply increases above previous levels.

Oxygen Uptake ($\dot{V}O_2$): The volume of oxygen extracted from the inspired air expressed in milliliters of oxygen per kilogram of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$).

Rate of Perceived Exertion (RPE): "One's subjective rating of the intensity of work being performed." (Morgan, W.P. 1973, p.97)

CHAPTER 2

REVIEW OF LITERATURE

Phases of the menstrual cycle are related to hormonal and basal body temperature fluctuations. These changes may have a direct effect upon various physiological and perceptual parameters, and therefore, may influence the rate and degree of fatigue during exercise. In order to investigate this, the relationship between body temperature and menstrual cycle phase needs to be established as well as previously documented physiological and perceptual changes during exercise at different phases during the menstrual cycle.

Determination of Ovulation Via Basal Body Temperature

As described in Physiology of Reproduction (1971), Natural Family Planning: The Ovulation Method (1978), and Ovulation: The Essentials of Human Reproduction (1958), the method of recording changes in basal body temperature to determine ovulation is a physiologically sound practice. Early in the menstrual cycle, estrogen is high in concentration in the blood while body temperature remains virtually unchanged. At approximately mid-cycle this concentration drops suddenly and high concentrations of progesterone appear in the blood of normally menstruating women (Human Anatomy & Physiology, 1981, pp.716,722). With this increase in progesterone, an increase in body temperature occurs indicating ovulation. Therefore, it is feasible to utilize the basal body temperature method of determining ovulation and it is a well-documented procedure when studying the menstrual cycle.

Several studies investigating the menstrual cycle have utilized the body temperature method of determining ovulation to establish menstrual cycle phases during which to test (Jurkowski, Jones, Walker, Younglai, & Sutton, 1978 and 1981; Hessemer & Bruck ,1985; Wells & Horvath, 1973; Dombovy, Bonekat, Williams, & Staats, 1987; and De Bruyn-Prevost, Masset, & Sturbois, 1984).

Because basal body temperature method is well documented and widely chosen as a reliable method for study, it was deemed a suitable tool for signifying ovulation for this investigation.

Physiological Parameters, RPE, and Exhaustion Time at Submaximal and Maximal Levels of Exertion

Several cardiovascular parameters such as $\dot{V}O_2$, $\dot{V}O_2max$, RQ, HR have been studied in relation to the menstrual cycle at submaximal and maximal levels. In addition, RPE and exhaustion time have also been followed in a few studies. The majority of research projects have examined these parameters using cycle ergometry as the mode of exercise due to its availability and ease of setting workloads. However, this study utilized the treadmill exercise as walking is a more representative mode of daily activity.

Oxygen Uptake

Because estrogens and progesterones have been shown to have an effect on ventilatory response (Gaensler, 1965), it is possible that oxygen transport and delivery may be affected at different phases of the menstrual cycle.

Therefore the $\dot{V}O_2$ response at various menstrual cycle phases merit investigation.

$\dot{V}O_{2max}$, extrapolated from a working capacity of 170 Watts on a cycle ergometer was found to be unaffected either by menstrual cycle phase of by the use of oral contraceptives in a study by DeBruyn-Prevost et al. (1984). This was in agreement with Jurkowski et al. (1978) which also used progressive cycle ergometry as the form of work while measuring submaximal $\dot{V}O_2$ and $\dot{V}O_{2max}$.

Later studies by Jurkowski et al. (1981) and Dombovy et al. (1987), both using cycle ergometry, found no difference in $\dot{V}O_2$ at submaximal or maximal levels at the luteal and follicular phases in the menstrual cycle. Therefore, these studies concluded that aerobic capacity is the same in follicular and luteal phases.

Contrasting results were found by Hessemer & Bruck (1985) who found submaximal $\dot{V}O_2$ to be 5.2 % higher in the luteal phase compared to the follicular phase. They reported this to be due in part to a higher exercise body temperature during that phase.

Heart Rate

Heart rate is a measure of somatic stress affected by emotions, temperature change, pain, and exercise. Therefore, it is possible that because all of these factors can change at various stages of the menstrual cycle, HR may respond differently at absolute work loads.

Gamberale, Strindberg, & Wahlberg (1975) found no significant changes in HR response in 12 women over three phases of the menstrual cycle. These phases were determined as; day 1-2 of menses; post-menstruation day 10-18; and premenstruation days 2-6.

Two other studies that further supported no significant differences in HR were Jurkowski et al. (1978) and Stephenson, Kolka, & Wilkerson (1982). The latter study measured HR at five different points of the menstrual cycle; days 2, 8, 14, 20, and 26.

Contrary to these findings, Pivarnik, Marichal, Spillman & Morrow (1990) and Hessemer & Bruck (1985) found exercise HR to be higher in the luteal phase than in the follicular phase. Both concluded that this could be due to normally occurring higher core temperature in the luteal phase

Respiratory Quotient

Estrogen and progesterone have also shown to affect carbohydrate and lipid metabolism as well as ventilation (Beck, 1975., Kalkhoff, 1975., Kim & Kalkhoff, 1975.). Because RQ value demonstrates the degree of substrate utilization through the analysis of expired gasses, differences may be observed at various stages of the menstrual cycle.

No differences were found in RQ value between two (luteal and follicular) menstrual cycle phases studied using maximal cycle ergometry (Hessemer & Bruck, 1985). At rest, and at four submaximal cycle ergometry workloads, Stephenson et al. (1982) also found no significant differences in RQ at five different points in the menstrual cycle.

Rating of Perceived Exertion

Several studies have investigated the use of ratings of perceived exertion during physical exercise (Fullerton & Cathell, 1892; Stevens & Mack,1959; Eisler, 1962; Hueting, 1965; and Cooper, Grimby, and Edwards,1979). However, it was Gunner A. Borg (1962) who was first to study the perception of aerobic exercise employing large muscle masses and found significant correlation ($r=.83$) between heart rate and physical exertion. The fifteen point scale developed from this study is widely used to equate a number value with descriptors to subjectively evaluate the intensity of exercise.

Because water retention, fatigue, general discomfort and emotional lability, all due to hormone fluctuations can alter perception of exercise intensity, RPE warrants investigation during various menstrual phases. However, few studies dealing with the menstrual cycle and exercise have studied this variable.

Dombovy et al. (1987) had subjects use the Borg scale only at the point of exhaustion during the maximal cycle ergometry tests. No significant differences were found between two phases (luteal and follicular) of the menstrual cycle.

More extensive use of RPE was made by Pivarnik et al. (1990) which tested eight eumennorheic females using cycle ergometry at 75% $\dot{V}O_{2max}$. RPE were measured every five minutes during the last twenty minutes of exercise. It was concluded that RPE was significantly higher in the luteal phase ($p<.05$).

Exhaustion Time

Physical endurance may be affected by water retention, desire to continue (mood), general fatigue, etc. Similarly, these factors may be influenced positively or negatively by hormone changes found in various phases in during the menstrual cycle. It is, therefore, beneficial to investigate the effects of various menstrual cycle phases on the length of time it takes to reach physical exhaustion.

For maximal cycle ergometry, exhaustion time was found to be greater in the luteal phase than in the follicular phase by 1.40 ± 0.33 miuntes ($p<0.02$). (Jurkowski et al., 1981) This was in agreement with an earlier study done by Jurkowski et al. (1978) using the same mode.

In contrast to these studies, Stephenson et al. (1982), also utilizing cycle ergometry, found no change in time to exhaustion associated with menstrual cycle phase.

Summary

Although most of the literature reviewed found similar results in that there were no differences in $\dot{V}O_2$ among the menstrual cycle phases, there were some contrasting results found on the other parameters investigated, such as HR, RQ and exhaustion time. This study intended to further investigate findings of previous studies on the same parameters, and investigate further into the variable of RPE.

Where the reviewed studies all used cycle ergometry, this research used treadmill walking as the mode of exercise allowing natural movement of arms as well as work with the legs in a more familiar form of motion representative of normal daily activity.

CHAPTER 3
METHODOLOGY

Subjects

Twelve female eumennorheic subjects not using oral contraceptives or hormone altering medication were selected through personal contacts from the Charleston, Illinois area. The subjects were all apparently healthy, of varying fitness levels, between the ages of 22 and 36 years old (mean = 27.4 years), with menstrual cycles lasting an average of 29 ± 2 days.

Preliminaries

A preliminary maximal graded exercise test (GXT) was performed on each subject to; a) orient the subjects to the treadmill; b) orient the subjects to the mouthpiece and breathing through the oxygen uptake system; and c) familiarize the subjects with Borg's 15-point Rating of Perceived Exertion Scale.

From the preliminary testing , it was concluded that the standard Balke treadmill protocol would be used during experimental testing to allow for accurate blood pressure measurements, and because the subjects indicated they were more comfortable with the 3.0 mph walking speed than the running pace of the latter stages of Bruce. None were accustomed to running, and, therefore, a walking protocol was used to obtain a better effort.

Due to the menstrual cycle irregularity and unavailability to complete the three testing trials, three subjects were dropped from the study. The nine remaining subjects were randomly divided into three testing groups. Each group began testing at a different phase in the menstrual cycle to control for learning effect and coincidental results.

Three phases of the menstrual cycle (onset of menses, ovulation, and cycle end) were chosen to be researched in accordance with Wells & Horvath (1973) and DeBruyn-Prevost et al. (1984) to obtain a wider range of data at varying hormone levels throughout the female menstrual cycle.

All subjects were instructed to commence recording oral basal body temperature (to signal ovulation) on a graph provided (Appendix A) according to Essentials of Human Reproduction (1958). Subjects were instructed how to plot the temperatures and at which points during the menstrual cycle to schedule testing time in the Human Performance Lab. When possible, each subject was tested at the same time of day to factor out diurnal rhythms, however, due to the undependable nature of the menstrual cycle and individual schedules, some variability resulted in testing times.

Subject Preparation

Upon arrival to the Human Performance Laboratory, subjects dressed in shirts, shorts, socks, and shoes were weighed in kilograms (kg) and an informed consent was signed (Appendix B). Subjects were then fitted with a Vantage heart rate monitor and instructed on how to use the RPE scale. Subjects were re-oriented to the treadmill and informed that they would be walking at a constant rate of 3.0 mph with a gradient increasing by 2.5% every two minutes, and that at the end of each stage, BP and RPE would be measured. Each subject was instructed to exercise to maximal exertion quantified by percent of age predicted maximum heart rate, RQ = >1.0, RPE of 19-20.

Subjects stood on the treadmill at rest while resting blood pressure (RBP) and resting heart rate (RHR) were measured and recorded, and then fitted with a mouthpiece attached to the on-line open circuit oxygen uptake system.

Testing Procedure

After the subject inserted the mouthpiece and was comfortable breathing into the one-way valve connected to the open circuit oxygen uptake system, the subject warmed-up walking on the treadmill at 1.2 mph and 0% grade for one minute. At the beginning of the test, the HR monitor, on-line system, and treadmill protocol were started simultaneously. $\dot{V}O_2$ and RQ values were recorded by computer every 15 seconds (s) via the computerized oxygen uptake system. Heart rates were recorded every minute with the Vantage watch memory, and BP and RPE were measured and recorded at minute 1:45 of each two minute stage.

The subject exercised to volitional fatigue followed by an eight minute cool down period walking at 1.2 mph and 0% grade. Recovery blood pressures (BP_{rec}) were measured at minutes one, three, five, seven, and eight of the cool down period. Recovery heart rates (HR_{rec}) were recorded every minute for the entire cool down period. Testing was terminated once HR had decreased below 100 bpm and BP had returned to near resting values.

Statistical Analysis

Group means for $\dot{V}O_2$, HR, RQ, RPE, and total treadmill test time at 50% $\dot{V}O_{2max}$, 75% $\dot{V}O_{2max}$, and $\dot{V}O_{2max}$ were compared between the three phases of the menstrual cycle (ovulation, onset of menses and cycle end).

A multivariate analysis of variance for repeated measures was used to determine the significance of the effect of menstrual cycle phase and exercise intensity on the dependent variables. An alpha level of 0.05 was used.

CHAPTER 4
RESULTS

This study was designed to evaluate and compare the physiological responses of VO_2, HR, RQ, as well as RPE and total time to exhaustion of eumennorheic women at three phases of the menstrual cycle using submaximal and maximal treadmill walking. Data reduction procedures involved determination of the mean of all the chosen parameters at 50%, 75%, and maximal exertion as determined by $\dot{V}O_2$.

Oxygen Uptake Response

Group mean values for $\dot{V}O_2$ between treatments showed some variability among the intensities, however, none were found to be significant at thealpha = 0.05 level of confidence (Appendix C).

$\dot{V}O_2$ 50%

At ovulation, the group mean $\dot{V}O_2$ (17.582 $ml \cdot kg^{-1} \cdot min^{-1} \pm 3.25$) was higher than at cycle end (17.447 $ml \cdot kg^{-1} \cdot min^{-1} \pm 3.278$). The lowest mean value being 17.311 $ml \cdot kg^{-1} \cdot min^{-1} \pm 4.501$ during menses.

$\dot{V}O_2$ 75%

The group mean $\dot{V}O_2$ at 75% $\dot{V}O_{2max}$ was found to be highest at cycle end (26.662 $ml \cdot kg^{-1} \cdot min^{-1} \pm 6.281$). At ovulation, the mean was 26.488 $ml \cdot kg^{-1} \cdot min^{-1} \pm 5.063$, making the menses phases, again, the lowest value at 26.109 $ml \cdot kg^{-1} \cdot min^{-1} \pm 4.842$.

$\dot{V}O_{2max}$

At maximal exertion, the ovulatory phase showed the highest group mean (35.32 $ml \cdot kg^{-1} \cdot min^{-1} \pm 6.711$) over the cycle end mean of 35.176 $ml \cdot kg^{-1} \cdot min^{-1} \pm 8.059$. The $\dot{V}O_{2max}$ mean during menses was 34.826 $ml \cdot kg^{-1} \cdot min^{-1} \pm 6.799$.

Heart Rate Response

Slight variability existed among the heart rate responses during each of the intensities and each recovery stage. However, differences found between the menstrual cycle phases were statistically insignificant (Appendix D).

In the data analysis of this parameter, only eight subjects were evaluated due to failure of the Vantage heart rate monitor to record heart rates on one subject for one GXT. As a result, none of her heart rate data was analyzed and N=8 for heart rate data.

HR 50%

The highest mean HR for the group (123 $\pm$ 12.817 bpm) occurred during menses. Cycle end showed the middle value of the three phases of 122.5 $\pm$ 12.627 bpm. The lowest mean HR (120 $\pm$ 10.043 bpm) occurred during the ovulatory phase.

HR 75%

At 75% $\dot{V}O_{2max}$, the highest mean HR (153.25 ± 7.146 bpm) occurred at ovulation. The lowest mean HR value was 152.625 ± 16.928 bpm during menses, and the cycle end mean was 152.75 ± 13.573 bpm.

HR_{max}

HRmax was highest at ovulation (175.75 ± 13.188 bpm) and lowest at menses (171.25 ± 14.23 bpm). Cycle end mean HR_{max} was 174.00 ± 17.004 bpm.

HR_{rec} - Minute One

After the first minute of recovery, mean HR was highest at ovulation (156.75 ± 13.101 bpm). Menses showed the middle mean value for the group at 146.375 ± 18.291 bpm. The lowest mean HR was at cycle end (143.25 ± 14.811 bpm).

HR_{rec} - Minute Five

At recovery minute five, the mean HR at ovulation was highest (117.375 ± 11.338 bpm). At menses the lowest mean HR value was found at 113.125 ± 13.778 bpm. Cycle end mean HR for the group was 114.75 ± 10.471 bpm.

HR_{rec} - Minute Eight

At recovery minute eight, the mean HR was greatest at 110.625 ± 11.904 bpm. At cycle end, mean HR was 110 .000± 14.541 bpm. The lowest mean HR occurred during menses (107.500 ± 11.674 bpm).

Respiratory Quotient

Some variability existed between the RQ values among the intensities and each recovery stage. No statistical significance was discovered, however, among the menstrual phases (Appendix E).

RQ 50%

At 50% of maximal exertion, the highest mean RQ occurred at cycle end (.826 ± .055). Ovulation showed a mean RQ of .812 ± .056, and the lowest mean value for RQ at 50% VO_{2max} was 0.808 ± 0 .041 at menses.

RQ 75%

At 75% of maximal exertion, the menses phase had the highest mean RQ (0.927 ± 0.061). Ovulation mean RQ was .909 ± .063, and cycle end mean RQ was 0.904 ± 0.066.

RQ_{max}

Mean RQ was highest during menses (1.047 ± 0.101) at maximal exertion. At ovulation the mean RQ was 1.03 ± 0.088, and the lowest mean RQ occurred at cycle end (1.011 ± 0.098).

Rating of Perceived Exertion

Some variability existed among the mean RPE at each intensity level measured, however, no statistical significance occurred (Appendix F).

RPE 50%

At 50% maximal exertion, identical means occurred at ovulation and menses (9.556 ± 2.068 and ± 1.333 respectively). Cycle end had the highest RPE of 10.000 ± 1.225.

RPE 75%

At 75% maximal exertion, similar means occurred at menses and cycle end (15.778 ± 1.202 and 15.111 ± 1.364 respectively). Ovulation showed the lowest mean RPE of 14.889 ± 2.147.

RPEmax

At maximal exertion, the mean RPE for ovulation, menses, and cycle end were 19.222 ± .667, 19.444 ± .882, and 19.000 ± 1.118 respectively.

Time to Exhaustion

Although no statistical significance occurred between the phases of the menstrual cycle in total time to exhaustion, slight variability among the three means existed (Appendix G). The highest mean time was 15.205 ± 3.902 minutes occurring at ovulation. At cycle end ,the mean time was 15.044 ± 3.815 minutes. The lowest mean time to exhaustion was with menses (14.845 ± 3.125 minutes).

CHAPTER 5

SUMMARY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the differences in physiological and subjective perceived exertion levels at maximal and submaximal treadmill exercise among three phases of the menstrual cycle in eumennorheic women.

Nine Charleston area females, of varying fitness levels were subjects in the study who performed three separate maximal treadmill GXTs using the Balke protocol. At each test, $\dot{V}O_2$, HR, BP, RQ, RPE,and total test time was recorded. During an eight minute recovery heart rate was monitored and recorded. The GXTs were administered at the onset of menses, at ovulation, and at cycle end in random order.

Group mean values for each menstrual cycle phase were calculated for $\dot{V}O_2$, HR, RQ, RPE and exhaustion time. Significant differences were calculated among the three phases. A multivariate analysis of variance was used to determine differences between group means.

Although some variability between the parametric means did occur between the menstrual cycle phases, because no statistical significance was found, the hypothesis that there would be a difference between physiological and perceptual exertion levels between the menstrual cycle phases was rejected.

Discussion of Results

Although no statistically significant differences were found among any of the parameters studied between the ovulation, menses, and cycle end phases of the menstrual cycle, trends were observed regarding the mean values on some of the variables investigated.

At the 50% maximal exertion level of intensity, no trends were observed regarding mean value for each parameter. However, as intensity increased, trends regarding cycle phases at which the highest and lowest mean values occurred became apparent.

Cardiovascular and aerobic performance may be unaffected by cycle phases, but when tested during the luteal (or ovulation) phase, progesterone concentrations in the blood increase by 15-50% with exercise (Jurkowski et al. 1978). The progesterone increases are greater with progressively more intense exercise. This could explain why this study found the highest mean cardiovascular ($\dot{V}O_2$, HR) values during the ovulation phase, when circulating progesterone levels are already high, at the75% and maximal intensity levels.

The findings of higher mean $\dot{V}O_2$ and mean HR at the ovulatory phase were also in agreement with Hessemer & Bruck (1985). This could be also due to increased core temperature caused by the increased progesterone levels associated with ovulation.

Mean values for time to exhaustion also proved to highest in the ovulation phase which shows an increased endurance to brief intensive exercise when progesterone levels are high. One possible explanation for this is that the exercise is associated with lower lactic acid levels circulating in the blood during the luteal phase as found by Jurkowski et al. (1981). The lower concentrations of lactic acid may delay the progression of fatigue.

The lowest mean values for the cardiovascular parameters ($\dot{V}O_2$, HR) and time to exhaustion all occurred with the menses phase. It is thought that iron loss can occur with menstrual flow. Moreover, 20-33% of eumennorheic women exhibit low levels of iron in the blood according to the Encyclopedia of Physical Education, Fitness, and Sports (1980, pp.335-343). Because of the role of iron in the formation of hemoglobin in red blood cells, myoglobin in muscle cells, and cytochromes in the mitochondria, a decrease in iron can inhibit oxygen transport to the tissues, transfer of oxygen to the muscle cells, and ATP production in the mitochondria. Therefore, during menses, $\dot{V}O_2$ and HR may be lower.

By the same token, the RQ value tended to be highest at menses at the 75% and maximal levels of intensity, when there is possibly less iron available in the blood due to blood loss. Inhibition of oxygen substrate utilization could cause RQ to be higher at this phase during which, as Jurkowski et al. (1981) found, blood lactate is higher producing a shift in the oxyhemoglobin dissociation curve.

In recovery, HR produced the highest mean values at ovulation which follows as more physical work was produced at this phase, therefore, recovery from exercise would take longer.

The RPE variable did not follow any notable trend in any phase or at any level of intensity.

It should be noted that all subjects, when asked how they were feeling on test day prior to testing, reported fatigue, malaise, and lack of desire to test at menses. Perhaps this due to low iron levels and/or an increase in blood lactate associated with this cycle phase. Interestingly, subjects also felt "stronger" and "more energetic" at ovulation, perhaps due to high progesterone levels (Jurkowski et al. 1981).

Conclusions

Based on the findings of this investigation, it was concluded that no significant differences in $\dot{V}O2$, HR, or RQ exist between the menstrual cycle phases. In addition, there was no statistical significance in RPE or total time to exhaustion between each phase. Therefore, the hypothesis of this study was rejected.

Although, this sample did not demonstrate statistical significance between the phases, it should be noted that some individual differences existed among the phases, and that group mean values for the ovulatory phase were generally highest among the parameters measured. Menses mean values were generally lowest.

Recommendations

Based on the findings of this study, the following recommendations are made:

1) A psychological test assessing mood should accompany each test phase to determine its effect on exercise performance and the link to hormone levels.

2) Hormone levels should be determined precisely through blood testing at each test phase.

3) A larger sample size followed through more than a single menstrual cycle may show more significant results.

4) It may prove beneficial to control for diet as dietary habits i.e. high fat, caffeine, salt at different phases of the menstrual cycle also may affect exercise performance and perception of it.

5) Closer observation among individual data may show that exercise performance of a percentage of females is, indeed, physiologically afftected by menstrual cycle phase, while for others it may not be.

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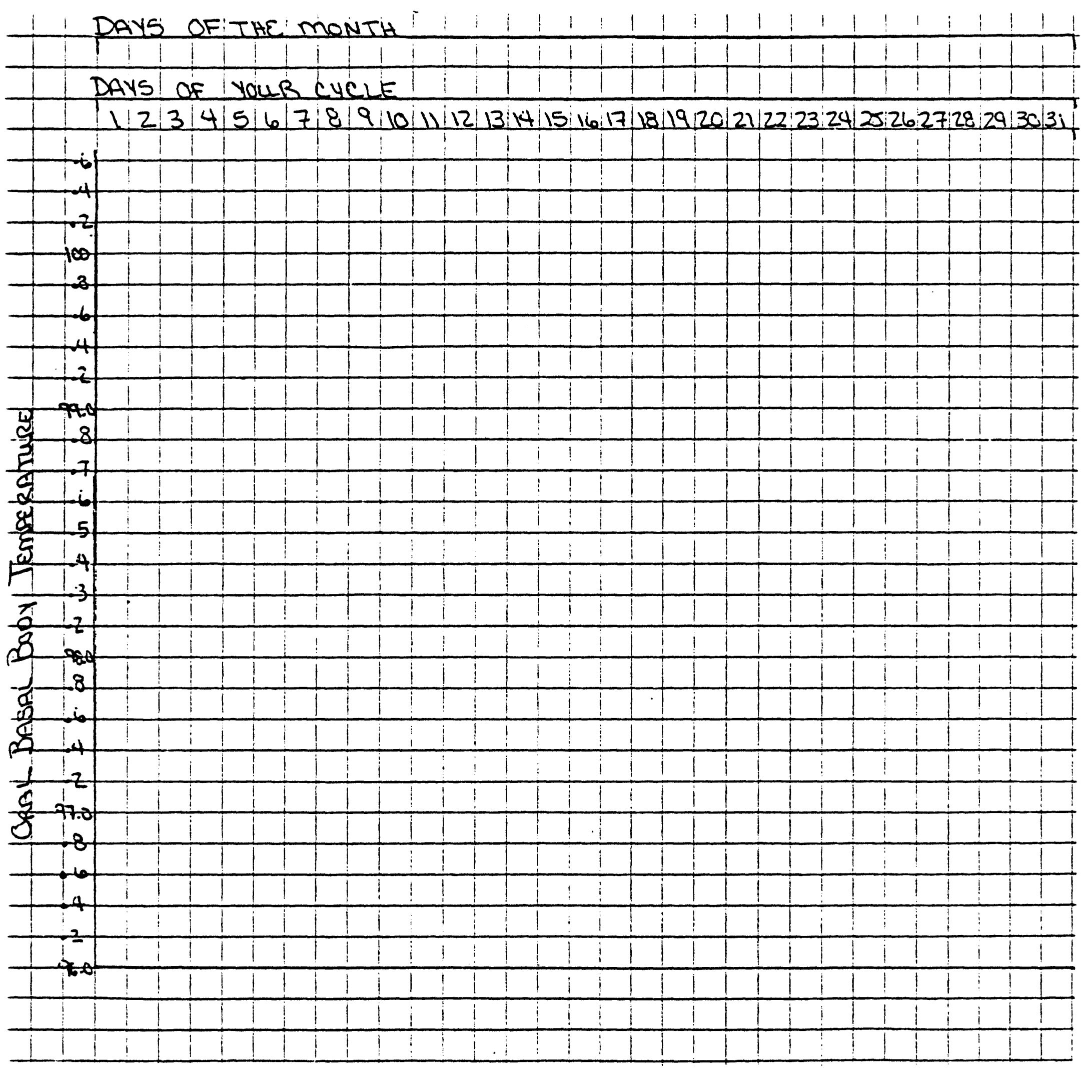
Appendixes

Appendix A

Body Temperature Chart



Appendix B

Informed Consent for Participation in a Research Study

I, ________________, state that I am over eighteen (18) years of age and give my consent to participate in a research project conducted by Kathleen McCune.

The purpose of this research is to determine whether or not exercise responses differ between three phases of the menstrual cycle during submaximal and maximal treadmill walking.

The study involves my cooperation in taking and recording a daily oral temperature, scheduling test times with the investigator on the appropriate days in the cycle (at ovulation, day 1 of menses, and 2-3 days prior to expected onset of menses), and three laboratory visits of approximately one hour each. During the one hour visits, I will be weighed and fitted with a heart rate monitoring device. I will perform a maximal treadmill walking test in which I must continue to exercise at the workloads given until I feel I cannot exercise any longer. Experimental data collection procedures will include measurement of blood pressure, heart rate, metabolic data (oxygen uptake, and respiratory quotient), and ratings of perceived exertion.

The personal risks involved are minimal and are those associated with any physical activity, such as temporary muscle fatigue, breathing discomfort, possible lightheadedness, and muscle soreness.

I have been informed that this procedure is not an exercise session, but an experimental test in which responses to physical demand can be studied, and is, therefore, not intended to benefit my health.

I acknowledge that Kathleen McCune has fully explained to me the procedures of the experiment, the risks involved, the need for the research, and has offered to answer any questions I may have at any time during the research project. I understand that I may withdraw myself from the study at any time and that I will receive a copy of this consent form.

I freely and voluntarily consent to my participation in this research project.

____

Signature of volunteer

____

Date

____

Witness

Appendix C

Oxygen Uptake

($ml \cdot kg^{-1} \cdot min^{-1}$)

	50%	75%	Max
Ov	17.582	26.488	35.32
Men	17.311	26.109	34.826
End	17.447	26.662	35.176
F-test	0.082	0.169	0.105

* significant at alpha = 0.05

Appendix D

Heart Rate

(bpm)

	50%	75%	Max
Ov	120.000	153.250	175.750
Men	123.000	152.625	171.250
End	122.500	152.750	174.000
F-test	0.200	0.011	0.800

* significant at alpha = 0.05

Recovery Heart Rate

(bpm)

	Min 1	Min 5	Min 8
Ov	156.750	117.375	110.625
Men	146.375	113.125	107.500
End	143.250	114.750	110.000
F-test	2.086	0.651	0.205

*significant at alpha = 0.05

Appendix E

Respiratory Quotient

	50%	75%	Max
Ov	0.812	0.909	1.03
Men	0.808	0.927	1.047
End	0.826	0.904	1.011
F-test	0.293	0.641	0.617

*significant at alpha = 0.05

Appendix F

Rating of Perceived Exertion

	50%	75%	Max
Ov	9.556	14.889	19.222
Men	9.556	15.778	19.444
End	10.000	15.111	19.000
F-test	0.283	1.276	0.914

*significant at alpha = 0.05

Appendix G

Time to Exhaustion

(minutes)

Ov	Men	End
15.205	14.845	15.044

F- test = 0.339

*significant at alpha = 0.05