Effect of Menstrual Cycle on Perceived Exertion and Running Economy During
Treadmill Running

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ABSTRACT

The purpose of this study was to explore how the menstrual cycle affects perceived exertion during treadmill running. A secondary purpose of this study was to explore how the menstrual cycle affects running economy. More specifically, the two purposes of this study were to compare male and female perceived exertion during a $\text{VO}_{2\text{max}}$ test and 80% sub maximal tests and to examine how the menstrual cycle affects female perceived exertion and running economy. A total of ten runners voluntarily participated in the study. All participants were tested to determine their $\text{VO}_{2\text{max}}$. Individual testing protocol was designed for 80% of maximum effort in which participants ran a series of 4 sub maximal runs on a treadmill. Throughout the duration of the study, each female participant was asked to chart their menstrual cycle. Results showed that the menstrual cycle did not significantly affect rate of perceived exertion (RPE) or running economy (RE) during the menstrual cycle. However, the standard deviation revealed more variance between men and women in regards to RPE (0.982) vs. RE (0.34). Therefore, suggesting there are variables affecting how women rate their perceived exertion. The possibility of implementing an individualized training protocol based on the runner's menstrual cycle may lead to improvements that would not have been achieved without taking this into consideration. Small sample size plays an important role in the lack of significance. As a result, continued research with larger sample sizes need to be continued to analyze these important initiatives.

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Dedication

This paper is dedicated to my parents, Robert and Virginia Harrison, who have established the work ethic I carry with me today; to finish everything I start. Thank you for always supporting me.

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Chapter 1

INTRODUCTION

There has been considerable research done in the area of menstrual cycle and athletic performance. Studies have shown that there is little to no effect on a female performance during the various stages of the menstrual cycle (Quadagno, Faquin, Lim, Kuminka, & Moffet, 1991, Eston 1984, Higgs, & Robertson 1981, Gamberale, Strindberg, & Wahlberg 1975). In addition, recent research has discovered that gender plays a role in predicting rate of perceived exertion (RPE). There has been speculation as to why men tend to predict ratings of RPE more accurately than women (Winborn, Meyers & Mullings, 1988). Individual variability including experience, nutritional status, hormones, pain threshold and sensory acuteness may be primary variables influencing RPE between men and women. Alternatively, gender differences including absolute workload and experience could relate to the onset of differences in RPE. In all likelihood these factors interact. One important area of inquiry, therefore, is to investigate why women report higher RPE values than men and determine possible links with their menstrual cycle periods. Due to the high inconsistency of research findings in the literature, more research needs to be done in the area of the menstrual cycle and running performance.

Statement of the problem

The purpose of this study was to examine how the menstrual cycle affects RPE and running economy. Specifically, the purpose explores the possibility that a female athlete's point in the menstrual cycle may cause them to judge their perceived effort to be higher or lower. Testing each participant at their VO_{2max} and then in a

series of 80% of maximum trials, simulated a realistic endurance training program to collect data that no other previous study has explored.

Significance of the Study

A major goal of this study was to have an applicable tool that coaches can use to aid in the development of training programs for athletes in regards to RPE. If RPE differences can be found in specific menstrual phases, coaches would be able to better understand the RPE ratings so they can be more effective in training. There has been substantial research (Quadagno, Faquin, Kuminka, & Moffet, 1991) indicating that the menstrual cycle does not seem to affect performance, however, gender differences tend to play a role in RPE. If a link can be established between these two variables, perhaps the conflicts in research will lessen.

Similarly, this area of study investigated mechanisms for the discrepancies between male and female RPE. Determining indicators that may affect how female athletes perceive exertion in an athletic setting would provide great gains in the research done on this topic. This type of research is warranted due to the high degree of female participation in sport. Since Title IX was established 35 years ago, there has been an increase in female athletic participation of 904% and at the college level by 456% (<http://www.womenssportsfoundation.org/Issues-And-Research/Title-IX.aspx>). Finally, running economy is a key indicator of performance (Saunders, Pyne, Telford & Hawley, 2004), therefore, another analysis of changes in running economy during the menstrual cycle were explored.

Research Hypothesis

The hypothesis of this study was trifold. They were as follows:

1) Female athletes would have a higher RPE than men during an equivalent relevant intensity.

2) The greatest discrepancies between men and women athletes in RPE would occur in the pre-menstrual phase of the cycle.

3) Female runners would be the least economical, during the pre-menstrual phase.

This hypothesis was based on previous research according to Eston (1984) stating that workloads involving 100% of $\text{VO}_{2\text{max}}$ were perceived to be significantly higher during premenstrual and menstrual phases of the cycle.

Delimitations

A major delimitation was made in order to narrow the scope of this study. This delimitation included the following:

1. Results may not generalize to the whole female athletic population. Majority of volunteers were NCAA Division III distance runners between the ages of 18-22 which were recruited for the study. Only two volunteers were over the age of 22 and not NCAA Division III distance runners. The results, therefore, the results may only generalize to that specific population.

Increased research needs to be conducted with a larger population of female and male athletes with a variance of sport of and level. Including female athletes that score above average on the MOOS Distress Questionnaire may help increase the female population. The tools to appropriately measure the major source of variance in the study become essential. Specifically, when measuring what phase of the menstrual cycle the female is in, the most appropriate tool would be progesterone serum along with blood testing.

Limitations

Some possible shortcomings or influences that could not be controlled include the following:

1. Equipment necessary for measurement of gas exchange, stop watches, heart rate monitors and treadmills were calibrated and provided valid measurements.
2. Limitations in the lab did not allow the most valid measurement of testing the phase of the menstrual cycle the female is in. The most appropriate method of menstrual cycle testing would be with progesterone serum and blood testing.
3. Limitations in the lab did not provide portable equipment necessary for outdoor testing. Results may not generalize to outdoor running as well.
4. Small sample size.

Assumptions

For purposes of this study that investigated the relationship between athletic performance, RPE and gender, a few integral assumptions were made. These included the following:

1. Heart rate, estimated maximum heart rate, and the Borg Rating of Perceived Exertion scale are all valid and reliable tests to measure.
2. All the participants understood the directions and were trustworthy on the questionnaires administered.

3. The fitness level of the subjects at the start of testing remained consistent through the 6 weeks of data collection.
4. The charting techniques for the menstrual cycle were accurate.
5. The majority of the non-physiological factors that may affect the subject's RPE were controlled.
6. No significant aerobic improvements occurred through the 6 weeks of data collection.

Threats to Internal Validity

Since this study did not take place over a long duration of time and each group was tested at the same time, maturation was not a significant threat to internal validity. Test practice has been controlled for by giving prior experience on the VO_{2max} test. The athletes have all had exposure to a VO_{2max} test and pre-test warm ups. By bringing a few participants back in for a final VO_{2max} test to see that the results remain the same, instrument accuracy and reliability has been controlled for. Statistical regression may become a threat to internal validity due to lack of random assignment to groups or lack of more than one score for subject classification. Another threat to internal validity was this group of athletes, are an intact group with only random selection within the intact group. There may be some slight selection maturation over the testing period. The potential of the subjects to become more aerobically fit over the 6 weeks was a possibility, however a random selection of 2 athletes retested, following the study with another VO_{2max} test to help assess this threat.

Threats to External Validity

There will be no pretest given, so there will be no reactive or interactive effects of testing. Since this study is looking at a select group of distance runners, the interaction of selection bias and experimental treatment become a threat to external validity. The results may not generalize well to the entire male and female athlete population; however this is innovative research hoping to be expanded on with future studies. The VO_{2max} treatment in the lab may be very effective on the treadmill, but may not carry over to “real life” competitive situations as well. The research design has been worked out to simulate the most ideal running conditions under these circumstances. The use of heart rate monitors were used to help with these discrepancies. An athlete working at certain heart rate on the treadmill can still produce those same heart rates out of the lab with a heart rate monitor worn during their workout.

Definition of Terms

For the purpose of this study, the following terms were operationally defined.

Athletic Performance: is the intensity worked at to gain the desired results.

Operationally, it is the performance on the VO_{2max} test.

Menstruation: Is the regular menstrual cycle of the female athletes, determined by basal body temperature. Menstrual cycle phases defined as cycle week 1 (pre-menstrual week), cycle week 2 (menstrual week), cycle week 3 and cycle week 4.

Premenstrual syndrome (PMS): PMS is measured by the MOOS Menstrual Distress Questionnaire with all female athletes. (Brooks, Gunn, Gargiulo, & Warren, 1986).

Perceived Exertion: Is a measure of how hard one feels when the body is working.

It was measured by using the Borg Rating of Perceived Exertion Scale. This scale used to measure a client's subjective rating of exercise intensity. (Heyward, 2002).

Menstrual Dysfunction: A condition when a woman has not experienced a regular menstrual cycle for a minimum of 8 weeks.

Basal Body Temperature: Average temperature of "36.64 degrees Celsius during the entire menstrual cycle" (Brooks-Gunn et al, 1986, p 189). "When basal body temperature decreases followed by a sharp rise this indicates the occurrence of ovulation" (Bemben, Salm, & Salm, 1995, p. 258).

VO_{2max}: Maximum rate of oxygen utilization by the muscles during exercise. (Heyward, 2002). This will be assessed with relative values using a graded exercise test on a treadmill.

Runner: The subjects tested in this study ran at least 35 miles a week and competed in at least one running event in the last month.

Running Economy: The body's oxygen consumption for a given running speed.

Chapter 2

LITERATURE REVIEW

This study was designed to explore possible reasons why men and women rate RPE at the same work-load differently. The purpose of this study was to determine if the menstrual cycle has an effect on female's RPE, and if so, where in the menstrual cycle this effect is located. This section discusses the influences of perceived exertion, as well as the physiological effects of the menstrual cycle and the limitations in measurement.

Influences of Perceived Exertion

Human performance and perceived exertion has been a considerable area of research for the past 50 years. There are physiological as well as non-physiological basis for the ratings of perceived exertion. To quantify effort expenditure, the ratings of perceived exertion scale (RPE) have been shown to be useful. Borg has been the primary person in research when it comes to RPE. His research has set the cornerstone for quantifying effort. Borg (1982) suggests that exercise intensity may be regulated through effort evaluation. However, it has not been shown that effort evaluation may be used to control pace during competition. The idea of athletic achievement and perception of effort is an area that is still not well understood. There are many variables that may have influences on the performer such as pain threshold, age, experience and gender.

The original development of quantifying RPE was introduced by Borg in 1962. A 21-point categorical rating scale for perceived exertion, with verbal expressions to correspond with different levels along the scale was developed. This

scale was created based upon a correlation of heart rate and perceived exertion. In 1970 a 15-point scale was developed to increase the linearity between the ratings and workloads (Borg, 1970). This new scale has slightly different verbal expressions and the mid-point was lowered. The sensitivity of the scale was also reduced due to compressing the lower degrees to compensate for non-linearity. Finally in 1982 Borg developed a 10-point category scale with ratio properties to incorporate decimals in RPE determination. This scale has been shown to be useful in anaerobic activity due to the verbal expressions set so that the semantic intensity grows according to a power function. According to Noble, (1982) both lactic acid production and pulmonary ventilation measurements which are present during anaerobic activity develop according to a power function with exercise intensity.

Reliability and Validity

Perceived exertion became more popular in research in the 1970's. Borg had established high correlations (0.77-0.90) between heart rate and RPE, however it was suspected that this relationship may be due to the experimental protocol or technique artifact (Stamford, 1976). Therefore Stamford conducted an experiment using the 15 point RPE scale to test the reliability and validity of the perceptual responses of 14 sedentary females. Each subject participated in five tests at the same time each day. Two tests were performed on a bicycle ergometer, two tests on a treadmill and one stepping test. Heart rate and perceived exertion were recorded at random times during each test. Subjects were unaware of the details of the test in regards to length and intensity.

Results indicated that perceptual ratings of exertion were “Highly reproducible under a variety of experimental circumstances” (Stamford, 1976, p.59). Consistency of effort related to fluctuations in workloads was demonstrated in this study. An important finding in this study was the high reliability of terminal ratings of perceived exertion of 0.90. This finding suggests that in the final minute of exercise the RPE was just as reliable as heart rate. According to Stamford, the RPE scale is supported, “As a valid and reliable instrument for assessment of the degree of encountered stress during work effort” (Stamford, 1976 p. 59).

An earlier study conducted by Skinner, Hustler, Bergsteinova and Buskivk, (1973) evaluated the reliability and validity of the Borg RPE scale. The researchers wanted to see if the subjects could perceive small differences in work intensity when work loads were presented in random order. Subjects aware of a progressive workload may have logically rated higher on the RPE scale with each increment. The researchers suggested the question of whether or not the ability to perceive effort versus the artifact of technique was present. Random testing not only addresses this issue but also tests the reliability of the RPE scale.

Eight lean and eight obese males participated in the study. Skinner et al. (1973) idea was if the testing proved to be reliable and valid, these participants would aid in future research. Two trials of progressively increased workloads to maximum and randomized loads were assigned. Heart rate, respiratory frequency and RPE were recorded. In order to make sure subjects were not aware of workload, the resistance gauge was covered.

Validity was measured using a two-way analysis of variance along with the Pearson product moment correlation of the mean data of each test. Results indicated no significant differences between any of the variables between groups. Subjects were able to identify small differences in work intensities on the bike, however no significant differences in physiological or perceptual variables were present (Skinner et al.,1973). The progressive test proved to save time and be suitably reliable and valid. One interesting finding in this study was that subjects with no prior experience showed a higher RPE until they were exposed to the testing where their ability to perceive different intensities became similar on the two tests. Therefore, the practice of using this scale is important.

Although the Borg RPE scale was showing tremendous credibility there is one area of concern. Since the scale is based solely upon the correlation of heart rate and perceived exertion, research done on highly trained endurance athletes show differences in correlations between the workload of the exercise and heart rate. Perhaps developing a different scale for the elite athletes may provide better results for the researchers.

In 2002, a team of researchers wanted to explore these areas of concern in relation to the validity of the Borg scale of perceived exertion (Chen, Fan, & Moe, 2002, p 873). They used a meta-analysis to combine the large amount of inconsistent findings with the Borg RPE scale. The purpose of this study was three fold. First the researchers wanted to integrate relationships between RPE and the six variables it was measuring (HR, blood lactate, % $\text{VO}_{2\text{max}}$, VO_2 ventilation, and respiratory rate). Secondly, they wanted to discover what study features may account for the

discrepancies in results in individual studies. Finally, they wanted to discover what the results of this meta-analysis mean for further use of RPE as a measure of exercise intensity.

A total of 437 studies were examined in this study. The seven characteristics studied included, sex, fitness level, RPE scale, exercise type, exercise protocol, RPE protocol, RPE mode and study quality. With the exclusion of study quality, the remaining six variables are considered to be criterion variables and also considered to be the major physiological processes that indicate physical exertion. Results indicated that RPE have the greatest correlations between RPE and the variables measured occurred when male subjects were tested maximally during an unusual task, or when the 15- point RPE scale is used. A huge finding in this study suggests that the “best indicator of physical exertion is respiratory rate” (Chen, Fan, & Moe, 2002, p. 894). This conclusion was determined with high correlations of 0.70 or higher on each variable tested. Under the four different measurements of oxygen, respiratory rate serves to be the most valid and reliable across all environmental testing conditions (Chen et al.). This suggests that breath counting serves to be the best predictor of perceived exertion. Finally the results of this study indicate that the use of the Borg scale of RPE and physiological criterion variables are not as high as originally thought (Chen et al.). However, the correlation exists between 0.8-0.9 which is still significant.

Physiological Basis

There is great complexity when examining the effort of perception incongruence with the physiological components upon which it is based. Due to the number of variables associated with this area, concrete results are hard to establish.

There is contradicting evidence to support the influence of blood lactate on perceived exertion. Blood lactate levels and RPE have been demonstrated to have strong correlations in some studies. “During incremental exercise, both blood lactate and RPE exhibit a similar, positively accelerating function when plotted against time” (Carton & Rhodes, 1985, p. 207). However, some studies indicate no relationship at all (Stamford & Noble 1974, Kay & Shepard, 1969). Yet, the information regarding blood lactate levels seem to affect perceived exertion when critical exercise intensities are reached.

Noble, Gunnar, Borg, Jacobs, Ceci and Kaiser developed a study in 1983 to study the relationship between RPE from Borg’s new category-ratio scale and physiological variables during exercise. The Borg RPE scale indicates perceptual ratings increasing linearly with power output and heart rates. However, according to Noble et al. (1983) lactate production is related to exercise intensity according to non-linear power functions. Borg developed a new scale to take this into account. Therefore, the purpose of their study was to look at the relationship between blood and muscle lactates and heart rate incongruence with Borg’s adjusted RPE scale.

Muscle biopsies were taken from ten males for fiber typing and lactate references. Each subject performed a progressive cycle ergometer test until voluntary

exhaustion. Leg effort, leg pain and perceived cardiorespiratory effort were the three rating of perceived exhaustion documented.

Results indicated that despite the linear appearance of the data, blood lactate data was quadratic in nature. It was established that muscle lactate varied moderately parallel to blood lactate. Muscle lactate accelerated a little faster than blood lactate or the perceptions. This suggests that perceptions may have been more related to blood lactate levels than muscle lactate. Noble et al. (1983) reiterated the controversy in research relating to lactate and the perceived exertion. According to Borg (1962), the two components that show the greatest influence on RPE are cardiorespiratory response and the muscle themselves. This can also be termed central and local factors. It has been suggested that local effort of sense is related to the build up of lactate (Nobel et al.). However previous studies have not been able to determine these results. One speculation is that at higher intensities where glycogen contribution is high, there would be less of a relationship between RPE and lactate. Lactate would rise quickly while RPE increases linearly with power output. This question of central vs. local factors could be better explained using Borg's category-ratio scale. In conclusion, the hypothesis that blood and muscle lactate would parallel RPE ratings and heart rate was not supported, therefore, supporting future usefulness of Borg's category ratio scale (Nobel et al.).

Circulating catecholamines have been linked similarly to blood lactate as an influence on perceived exertion. In 1976, Howley explained, that anticipating a potentially stressful environment may change the activity of the sympathetic nervous system. The purpose of his study was to examine the excretion of epinephrine and

norepinephrine under three different workloads. Results indicated an increase in norepinephrine as the workload increased.. The rate of excretion in each workload proved to be significant. It has been proposed by Howley, that the point where catecholamine levels are enhanced coincides with a decrease in muscle glycogen. Paradoxically, ingestion of glycogen prior to exercise reduces RPE during prolonged work. Since muscular fatigue is connected to a decrease in muscle glycogen depletion, it is speculated that the increase of catecholamines may be related to perception of fatigue not necessarily perception of effort. This would be hard for a subject to differentiate. Howley's study solidified factors other than exercise have an influence on RPE.

Robertson, Gilletie, McCarthy and Rose (1979) concluded that physical strain in the exercising muscles have a superior impact upon the perception of effort at low work levels. It is thought that RPE during dynamic exercise will originate from either local or central physiological processes. Local perceptions yield from active muscles and joints, while central signs originate from cardio-respiratory adjustments to increased metabolic demand. The researchers hypothesized that regional reports from the legs and chest should be consistent with local and central physiological adjustments during a sub-maximal cycle ergometer exercise test (Robertson et al.).

A total of 50 males participated in the study. They endured three, 6 min random pedaling (40, 60, 80 rpm) conditions with a constant power output of 840 kpm/min. The data collected included, heart rate, expired gas, oxygen uptake, pulmonary ventilation and respiratory rate, blood samples (to indicate ph levels, and

blood lactate) RPE and $\text{VO}_{2\text{max}}$. The Borg 9-point category scale was implemented due to the high validity and reliability of the test.

It was thought that with local signals there would be a greater production of tissue lactate which accompanies small muscle contractions of the type required for this type of test. While pedaling at 40 rpm, the researchers believed there would be an increased intensity of regional signals which would correlate with an elevated anaerobic metabolic rate (Robertson et al.). The researchers were shown to be wrong, due to lactic acid not providing a strong cue for the ratings in the legs. There was a modest correlation between lactic acid in the legs and RPE. Ratings of chest exertion were higher which supported the central signals hypothesis. As respiratory function was influenced by the aerobic requirements, it was shown that a higher regional chest signals at 40 rpm were connected to greater heart rate and oxygen uptake. These findings suggest that regional signals reflect not only respiratory adjustments, but aerobic as well.

In conclusion, there seems to be a two-factor theory for physiological input into the perception of effort. During low levels of activity, physical strain in the working muscles appears to be the primary stimulus for effort perception. When work intensity exceeds the lactate threshold, blood lactate complements peripheral input from neuromuscular mechanisms. Central input contributes to perceived exertion when absolute ventilatory threshold is reached. Exceptions, extremely fit individuals and zero workloads. With such contradicting evidence it is apparent that continued research needs to be done to eliminate pending questions of what may alter perceived exertion.

Non-Physiological basis

Perceived exertion cannot be described alone in terms of physiological input. According to Morgan (1973), only 67% of total variance is explained by physiological influences in terms of perceived exertion. Time of day, sleep deprivation, depressive state, age and sex, environment, nature and duration of the exercise all have some impact on the individual's RPE. Some affect RPE more than others, for instance little research has yet discovered how much influence circadian rhythms or tiredness have on RPE in terms of the time of day.

There is primary interest with gender in regards to the menstrual cycle. According to Eston (1984) workloads involving 100% of $\text{VO}_{2\text{max}}$ were perceived to be significantly higher during premenstrual and menstrual phases of the cycle. However, the researchers attributed this to physiological symptoms associated with dysmenorrhoea. The evidence surrounding RPE and menstrual cycle is very contradicting. Some researchers like Eston, have discovered differences in RPE, while Higgs, and Robertson (1981) and Gamberale, Strindberg, and Wahlberg (1975) found no significant changes in RPE.

It has been suggested that, women on average, elect to exercise at a lower intensity than men (King, Blair, Bild, Dishman, Dubbert, Marcus, Oldridge, Paffenbarger, Powell, & Yeager, 1992). This raises the possibility that sex differences in pain sensitivity or tolerance could contribute to changes in RPE. It has been indicated that women report pain earlier, and exhibit higher pain ratings during a harmful stimulation in comparison to men. The majority of research around pain tolerance between men and women has not been focused on muscle pain during

exercise. Therefore, Cook, O'Connor, Oliver and Lee (1998) conducted a study to examine sex differences in pain during a ramped cycle exercise to maximum tolerance. They hypothesized that at any given absolute power output, females would rate leg muscle pain as more intense compared to males. A total of 26 active college-aged females served as participants. Twenty six males from a previous study were used as the male subject pool. Although no females were on medication, 27% were taking birth control pills. The protocol was identical for both men and women, however the females were categorized into either a follicular phase (1-14 days after start of menstruation) and the remaining were placed into a luteal phase group. It is important to indicate this method of categorizing is not the most precise technique in assessing menstrual cycle indications. All testing occurred between 12:00 noon and 5:00 p.m. to minimize diurnal influences. All subjects performed a graded maximal exercise test on a braked cycle ergometer. Pain assessment was testing using Borg's 0-10 category-ratio scale with slight modifications. Verbal modifications were made according to the Pain Perception Profile (PPE). RPE were obtained during and following the test with the standardized 6-20 Borg scale. After each pain rating, PPE was taken. A metabolic cart was used to collect data every 20 seconds in measurements of VO_2 , VCO_2 and Ve . The Eysenck Personality Questionnaire (EPQ) was used to assess the role of personality on pain response to exercise.

Results indicated no sex differences in leg muscle pain threshold largely in part due to the large variability of pain threshold. The main finding in this experiment was that, "When expressed relative to peak power output, females report leg muscle pain as less intense than males during maximal cycling exercise" (Cook et al.1998,

p.,200). This finding contradicted previous research. According to the researchers, one reason this result may have occurred is due to the greater exercise capacity of men. The men were exercising at nearly 100 watts more power, and for approximately 4 minutes longer. This combination may have created an increase of noxious metabolites within the muscle. In all six absolute exercise intensities examined the females had a higher RPE then the males. The reasons for the differences in RPE are not clear, but may have to do with the fact that on average males possess a greater capacity then females. Although the methods to assess menstrual cycle indications were not as precise as other studies, results indicated no significance on the influence of data analysis. The primary aim of their study was not to examine the relationship of RPE and menstrual cycle, hence the attention to detail does not allow any speculation on possible interference with muscle pain or RPE. This leaves a very interesting idea for future research. There is an indirect suggestion that, “Leg muscle pain during recovery from exercise is linked to the removal of noxious bio-chemicals from the leg muscles” (Cook et al., 1998, p.200), thus supporting the idea that men working at higher capacity would experience more muscle pain then women working at a lower capacity.

In attempt to examine gender and athletic experience differences in RPE, Winborn, Meyers and Mullings conducted a study in 1988. The goal was to examine if gender, experience or an interaction of these factors influenced RPE. The researchers hypothesized that any differences would be from experience, and expected that higher experienced individuals of both genders would be able to demonstrate more accurate RPE then lower experienced individuals. Two groups of

highly athletic experience of each gender and two groups of low athletic experience of each gender were formed with 12 subjects in each group. The subjects were tested twice. The first session they were told they were going to perform an endurance test and the second session they were told they were going to do the same test with some variation to it. One important aspect of the study was the manipulation of workloads to see if the subjects were able to physiologically and perceptually distinguish differences (Winborn et al., 1988). This manipulation of the experiment was effective as there were significantly different heart rates and RPE's at each workload.

Gender was shown to be an indicator in aerobic fitness performance due to the differences in heart rates between genders and experience of subjects. It was suggested from the data analysis of RPE, that there was a significant gender-by-athletic experience interaction. The trend established indicates that low athletic experienced women may not have sufficient athletic experience to make accurate judgments about how hard they are working. Data indicated that high experienced men had higher RPE than lower experienced men which was expected due to the higher absolute workload than the other three groups. It was suggested that the higher experienced men were able to be more realistic with RPE due to the level of effort they exerted. It is thought that lower experienced athletes tend to disassociate from their physical performance. The researchers concluded that, "The accuracy of higher experienced male's rate of perceived exertion, at all work levels supported the roles of both gender and previous athletic experience in determining RPE accuracy (Winborn et al., 1988, p. 29). Another aspect of previous athletic experience was demonstrated by the highly experienced women expressing the most accuracy in RPE

at 70% of their $\text{VO}_{2\text{max}}$. It was shown that gender does have an effect, however previous experience is more significant in accuracy of RPE. Data examining heart rate and RPE concluded similar findings.

To summarize this literature review on RPE, it is clear that there are numerous variables indicating influence. Most importantly the Borg RPE scales have been shown to be useful, valid and reliable in all studies. The study conducted by Noble et al. (1983) examined the relationship between blood lactate, heart rate and RPE.

Although the hypothesis that blood and muscle lactate would parallel RPE ratings and heart rate was not supported, the use of Borg's category ratio scale did show evidence of being functional. It is clear that both physiological and psychological influences will affect RPE. As Winborn et al. (1988) established, there were significant findings related to gender and level of experience associated with RPE accuracy. An interesting finding is the contradicting research indicating the menstrual cycle influencing RPE. There are unknown explanations to why women may have higher RPE than men. Eston (1984) discovered that different phases of the menstrual cycle evoke higher RPE during the same workload. The key in future research is to eliminate as many of the extraneous variables that may have a hidden influence not yet discovered.

Future research suggests focus on training related studies, with attention on the reduction of RPE at a given sub-maximal workload after physical conditioning occurs. This area would include studies with elite or highly trained individuals.

Physiological Effects of the Menstrual Cycle and the Limitations in Measurement

There has been a large increase of women involved in competitive sports in the last 30 years. Due to this increased level of participation there has been a strong interest in the effects of the menstrual cycle on athletic performance. Unfortunately, there have been few studies done to determine how the menstrual cycle may affect athletic performance. The results of these studies have created some controversial and conflicting results. Some athletes have reported that the menstrual cycle has impaired performance while others have reported that it has enhanced performance (Quadagno, Faquin, Lim, Kuminka, & Moffet, 1991). Further studies suggest that during different phases of the menstrual cycle there have been advantages and disadvantages taking place in performance (Eston, 1984).

Female athletes, as well as their coaches, have been questioning the relationship between the menstrual cycle and performance (Quadagno, et al., 1991). However, this is a controversial area of study. The efficiency of the female during phases of the menstrual cycle has not been measured effectively due to methodological inconsistencies. Particularly, the premenstrual phase rather than the menstrual cycle itself, has been observed to display the poorest performances (Eston, 1984). This brings into account perceived exertion and self-perceptions of the female athletes. Perceived exertion has become a new area of measure in relation to research in the menstrual cycle. This measure is considered to be a chief variable within studies because it deals with psychological aspects of performance rather than the physical. Some research indicates that it is the objective measurements, such as

perception of exertion and menstrual distress that yields a large degree of inter-subject variability that athletic performance is affected (Eston, 1984).

Regardless of the conflicting research, there has been poor documentation in earlier studies to identify the phase of the cycle that affects human performance the most. Therefore, the purpose of this literature review is to examine how the menstrual cycle may or may not affect female human performance and review some of the major limitations within methodology.

It becomes apparent that research needs to continue due to limited articles found on what phase of the menstrual cycle the greatest effect on athletic performance has. Conflicting results are due to the different types of statistical methods used while comparing physical and psychological factors. External variability becomes compromised in any given study due to the amount of psychological variables examined. One consistent finding throughout the literature is that there are many methodological constraints and room for improvement in this area of research.

Methodological Concerns

One major consideration in methodological testing is the timing of testing, and to accurately verify the menstrual cycle phase. Earlier studies have shown inconsistencies with how to verify in what phase the participant was in. Counting days or charting to onset of menses was a popular approach which therefore resulted in misleading information about what phase the participant actually was. Another method of testing was taking basal body temperature. Information regarding length of luteal and follicular phase was able to be identified, as well as the approximate day of

ovulation. However, this method does not give any information about hormone levels. Moreover, the relationship between basal body temperature and ovulation is variable, because some females do not show the increase in temperature during the luteal phase. Bauman (1981) conducted an experiment to establish that basal body temperature was not an effective way to measure ovulation detection. The results indicated a low correlation between basal body temperature and progesterone levels. A third measure of testing was within urinary (LH) luteinizing hormone concentration. When the LH surge occurs, between 14-26 hours ovulation will occur. There is a confidence level of 95% associated with this method of testing. Finally, the measurement of estrogen and progesterone via saliva or in the metabolite concentrations in urine are the most recent forms of testing. This method is the only one that can identify between the three phases accurately.

Brooks-Gunn, Gargiulo and Warren (1986) conducted a study with swimmers' who competed at national levels during a 12-week period. Six adolescent swimmers who had experienced their first menstrual cycle between the ages of 14 and 18 participated in the study. They swam four to five hours a day during the study. Each day their body temperature was recorded to classify what part of the cycle they were in. Biweekly the subjects completed the Moos Menstrual Distress Questionnaire (MDQ). This questionnaire looks at various symptoms associated with the menstrual cycle and how one perceives it to affect their athletic performance. Twice a week the coach tested the participants in the 100-yard freestyle and 100 yard best during each of the four phases of the menstrual cycle. The researchers defined the four phases of

the menstrual cycle; “entire cycle, midfollicular, premenstrual, and menstrual” (Brooks-Gunn, et al., 1986, p. 189.).

The results point towards significant changes in the swimmers performance during certain phases of the menstrual cycle. All participants had faster times recorded during menstruation and slower times during pre-menstruation. The data remained constant during the whole study, which helps conclude that the study of the phases on athletic performance is warranted. However, this is a classic example of a substantial limitation in the methods. Basal body temperature was used to detect what phase of the menstrual cycle the participants were in, which has since been established to be not as effective as other methods of testing.

Quadagno, Faquin, Lim, Kuminka, and Moffet (1991) completed a study to see how the menstrual cycle affects different types of athletes. Five hundred athletes were questioned about their athletic performance during the different stages of the menstrual cycle. Results indicated that 15% thought their performance was enhanced while 31% thought their performance was impaired. Interesting variables were questioned, such as the type of sport, the amount of effort required and duration. So to further the investigation, 12 weight lifters and 15 swimmers were studied.

Contradicting results were found when studying these athletes. The weight lifters were tested during the three phases of the menstrual cycle, defined in this study as, pre-menstrual, during the menstrual cycle and post-menstrual. The last three months of each subject’s menstrual cycle were charted to predict when their pre-menstrual phase would occur. “These women trained for 30 minutes or more per day, 3 days per week” (Quadagno, et al., 1991, p. 122). The weight was recorded for each lift in the

bench press and leg press. Swimmers were timed during a freestyle event of 100 and 200 meters and again their times were recorded in each phase. They trained for two to three hours a day for six days a week. The results stated no affect on performance measured through strength and swimming speed. A conclusion was that female athletes perceive that their performance is affected more than it actually is. The researchers indicated that results would most likely be different in each sport studied due to the different variable of the athlete as well as the sport. Short and long term duration studies were suggested for further research. Again, another limitation in this study was the method of which to predict ovulation. Charting previous cycles, does not indicate any hormonal changes, and may be the most unreliable method from which to choose from.

Lebrun, McKenzie, Prior and Taunton (1995) performed a study to “examine the effects of menstrual cycle phase on four selected indices of athletic performance: aerobic capacity, anaerobic capacity, isokinetic strength, and high intensity endurance” (p.437). To determine what cycle the female was in, the researchers used serum progesterone as well as taking basal body temperature. Previous research has only used Basal body temperature to indicate the cycle, however “hormonal levels are still the most valid criteria for absolute documentation of the cycle phase” (Lebrun et al., 1995, p. 437). Researchers defined the stages to be tested in this study as the follicular and luteal phases. The object of this study was to “control for many of the variables that may have influenced the outcome of previous studies” (Lebrun et al., 1995, p. 438). The subjects of this study were women between the ages of 18-40 years, experiencing regular menstrual cycles and no one had been taking oral

contraceptives for at least six months. One requirement to be involved in the study was that the female athlete had to score a certain level on the VO_{2max} test to be considered “trained”. Aerobic capacity was tested using a VO_{2max} Test, anaerobic performance was tested through an Anaerobic Speed Test (AST), isokinetic strength was measured as peak torque generated by knee flexion and extension and finally endurance performance was tested using 90% of the VO_{2max} test at a constant rate. Results showed that with this group of athletes, VO_{2max} appeared to be slightly lower during the luteal phase of menstrual cycle. All other variables tested did not show significant effect on performance. “The magnitude of the effect (of aerobic capacity) varies substantially between subjects, and may be important on an individual basis” (Lebrun, et al., 1995, p. 443). This study implemented the most valid method in methodological considerations and therefore yielded the most accurate results.

Cardiovascular Function

To investigate cardiovascular functioning during the menstrual cycle, a collaboration of researchers conducted a study to provide a “methodologically rigorous exploration of the hypothesis that cardiovascular functioning varies during the normal menstrual cycle in ways that are consistent with established cardiovascular effects of female-sex hormones” (Moran, Leathard, & Coley, 2000, p. 497). The objective in their study was to improve on past methodological problems which resulted in conflicting results on blood pressure fluctuations during the menstrual cycle. The sample used in this study was to replicate a sedentary healthy population, instead of athletes. The testing lasted 5 weeks and no longer than 30 minutes a day. A total of 26 females between the ages of 20-48 years participated in the study. This

aspect of the study was part of a larger study that was conducting the physiological and psychological changes in the menstrual cycle. Resting blood pressure, resting heart rate and rate-pressure product were all recorded at each testing time. The Schneider Index was used to derive cardiovascular fitness on a daily basis and to seek any menstrual cycle-variations (Moran et al.). Due to the fact that these participants were not athletes, the researchers felt this index held validity. In short, the higher the index score, the better fitness level of the subject after the testing protocol was followed. A one-way analysis of variance was used to test any differences between cycle phases.

This study offered accurate measurements of cardiovascular functioning in normal healthy women during the menstrual cycle. The strengths of this study include a reliable data set with little to no data contamination which other studies have encountered. Results indicated a significantly higher resting systolic blood pressure in the ovulatory phase. Resting diastolic blood pressure did not differ. Resting heart rate showed significant elevations in the ovulatory and luteal phases. Rate pressure product was significant higher during the ovulatory phase and the Schneider Index showed fitness scores were the highest during the follicular phase. Practical applications of this study suggest, “ that the raised level of fitness in the follicular phase, which incorporates low heart rate, low systolic pressure and faster recovery rate after exercise, for example, may enable women to exercise more efficiently during this phase of the their cycle” (Moran et al., 2000, p. 503).

Metabolic and Ventilatory Responses

Findings concerning the effects of the menstrual cycle phase on metabolic responses to exercise have been unclear. As well as “discrepancies in menstrual cycle variations in ventilatory responses to exercise have been noted” (Bemben, Salm & Salm 1995, p. 257). In order to try to challenge these discrepancies, Bemben et al. (1995) conducted an experiment to examine ventilatory and blood lactate responses to maximal treadmill exercise during the three phases of the menstrual cycle. Although there were many limitations to this study, the premise of whether or not ventilatory or metabolic responses were affected showed validity. Previous studies have indicated an increase in minute ventilation (V_E), during exercise in the luteal phase in comparison to the follicular phase. Therefore, the first hypothesis stated, they would expect to find, “higher increased V_E and lower VCO_2 in the luteal phase would result in a lower ventilatory threshold (VT) compared to the follicular phases” (Bemben et al., 1995, p.258). The second hypothesis followed in stating that “blood lactate levels would be lower and times to exhaustion would be greater in the late follicular and luteal phases compared to the early follicular phase” (Bemben et al., 1995, p.258). This study involved 5 female participants between the ages of 20-25. Metabolic and ventilatory variables were collected every 20 seconds by an open-circuit spirometry system. Heart rate, ventilatory threshold and venous blood samples were also obtained.

Results in terms of ventilatory responses showed the relative ventilatory threshold occurring at significantly higher percentages of VO_{2max} in the early follicular compared to the mid luteal phase. All other areas of interest showed no

significance in findings. In terms of metabolic responses, the variables did not show any significant variations during any phase of the menstrual cycle. Among all three phases, heart rate, time to exhaustion and $\text{VO}_{2\text{max}}$ showed no significant changes. There were also no significant differences between lactate levels during rest and after exercise which are in agreement of previous studies.

An important result within this study indicated, “that setting a submaximal exercise intensity based on the VT determined in a different phase of the menstrual cycle could result in the subject exercising at a higher or lower relative workload than desired” (Bemben et al., 1995, p. 261). The reason for this is due to the VT occurring at a higher percentage of $\text{VO}_{2\text{max}}$ in the early follicular then luteal phase. Although the findings in this study were not what the researchers hypothesized, it is important to recognize the contradictory results between studies. It is also imperative to recognize that this very topic has shown to be difficult to account for all extraneous and inter-intra individual variables.

Temperature Regulation

During the menstrual cycle there are fluctuations in the hormones estrogen and progesterone. These changes in hormone levels may affect more than the reproductive system. Immediate limitations in measuring hormone levels are differences in timing of testing, variability of estrogen and progesterone concentration, interaction and secretion levels. All of these variables may obscure effects of the menstrual cycle on performance. It is important not only to document the concentration, but the ratio as well since there are large amounts of both hormones during certain phases of the cycle. Although these limitations are present,

the fluctuation of these hormones effect thermoregulation which have implications towards heat illness in female athletes.

A shift of interest from short anaerobic, strength specific sports to longer endurance activities are being documented. Previous research indicates little to no change in $\text{VO}_{2\text{max}}$, heart rate and time to exhaustion in shorter duration activities, however “several studies report a higher cardiovascular strain during moderate exercise in the mid-luteal phase” (Xanne & Janse, 2003, p. 833). One key factor is temperature regulation.

As early as 1932, research has been conducted on basal body temperature during the course of the menstrual cycle (Xanne & Janse, 2003). Increased progesterone levels during the luteal phase cause an increase in both core and skin temperatures which alters the temperature at which sweating begins (Marsh & Jenkins, 2002). It is now well established that basal body temperature increases about 0.3-0.5° Celsius after ovulation and remains there during the luteal phase. Prolonged exercise may be affected with the combination of elevated temperatures, changes in fluid regulation, hematology and minute ventilation (Xanne & Janse, 2003). These changes may be more noticeable in hotter temperatures and show validity in research due to overheating, heat exhaustion and changes in VO_2 . According to Xanne & Janse, a female athlete’s core temperature is important because it can provide information on how efficient the thermoregulatory system is working.

Perceived Exertion and Physical Work

A key study that expands on perceived exertion and physical work was conducted by Higgs and Roberston (1981). They worked from two classic studies

from the 1960's that were researching how the menstrual cycle may influence athletic performance. Due to the discrepancies in results, they conducted a study to compare RPE, physical work capacity, strength, and exercise heart rate in four different phases of the menstrual cycle in hopes to find some consistency in results.

A total of 12 females between the ages of 19-23 years participated in the study. All females were concluded to have normal menstrual cycles and none of them were on any type of oral contraceptive. Researchers controlled for practice and training effects by dividing the subjects into four groups while testing began at a different cycle phase for each group (Higgs & Roberston, 1981). The study lasted for five months and data collection occurred over two menstrual cycles with no change in activity level during this time. The researchers concluded the four testing days were as follows.

1. 48 hours prior to the onset of menses.
2. Day 1, 24 hours prior to the onset of menses.
3. Post menses 48-72 hours following menses.
4. Mid cycle defined as 48 hours of the cycle mid-point.

Work intensity was established through a VO_{2max} test on a treadmill following the protocol of Taylor, Buskirk, & Henschel (1955). After data was collected, the researchers were able to predict 90% of VO_{2max} and used for the following testing days. Grip strength, knee extension, 3 min run at VO_{2max} , 3 min run at 90% VO_{2max} and finally a supra-max test (7 m.p.h. at 7-7.5% incline) concluded the test cycle. Between each running test, each subject got a six minute recovery period.

Results indicated that RPE for work at 100% $\text{VO}_{2\text{max}}$ is increased during the pre-menstrual and day 1 phases as compared to mid-cycle. It was also concluded that performance for short term, intensive exercise is decreased in the pre-menstrual phase. No strength or variations in heart rate were discovered, which does not support other studies where strength was improved in the post-menstrual phase. The findings of the present study suggest that physiological and psychological factors are influences of this change in RPE.

The main area of concern when critiquing this study is the lack of detail situated around charting the menstrual cycle. Although a time frame was established to see patterns in the menstrual cycle, no attempt was made to determine exact phases of the cycle. More importantly, this critique has served as a baseline for additions for future research in this area.

Running Economy

As early as the 1920's, scientists have been interested in investigating oxygen requirements for running at given speeds. Running economy is the body's oxygen consumption for a given running speed (Morgan, Martin & Krahenbuhl, 1989). Running economy has been shown to account for the variation in performance in distance runners, especially elite runners, when $\text{VO}_{2\text{max}}$ is comparable. When measuring running economy higher values indicate a less economical runner. Runners with good running economy use less energy resulting in using less oxygen than runners with poor running economy (Saunders, Pyne, Telford & Hawley, 2004). An area of concern when measuring this value, is the amount of inter subject variation including range, standard deviation and percent changes in $\text{VO}_{2\text{submax}}$ measurements.

Factors that may affect overall running economy include training, environmental factors, physiology and biomechanical anthropometrical properties.

Typically, running economy is measured on a treadmill. There is no wind resistance and the use of hamstrings is different during treadmill runs. Wind resistance can alter VO_2 between 2-8% depending on the distance covered. Taking these measures into account, it has been concluded that reliable measures of running economy need to be obtained at speeds of 85% or greater of $\text{VO}_{2\text{max}}$ of highly trained distance runners (Saunders et al., 2004).

Physiological changes in core temperature, heart rate, ventilation and lactic acid are related to changes in running economy during competition. Studies have shown that when these variables increase, there is a decrease in running economy (Saunders et al., 2004). Muscle fiber composition has been shown to affect running economy as well. The more slow-twitch muscle fibers are present, the higher efficiency is present. The actual speed of contractions of the muscles is what may be influencing running economy. A reduction in myocardial VO_2 would result in an improved running economy due to a decrease in heart rate and increase in stroke volume. It would be a realistic conclusion that during pre-menstrual phase of the menstrual cycle, with a slightly elevated core temperature that running economy would be affected.

The way a runner carries his or her body mass is another important physiological indicator of running economy. A lower vertical displacement of the runner's center of mass yields better running economy (Saunders et al., 2004). With an increase of endurance training there is an increase in respiratory capacity of

skeletal muscle. This allows runners to use less oxygen per mitochondrial respiratory chain for a given sub maximal running speed, which would lead to better running economy.

Biomechanical factors can also influence running economy (Saunders et al., 2004). It would be a desired outcome, if running mechanics could be altered to result in a runner using less energy at any given speed. There are 13 different biomechanical factors related to better economy in runners. Some include height, body fat, foot size, stride length, elastic energy and training status. Some of these factors a runner cannot change, such as foot size and height, however the areas that can change yield small changes, however for elite runners it can make a large difference. For example, in 1983 a study was performed to measure the effects of shoes and surfaces on the economy of locomotion. Results indicated a well cushioned shoe can decrease oxygen expenditure up to 2.8% over shoes of the same weight that are not as well cushioned. Anthropometry, kinematics and kinetics, flexibility and ground reaction forces all have optimal levels in regards to running economy, however altering them to improve running economy proves harder than just losing body fat or even stride length. Many studies have concluded that although there are many biomechanical factors contributing to running economy, overall the physiological factors seem to have more of an influence on decreased running economy during a fatigued state economy (Saunders et al.2004).

There are three realistic ways to improve running economy. Strength training, altitude training and training in the heat have all been shown to develop running economy. These strategies are widely used by runners who already have a high level

of endurance and a well developed running economy. The reason why strength training is so effective in improving running economy is because it enhances anaerobic characteristics. A particular type of strength training is plyometrics. This type of training allows muscles to generate power by amplifying the stretch-shorten cycle. The body can also store and utilize elastic energy better with an increase in stiffness in the muscle-tendon system. Plyometrics allow this adaptation to occur. With the development of the neuromuscular function through plyometrics, it is concluded to be an applicable and realistic method in improving running economy (Saunders et al.2004).

Altitude training can potentially improve running economy by adaptations both centrally and peripherally improving oxygen delivery and utilization (Saunders et al.2004). What makes altitude training appealing is the increase in red blood cell mass and improved skeletal muscle buffer capacity. There are three ways in which an athlete can reap the benefits from altitude training. They can live and train in moderate natural altitude or they can live-high train-low (LHTL) which is a method where the athletes live and sleep in altitude, but train near sea level. Finally, normobaric hypoxia through nitrogen dilution methods allows athletes to attain the LHTL benefits without being in altitude. In 2000, Green, Roy, Grant, Hughson, Burnett, Otto, Pipe, McKenzie & Johnson, conducted a study to examine increases in sub maximal cycle efficiency mediated by altitude training. They suggested that improvements in efficiency were related to the reduced energy requirement of the processes of excitation and contraction of the working muscles. There was a decrease in the by-product accumulation of ADP, hydrogen and inorganic phosphate from the

altitude exposure, which in turn increased the amount of free energy released from ATP hydrolysis which decreased the need to maintain these rates prior to acclimatized levels. Finally, an advantage of altitude training allows athletes to workout at a given intensity with lower amounts of lactic acid production post altitude acclimatization. An increase in skeletal muscle oxidative enzyme capacity occurs from anaerobic to aerobic shift in metabolism.

Training in the heat increases core temperature slightly which increases the efficiency of the working muscles which in turn increases running economy (Saunders et al.2004). Increased circulation, ventilation and sweating will decrease the energy requirements associated with heat stress. An end result of lower myocardial work is attributed to the increase in plasma volume which helps with the maintenance of stroke volume. Two variables that affect running economy are heart rate and core temperature. Adaptations from training in the heat allow runners to work at any given workload with a lower heart rate and core temperature which can enhance running economy. Although the implication for improving running economy exists with training in the heat, limited research is available.

In 1998, Sherman and Jackson wanted to determine in variance in running economy could be explained with a regression analysis in healthy adults running at 50-80% of their VO_{2max} . A total of 22 males and 21 women between the ages of 18-35 years who worked out for a minimum of three times a week participated in the study. Anyone with a VO_{2max} lower than $35 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ were excluded from the study. VO_{2max} was measured with an open circuit method. O_2 and CO_2 were measured with applied

electrochemistry S-3A and Cavitron Amard analyzers. The Bruce treadmill test was administered as the graded exercise test. Polar heart rate monitors were used to indicate heart rate measurements throughout the test. On the first day of testing, informed consent, body density, skin fold measurements, RER, RPE, HR and VO_{2max} were measured. On the second day of testing, all subjects were weighed with their running shoes on. A sub maximal work out was preformed for 6 minutes at 0% incline. Each subject was running at a workload of 75% of their VO_{2max} . This workload was determined because it was an intensity recommended for developing and maintaining cardiovascular fitness (Sherman & Jackson). To determine running speed the following equation was used: $RS(mph) = (VO_{2max} \times 0.145) + (\% VO_{2max} \times 0.08) - 6.662$. Sub maximal heart rate data was collected in the last 15 seconds of each minute. Stride length was also measured during the 5th and 6th minute of the sub maximal workout. Stride length was estimated by the quotient of strides/min/treadmill speed.

In this study all runners were economical or uneconomical based on sub maximal runs. This reduced variability in the regression analysis. A Multiple Regression Stepdown analysis was used to identify variables that predicted running economy. The dependant variable was $VO_{2submax}$. The following variables were then entered in this order; running speed, exercise intensity, % body fat and stride length. A cross validation on a different group of runners was tested to ensure the accuracy of the running economy model. The objective of the study was to see if running economy was a function of running speed, HR%, body composition, stride length or gender. It was determined that a single model can be used to estimate VO_2 for a given

running speed for men and women. A multiple regression was then used to develop a full model for predicting running economy. In doing so, it was determined that HR% had a significant impact on increasing R^2 . No other variable had any significance. In previous research, examination of stride length changes of +/- 10% showed possible affects on running economy, however in this study, stride length did not prove to be significant. The cross validation showed accuracy in estimating VO_2 ($R^2 = 0.901$). Results indicated that there were no age differences between men and women, however the men were taller, leaner, heavier and had higher VO_{2max} values. Woman ran at 3% higher intensity, while men ran faster. There was a small gender difference between RPE, HR and RER. Results indicate that men and women were running at similar intensities, but men were running about 2 mph faster, reflecting higher aerobic capacities (Sherman & Jackson, 1998).

In past studies, subjects all ran at the same speed. A major difference in Sherman and Jackson's study was that each runner was working at 75% of their maximum capacity. Running speed was then statistically controlled using the regression model. Despite this controlling this variable, there was still a significant effect on running economy. Running speed in theory, should be the first variable entered into the running economy regression model because running economy is defined as the VO_2 for a given running speed (Sherman & Jackson, 1998). Only 8.3% of total variance was due to other variables presented in this study.

In 1992 Daniels and Daniels designed a study to evaluate running economy over a range of sub maximal speeds among elite female and male middle and long distance runners. Twenty female and forty five male NIKE, Inc. sponsored athletes

participated in the study. Eighteen of the twenty and forty one of the forty five men qualified for the Olympic Trials, twelve men and eight women reached the Olympic Games, with two women and three men winning medals. Protocol began with a series of sub maximal tests lasting 6 minutes. Heart rate and post blood lactate measurements were taken, as well as expired air samples during the last 2 minutes of each run. When blood lactate levels reached $4.0 \text{ mmol} \cdot \text{l}^{-1}$ then the sub maximal tests were completed, and a five to ten minute recovery began. After recovery, a $\text{VO}_{2\text{max}}$ test began. Gas volumes, blood lactate and heart rate measurements were collected.

Running economy was determined by plotting VO_2 data against running velocity. Individual regression equations were used to obtain VO_2 values for the speeds ran in the sub maximal tests. There were three common testing speeds where the male runners were more economical than females. The men and women were compared in absolute terms which indicate a 14% difference in the combined $\text{VO}_{2\text{max}}$ and running economy (Daniels & Daniels, 1992). If the athletes were compared relatively there would only be a 1-2% difference in running economy. Blood lactate data also suggests that females were the same as men relatively measured when comparing to $\text{VO}_{2\text{max}}$ and heart rate at $4.0 \text{ mmol} \cdot \text{l}^{-1}$. However, in an attempt to clarify this relationship between $\text{VO}_{2\text{max}}$ and running economy vs. gender, 8 men and women with closely matched $\text{VO}_{2\text{max}}$ values were compared. The males were significantly favored in economy and in $\text{VO}_{2\text{max}}$. An interesting find was that the female with the highest $\text{VO}_{2\text{max}}$ did not have the best running economy. Daniels & Daniels then took the top 8 economical female runners and compared them to males with equal running

economy. This comparison showed a 14% $\text{VO}_{2\text{max}}$ advantage for men, and provided information necessary to conclude that men have a better aerobic profile.

Daniels & Daniels (1992) suggest that an even better predictor of running success is from $v\text{VO}_{2\text{max}}$. This is the velocity at $\text{VO}_{2\text{max}}$ that provides information on how fast an athlete can run when working at either max or sub maximal levels. They also suggest that testing running economy should be at 95% of maximum, reflecting a more realistic race pace and creating a better aerobic profile for the runner.

In review of the literature summarized, it is important to indicate how much variability is within this realm of research. Although more recent studies are using the most effective methods for testing, limitations are still present. As past studies have expressed, larger sample sizes, and sport specific testing is required. Individual variables and perceptions have altered results in many cases. Methods of testing have created a decrease in validity amongst studies. Due to the increasing amount of variables associated with this topic, it is hard to conclude that just one factor results in a change in performance. This literature review suggests that little to no variance in performance was detected in most studies. On the other hand, an emphasis on temperature regulation during the luteal phase suggests female athletes more prone to heat related effects.

This research is important because it provides evidence that there is a high degree of variability in the results of these studies. The study conducted by Quadagno et al (1991) imply the menstrual cycle has no effect on athletic performance, while Lebrun et al (1995) and Brooks-Gunn et al (1986) suggest there is significant effects on athletic performance. Future research suggests that sport specific studies should be

researched, as well as the effects on highly trained athletes. A small variance in athletic performance may be more detrimental to their results than an average athlete. A practical example of this would be the effect of a few seconds added to an elite marathoner's time resulting in a first or second place finish. If the physiological factors seem to show little effect on performance, then one is lead to believe that psychological influences may have a stronger effect on athletes performance then may be understood at this time. Physiological factors such as heart rate and core temperature have been shown to affect running economy. Since these variables are all related in terms of the menstrual cycle and performance, it is a realistic thought to link running economy into this exploration. This topic provides tremendous room for continued research.

Chapter 3

METHODS AND PROCEDURES

The purpose of this study is to examine if a possible discrepancy in rating of perceived exertion exists due to the menstrual cycle when testing male and females with the same protocol. A secondary purpose was to explore changes in running economy during menstrual cycle. To determine if the menstrual cycle has an effect, menstrual charting throughout the duration of the study was conducted.

Participants

Three male and seven female runners, ranging from the age of 19-33 years were randomly selected from a group of well trained distance runners at the State University of New York (SUNY). The mean age of male participants was 19.66 years. Their mean weight was 144.20 lbs. with a standard deviation of 15.37 lbs. Their mean $\text{VO}_{2\text{max}}$ was $73.20 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ with a standard deviation of $5.7 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. The mean age of women participants was 22 years. Their mean weight was 126.20 lbs with a standard deviation of 18.10 lbs. Their mean $\text{VO}_{2\text{max}}$ was $54.05 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ with a standard deviation of $5.36 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Women all had regular menstrual cycles 25-36 days in length. Menstrual cycle (EF days 2-5; LF days 12-15; ML days 20-23) verified by basal body temperature. Any participant with lower than $38 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (for women) or a $45 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ $\text{VO}_{2\text{max}}$ (for men) test was excluded from the study. Any female with menstrual dysfunction or taking birth control was excluded from the study. Finally, any female reporting a 5 or 6, three times or more on the MOOS Distress Questionnaire (Appendix A) were excluded from the study.

Instrumentation

Borg RPE Scale. Due to ASCM recommendations, the original Borg Scale (6-20) will be used (Appendix B). The participants were given the test while they were running. The test examines feelings of exertion while exercising (Physical Activity, 2005). It is not something that is observed by the researchers so it is not subjected to researcher bias. The Center for Disease Control and Prevention also recommends this test due to the fact that it is based on how one feels (Physical activity, 2005). After heart rate data was collected, the participant was asked to point to the number that corresponds to how hard they believe they are working. In congruence to having each subject tell the researcher what level of RPE they are at, the respiratory rate was also collected.

MOOS Distress Questionnaire (MDQ). This is a self administered questionnaire that is concern with various menstrual cycle symptoms (Appendix A). The scale is rated from one (if no symptoms) to six (if severe symptoms of pain) (Brooks-Gunn, Gargiuo, & Warren, 1986). “Internal consistency and intercycle stability are high, suggesting that the MDQ is suitable for longitudinal reports of menstrual symptoms” (Brooks-Gunn, et al.,1986, p. 188). Although there have been modified versions of this questionnaire to reduce bias and improve statistical analysis, the researchers wanted to use the original version of the questionnaire. Based on past experiments the researchers found this version of the MDQ to be the most consistently used form. This does not compromise any validity in the data. “The MDQ remains the most widely used single instrument in the menstrual cycle research” (Walker,1977 p. 61).

VO_{2max} Test. This test is a graded exercise test to measure maximum aerobic capacity. Refer to Appendix C for test administration, test procedure and VO_{2max} scales. (Heyward, 2002). This capacity is indicated when the oxygen uptake plateaus and does not increase by more than 150 ml•min⁻¹ with a further increase in workload. According to ACSM guidelines used to indicate VO_{2max} are the following: (Heyward, 2002).

- Failure of the heart rate to increase with increases in exercise intensity
- Venous lactate concentration exceeding 8 mmol•L.
- Respiratory exchange ratio (RER) greater than 1.15
- Rating of perceived exertion greater than 17 using the original Borg scale (6-20).

Digital Thermometer. A digital oral thermometer was used to record each participant's basal body temperature. Using a digital thermometer can decrease human error however there is a threat of instrument accuracy to the internal validity of the study. The participant's temperature helps determine in what phase of the menstrual cycle they are. Both Brook-Gunn et al. (1989) and Bemben, Salm and Salm (1995) used this technique. There is a decrease in temperature when in premenstrual phase and then a sharp rise which indicates the "occurrence of ovulation" (Bemben et al.1995). Each female participant charted her menstrual cycle including a daily temperature reading each day at the same time. Although other methods of tracking the menstrual cycle are recommended to have higher accuracy, this method proves to be the most applicable. Refer to Appendix B for menstrual charting and procedure.

Heart Rate Monitor. A heart rate monitor (Polar Accurex Plus) was worn by each participant during the graded exercise test. Females strapped the heart rate monitor right underneath their sports bra and men placed the monitor approximately 2 inches below the nipple. Heyward indicates, “Chest strap wire and wireless ECG-type monitors tend to be more accurate and reliable than pulse monitors, especially during vigorous exercise” (2002 p.27). A digital watch was placed next to each subject that displays the heart rates transmitted from the monitor. Every minute heart rate data was collected and recorded.

Open Circuit Spirometry. In this procedure, the subject breathed through a low-resistance valve (with nose occluded) while pulmonary ventilation and expired fractions of O₂ and CO₂ are measured. Detailed print outs of test results are provided (Appendix D).

Procedures

Each participant was given an informed consent form which outlined the study and asked them to participate (Appendix E). Analysis of the MOOS Distress Questionnaire was evaluated at submission. If any participant answered above the acceptable range of discomfort in more than 2 areas in 3 or more sections, they would have been considered irregular, and not able to participate in the study. All answers were in an acceptable range of discomfort for all 8 areas in question for all female subjects. Data were collected a total of 6 testing days in the Exercise Physiology lab at SUNY Cortland. All data were entered into the Excel spreadsheet for data management and calculations. Each test was administered at the same time for each subject each week on the same day. The tests took no more than ten minutes, with

additional time to warm up and cool down. All data were calculated by the computer analyzer attached to the gas exchange analyzer. The initial $\text{VO}_{2\text{max}}$ test was confirmed by the RER value of 1.15 or higher. This value indicates the change over of fuels being utilized from carbohydrates to fats. The participant's instructions for each administered $\text{VO}_{2\text{max}}$ test appears in Appendix C & C1.

Each female participant started at a 7.0 miles per hour (mph) and males at 8.0 mph, and gradually increased in incline by 3% until reaching maximum work rate was reached. The researcher collected HR measurements every 30 seconds and then proceeded to ask the participant to confirm the number on the RPE scale that correlates with how hard you think you are working. The scale began at 6 (no exertion at all) and reached 20 (maximal exertion). An open circuit spirometry analyzer was used to measure $\text{VO}_{2\text{max}}$. Each subject breathed through a low-resistance valve while pulmonary ventilation and expired fractions of O_2 and CO_2 are measured as per ASCM guidelines. The test would be terminated if at any time the participant felt faint, dizzy, sick, or unable to complete the testing. Protocol was established through pilot testing in the lab prior to data collection.

After the initial $\text{VO}_{2\text{max}}$ test was taken for baseline data, individual testing charts were developed (Appendix F) for each subject for the four consecutive testing days. Each subject warmed up for a period of 5 minutes and then ran at their individual pace at 80% of maximum for 2 miles. There were three important reasons why testing occurs at 80% max in the four week testing. First, the need to replicate the most natural running conditions is important to the results of this study. Running without the face mask on creates less pressure and discomfort while testing.

Secondly, past research has indicated that at approximately 80-90% of max females tend to over estimate how hard they are working. One addition to testing at 80 % of maximum occurred 1 mile into the run. For two minutes each subject was hooked up to the metabolic cart (with no face mask) to collect data for further analysis. Finally, typical training programs for this type of runner would be held at 80% of VO_{2max} , so it is important from a coaching perspective to know where this discrepancy of RPE exists.

The pace of each subject was determined by using the ACSM conversion spreadsheet (Appendix G). Continued analysis was studied to verify accuracy of the ACSM conversion. Figure 1 represents the actual 80% of each subject's VO_{2max} vs. the predicted 80% of VO_{2max} . The pace predicted from the ACSM guidelines never matched the actual 80% calculated from each subject's VO_{2max} .

Figure 3-1. Actual 80% of VO_{2max} vs. Predicted 80% of VO_{2max} using ACSM guidelines. Figure indicates that using the prediction formula to calculate pace at 80%

of maximum, never matched the actual 80% calculated from raw data. Male subjects were 5, 6 and 7.

Visual cues of incline were not available to each subject to eliminate any extraneous feedback of perceived exertion. Metabolic and ventilatory variables and heart rate were measured continuously during the tests. Ventilatory threshold was estimated from ventilatory parameters ($\dot{V}_E$ - $\dot{V}O_2$ and $\dot{V}CO_2$ - $\dot{V}O_2$ curves). Each female subject was asked to chart their menstrual cycle (Appendix H & H1 for menstrual cycle instructions and charting). This process included taking their temperature orally each day at the same time. This was used to determine when the female was in the pre menstrual phase. They were also asked to control for as many non-physiological variables as follows during the testing weeks (Appendix H for variables). Each male subject performed the same testing protocol once a week excluding the menstrual charting.

Pilot Study

Pilot work took place in August 2007 to ensure that the testing was feasible at SUNY Cortland. The $\dot{V}O_{2\max}$ testing protocol was effective and verified that it would take no more than 10 minutes to accomplish. This is important due to the high volume of athletes being tested and the coordination that will take place during their pre-season practices. All equipment was calibrated and collected the appropriate data necessary. The simplicity of the testing and pure repetitiveness of procedure allows the protocol to be reproduced easily. Each testing date will occurred at the same time. Limitations in the lab for the most accurate measure of menstrual cycle testing has been advantageous for this study. In terms of what will be the most applicable

tool for coaches, the charting system used can be implemented at any level of competition. The research design has proven to be repeatable and time efficient.

Data Analysis

The data from the sub maximal testing were entered into the statistical software SPSS Version 16.0 for data analysis. Minor corrections were made for calibration of treadmill speed, and ventilation measurements. Flow was corrected by a calibration curve and using a known 3 liter volume. The data for the sub maximal runs were analyzed using a 2(sex) x 4(cycle) mixed ANOVA with repeated measures on the second factor. Repeated measures are used in situations in which the measurements are repeated on the same subject. In this experiment RPE, RER, running economy and VO_2 all were repeatedly tested during each of the 80% treadmill tests.

The level of significance was set at an alpha level of 0.05. This analysis provided any statistically significant differences between weeks 1 to week 4 within the subjects and showed any significant differences between running economy, RPE, VO_2 and RER.

Chapter 4

RESULTS AND DISCUSSION

The purpose of this study was to examine the effect the menstrual cycle had on the rate of perceived exertion (RPE) and running economy during treadmill running. Participants were first tested to determine their VO_{2max} level indicated. Afterwards, each participant was tested 4 times, once a week in a series of 80% sub maximal runs on a treadmill. After the female's data was collected, it was then organized so cycle week one of each subject was their pre-menstrual and cycle week 2 was their menstrual week regardless of when they tested. Men's data was not re-organized and kept testing week 1, as cycle week 1. Each week to follow corresponded to the different phases of the menstrual cycle.

Results

The one variable of the study which displayed significance was within the VO_2 data. As shown in Figure 2, there was a consistent significant difference between men and women across all 4 cycle weeks. Although there was only one variable of significance, the descriptive statistics reveal interesting aspects, including the most economical week of female subjects and how RPE is related.

Figure 4-1. Average 80% of VO_{2max} for men and women across 4 cycle weeks. Bars indicate standard error.

A 2 (sex) x 4 (cycle) mixed ANOVA was performed in order to analyze the changes in performance during the 80% sub maximal running series. There was no significant main effect of basal body temperature between the days prior to menstrual cycle: $F(4,24) = 1.261$, $p = 0.313$, partial $\eta^2 = 0.174$. There was no significant main effect of RER on cycle: $F(3,24) = 0.835$, $p = 0.488$, partial $\eta^2 = 0.095$. There was no significant main effect of RPE on cycle: $F(3,24) = 2.746$, $p = 0.065$, partial $\eta^2 = 0.256$. There were no significant main effects of VO_2 on cycle, $F(3,24) = 1.243$, $p = 0.316$, partial $\eta^2 = 0.135$, or of running economy on cycle, $F(3,24) = 1.085$, $p = 0.374$, partial $\eta^2 = 0.119$.

There was a significant main effect of gender on 80% of VO_{2max} : $F(1,8) = 23.466$, $p = 0.001$, partial $\eta^2 = 0.746$. This effect tells us that if we ignore all other variables, male participants' ratings were significantly different to females when it

comes to 80 % of $\text{VO}_{2\text{max}}$. The average for women was $38.95 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for all 4 testing weeks, while males averaged $55.60 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

The average RPE for males and females during all 4 cycle weeks are reflected in figure 3. These data suggests that females perceived working the hardest cycle week 1, which is the pre-menstrual phase for all females. It also suggests that on average, men perceived working harder than females. Males has less variance then females overall during the 4 testing weeks. Averaging 0.768 while women averaged 1.175 shows consistency with previous findings (Winborn, Meyers & Mullings, 1988).

Figure 4-2. Average RPE for men and women over 4 testing weeks. Bars indicate standard error.

There was no significant main effect of gender on RER $F(1,8) = 0.085$, $p = 0.771$, partial $\eta^2 = 0.011$. There was no significant main effect of gender on RPE

$F(1,8) = 0.387$, $p = 0.551$, partial $\eta^2 = 0.046$. There was no significant main effect on gender on RE $F(1,8) = 1.207$, $p = 0.304$, partial $\eta^2 = 0.131$.

The respiratory exchange ratio between VCO_2 produced/ VO_2 consumed is reflected in figure 4. RER values reaching 1.0 or higher utilize primarily carbohydrates, and the excess CO_2 is a result of anaerobic metabolism. Reaching values of 1.15 or higher is an indicator of reaching maximal workload. The mean average RER for women across the 4 weeks of testing was 0.983 while men averaged 0.972. These statistics suggest that across the 4 cycle weeks, women were actually working slightly harder due to RER, however, according to Figure 3, the RPE suggest that they perceive to work slightly less.

Figure 4-3. Average RER values for men and women over 4 weeks of testing. Bars indicate standard error.

The final analysis of running economy was performed to indicate if at any week of the cycle the female runners proved to be less economical. The results

illustrated in Figure 5 suggest that females were the most economical during cycle week 2, which was menstrual week for all females. Week 3 was the most economical week for males. The least economical week for females was week 4, along with the lowest average RPE. Males were the least economical at week 1. Overall, women averaged to be more economical with a $10.679 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{km}^{-1}$ difference. Data suggest that RPE and RE did not relate with the lowest RPE being the most economical for females. An interesting finding was that men displayed the lowest RPE averages during cycle week 2 and 3, at which point they were the most economical. Overall standard deviations reveal that; men averaged 17.07 while women averaged 17.41. This shows that there is less variance between male and females in terms of running economy; however more variance was shown in terms of RPE.

Figure 4-4. Average running economy for men and women during 4 weeks of testing.

Bars indicate standard error.

Discussion

Although the majority of the results show no significance, there are some important areas to explore. Cycle 1 for each female represents their pre-menstrual week, regardless of testing week. As indicated, the highest week of RPE was in Cycle 1, however the men's highest RPE was in Cycle 1. Both the men and female subjects average RPE declines with each testing cycle. Males perceived to work harder than females in Cycle 1. Perhaps the subjects became more comfortable with the testing with each cycle week. As each Cycle of testing progressed there seemed to be less variability in the means between men and women. Week 1 the difference between male and female standard deviation was 1.049. Week 2, 0.48, week 3, 0.01 and week 4, 0.109. Across all 4 cycles, men revealed a smaller standard deviation than females. The standard deviation between male and female from each Cycle week was 0.139 times lower than females across the 4 Cycle weeks. Perhaps this indicates a slightly higher rate of accuracy in terms of reporting constancy in RPE since men have fewer variables than females to account for. These results support the findings of previous research that indicate interactions of various factors that influence RPE. Winborn, Meyers and Mullings (1988) examined gender, experience or an interaction of these factors influencing RPE. Results indicated that there was a significant effect of gender and athletic experience on RPE. A trend was established indicating lower athletic experienced women may not have the ability to make accurate judgments about RPE. The study also suggested that lower experienced athletes tend to disassociate from their physical performance. However, the accuracy of RPE and males with higher athletic experience support the roles of both gender and previous

experience. In this study, men showed lower standard deviation across all 4 testing weeks indicating more accurate reporting of RPE scores. This study also displayed different RPE data for each cycle week, which is in support of the findings Eston discovered in 1984, stating different phases of the menstrual cycle evoked higher RPE during the same workload. Most studies reviewed yielded differences during the luteal phase. This study found the highest RPE during cycle week 1 (pre-menstrual phase), which is during the luteal phase. Furthermore, a study conducted by Moran et al., 2000, concluded that women may be able to exercise more efficiently during the follicular phase. This study revealed women the most economical during cycle week 2 (menstrual week) which would be during the follicular phase.

Although the results were not significant in this study, females showed a higher degree of variance in RER. Females reported 0.11 times higher in RER values and 0.191 higher in standard deviation than men. Results suggest that although females seem to be working slightly harder than men, RPE results do not support the slight increase in effort. However, it does indicate a higher degree of fluctuation in reporting RPE. The lack of difference in temperature during cycle week 1 may be attributed to the fact that not all females report an increase in temperature. Data suggests that the slight increase in temperature was during cycle week 2 (menstrual week) indicating that an increased progesterone level was still present, affecting core temperature. A larger sample size may yield different results during the pre - menstrual phase.

Chapter 5

SUMMARY, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to examine the effects of the menstrual cycle on RPE during treadmill running. The hypothesis was that there would be a significant difference in RPE in the pre menstrual phase of the menstrual cycle during the series of treadmill running tests for the same workload. Participants were 10 well trained distance runners. All participants followed the exact same protocol for men and women, with the exception of females charting menstrual cycle. Statistical analysis showed no significant differences across cycles in RER, RPE, RE and body temperature. However, there was a significant difference between gender and 80% of VO_{2max} . It is important to discuss how close to significance the results were for RPE ($p = 0.065$). There were significant findings between cycle 1 and cycle 2 with regards to RPE. An interesting finding was that men displayed the lowest RPE averages during cycle week 2 and 3, at which point they were the most economical.

Conclusions

The results of the study provide sufficient support to warrant continued research on how menstrual cycle affects RPE during treadmill running. There is reason to believe that with a larger sample size, significance may be found. This study was only 0.015 away from achieving significance with seven well trained female runners. It would be reasonable to conclude that with further research the link may be found.

Implications

The results of this study could have vast implications on the way running coaches approach training protocols, particularly at the collegiate level and post collegiate level where small adjustments in training plans can make a big difference in finishing times. This study shows that there are a variety of variables that affect RPE, however challenging to test. The implementation of adjusted training plans, according to menstrual cycle, could allow females to be more successful during specified workouts if more attention was met during higher times of perceived exertion. Self confidence could improve as well, due to the increase in successful workouts. The more educated females are in relation to how their bodies respond to different variables during the menstrual cycle, the better their performances may become.

Recommendations

With the implementation of menstrual charting for collegiate and post collegiate runners, coaches can continue to learn the science of running and develop more successful programs. A realistic concern of this implementation is that male coaches may not want to be as involved in their athlete's menstrual cycle. If however, future studies can focus on a larger sample size, and significance is found, more male will likely pay attention to these effects on female runners. A recommendation to increase sample size would be to include a control group on birth control, and or include females with a wide array of menstrual symptoms (not just an average cycle). If social norms of the menstrual cycle can become neutralized through this implementation, major impacts on training protocols could be established. If in fact,

significance can be found that some women are affected more than others in regards to RPE and menstrual cycle, it would be interesting to see how an individualized training protocol could enhance performance. Another interesting possibility is to examine at what point performance declines in individual female runners in regards to temperature.

Due to limitations in the lab, the most accurate testing for what phase of the menstrual cycle the female is in, (hormone testing) was compromised. However, the method used in this study proves to be a more applicable method to the population of coaches that may use this information as a workable tool. Once the pre-menstrual phase is deciphered in each female athlete, new methods of training programs can start to develop. Future research is necessary to continue the examination of athletic experience and how that affects RPE and running performance. A larger scale of testing can look at Division I, II and III runners to see if experience at each competitive level makes a difference. Future studies should also look at creating different sub maximal percentages while testing, to see if there is a higher or lesser workload that could affect significant difference in RPE. Furthermore, future studies should focus on testing outdoors. Finally, it would be interesting to see if a study could be created to compare the success rate of female runners on an implemented training plan vs. not taking into account menstrual cycle at all.

The results of this study prove beneficial because it may help to dispute the idea held by many coaches and runners, that the menstrual cycle does not have any effect on running performance. It may serve to encourage future studies to find a link

between enhancing female performances through individualized training protocol, rather than only gender specific strategies.

REFERENCES

- Bauman, J.E. (1981). Basal body temperature; unreliable method of ovulation detection. *Fertility & Sterility*, 36(6), 729-733.
- Bemben, D. A., Salm, P. C., & Salm A. J. (1995). Ventilatory and blood lactate responses to maximal treadmill exercise during the menstrual cycle. *The Journal of Sports Medicine and Physical Fitness*, 35(4), 257-262.
- Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, 2, 92-98.
- Borg, G. (1982). Psychological basis of perceived exertion. *Medicine & Science in Sports & Exercise*, 14, 371-381.
- Brooks-Gunn, J., Gargiulo, J. M., & Warren M. P. (1986). The effect of cycle phase on the adolescent swimmers. *Physician and Sportsmedicine*, 14(3), 182-191.
- Burrows, M., & Bird, S. (2000). The physiology of the highly trained female endurance runner. *Sports Medicine*, 30(4), 281-297.
- Carton, R., & Rhodes, E. (1985). A critical review of literature on ratings scale for perceived exertion. *Sports Medicine*, 2, 198-222.
- Chen, M., Fan, X., & Moe, S. (2002). Criterion-related validity of the borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *Journal of Sport Sciences*, 20(11), 873-899.
- Cook, D.B., O'Connor, P.J., Oliver, S.E., & Lee, Y. (1998). Sex differences in naturally occurring leg muscle pain and exertion during maximal cycle ergometry. *International Journal of Neuroscience*, 95, 183-202.
- Daniels J., & Daniels N. (1992). Running economy of elite male and elite female runners. *Medicine & Science in Sports & Exercise*, 24(4), 483-490.
- De Souza, M. J. (2003). Menstrual disturbances in athletes: A focus on luteal phase defects. *Medicine & Science in Sports & Exercise*, 35(9), 1553-1563.
- Eston, R.G. (1984). The regular menstrual cycle and athletic performance. *Sports Medicine*, 1, 431-445.
- Gamberale, F. (1972). Perceived exertion, heart rate, oxygen uptake and blood lactate in different work operations. *Ergonomics* 15, 545-554.

- Gamberale, F., Strindberg, L., & Wahlberg, I. (1975). Female work capacity during menstrual cycle – physiological and psychological reactions. *Scandinavian Journal of Work Environment and Health*, 1, 120-127.
- Gillespie, R.L., McCarthey, J., & Rose, K.D. (1979). Differentiated perceptions of exertion: Part 1. Mode of integration of regional signals. *Perceptual and Motor Skills*, 49, 683-689.
- Green, H.L., Roy, B., Grant, S., Hughson, R., Burnett, M., Otto, C., Pipe, A., McKenzie, D., & Johnson, M. (2000). Increases in submaximal cycling efficiency mediated by altitude acclimatization. *Journal of Applied Physiology*, 89 (3), 1189-1197.
- Heyward, (2002). *Advanced Fitness and Exercise Prescription*. Champaign, Illinois: Human Kinetics.
- Higgs, S.L., & Roberston, L.A. (1981). Cyclic variations in perceived exertion and physical work capacity in females. *Canadian Journal of Applied Sport Sciences*, 6, 191-196.
- Howley, E. (1976). The effect of different intensities of exercise on the excretion of epinephrine and norepinephrine. *Medicine & Science in Sports*, 8 (4), 219-222.
- Kay, C., & Shepard, R.J. (1969). On muscle strength and the threshold of anaerobic work. *Internationale Zeitschrift fur Angewandte Physiologie* 27, 311-328.
- King, A.C., Blair, S.N., Bild, D.E., Dishman, R.K., Dubbert, P.M., Marcus, B.H., Oldridge, N.B., Paffenbarger, R.S., Powell, K.E. & Yeager, K.K. (1992). Determinants of physical activity and interventions in adults. *Medicine & Science in Sports & Exercise*, 24, S221-S236.
- Lebrun, C. M., McKenzie D. C., Prior J. C., & Taunton, J. E. (1995) Effects of menstrual cycle phases on athletic performance. *Medicine & Science in Sports & Exercise*, 24(3), 437-444.
- Lebrun, C. M. T. (1993). Effects of the menstrual cycle and oral contraceptives on athletic performance. *Dissertation Abstract University of British Columbia*
- Marsh, S., & Jenkins, D. (2002). Physiological responses to the menstrual cycle, implications for the development of heat illness in female athletes. *Sports Medicine*, 32(10), 601-614.
- Michael, E., & Eckardt, L. (1972). The selection of hard work by trained and non-trained subjects. *Medicine and Science in Sports*, 4 (2), 107-110.

- Moran, V.H., Leathard H.L., & Coley J. (2000). Cardiovascular functioning during the menstrual cycle. *Clinical Physiology*, 20(6), 496-504.
- Morgan, W.P. (1973). Psychological factors influencing perceived exertion. *Medicine & Science in Sports*, 5, 91-103.
- Morgan, D.W., Martin P.E., & Krahenbuhl G.S. (1989). Factors affecting running economy. *Sports Medicine*, 7(5), 310-330.
- Noble, B.J., Borg, G., Jacobs, I., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Medicine & Sports in Exercise*, 15(6), 523-528.
- Quadagno, D., Faquin L., Lim G., Kuminka, W., & Moffet, R. (1991). The menstrual cycle: Does it affect athletic performance? *The Physician and Sportsmedicine*, 19(3), 121-124.
- Robertson, R.J., Gillespie, A.L., McCarthy, J. & Rose, K.D. (1979). Differential perceptions of exercise: Part II. Relationship to local and central physiological responses. *Perceptual and Motor Skills*, 49, 691-697.
- Saunders P.U., Pyne D.B., Telford, R.D., & Hawley, J.A. (2004). Factors affecting running economy in trained distance runners. *Sports Medicine*, 34(7), 465-485.
- Sherman, N.W., & Jackson, A.S. (1998). Utilizing regression analysis to evaluate running economy. *Measurement in Physical Education and Exercise Science*, 2(3), 165-176.
- Skinner, J.S., Hutsler, R., Bergsteinova, V., & Buskirk, E.R. (1973). The validity and reliability of a rating scale of perceived exertion. *Medicine & Science in Sports*, 5(2), 94-96.
- Stamford, B.A., & Noble, B.J. (1974). Metabolic cost and perception of effort during bicycle ergometer work performance. *Medicine & Science in Sports & Exercise*, 6, 226-231.
- Stamford, B.A., & Noble, B.J. (1976). Validity and reliability of subjective ratings of perceived exertion during work. *Ergonomics*, 19(1), 53-60.
- Taylor, H.L., Buskirk, E., & Henschel, A. (1955). A maximal oxygen intake as an Objective measure of cardio-respiratory performance. *Journal of Applied Physiology*, 8, 73-80.

- Warren, M. P., & Shantha, S. (2000). The female athlete. *Bailliere's Clinical Endocrinology and Metabolism*, 14(1), 37-53.
- Whaley, M (Ed.). (2006). *ASCM's Guidelines for exercise testing and prescription*. Baltimore, MD: Lippincott Williams & Wilkins.
- Winborn, M.D., Meyers, A.W., & Mulling, C. (1998). The effects of gender and experience on perceived exertion. *Journal of Sport & Exercise Psychology*, 10, 22-31.
- Xanne, A.K., & Janse, J. (2003). Effects of the menstrual cycle on exercise performance. *The Journal of Sports Medicine*, 33(11), 833-851.
- (Physical activity) for everyone: Measuring physical activity. (2005). Retrieved July 11, 2005, from CDC Centers for Disease Control and Prevention Web site: http://www.cdc.gov/nccdphp/dnpa/physical/measuring/perceived_exertion.htm

APPENDIX A

Replication of the MOOS Distress Questionnaire (MDQ)

Originated by Rudolph H. Moss PhD. (1968)

“The Development of a Menstrual Distress Questionnaire”

Six point Scale

1: No experience of the symptom

6: Acute or partially disabling experience of the symptom

ARE YOU CURRENTLY TAKING BIRTH CONTROL PILLS? _____Y _____N
(please check yes or no)

1. Pain

a. Muscle Stiffness	1	2	3	4	5	6
b. Headache	1	2	3	4	5	6
c. Cramps	1	2	3	4	5	6
d. Backache	1	2	3	4	5	6
e. Fatigue	1	2	3	4	5	6

2. Concentration

a. Insomnia	1	2	3	4	5	6
b. Forgetfulness	1	2	3	4	5	6
c. Confusion	1	2	3	4	5	6
d. Lowered Judgment	1	2	3	4	5	6
e. Difficulty concentrating	1	2	3	4	5	6
f. Distractibility	1	2	3	4	5	6
g. Accidents	1	2	3	4	5	6
h. Lowered motor coordination	1	2	3	4	5	6

3. Behavior Change

a. Lowered school or work performance	1	2	3	4	5	6
b. Take naps; stay in bed	1	2	3	4	5	6
c. Stay at home	1	2	3	4	5	6
d. Avoid social activities	1	2	3	4	5	6
e. Decreased efficiency	1	2	3	4	5	6

4. Autonomic reactions

a. Dizziness, faintness	1	2	3	4	5	6
b. Cold sweats	1	2	3	4	5	6
c. Nausea, vomiting	1	2	3	4	5	6
d. Hot Flashes	1	2	3	4	5	6

5. Water retention

a. Weight gain	1	2	3	4	5	6
b. Skin disorders	1	2	3	4	5	6
c. Painful breasts	1	2	3	4	5	6
d. Swelling	1	2	3	4	5	6
6. Negative affect						
a. Crying	1	2	3	4	5	6
b. Loneliness	1	2	3	4	5	6
c. Anxiety	1	2	3	4	5	6
d. Restlessness	1	2	3	4	5	6
e. Irritability	1	2	3	4	5	6
f. Mood swings	1	2	3	4	5	6
g. Depression	1	2	3	4	5	6
h. Tension	1	2	3	4	5	6
7. Arousal						
a. Affectionate	1	2	3	4	5	6
b. Orderliness	1	2	3	4	5	6
c. Excitement	1	2	3	4	5	6
d. Feelings of well being	1	2	3	4	5	6
8. Control						
a. Feeling of suffocation	1	2	3	4	5	6
b. Chest pains	1	2	3	4	5	6
c. Ringing in the ears	1	2	3	4	5	6
d. Heart pounding	1	2	3	4	5	6
e. Numbness, tingling	1	2	3	4	5	6
f. Blind spots, fuzzy vision	1	2	3	4	5	6

APPENDIX B

Instructions for Borg Rating of Perceived Exertion (RPE) Scale

While performing the VO₂max test and the 80% max test, your rate of perceived exertion will be measured. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

The rating scale will be placed straight ahead of you during the test at eye level. It ranges from 6 to 20, where 6 means “no exertion at all”, and 20 means “maximal exertion”. Choose the number from the scale that best describes your level of exertion.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people. Look at the scale and the expressions and then with the researchers cues confirm the number that corresponds with your exertion.

- 6 No exertion at all
- 7
- Extremely light
- 8
- 9 Very light
- 10
- 11 Light
- 12
- 13 Somewhat hard
- 14
- 15 Hard (heavy)
- 16
- 17 Very hard
- 18
- 19 Extremely hard
- 20 Maximal exertion

9 Corresponds to a “very light” exercise. For a healthy person, it is like walking slowly at his or her own pace for a few minutes

13 Corresponds with “somewhat hard”, but still feels OK to continue.

17 Corresponds with “very hard” which is very strenuous. A healthy person can still go on, but he or she really had to push him-herself. It feels very heavy, and the person is very tired.

19 Corresponds with an “extremely hard” exercise level. For most people this is the most strenuous exercise they have every experienced.

Borg RPE Scale

© Gunner Borg, 1970, 1985, 1994, 1998

APPENDIX C

Instructions for VO2 Max Test

This test is a measure of your oxygen uptake during maximal aerobic exercise. It reflects the capacity of heart, lungs and blood to transport oxygen to the working muscles and the utilization of oxygen by the muscles during exercise.

You will be wearing a heart rate monitor around your chest and a face mask to attach a breathing device to measure oxygen flow. This device is connected to a machine to analyze data with an umbilical chord.

There are three commands that you will be using.

1. Thumbs up = YES, I AM READY
2. Thumbs down = NO, I AM NOT READY
3. Hand at your throat = STOP TERMINATE TEST

There will be a total of 5 people assisting in this test. I will be located besides you. My primary job is to make sure you are ok at all times during the test. I will be the only person communicating with you. All assistants are aware of the commands, and if **anytime they see you wanting to terminate the test they will be available to do so.**

Assistant 1 will be writing down data

Assistant 2 will be standing by computer system to make sure it is working at all times

Assistant 3 will be standing behind treadmill for safety measures

Assistant 4 will be holding umbilical cord during test for your comfort

The protocol is as follows:

Min 1-5 is your warm up at your chosen pace and at 1.0 incline.

At the start of the test your speed will be 7.0 for women and 8.0 for men.

This will stay steady through the entire test.

Each minute there after, your incline will increase by 2% until you reach your maximum capacity. When you enter the red zone (16 on the chart) we will increase your incline by 1% instead of 2% each minute.

At the end of each minute, your Heart Rate and Rate of Perceived Exertion will be recorded. We will be using the Borg Rating of Perceived Exertion Scale which has been established to indicate how hard you believe you are working. I will hold the chart in front of you and you will point to what number you feel you are working at. This is a very important part of the test. I will then ask you if you are ready to increase the incline. You will respond with a thumbs up or a thumbs down.

AT THIS TIME DO YOU HAVE ANY QUESTIONS?

APPENDIX C1
VO₂Max Protocol

RESTING HR:				
Incline %	Speed MPH	Time Min	HR BPM	RPE
1.0	Your choice	1-5 Min	WARM	UP
3.0	8	1 Min		
5.0	8	1 Min		
7.0	8	1 Min		
9.0	8	1 Min		
11.0	8	1 Min		
13.0	8	1 Min		
15.0	8	1 Min		
16.0	8	1 Min		
17.0	8	1 Min		
18.0	8	1 Min		
19.0	8	1 Min		
20.0	8	1 Min		
MAX HR:				
COOL DOWN	Your choice	5 Min		

Women's Protocol is the same except speed is at 7.0
This information will then be used to find 80% of maximum effort.

APPENDIX D

Detailed Print out of a portion of VO_{2max} Test Results

Time (min)	Speed (MPH)	Grade (%)	VO2 (mL/kg/min)	VO2 (mL/min)	VCO2 (mL/min)	RER	RR (br/min)	Vt BTPS (mL)	VE BTPS (L/min)
0:07	0	0	21.2	1443	1025	0.71	25	1176	29
0:08	0	0	31.5	2145	1436	0.67	34	1309	44.4
0:10	0	0	31.3	2127	1412	0.66	36	1211	43.3
0:12	0	0	26.9	1832	1267	0.69	31	1208	37.7
0:14	0	0	28.7	1953	1324	0.68	34	1146	38.6
0:16	0	0	29.1	1979	1321	0.67	34	1133	38.2
0:18	0	0	27.5	1874	1240	0.66	30	1167	34.8
0:20	0	0	27.5	1873	1240	0.66	30	1167	34.8
0:22	0	0	27.9	1898	1225	0.65	28	1225	33.9
0:24	0	0	28.1	1911	1228	0.64	28	1187	33.5
0:26	0	0	32.3	2199	1412	0.64	28	1403	38.8
0:28	0	0	32.7	2226	1461	0.66	27	1465	40.2
0:29	0	0	33.4	2273	1512	0.67	28	1485	42.1
0:32	0	0	34.5	2350	1603	0.68	30	1478	44.4
0:34	0	0	36.3	2470	1648	0.67	30	1538	46.1
0:35	0	0	37.9	2581	1769	0.69	33	1546	50.6
0:37	0	0	37.3	2535	1760	0.69	36	1376	49.7
0:40	0	0	34.4	2337	1652	0.71	30	1472	44.3
0:43	0	0	35.4	2406	1692	0.7	30	1492	45.2
0:46	0	0	37	2519	1877	0.75	26	1924	50.9
0:49	0	0	37	2520	1877	0.74	26	1924	50.9
0:50	0	0	38.5	2621	1981	0.76	29	1848	53.7
0:53	0	0	40.3	2741	2115	0.77	25	2234	56.6
0:54	0	0	38.8	2638	2056	0.78	25	2190	55.8
0:55	0	0	40.5	2755	2181	0.79	30	2009	61.1
0:58	0	0	34.1	2320	1785	0.77	31	1616	49.3
1:02	0	0	35.4	2406	1775	0.74	29	1622	47.3

APPENDIX E

Adult Informed Consent

State University of New York College at Cortland

The research in which you have been asked to participate is being conducted by Kimberly Harrison of the Exercise Science Department at SUNY Cortland. We request your informed consent to be a participant in the project described below. *Please feel free to ask about the project, its procedures, or objectives.*

Information and Procedures of This Research Study:

The purpose of this study is to investigate athletic performance and perceived exertion in congruence with the menstrual cycle. Your maximal effort and perceived exertion will be measured by a VO_{2max} test. This test poses no physical harm to you, may create slight discomfort and will only last a maximum of 10 minutes. You will be asked to confirm how hard you believe you are working during this graded exercise test, and run until maximum capacity. A series of 4 sub-maximal tests will occur in weekly sequence to complete the data collection which will require less exertion than the maximal test. Menstrual charting will take place and instruction on how to chart this information will be provided.

Before agreeing to participate you should know that:

A. Freedom to Withdraw

You are free to withdraw consent at any time without penalty. Even if you begin answering questions and realize for any reason that you do not want to continue, you are free to withdraw from the study. Additionally, you may ask the researcher to destroy any responses you may have given.

B. Protection of Participants' Responses

Your responses are strictly confidential. Only the presiding faculty member and research assistants will have access to your responses. **You will use the last 4-digits of your ID number throughout the course of this study. Only your ID number will be connected with your responses. Your name will not be connected with your responses. All responses are kept in a locked cabinet in the office of the chair of the thesis committee and any identifying information will be destroyed at the end of the study.**

C. Length of Participation and Remuneration

The completed study will have a total of 5 testing sessions that will take no longer than 15 minutes total. The first test will be a VO_{2max} Test, and then 4 proceeding tests will be at 85% max. A sixth testing session will take place with only a few individuals and be another VO_{2max} to ensure there is no selection maturation. There will be no remuneration for participating in this study.

D. Full Disclosure

In some experiments, it may be necessary to withhold certain information in the interests of the particular research. Should this occur, at the end of the experiment all individuals will be furnished with a full explanation of the purpose and design of the project.

E. Risks Expected

Although you should not experience any discomforts or risk due to participating in this study, in rare cases individuals may learn something about themselves that might make them uncomfortable. In the event this

occurs, please discuss this with the person conducting the study. In the event this is not sufficient, please contact the Counseling Center at SUNY Cortland at 607-753-4728.

F. Benefits Expected

From participating in this study you should expect to come to a greater understanding of the way in which research is conducted. Your participation should greatly enhance your understanding of research design and how scientists answer theoretical and practical research questions.

G. Contact Information

If you have any questions concerning the purpose or results of this study, you may contact Kimberly Harrison at 607-342-3367 or e-mail her at kimpharrison@hotmail.com. **For questions about research or research subjects' rights, contact Amy Henderson-Harr, IRB Designee, Office of Research and Sponsored Programs, SUNY Cortland, at (607) 753-2511.**

I _____ have read the description of the project for which this consent is requested, understand my rights, and I _____ hereby consent to participate in this study.
(print name)

Signature

Date _____

APPENDIX F
Individualized Data Collection Chart
80% Sub Maximal Testing Week 1

# 1 VO2 max= 63 80%= 7:10 8.4 Actual 80% 50%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>12</td><td>163</td><td>3:35</td></tr><tr><td>1</td><td>12</td><td>163</td><td>7:10</td></tr><tr><td>1.5</td><td>12.5</td><td>169</td><td>10:45</td></tr><tr><td>2</td><td>13</td><td>170</td><td>14:18</td></tr></table>	Distance	RPE	HR	Splits	0.5	12	163	3:35	1	12	163	7:10	1.5	12.5	169	10:45	2	13	170	14:18	Weight 105	AGE 22	max hr 198	80% 158.4 159.2 160 159.2 161.6 159.2
Distance	RPE	HR	Splits																						
0.5	12	163	3:35																						
1	12	163	7:10																						
1.5	12.5	169	10:45																						
2	13	170	14:18																						
# 2 VO2 Max= 71.6 80 % = 6:15 9.6 Actual 80% = 57%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>12</td><td>171</td><td>3:07</td></tr><tr><td>1</td><td>13</td><td>173</td><td>6:15</td></tr><tr><td>1.5</td><td>13</td><td>172</td><td>9:22</td></tr><tr><td>2</td><td>14</td><td>173</td><td>12:30</td></tr></table>	Distance	RPE	HR	Splits	0.5	12	171	3:07	1	13	173	6:15	1.5	13	172	9:22	2	14	173	12:30	Weight 152	21	199	
Distance	RPE	HR	Splits																						
0.5	12	171	3:07																						
1	13	173	6:15																						
1.5	13	172	9:22																						
2	14	173	12:30																						
# 3 VO2 max = 68.4 80%= 6:34 9.1 Actual 80%= 54%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>13</td><td>175</td><td>3:17</td></tr><tr><td>1</td><td>14</td><td>178</td><td>6:34</td></tr><tr><td>1.5</td><td>14</td><td>175</td><td>9:51</td></tr><tr><td>2</td><td>14</td><td>175</td><td>13:12</td></tr></table>	Distance	RPE	HR	Splits	0.5	13	175	3:17	1	14	178	6:34	1.5	14	175	9:51	2	14	175	13:12	Weight 155	20	200	
Distance	RPE	HR	Splits																						
0.5	13	175	3:17																						
1	14	178	6:34																						
1.5	14	175	9:51																						
2	14	175	13:12																						
# 4 VO2 Max= 55.3 80% = 8:15 7.3 Actual 80%= 44%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>10</td><td>178</td><td>4:07</td></tr><tr><td>1</td><td>10</td><td>180</td><td>8:15</td></tr><tr><td>1.5</td><td>10</td><td>182</td><td>12:22</td></tr><tr><td>2</td><td>10.5</td><td>182</td><td>16:26</td></tr></table>	Distance	RPE	HR	Splits	0.5	10	178	4:07	1	10	180	8:15	1.5	10	182	12:22	2	10.5	182	16:26	Weight 101	21	199	
Distance	RPE	HR	Splits																						
0.5	10	178	4:07																						
1	10	180	8:15																						
1.5	10	182	12:22																						
2	10.5	182	16:26																						
# 5 VO2 Max= 79.6 80%= 5:50 10.2 @ 2% Actual 80%= 63%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>12</td><td>174</td><td>2:55</td></tr><tr><td>1</td><td>13</td><td>178</td><td>5:50</td></tr><tr><td>1.5</td><td>14</td><td>178</td><td>8:05</td></tr><tr><td>2</td><td>15</td><td>178</td><td>11:00</td></tr></table>	Distance	RPE	HR	Splits	0.5	12	174	2:55	1	13	178	5:50	1.5	14	178	8:05	2	15	178	11:00	Weight 123	18	202	
Distance	RPE	HR	Splits																						
0.5	12	174	2:55																						
1	13	178	5:50																						
1.5	14	178	8:05																						
2	15	178	11:00																						
#6 VO2 Max= 51.2 80%= 8:59 6.7 Actual 80%= 40%	<table><tr><th>Distance</th><th>RPE</th><th>HR</th><th>Splits</th></tr><tr><td>0.5</td><td>11</td><td>157</td><td>4:29</td></tr><tr><td>1</td><td>12</td><td>162</td><td>8:59</td></tr><tr><td>1.5</td><td>12</td><td>163</td><td>13:28</td></tr><tr><td>2</td><td>12</td><td>163</td><td>17:54</td></tr></table>	Distance	RPE	HR	Splits	0.5	11	157	4:29	1	12	162	8:59	1.5	12	163	13:28	2	12	163	17:54	Weight 136	19	199	
Distance	RPE	HR	Splits																						
0.5	11	157	4:29																						
1	12	162	8:59																						
1.5	12	163	13:28																						
2	12	163	17:54																						

Room Temp	25 C	77 F
BP	730 mg	

APPENDIX G

80% Conversion Spreadsheet to acquire pace on treadmill

VO2 Max	58.1	ml/kg/min
% of VO2 Max	80	
Grade (%)	1	%
Speed (meters/min)	205.64593	
Speed (miles/min)	0.1278098	
Speed (min/mile)	7.8241275	
Speed (min/mile)	7 : 49	

	VO2 Max	Pace @ 1%
	63	7:10
	55.3	8:15
	51.2	8:59
	71.6	6:15
	79.6	5:35
	68.4	6:34
	46.6	9:57
	50	9:03
	53.4	8:34
	58.1	7:49

Speed (meters/min) = ((B2*(B3/100)-3.5)/ (0.2(0.9*(B4/100))))

Speed (miles/min) =B5/1609

Speed (min/mile) =1/B6

APPENDIX H

Instructions for Menstrual Charting

You will be required to take your basal body temperature each morning at the same time. It is very important that you are consistent with the time you take your temperature, or the results of the study may be compromised. This data will help indicate what phase of the menstrual cycle you are in.

Your **Basal body temperature** is the body temperature measured immediately after awakening and before any physical activity has been undertaken. That means that you take your temperature before you stand up, go to the bathroom, take a sip of water, brush your teeth, or even talk on the phone. Your routine should consist of the alarm going off and putting the thermometer in your mouth. Your body reaches its basal body temperature after 4 hours of sleep. If you find yourself a very restless sleeper, take your temperature after your longest period of sleeping.

To be accurate, the temperature must be taken at the same time every day. If you wake up at 8 during the week, it means that you must take your temperature at 8 am on the weekends as well. You don't have to fully awaken; just take your temperature and then go back to sleep.

There are factors that need to be controlled for the best you can while involved in this study to get accurate temperature readings.

- If you are of age and have been drinking **alcohol** during the evening, your BBT may be high the next morning. Alcohol will actually disturb your sleep so that you sleep less deeply and may cause you to wake up a few hours later. And if you've been up late the night before your BBT may be raised the next morning, which makes for a confusing temperature reading the next day.
- **Stress, anxiety, illness, and infection** also can raise your BBT temporarily.

You will be charting your temperature throughout the entire study. Attached your blank copy to record your temperature and control for as many factors as possible.

A digital thermometer will be provided to you for the duration of the project. An instruction manual will be included in packaging. If batteries are needed, they will be provided as well. You must place the thermometer under your tongue, before getting out of bed, allow it to read temperature, and when it beeps, read temperature and chart on graph.

APPENDIX H1

Menstrual Charting

[illegible]