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Menstrual Cycle and Training Effects on Physical Work Capacity

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MENSTRUAL CYCLE AND TRAINING EFFECTS ON PHYSICAL WORK CAPACITY

by

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ABSTRACT

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ON PHYSICAL WORK CAPACITY

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The present study examined the effects of women's menstrual cycles on their capacity to perform physical work. Most of the studies of the effects of the menstrual cycle on performance have reported no differences; however, the lack of demonstrated effects could be attributed, in part, to the inability of experimenters to specify the critical phases of the menstrual cycle. The length of the menstrual cycle (between and within subjects) is more variable than commonly expected and this fact, in combination with the inadequacy of current predictors of phase onset, tends to produce error variability in the menstrual cycle independent variable. The present study attempted to overcome the phase specification problem by assessing work capacity of females on alternate days throughout two complete menstrual cycles, thereby avoiding the problem of a priori phase prediction. Physical work capacity was measured in this study by requiring twelve female subjects to cycle to exhaustion on a bicycle ergometer. The results indicated that performance was not affected by the menstrual cycle. A significant training effect was noted

during the first menstrual cycle (i.e., performance increased during the cycle); however, performance during the second cycle was lower than during the first cycle. The failure to demonstrate menstrual effects was interpreted as further support for the position that the menstrual cycle does not affect performance. Several hypotheses were offered to account for the training effects.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

The increased and more varied employment of women in today's work force emphasizes the need for better specifications of woman's work capacity. The increasing availability to women of traditionally male work positions in numerous commercial, industrial, and governmental organizations (as mandated by law and court rulings regarding non-discriminatory hiring practices) makes very important the identification of job-relevant differences between women and men. This is particularly true in the domains of physical abilities and skills, wherein men and women are believed to be most different.

Thus, the specification of woman's physical capabilities relative to men's, and the documentation of the relative assets and limitations of women with respect to physical work should be of considerable relevance to the information needs of the present. For example, an assessment (measurement and evaluation) of the physical performances of women appears quite relevant, especially since centuries of folklore suggest that such effects exist and are universally detrimental while the relevant scientific literature generally provides little or no objective data to support or deny this suggestion.

The present study was designed to measure the extent to which the menstrual cycle affects certain physical performances of women. In assessing physical performance, physical work capacity is often used as a physical fitness index or general physical performance measure; employing a measure of all-out performance allows for maximal probability that any menstrual related performance decrement, if it exists, will be evident. In assessing the effects of the menstrual cycle, however, one needs also to be aware of and control for other factors which may concomitantly affect physical work capacity. In addition, it is necessary to consider the problems inherent in employing the menstrual cycle as a variable. Therefore, one needs to examine physical work capacity as a performance measure, factors known to influence physical work capacity, and the nature of the menstrual cycles as a variable, in order to begin to assess physical work capacity in women.

Physical Work Capacity

Astrand and Rodahl (1977) suggested that three factors are responsible for physical performance: (1) capacity for energy output which is measured with aerobic and anaerobic capacities, (2) neuromuscular functions such as strength and technique, and (3) psychological factors such as motivation and tactics. The major determinants of these factors in any individual include genetic endowment, environmental modifiers, and training. Astrand and Rodahl asserted that it is impossible to present a single formula that takes into account all of a person's maximal capacity since capacity measurements are a function of measurement situations and the demands they produce.

Energy output is determined by both anaerobic and aerobic processes. At rest and during moderate exercise, sufficient oxygen is present in the muscle tissue so that energy production is primarily aerobic. At the onset of exhaustive exercise, however, oxygen stores are quickly depleted, and until the aerobic process can be speeded up to meet the demands, anaerobic breakdown of carbohydrates supplies most of the required energy. Anaerobic processes provide quick release of relatively small amounts of energy along with a waste product, lactic acid, which causes muscle fatigue if allowed to accumulate. Continued production of anaerobic energy would eventually deplete the supply of energy material, forcing exercise to terminate unless oxygen were delivered to the muscle tissue.

Aerobic processes take over proportionately more energy production with continuation of moderately strenuous exercise. Thus, corresponding increases in oxygen intake and heart rate result in more oxygen being delivered to the working muscles. Aerobic processes produce almost 20 times the amount of energy as do aerobic from the same amount of energy material, providing much more efficient energy. The presence of sufficient oxygen in the working muscle prevents the buildup of lactic acid that occurs during anaerobic energy production, and allows for exercise to be maintained at a "steady state." The ability to maintain this "steady state" is dependent upon exercise intensity; for example, exercise lasting more than a few minutes must be less than 50% of a person's maximal capacity in order to maintain a "steady state."

As exercise continues beyond this "steady state," aerobic processes are no longer sufficiently able to prevent lactic acid buildup, and continued exercise at that level will result in reaching aerobic capacity. Exercise intensity must either be reduced to accomodate one's aerobic capacity, or fatigue will cause exercise to stop. The rapid labored breathing that occurs following exhaustive exercise is the result of this muscle oxygen deficiency or oxygen debt and the heavy breathing during recovery contributes to payment of this debt (see Tuttle & Schottelius, 1961; Astrand & Rodahl, 1977).

Different types of exercise will reflect different proportions of aerobic and anaerobic energy. Performance up to the first two minutes of maximal exercise is primarily of an anaerobic nature. Sprint races, wherein quick bursts of energy are required, are examples of this. Prolonged performance, requiring endurance beyond two minutes generally reflects aerobic processes--long distance running is an example of this.

Exercise physiologists suggest that capacity for enduring performance plays a major role in overall performance. Wilmore (1977) suggests that even though a football team's performance consists mostly of anaerobic spurts of energy, endurance may be a major factor in the team's ability to continue these bursts of energy. The same is true for the non-athlete; Astrand (1960) suggests that housewives will be able to perform household chores easier when their endurance (aerobic capacity) is greater.

Aerobic capacity is thought by many to be the most fundamental physiological factor determining work capacity (Montoye, 1970; Wilmore, 1977; Astrand & Rodahl, 1977). Oxygen uptake ($\dot{V}O_2$), or the amount of oxygen consumed during exercise, is considered the most valid index of aerobic capacity (Astrand & Rodahl, 1977). Oxygen uptake increases linearly as work load increases up to a maximum point where $\dot{V}O_2$ levels off; this maximal level, $\dot{V}O_{2\ max}$, is considered the most objective and reliable criterion of work capacity.

Another index of aerobic capacity, more easily obtained than $\dot{V}O_2$, is heart rate, which also increases linearly with work intensity (Wilmore & Norton, 1974). Heart rate reaches its maximal level (HR_{max}) slightly sooner than does $\dot{V}O_2$, and, therefore, HR_{max} is not as accurate an indicator of the exhaustive level. However, heart rate, when recorded during exercise as work intensity increases, is an excellent indicator of $\dot{V}O_2$ (Wilmore, 1977). Astrand (1960) has devised tables that employ submaximal heart rate, work intensity, and age to predict $\dot{V}O_{2\ max}$. Although she admits that prediction error may be as great as $\pm$ 15% using untrained subjects, she suggests that heart rate is a valid measure for within-individual comparisons.

In measuring aerobic capacity, performance is generally examined under laboratory conditions. Although fitness test batteries are sometimes used, there are disadvantages to these techniques. First, correlations of performance on a fitness test and $\dot{V}O_{2\ max}$ on a laboratory task are low (Montoye, 1970); and, secondly, in order to determine the functional relation between exercise as a stimulus and the resulting adaptation of the body, one needs to be able to measure both the exercise loading and? the response (Astrand & Rodahl, 1977). The fitness tests measure only the response, and not work load.

There are three ways that work capacity is typically measured in the laboratory: the Step test, the motor-driven treadmill, and the bicycle ergometer (Astrand & Rodahl, 1977; Wilmore, 1977). The Step test consists of having the individual step up and down on a bench of standard height at a fixed rate of stepping with the performance measure being rate of heart rate recovery following exercise (see Montoye, 1970). Although the Step test is easy to administer and the equipment is inexpensive and portable, work load is greatly dependent upon the weight of the subject, and direct variation of work load is limited (Astrand & Rodahl, 1977).

The treadmill is a device in which a motor driven belt travels at a set speed and the individual walks, jogs, or runs in the opposite direction of the moving belt in an attempt to remain in the same relative position (see Astrand & Rodahl, 1977). The treatmill seems to provide the highest maximum physiological responses to exercise, and it maintains a constant work rate during exercise. Disadvantages are, however, that work load is somewhat dependent on the weight of the subject, the equipment is quite expensive, and, with untrained subjects, there is a danger of the person falling or being unable to dismount safely when exhausted (Astrand & Rodahl, 1977; Wilmore, 1977).

The bicycle ergometer is a stationary bicycle designed so that pedal frequency may be either dependent or independent of work load. In the work load-independent type, a certain work level is set, and the pedal resistance increases as the pedaling frequency decreases; conversely, the resistance decreases as the pedaling frequency increases. The bicycle ergometer has the advantage of being relatively easy to administer, safe for the untrained subjects at exhaustive levels (e.g., it is easier to stop pedaling the bicycle when exhausted than to safely dismount the moving treadmill), and suitable for recording physiological responses during exercise. In addition, work load can be defined accurately, and, because the subject is seated on the bicycle, work load is relatively independent of body weight. A disadvantage is that maximal $\dot{V}O_2$ $_{max}$ on a bicycle ergometer is somewhat lower than the treadmill, but this is thought to be due to local fatigue of the leg muscles and perhaps a cause for the individual to stop exercising before overall exhaustion is actually reached. Heart rate has been found to reach approximately equal maximal values with the treadmill and the bicycle ergometer (Astrand & Rodahl, 1977; Ekblom & Goldbarg, 1971).

Since measuring work capacity by recording physiological response to exercise is difficult in field situations, subjective estimates of the physiological cost of exercise have been examined to determine their relation to actual physiological cost. Borg (1962) has reported that psychophysical methods of measuring subjective work load are reliable and highly correlated (r = .85) with objective heart rate indicators. In Borg's technique a Rating-of-Perceived-Exertion Scale (RPE) that ranges from 6 to 20 is used; the individual is asked to rate his current level of exertion within that range. It is thought that RPE is determined by at least two factors: a local factor or feeling of strain in specific muscles, and a central factor of perceived cardiovascular strain.

Factors Affecting Work Capacity

Although maximal heart rate and $\dot{V}O_{2\,max}$ are considered indicators of work capacity, they are also subject to change due to certain other factors. Astrand and Rodahl (1977) suggest that $\dot{V}O_2$ is affected by the nature of work (duration, intensity, rhythm, technique, and position), somatic factors (sex and age, body dimensions, and health), psychic factors (attitude and motivation), environment (altitude, high gas pressure, heat, cold, noise, and air pollution), and training adaptation. When measuring work capacity, one needs to take into account the possible effects of these factors.

Training effects on work capacity can be demonstrated even though they may be limited by genetic endowment. Wilmore (1977) illustrated the type of change that results from training by comparing a sedentary-normal individual, before and after training, to a world-class endurance runner of the same age. The sedentary-normal "person" was hypothetical, as was the training program which consisted of jogging 3-4 times per week, 30 minutes per day at 60% of $\dot{V}O_2$ $_{max}$. The hypothetical results are shown in Table 1. During exercise, the better conditioned individual performs the same level of work at a lower heart rate.

Table 1

Effects of Training on Physiological

Indices of Work Capacity

	Hypothetical Sedentary Pre-training	Hypothetical Normal Post-training	World-Class Endurance Runner
$\dot{V}O_2$ $_{max}$ (ml/kg x min)	40.5	49.8	76.7
HR $_{rest}$ (beats/min)	71.0	59.0	36.0
HR $_{max}$ (beats/min)	185.0	183.0	174.0

(Adapted from J. H. Wilmore, 1977, p. 62)

Implicit to the hypothetical data of Table 1 is the effect of the initial fitness level on training. Had data for the world-class endurance runner been included before and after the same training program, his $\dot{V}O_2$ $_{max}$ and HR would have changed little, certainly not as substantially as with the sedentary-normal individual. An empirical example of the effects of the "pre-condition" factor has been presented by others in an examination of the performances of both conditioned and sedentary subjects during a 20-day bed rest followed by a 50-day training period. After the 20-day bed rest, the increase in $\dot{V}O_{2\,max}$ for the sedentary subjects was significantly greater than for the conditioned subjects (Saltin, Blomqvist, Mitchell, Johnson, Wildenthal, & Chapman, 1968).

Aerobic capacity is also affected by age. $\dot{V}O_{2\,max}$ decreases with age, apparently as a function of decreasing heart rate and increasing inactivity (Astrand & Rodahl, 1977). Astrand and Christensen (1964) report that HR_{max} decreases with age 25 to 65. This means that the older individual will perform the same level of work at a lower heart rate than the younger person of comparable fitness. On the other hand, the older individual has a lower HR_{max} (Wilmore, 1977).

Maximal aerobic capacity is also related to the sex of the individual (Astrand & Rodahl, 1977). Until puberty, males and females do not differ in aerobic capacity, but after puberty females have a maximal capacity that is on the average 70 to 75% of that for males. Much of this difference is due to the differences in the size or weight of males and females. Thus, aerobic capacity is often expressed relative to body weight thereby allowing more equitable comparisons (Wilmore, 1977). When $\dot{V}O_{2\,max}$ is expressed in terms of an athlete's lean body weight rather than absolute body weight (since males have proportionately more muscle tissue than females), the differences due to sex almost completely disappear. There are large individual differences, however, and Hermanson and Anderson (1965) reported that athletic women had average maximal aerobic capacities that were 25% greater than sedentary men. It is not clear to what extent the difference in aerobic capacity between persons of different sex is due to differences in biological as contrasted with socialization variables.

Menstrual Cycle Effects on Performance

In a review of previous studies investigating the effect of the menstrual cycle on behavior, Sommer reported that studies employing non-objective response measures based on self report and social behavior generally indicate a decrement in behavior as a result of the menstrual cycle. In contrast, those studies using objective behavioral measures have found, for the most part, no behavioral effect due to the menstrual cycle (Sommer, 1973). The studies presented below are primarily concerned with behavior of a physical nature, and the areas investigated are women's athletic performance, psychomotor performance, activity levels, muscular strength, and cardiovascular endurance.

Women Athletes. The preponderance of evidence concerning the effect of the menstrual cycle on physical performance has been determined through interviewing or examining the performance of women athletes. Ryan (1975) presented a review of results from numerous studies on the performance of sportswomen from different countries. Varying percentages of women showed either better performance (13 to 29%), worse performance (8 to 40%), or no change (42 to 63%) during menstruation as contrasted with other phases of the cycle. Conclusions were drawn suggesting that the poorest performance may be expected during premenstruum and the first two days of menstruation, and best performance during the immediate postmenstrual period and up to the 15th day of the cycle. No statistical information was included in Ryan's summary, which therefore failed to provide precise data for the conclusions reached.

Psychomotor Performance. Studies of psychomotor performance have generally failed to show conclusively that there are cycle effects on performance. Pierson and Lockhart (1963) found no difference in simple reaction time (RT) and arm movement time when examined on Days 2, 8, 18, and 26 of the menstrual cycle. Loucks and Thompson (1968) examined simple RT performance on Days 1, 3, 6, and 20 and found no significant difference on those days. Kopell, Lunde, Clayton, and Moos (1969) examined GSR potential, simple RT, two-flash threshold, and time estimation on Days 3, 14, 24, and 28 of the cycle; only time estimation showed any significant phase differences, with a given time interval being assigned a longer value during the premenstrual phase--a part of the cycle which they did not clearly define.

Zimmerman and Parlee (1973) examined arm-hand steadiness, RT for an auditory stimulus, simple RT, choice RT, time estimation, and the digit-symbol subtest of the Wechsler Adult Intelligence Scale during the menstrual (Days 1-4), the follicular (Days 6-12), the luteal (Days 17-21), and the premenstrual (Days 23-27) phases. Only the arm-hand steadiness task showed a significant relation to phase of the menstrual cycle, with performance better during the luteal than the premenstrual. Sommer (1971) examined performance on aiming, flexibility of closure, number facility, speed of closure, and visualization tasks (subtests of the Repetitive Psychometric Measures described in Moran & Mefferd, 1959) on Days 2, 6, 10, 14, 18, 22, and 27 of the menstrual cycle (with adjustments for shorter or longer cycles; no significant difference effects due to the menstrual cycle were reported.

Activity Levels. Morris and Udry (1970) recorded activity levels from a pedometer worn by 34 subjects over periods of from one to three menstrual cycles. A significant increase of activity at mid-cycle for menstruation and premenstruation (Days 2 and 27) were reported. Stenn and Klinge (1972) examined arm-movement activity in seven females for a total of 17 menstrual cycles. Activity was examined for four phases of the menstrual cycle: five days prior to menstruation, five days after menstrual onset, five days prior to thermal shift (approximately ovulation), and five days after thermal shift. There was no difference in activity level when the seven subjects were compared as a group to that of male control subjects, but when the data were analyzed for individual subjects, two of the subjects showed a significant phase effect with the greatest activity occurring five days prior to menstrual onset.

Muscle Strength. Snook and Ciriello (1974) examined lifting work load differences between males and females, and in the process they looked at the effect of menstruation on lifting performance. Of the 15 women examined, who were employed in an industrial setting, seven of them were menstruating during one or more of the test sessions, and of these seven, one woman showed a performance decrement of 17%. Lifting performance was also examined in 16 housewives, 12 of whom were menstruating during testing; four showed a performance decrement.

Petrofsky, LeDonne, Rhinehart, and Lind (1976) examined maximum grip strength and grip-strength endurance using a hand-held dynamometer for five subjects, two of whom were control subjects taking birth control pills. Results showed no difference in the maximum strength measure for all five subjects. However, the three normally cycling subjects showed endurance differences during the cycle, with their peak performances occurring during the mid-ovulatory phase, and their lowest performances during mid-luteal phase. The two control subjects showed no endurance differences throughout the cycle.

Cardiovascular Endurance. Doolittle and Lipson (1971) examined performance for eight females on the 1.5 mile run-walk. Subjects were tested nine or ten times throughout a 35-day period, a period sufficiently long to span at least one menstrual cycle for each subject. No performance differences were found throughout the menstrual cycle, and there were no significant training effects. Sloan (1961) examined the performances of women at various times over a period of nine months, but found no differences between menstruating and non-menstruating women. Garlick and Bernauer (1968) found no significant difference in submaximal performances on a bicycle ergometer for 18 women on Days 1 and 14 of their menstrual cycle.

Summary. A failure to find significant differences is not sufficient to conclude that no real difference exists in the variable examined. However, the preponderance of studies cited above which find no differences in performance as a function of the menstrual cycle, lends support for the conclusion that the menstrual cycle has no effect on performance. No significant menstrual differences were found for simple RT (four studies), GSR potential, two-flash threshold, choice RT, auditory RT, time estimation, digit task, aiming, flexibility of closure, number facility, speed of closure, visualization, maximum grip strength, 1.5 mile run-walk, modified Harvard Step test, and submaximal performance on a bicycle ergometer.

In contrast, significant menstrual differences were found only in time estimation, arm-hand steadiness (conflicting with the above lack of significance), activity level (two studies), muscular strength, and grip strength endurance. It is difficult to conclude that the menstrual cycle affects performance on the basis of these few activities, however, and this is compounded by the fact that the studies lack consistency in the manner in which their results were examined. Although group performance was poorer during the premenstrual phase for time estimation and arm-hand steadiness tasks, menstrual effects in two activity level studies and two strength studies were found only after examining individual performances. This suggests that a menstrual effect may not be powerful enough to affect women differentially and menstrual effects become evident only through examining individual differences.

The Menstrual Cycle as a Variable

The studies cited above serve to illustrate not only the findings, but also some of the difficulties inherent to the use of the menstrual cycle as an independent variable. The most prominent problems are related to cycle length, phase definition, and the selection of phases to be examined.

Cycle Length Variability. The menstrual cycle is highly variable both between and within individuals. Chiazze, Brayer, Maisco, Parker, and Duffy (1968) examined 30,655 menstrual cycles in 2,316 women and found that the mean cycle length was 28.1 days with a standard deviation of 3.95 days; the range of cycle lengths which included the middle 95% of the women was from 15 to 45 days duration. No age group had a 28-day cycle more than 16% of the time. However, Vollman (1977) has reported that the variability in cycle length is high in adolescents and declines steadily to a minimum for adult women between the ages of 35 to 39. In examining cycle lengths in first year nursing students, Hain, Linton, Eber, and Chapman (1970) found that 15% of the women had a difference of 14 days between their longest and shortest cycle.

Thus, a procedure based on testing a group of women at several points during a hypothetical 28-day cycle introduces potentially serious errors. If results are negative, it is virtually impossible to determine whether that is because the menstrual cycle has no effect on performance, or because the subjects were not tested at the indicated phases in their variable menstrual cycles.

In order to reduce the variability in cycle length, some studies eliminate from the experiment those persons who report having irregular menstrual cycles, thereby altering the population being studied, and precluding any proper generalizations of the results to the population of women as a whole. Phillips (1968) examined the effect of the menstrual cycle on physical performance, but data from the 25% of her subjects with "irregular" cycles were not analyzed (she did not define regular or irregular cycles). The non-significant results obtained by Phillips are really only for females with "regular" menstrual cycles.

Phase Definition and Selection. In addition to individual variations with respect to cycle length, there are also individual differences in the time that lapses between certain reference points in the cycle. For example, the menstrual phase may vary from 1 to 8 days, but has an average duration of 4 to 6 days (Chaffee & Greisheimer, 1974). The time between ovulation and the onset of menstruation, usually 14 days, is thought to vary the least of all the cycle's intervals, yet the variation among individuals have been reported to range from 9 to 17 days (Southam & Gonzaga, 1965). The preovulatory phase is even more variable with the variation thought to be positively related to variations in cycle length.

There is also some difficulty associated with measures used to determine the point in time at which ovulation occurs. For example, basal body temperature changes have been used for this purpose, but discrepancies of as much as four days have been reported between the "crucial" biphasic temperature shift and the actual occurrence of ovulation as established by endometrial and ovarian histology (Southam & Gonzaga, 1965).

A related problem is that of the method of obtaining the menstrual information for which test points are determined. In view of intra-individual differences from cycle to cycle, the use of retrospective self report information is of questionable value--i.e., the test points for the predicted menstrual cycle to be examined may not be predictable from the previous cycle. Sommers (1971) may be faulted on this point because in her study the testing cycle days (2, 6, 10, 14, 18, 22, and 27) are based on the reported dates of the subject's previous menstrual cycle, without any indication in the study that these cycle days were otherwise validated.

Finally, a problem exists in that some studies examine menstrual effects by measuring performance on specific days of the cycle while others separate the cycle into numerous phases and look for phase differences throughout the cycle. Although Phillips (1967) found no differences between mean phase performance and performance on the corresponding "critical" days for each phase, this does not eliminate the possibility that differences may actually exist. There is little agreement (as is evident in the research cited above) from study to study in the number of phases the cycle is broken into and/or the precise "critical" days employed.

Thus, the indications are clear: In order to determine whether the lack of a menstrual cycle effect is real or not, individual differences need to be considered. Each person's cycle length and reference points should be determined individually. Because subjects cannot be treated as having identical menstrual cycle lengths, and because it is difficult to pinpoint precisely where an individual is with respect to phases of her cycle, it seems necessary to measure subjects as frequently as possible in order to be able to draw valid conclusions about menstrual effects. If subjects who keep a menstrual record are tested on alternate days through at least one menstrual cycle, it is possible to use basal temperatures and menstrual information retrospectively to determine where the phases of the cycle did occur. Certainly, at the present time, such a retrospective identification of the cycle points and intervals appears likely to provide more nearly valid information than any known method of trying to predict the cycle beforehand.

Purposes of the Study

The specific purposes of the present investigation are to examine the effects of the menstrual cycle on work capacity as measured by exhaustive performance on a bicycle ergometer over two menstrual cycles, and the effects of the physical training or conditioning that results from regularly scheduled exhaustive performance. Performance was assessed on alternate days during each subject's two menstrual cycles, and menstrual records were secured retrospectively to determine individual menstrual phases. Since previous studies have generally failed to find performance differences due to the menstrual cycle, physiological and subjective measures were also obtained each session in addition to the performance measure. It was thought that these additional measures may provide some information concerning the relationship between the menstrual cycle and performance. Thus, heart rate response was monitored and Ratings-of-Perceived-Exertion were obtained during performance. The study was designed to answer the following questions:

(1) To what extent does the menstrual cycle affect work capacity, heart rate, and Ratings-of-Perceived-Exertion?

(2) To what extent does the training result in increased performance over the two menstrual cycles?

Method

Subjects

Thirteen untrained female students at Old Dominion University served as subjects. Each subject was determined to be physically capable of participating in strenuous physical exercise by a physician; three volunteers were not allowed to serve as subjects for medical reasons. Subjects were limited to those who experienced biphasic temperature shifts and who were not taking oral contraceptives or any regular medication. In order to encourage reliable attendance for repeated testing appointments, subjects were paid to participate in the study. Participation in the study was approved by the Old Dominion University Review Board for the Protection of Human Subjects. Data from one subject were not included in the analysis due to excessive absences (unrelated to her menstrual cycle). The age, height, weight, and menstrual cycle information for each of the 12 subjects who completed the study are given in Table 2.

Dependent Measures

Three indices of performance were obtained during each test session--an objective measure (work capacity), a physiological measure (heart rate), and a subjective measure (Ratings-of-Perceived-Exertion).

Objective Measure. The following terms are defined according to Astrand and Rodahl (1977, p. 450):

Table 2

Description of Subjects

Subject #	Age*	Weight* (lbs/kg)	Height* (in/cm)	Menstrual Cycle Length (3 cycles) Mean (days)	S.D.**
1	19	132.0/59.87	65.50/166.37	31.00	1.63
2	21	97.0/44.00	60.75/154.31	22.76	2.62
3	20	136.0/61.69	66.75/169.55	27.00	2.83
4	26	132.0/59.87	64.00/162.56	21.00	.82
5	20	121.5/55.11	61.25/155.58	26.33	.94
6	23	113.0/51.26	65.50/166.37	29.67	1.25
7	20	133.0/60.33	66.25/168.28	27.33	.47
8	26	109.5/49.67	64.50/163.83	31.00	.00
9	20	121.0/54.88	64.00/162.56	36.00	6.16
10	22	130.5/59.19	65.50/166.37	28.00	.82
11	21	152.0/68.95	66.25/168.28	26.67	3.68
12	21	131.0/59.42	62.00/157.48	30.00	3.56
Mean	21.58	124.96/56.68	64.35/163.45	28.06	4.64

* Baseline Day

** Standard Deviation

(1) Work is energy and is derived from the formula force times distance; the unit of measure is the kilopond meter (kpm)--one kilopond is the force acting on the mass of one kilogram at normal acceleration of gravity. One kilopond meter is the work produced by one kilopond through a distance of one meter.

(2) Power is the rate of work; the unit of measure is kpm/min.

(3) Work load is the burden placed on the worker.

(4) Work capacity is the maximum power output or total energy available to an individual.

Since the rate of work was held constant across subjects each test session, work capacity was expressed in terms of the total amount of work performed until exhaustion was reached.

Physiological Measure. To obtain a physiological indicator of work capacity, the subject's heart rate was measured during each performance session. Heart rate was obtained each session in terms of the individual's resting heart rate, during performance, and final heart rate.

Subjective Measure. Subjective estimates of muscular and cardiovascular exertion were obtained through the use of Borg's Ratings-of-Perceived-Exertion (RPE)--a 15 point scale extending from six to twenty. The rating scale was displayed vertically in front of the subject as follows:

Table 3

Rating Scale

LOCAL--CV
6
7 - very, very light
8
9 - very light
10
11 - fairly light
12
13 - somewhat heavy
14
15 - heavy
16
17 - very heavy
18
19 - very, very heavy
20

Subjects were told to use the scale as an equal-interval scale, rating perceived exertion with respect to two types of exertion, local muscular fatigue and cardiovascular fatigue (indicated at the top of the scale).

Apparatus

A Quinton instruments Uniwork bicycle ergometer (Model 844) was used for measuring work capacity. The ergometer produced a constant work load regardless of pedaling frequency by means of increasing pedal resistance as pedaling frequency decreased. The gauge which monitored pedaling rpm was not visible to the subject. Work load could be set by varying pedal resistance from 200 kpm to a maximum level of 2400 kpm in increments of 100 kpm. The bicycle seat height was adjustable.

Heart rate was monitored during exercise with a Narco Bio-Systems physiograph (E & M Instrument Company, Model PMP). Heart rate was determined by counting the number of beats that occurred during 20 second intervals as measured on the physiograph recording paper. Electrodes were attached to three locations on the subject's chest for measuring the EKG on the physiograph.

Procedure

Each subject met initially with the experimenter for a briefing on the experimental procedure. Subjects were told that the purpose of the experiment was to study the effect, if any, of the menstrual cycle on performance. They were told that the study would involve exercising on a stationary bicycle ergometer at increasing levels of difficulty until they were unable to sustain a minimum pedaling frequency; they would be required to bicycle in that manner on alternate days for two complete menstrual cycles or a minimum of eight weeks.

A menstrual history was then obtained from each subject to determine the nature of her menstrual cycle with respect to cycle length and cycle regularity. Subjects were asked to take their daily basal body oral temperature using a Becton-Dickinson Basal Temperature Thermometer provided by the experimenter. They were given instructions on the use of the thermometer and were given data sheets to record each reading. Additional information was recorded daily on the data sheets concerning onset and duration of menstruation and any other symptoms experienced during their menstrual cycles. Menstrual data sheets were returned to the experimenter weekly.

Subjects were then taken to the laboratory and shown the bicycle ergometer to demonstrate the procedure to be used throughout the study and to be given a practice session. Each subject was weighed on the laboratory scales and her weight was recorded. Subjects were asked not to eat, smoke, or exercise during the hour immediately preceding each subsequent testing session (and were questioned about these activities prior to bicycling each session). After the electrodes had been attached, resting heart rate was measured.

The subject then sat on the bicycle seat and put her feet on the pedals. The seat was adjusted so that her legs were almost completely stretched when the pedal was in its lowest position, and the adjustment recorded so that a constant seat height could be employed in all testing sessions during the study.

Subjects were shown the RPE scale which was posted directly in front of the bicycle. They were told that the scale was to be used to provide an estimate of their subjective fatigue during each minute of exercise. The two types of RPE were labeled on the chart: local (L) and cardiovascular (CV). They were told that periodically during the exercise session the experimenter would ask for their RPE, and they were to respond by first, assigning a number which corresponded to their local muscular fatigue (leg muscles) at that time, and second, assigning a number corresponding to their cardiovascular fatigue (breathing rate and heart rate).

Bicycle work load was turned off and the subject was instructed to begin pedaling. When she reached a pedaling rate of 70 rpm, she was told to try to maintain that speed. Heart rate was recorded and RPE's obtained during the last 20 seconds of that minute. Zero work load was presented for one minute, then work load was turned on, being set to 200 kpm for one minute, and was thereafter increased each subsequent minute in 100 kpm increments. Heart rate was monitored and RPE's obtained during the last 20 seconds of each minute of the practice session until the subject's heart rate reached 150 beats per minute, whereupon the session was terminated.

After the initial exercise practice, each subject was instructed to contact the experimenter by telephone at the onset of her next menstruation (Day 1) so that the initial session could be scheduled. An approximate date had previously been obtained from the menstrual history information. Subjects were instructed to wear gym clothing during each testing session (gym shorts, t-shirt, tennis shoes) and to wear the same type of clothing for each session. Prior to initial anticipated menstruation, each subject was examined by a physician and determined to be in good physical health.

An initial fitness level, or baseline, was recorded for each subject on the fourth day following onset of menstruation (Day 4), after which, subjects began the alternate day testing sessions. The procedure for the baseline session and each subsequent session during the study was identical to the initial practice session with the exception that the subject was told to continue pedaling until she reached exhaustion. Exhaustion was defined as that point during performance when the subject's pedaling speed dropped below 40 rpm. The length of time from the beginning of exercise until exhaustion, as defined, was recorded with a stopwatch.

After the baseline was measured, subjects began the exercise testing sessions at one of three different points in their menstrual cycles. These starting points were selected in an attempt to obtain three points in the cycle least likely to affect performance differentially. Each subject was randomly assigned to a starting day to begin exercise testing on either Day 6, 12, or 20 of the current menstrual cycle, with the restriction that an equal number of subjects be assigned to each day.

Once the subject began the exercise testing program, she was scheduled to return for testing every other day (including Saturday and Sunday) until she had completed testing for a time period consisting of two menstrual cycles from her testing starting day. Subjects were scheduled for testing between 8:30 AM and 5:00 PM and care was taken to reschedule each subject at the same time on successive testing days.

Each subject maintained a menstrual record that included basal body temperatures and time of menstrual onset. Temperatures were graphed for each menstrual cycle with the method recommended by Vollman (1977) as a means of maximizing the identification of the biphasic shift. Subjects recorded menstrual data for three complete menstrual cycles; two of these cycles spanned the testing period, but for different subjects the testing occurred on different intervals within those three cycles depending on whether the subject began the testing sessions on Day 6, 12, or 20 of the first cycle. The temperature graphs enabled the selection of critical events in a subject's individual menstrual cycle. For example, ovulation was determined by examining the biphasic shift in each cycle.

Results

The data of the 12 subjects who completed all aspects of the study were analyzed for each of the dependent variables. A total of nine dependent variables were selected for analysis. To assess the effects of the menstrual cycle and training on capacity for work, the dependent variable selected was "work performed," which was computed as the actual work load imposed (kpm) multiplied by the length of time (minutes) the load was endured; the measure is expressed as kpm.

The effects of the independent variables on objective cardiovascular output were assessed by four measures: (a) resting heart rate, (b) final heart rate, (c) rate of change in heart rate during the session, represented by the slope of heart rate over time, and (d) the average heart rate during the session. Two measures of perceived exertion were employed for the muscular ratings and the cardiovascular ratings: (a) rate of change within session or slope of RPE, and (b) average RPE.

Since the number of test sessions per menstrual cycle varied both between and within subjects because of differing cycle lengths, the raw scores for each dependent measure had to be adjusted to represent equal proportions of the menstrual period. This transformation was accomplished by converting data based on sessions to data based on deciles of the menstrual cycle. The mechanics of the conversion involved dividing the total length of a subject's menstrual cycle by ten, then estimating each of the ten scores by taking the proportional average of the raw scores bounding the desired point. The raw score data were arranged according to "day-of-training"; thus, the first decile score was the proportional average performance representing the first tenth of the training sessions for the first menstrual cycle. Since subjects began the training at one of three different points in their cycle (Day 6, 12, or 20), these deciles reflected a different point in the cycle according to which starting group each of the 12 subjects was assigned.

The transformed data were analyzed to determine the effects of each variable of interest (menstrual and training effects) on each dependent measure. A three-factor analysis of variance (10 x 2 x 3) was computed for each dependent measure with the deciles as one factor, the two menstrual cycles as a second factor, and the three starting points as the third factor; four subjects were nested in each level of the third factor. Post hoc analyses of significant effects employed the Studentized Range Statistic (Winer, 1971, p. 185).

To assess the extent to which neutral times in the cycle were selected as the three starting points for training, the main effect due to starting points is of primary interest. The extent to which there is a menstrual effect is assessed through the interaction of deciles and starting groups. To determine the significance of a training effect, the main effect of cycle and the interaction of deciles and menstrual cycles are expected to be the relevant sources of variation.

Measure of Work Performed

Of primary interest is the dependent measure of work performed, obtained by measuring work performed until exhaustion was reached. The analysis of variance of this measure is summarized in Table 4. As indicated, there was a significant effect due to cycle; means for the first and second cycle are 2386.3 and 1857.8 kpm-min, respectively (a summary table of means for each dependent measure is presented in Appendix A). The significant cycle-by-decile interaction of this analysis indicates that there is a training effect evident. The mean decile scores for each cycle are presented in Figure 1. Post hoc examination of this interaction revealed that deciles 5 through 10 of cycle one were significantly higher than the same deciles of cycle two. It is evident from these data that the training effect due to repeated testing was such that performance increased during the initial deciles of the first cycle, but then gradually declined through the second cycle.

There appears to be no overall difference between the starting groups. In addition, no apparent menstrual effect is evident as is indicated by lack of significance in the group-by-decile interaction. Regardless of the three starting points (with respect to menstrual cycle), the training curves are similar for each group.

Table 4

Summary of Analysis of Variance of Work Performed

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	29428000.0	14714000.0	2.1346
Cycle (C)	1	16752660.0	16752660.0	24.2318**
Deciles (D)	9	1904054.0	211561.6	2.3748
Subjects w/in Groups	9	62938740.0	6893193.0	------
G X C	2	2107949.0	1053974.0	1.5245
G X D	18	1524403.0	84689.1	.9507
C X D	9	6358727.0	7065125.2	6.5608**
C X S (G)	9	6222151.0	691350.1	------
D X S (G)	81	7215825.0	89084.3	------
G X C X D	18	593833.4	32990.7	.3064
C X D X S (G)	81	8722798.0	107688.9	------

** $p < .01$

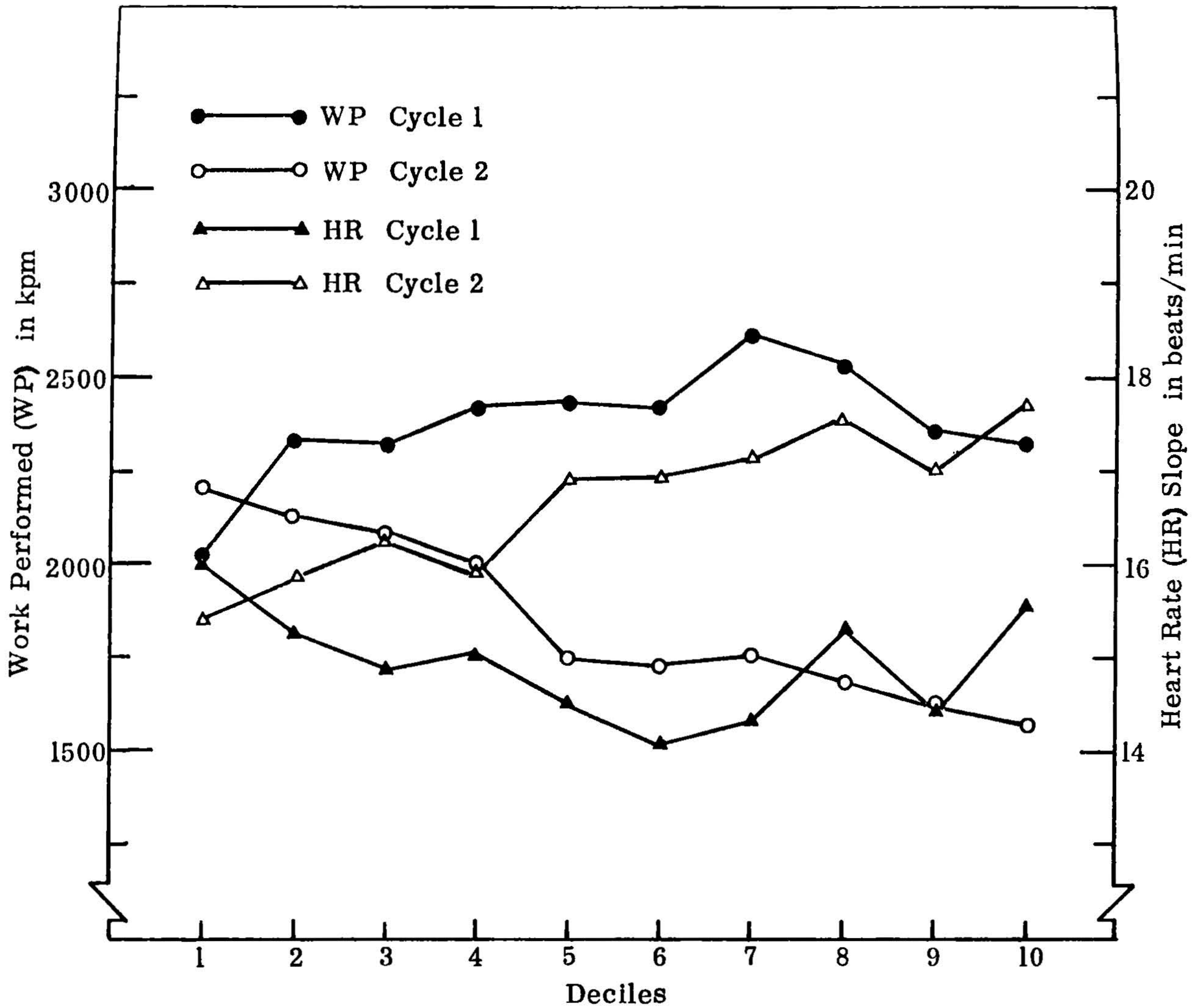


Figure 1: Decile means for both menstrual cycles as a function of work performed (WP) and heart rate (HR) slope.

Heart Rate Measure

As indicated above, heart rate (HR) was analyzed in four respects: resting HR, final HR, HR slope, and average HR during performance. Each set of measures was transformed into decile scores and analyses of variance computed employing the same three factors as above. Table 5 presents the F-values for all four analyses (ANOVA summary tables are presented in Appendix B). As indicated by the significant cycle effects, a training effect was found in three of the heart rate indices. Final HR was significantly lower for the second menstrual cycle, with means of 173.8 and 170.6 beats/min for the first and second cycles, respectively; a similar effect was apparent for average HR with means of 140.6 and 137.3 beats/min for the two cycles, respectively. HR slope, on the other hand, was significantly higher during the second cycle than the first (means of 15.02 and 16.67, respectively). The cycle-by-decile interaction for HR slope was also significant; the means for this interaction are presented in Figure 1. It will be noted that this graphical presentation of the interaction of HR slope resembles an inversion of the work performance interaction.

As indicated, no group differences were observed for any of the HR measures. However, since the three groups differed with respect to phase of menstrual cycle at each test point, it is possible that the significant interaction of groups with decile for HR slope, presented graphically in Figure 2, could be attributed to a menstrual effect. Post hoc analysis

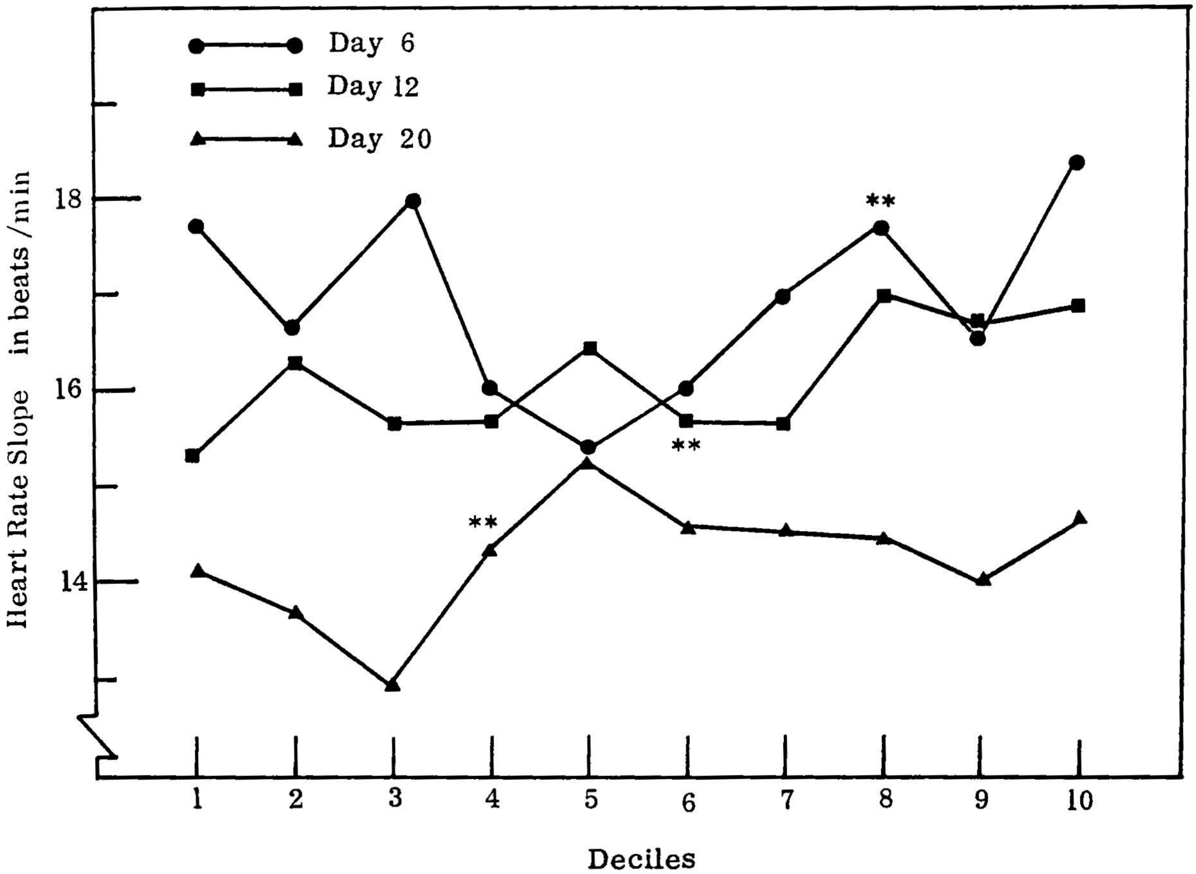
Table 5

Heart Rate F-Values

Source of Variation	df	Resting HR	Final HR	HR Slope	Mean HR
Group (G)	2/9	.6760	2.1648	.6809	.6340
Cycle (C)	1/9	1.1316	10.0305*	28.6107**	10.3548*
Decile (D)	8/81	.8010	1.3314	2.8748**	2.3387
G X C	2/9	.7833	3.1957	.9830	3.9900
G X D	18/81	1.9465*	.8777	3.4472**	1.0950
C X D	9/81	.6381	.3831	3.5510**	1.1826
G X C X D	18/81	1.1348	.2873	1.2018	.9157

* $p < .05$

** $p < .01$



** Indicates the decile including onset of menstruation

Figure 2: Decile means for the groups beginning training on Day 6, 12, and 20 of their menstrual cycle as a function of heart rate slope.

showed that the significant interaction was primarily due to the higher scores of the starting Day 6 group over starting Day 20 group during the first three and last three deciles, as Figure 2 indicates.

To determine the contribution of the menstrual cycle to this interaction, the decile data were rearranged to align the groups according to onset of menstruation. Although the differences between groups across deciles remained in evidence, there was no indication of an effect due to menstrual cycle; the realigned data for the HR slope measure is presented in Figure 3. Post hoc analysis of the significant group-by-decile interaction for resting HR showed a similar pattern as with HR slope, where the difference appeared mainly due to higher scores for the Day 20 starting group as contrasted with the Day 6 group. Again, realigning the deciles with respect to menstrual cycle of each group revealed no indication of a menstrual effect.

Perceived Exertion Measures

The two subjective measures were the ratings of perceived local muscular exertion (RPE-M) and ratings of perceived cardiovascular exertion (RPE-CV). Each of these measures was analyzed with respect to their rate of change as a function of time during the performance (slope) and the average perceived exertion per test session. Thus, four ANOVA's were computed on the transformed deciles using the same three factors as above. The F-values for the subjective

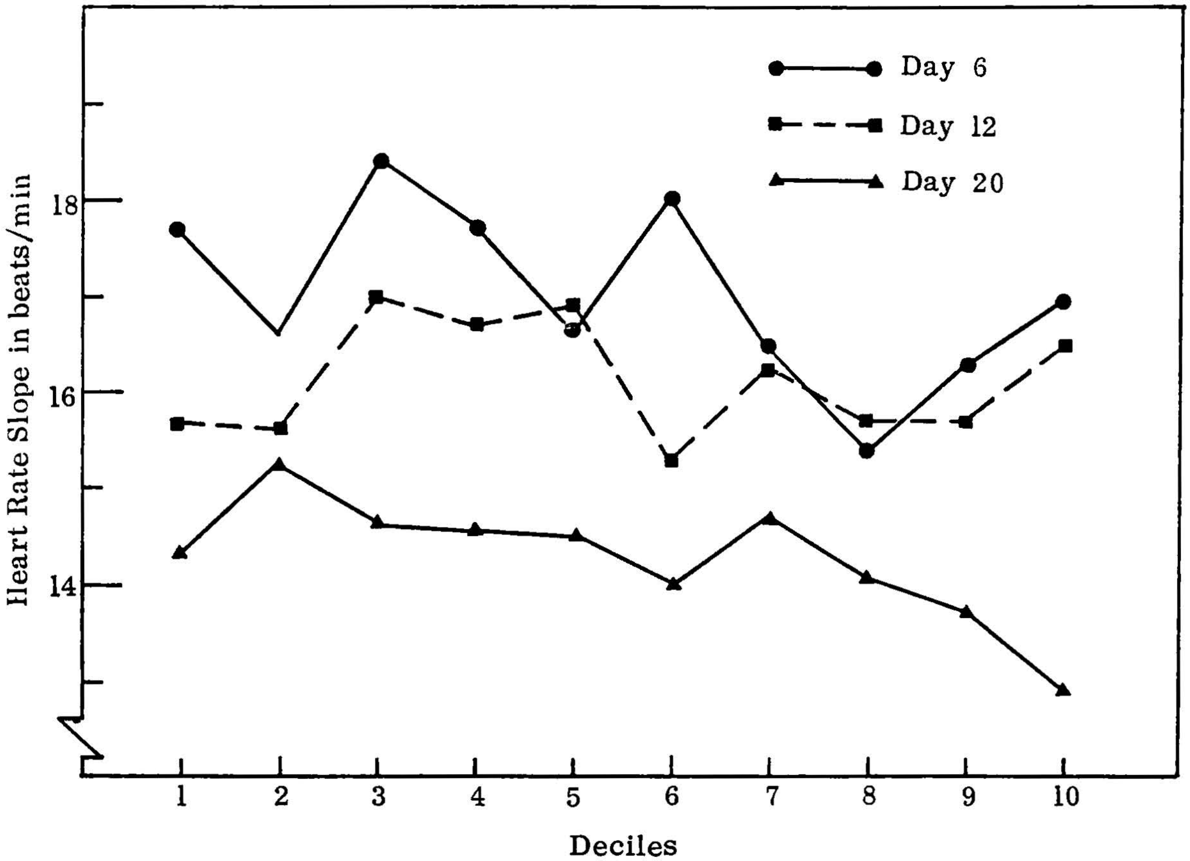


Figure 3: Decile means for the groups beginning training on Day 6, 12, and 20 of their menstrual cycle as a function of slope. The decile means are realized along the abscissa so that "decile one" represents onset of menstruation.

measures are presented in Table 6 (complete summary tables are presented in Appendix C).

A training effect was evident for three of the perceived exertion measures. The slopes of RPE-M and RPE-CV were greater for the second cycle (mean RPE-M slope = 2.01, mean RPE-CV = 1.79) than the first (mean RPE-M slope = 1.88, mean RPE-CV slope = 1.61). The average perceived muscular exertion, on the other hand, was significantly lower during the second cycle (mean = 12.27) than it was for the first (mean = 12.50). The graphical plots of the significant interaction of cycle-by-decile for both slope measures, presented in Figure 4, are similar to HR slope. Post hoc analysis revealed that for both slope measures, the significance was primarily due to the difference between the deciles towards the end of both cycles, with higher slopes occurring during the second cycle.

The significant group-by-cycle interaction for RPE-CV slope and average RPE-M are presented graphically in Figure 5. As noted, there are no significant differences between the groups on the four measures and no group-by-decile interactions, and, therefore, no evidence of a menstrual cycle effect.

Table 6

Perceived Exertion F-Values

Source of Variation	df	RPE-M Slope	RPE-M Average	RPE-CV Slope	RPE-CV Average
Group	2/9	1.9542	.4746	.5513	.6336
Cycle	1/9	8.0634*	8.2392*	13.5742**	.3356
Decile	9/81	.8061	.8353	1.1009	1.0877
G X C	2/9	1.1402	12.8252**	5.3111*	4.0686
G X D	18/81	.8407	.9687	1.1703	1.3258
C X D	9/81	2.8989*	.5412	3.4964*	.3421
G X C X D	18/81	.7845	.8273	1.8560	.6147

* $p < .05$

** $p < .01$

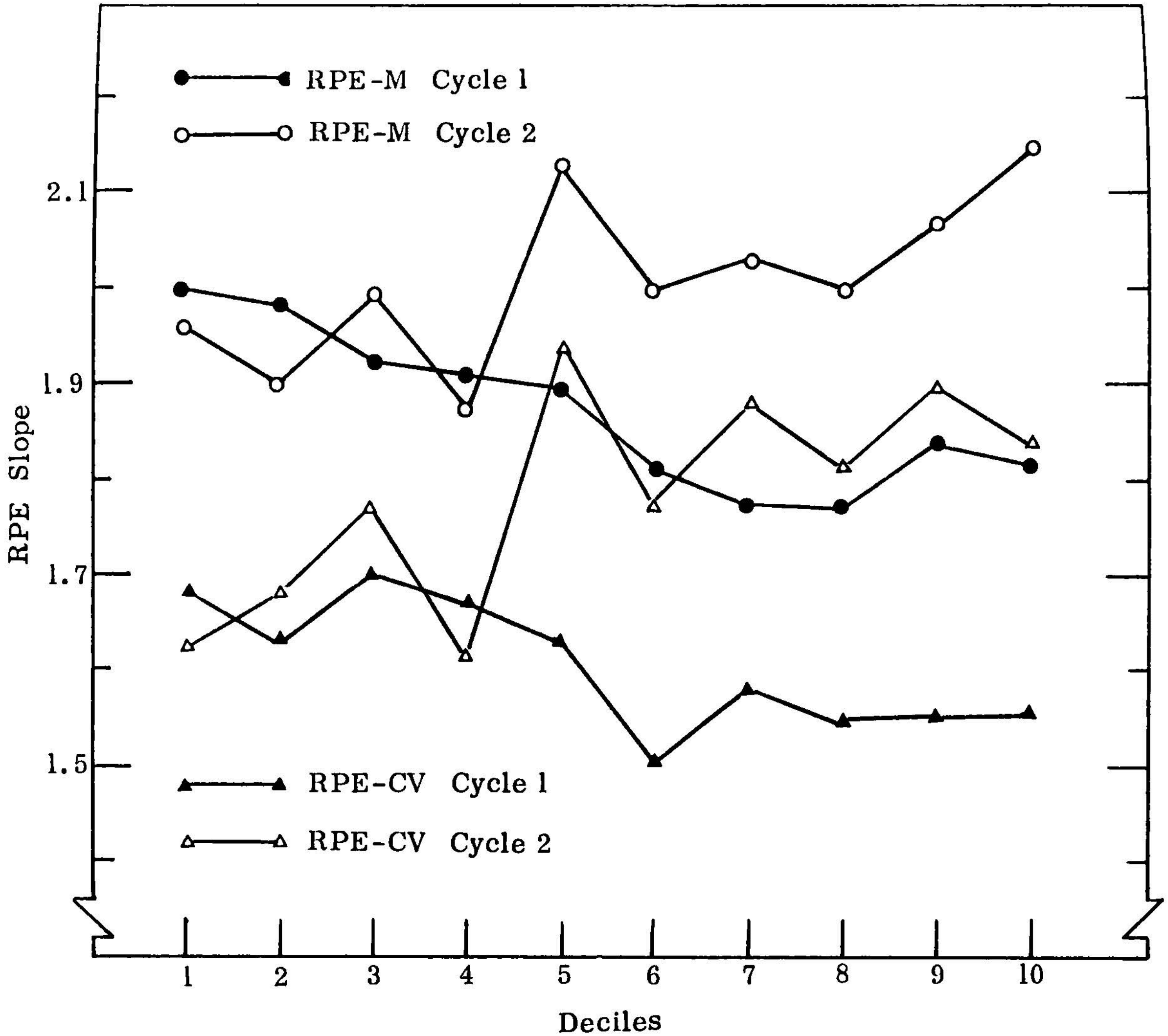


Figure 4: Decile means for both menstrual cycles as a function of ratings of perceived muscular exertion (RPE-M) and perceived cardiovascular exertion (PRE-CV).

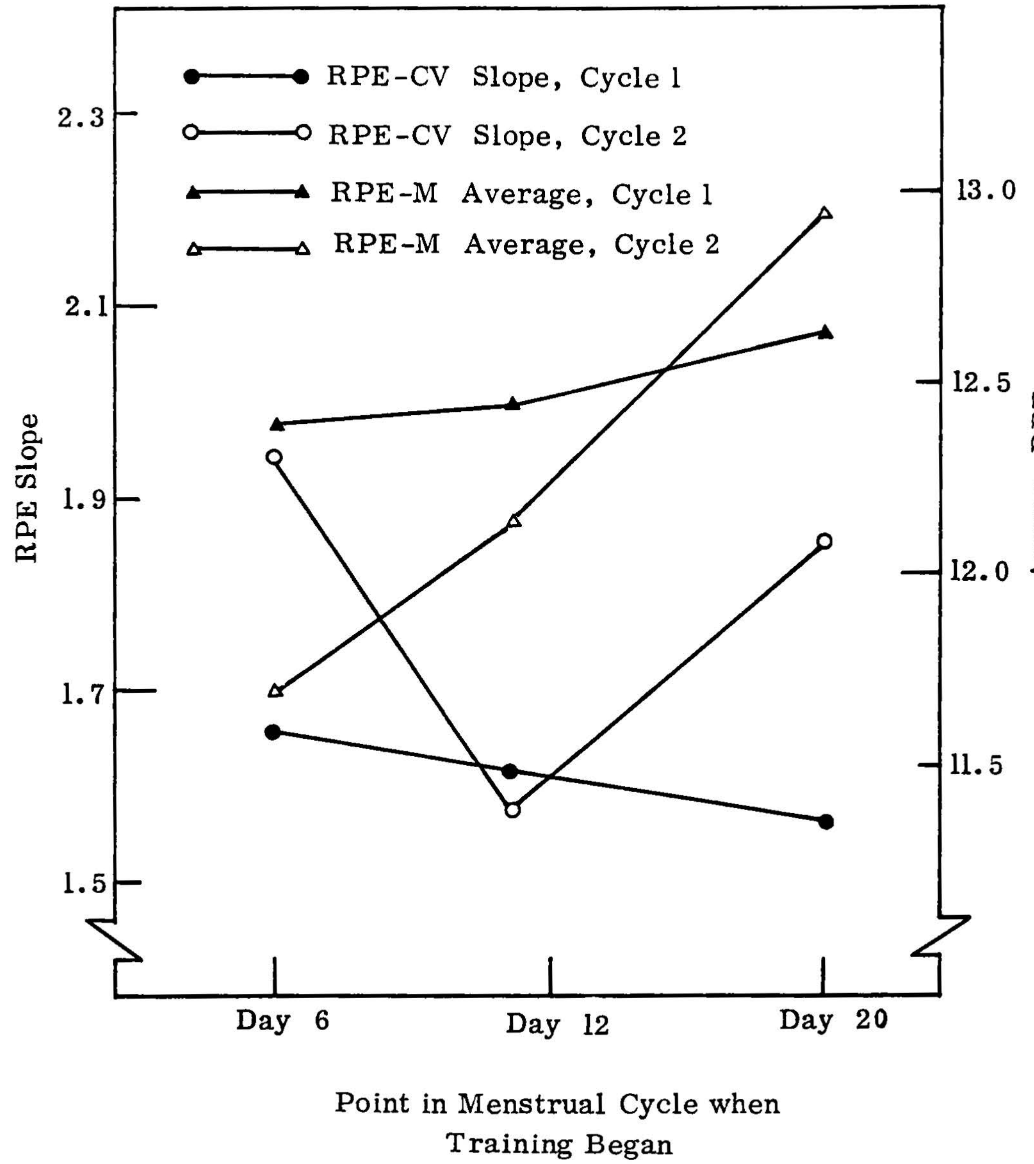


Figure 5: Decile means for the three starting groups as a function of perceived cardiovascular exertion (RPE-CV) slope and average perceived muscular exertion (RPE-M).

Discussion

The present study was designed to determine the extent to which the menstrual cycle affects work performance on a physical task and to determine the extent to which performance would improve over repeated testing on the task (training effect). It was predicted that a training effect would be such that performance would increase rapidly during initial practice on a new task, but after this increase, subsequent performance would increase only gradually and then reach a plateau.

The nature of the menstrual cycle variable was not clearly predictable from previous studies, since most of the empirical literature reports no significant menstrual effects. Those who do report menstrual effects do not agree on how the cycle affects performance. Yet, recognizing the problems inherent in employing the menstrual cycle as a variable (which has resulted in questionable results for much of the previous research), the present study was designed to take these problems into consideration. Having controlled for many factors which could have contributed to the lack of significance in previous studies, it was felt that if the menstrual cycle was well defined and if it actually does affect performance, it would become readily evident. Even with these precautions, however, a menstrual effect was not found.

The results of both menstrual and training effects need to be examined more closely to integrate what was found for each dependent measure employed.

Training Effects

The results of the present study do show a training effect, but not as expected. The primary measure, work performed, demonstrates clearly that while a "practice effect" occurred early in the first menstrual cycle, performance peaked between deciles seven and eight (after approximately 10 to 12 test sessions), and except for a brief performance increase just prior to the end of the study, performance gradually declined during the second cycle. Surprisingly, the level of performance at the end of the study was lower than at the beginning.

The heart rate measures (with the exception of resting HR) show approximately the same pattern, yet much of this may be due to the nature of the work capacity measure. To measure work capacity, a person must perform to exhaustion, and exhaustion is difficult to define precisely. In the present study the subjects were initially told to pedal until they were no longer able, but "no longer able" is of course a personal decision made by each individual. The final HR and the average HR during performance both were significantly lower during the second cycle, and this may indicate that the subjects were not pushing themselves to exhaustion during the second cycle.

The slope measures show consistency for both HR and the perceived exertion measures--significant cycle effects and cycle-by-decile interaction effects for all of these measures indicate an inverse relationship between slope and work performance. If slope is a measure of the physiological and subjective rate of increasing difficulty, it would appear that the task increased in rate of difficulty for the subjects during the second cycle, resulting in less work output. The average ratings of perceived exertion showed that the overall level of difficulty was lower for the perceived muscular exertion, but unchanged for the perceived cardiovascular exertion; in other words, the subjects perceived no difference in heart rate for the two cycles, but perceived exertion of leg muscles decreased for the second cycle.

What would the reasons be for obtaining such results such that as the study progressed, the task seemed to become more difficult rather than easier, and work output was lower. Although there is no definitive answer at this point, there are several possibilities. First, the nature of the task which required the subjects to perform to exhaustion may have had an effect on the subject's attitude towards the task. Although all subjects were completely aware from the beginning of the study what the task involved, and were highly motivated to participate in a study which provided a potential fitness benefit, it must be recognized that after completing 10 to 12 test sessions, the appeal may have worn off, causing a decreased desire to push to one's physical limits. While a post-study interview with each subject did not reveal any negative feelings towards the task, the subjects may have been unaware of such a change in attitude or unwilling to reveal it.

Secondly, there may have been an adaptation to exhaustion itself, and the relationship between the physiological and subjective measures suggests this. Although average heart rate was lower for the second cycle than the first, perception of that heart rate was unchanged. Subjects may have changed their internal definition of exhaustion so that while they felt they were taking themselves to their limits, they actually were not.

A third explanation involves the apparatus itself. Three quarters of the way through the experiment the experimenters suspected a change in the bicycle loading. It was not feasible to recalibrate the bicycle at that time, but the data were examined with respect to calendar day, and no systematic pattern of increased bicycling difficulty was evident. Although it was concluded that the bicycle was operating at the correct work load, the possibility exists that the loading mechanism may have contributed to the declining performance.

Finally, while increased heart rate and perceived exertion slopes suggest that the task may actually have been more difficult during the second cycle, this could also be explained by the previously mentioned change in attitude. If the subjects were less enthusiastic about the task as the study progressed, this could have produced an attitude where the subject wanted to "get it over with" as quickly as possible; she may have been concentrating less on pacing her energy and more on working hard to get finished with the task. Although none of these explanations is expected to account for the present results alone, they are all possibilities and they represent problems that should be considered when repeated all-out performance is involved.

Menstrual Effects

The present experiment was designed to eliminate some of the methodological problems which have occurred in previous studies. In order to allow for inter- and intra-individual variation in the menstrual cycle, daily records were kept for three menstrual cycles. Performance was measured frequently so that retrospectively, menstrual records could be employed to determine where in the menstrual cycle each test session fell. No data were discarded due to irregular cycle lengths, and critical days for performance measurement were selected not by a predetermined formula, but by examining individual menstrual cycle graphs.

While the null hypothesis cannot be proven, of course, there are certain circumstances where continued failure to reject the null hypothesis lends support that no real difference exists. Most studies reviewed have failed to reject the null hypothesis, and almost all of them concluded from the lack of significance that the menstrual cycle did not affect the measure of interest. After examining the methods used to measure a menstrual cycle effect in these previous studies, however, it was felt that the methodological problems existing in the studies may have been responsible for masking a menstrual effect.

The present study thus controlled for these problems so that there would be no question that the menstrual cycle was systematically varied, and still no menstrual effect was observed. The task was certainly strenuous enough that decrement in performance due to the menstrual cycle should have been evident if the cycle actually affects performance in that manner. In addition, it was thought that if work output per se does not change as a function of the menstrual cycle, then perhaps the physiological or subjective measures would be sensitive to the possible effects of the cycle. The present study found no evidence that the cycle affected either the work performance, the physiological measures, or the subjective measures.

It would appear that the folklore which has long espoused the detrimental effect of the menstrual cycle on performance, is without evidence. Empirical studies continue to fail to find such an effect, and if it exists, it is either so highly individualized that it is not evident in a heterogeneous group, or so weak that it is erased by other factors affecting performance.

Implications for Future Research

Results of the present study suggest several implications for future research. Although the observed "training effect" did not occur in the manner as expected, the information provided by the data is interesting in itself. Future research should be conducted to investigate the nature of performance when the task is repeated numerous times and is of an exhaustive nature. The obtained results indicate that over time, performance on a strenuous task decreases. These results should be replicated, and, if this is successfully done, the precise conditions under which this decrement will occur should be specified. Whether it is related to the type of task, the time involved with a known termination date in sight, the type of individual involved (whether male, female, trained, or untrained), and the motivation for participation (whether it be volunteer or mandatory) should be determined. With today's interest in physical performance, further knowledge about the nature of repeated, exhaustive performance would be of great value.

Finally, the lack of a menstrual effect in the present results suggests that women's performance need not be qualified by specifying where she is in her menstrual cycle. While, of course, there may be some minority of women who have menstrual problems which affect performance, the continued failure to observe a systematic menstrual effect demonstrates a wide range of performance which is not sensitive to menstrual-related change in most women. Although there are certainly differences in performance between men and women, especially with respect to physical performance, it seems to be the case that the differences are more likely due to size and differential socialization practices. Future research needs to concentrate more on these factors.

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APPENDIX A

Tables of Means

SUMMARY DATA FOR MEASURE # 11 RESTING HEART RATE

TABLE OF MEANS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE 1 CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE 2 CYCLE MEAN	DECILE MEAN
DECILE									
1	76.6000	82.8000	89.4000	82.9333	73.7000	76.7000	83.9000	78.1000	80.5167
2	77.0000	75.8000	88.6000	80.4667	80.2000	77.4000	82.6000	80.0667	80.2667
3	76.9000	78.3000	89.0000	81.4000	68.0000	80.1000	88.4000	78.8333	80.1167
4	74.4000	79.6000	85.8000	79.9333	78.4000	78.8000	79.2000	78.8000	79.3667
5	78.5000	81.0000	79.0000	79.5000	82.5000	75.5000	77.5000	78.5000	79.0000
6	82.2000	79.4000	81.4000	81.0000	81.0000	73.8000	85.2000	80.0000	80.5000
7	80.6000	79.4000	80.0000	80.0000	74.4000	75.9000	84.8000	78.3667	79.1833
8	73.6000	73.2000	82.6000	76.4667	73.0000	75.0000	86.0000	78.0000	77.2333
9	79.7000	77.1000	86.2000	81.0000	75.3000	74.8000	90.1000	80.0667	80.5333
10	72.5000	75.0000	82.0000	76.5000	77.0000	71.0000	90.0000	79.3333	77.9167
MEAN	77.2000	78.1600	84.4000	79.9200	76.3500	75.9000	84.7700	79.0067	

TABLE OF STANDARD DEVIATIONS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE 1 CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE 2 CYCLE MEAN	DECILE MEAN
1	17.5530	20.6791	2.2978	15.2280	15.1521	18.4936	8.0291	13.9089	14.4749
2	17.1627	10.0213	13.8622	14.0170	14.4941	6.8000	5.0332	9.0410	11.5370
3	15.0957	14.9251	6.1057	12.8425	12.0444	14.4974	3.9463	13.3293	12.8675
4	14.8522	13.8024	6.6091	12.1540	13.8718	15.2420	4.2833	10.9982	11.3505
5	13.6991	14.3759	2.0000	10.4838	15.9478	15.3514	13.9881	14.0162	12.1154
6	17.4951	16.2431	10.5198	13.6794	14.9862	8.1943	5.0807	10.5251	11.9473
7	17.1285	15.6239	3.9732	12.2946	12.6786	11.6040	7.2443	10.8564	11.3735
8	10.1823	9.4319	7.4869	9.4007	14.4499	12.6048	5.8606	12.0532	10.6000
9	15.7052	9.0943	13.7230	12.5365	9.8651	11.5839	1.5099	10.8956	11.4965
10	16.0312	10.5198	5.1640	11.1885	15.0997	13.6137	10.5830	14.5561	12.7788
MEAN	14.0405	12.5258	8.1363	12.1654	12.9495	11.8516	7.6441	11.7014	

SUMMARY DATA FOR MEASURE # 21 FINAL HEART RATE

TABLE OF MEANS

	**************CYCLE 1************* GROUP 1	GROUP 2	GROUP 3	CYCLE MEAN	**************CYCLE 2************* GROUP 1	GROUP 2	GROUP 3	CYCLE MEAN	DECILE MEAN
DECILE									
1	171.3000	177.9000	177.0000	175.4000	163.9000	173.6000	175.5000	171.0000	173.2000
2	170.8000	177.5000	177.4000	175.2333	163.6000	177.4000	177.8000	172.9333	174.0833
3	168.9000	175.8000	173.9000	172.8667	164.7000	178.8000	176.7000	173.4000	173.1333
4	168.2000	177.0000	181.0000	175.4000	160.1000	173.2000	178.0000	170.4333	172.9167
5	164.5000	177.5000	178.0000	173.3333	157.5000	175.0000	175.5000	169.3333	171.3333
6	161.4000	173.8000	177.2000	170.8000	159.6000	171.0000	178.2000	169.6000	170.2000
7	167.5000	175.9000	181.6000	175.0000	153.4000	175.7500	181.9000	170.3500	172.6750
8	169.0000	180.5000	179.2000	176.2333	162.8000	173.8000	178.4000	171.6667	173.9500
9	163.5000	174.6000	176.0000	171.3667	155.9000	173.8000	174.8000	168.1667	169.7667
10	164.0000	174.5000	180.0000	172.8333	158.5000	174.5000	174.0000	169.0000	170.9167
MEAN	166.9100	176.5000	178.1300	173.8467	160.0000	174.6850	177.0800	170.5883	

TABLE OF STANDARD DEVIATIONS

1	13.1954	7.1953	10.3768	10.0145	13.4912	12.0974	15.2048	13.4446	11.8095
2	13.2182	5.0000	11.6550	10.1113	20.3908	11.7098	7.0161	14.5521	12.3108
3	12.0327	7.5648	20.1577	13.2345	17.4490	10.1298	13.4040	14.2165	13.4352
4	15.0714	6.0000	13.9847	12.5016	12.9754	4.9960	5.1640	11.0647	11.8210
5	17.0783	10.7548	15.4919	14.8038	21.5019	8.2462	3.4157	14.9747	14.7048
6	12.5878	11.5077	7.6594	12.0677	17.3005	6.8313	5.1999	12.8725	12.2177
7	18.6258	10.7350	13.5292	14.5792	15.7056	7.1803	7.8477	16.1777	15.2468
8	14.8862	10.3763	14.4738	13.2582	11.6573	1.6491	6.5645	9.8126	11.6430
9	18.2644	9.2865	15.1789	14.5412	19.2565	7.4868	6.8352	14.5402	14.3147
10	16.3299	12.3693	3.2660	12.8617	13.2035	6.4031	8.3267	11.7396	12.2009
MEAN	13.7962	8.4498	11.9112	12.5294	15.0115	7.5235	7.8906	13.0499	

SUMMARY DATA FOR MEASURE # 3: RATINGS OF PERCEIVED MUSCULAR EXERTION--SLOPE

TABLE OF MEANS

	*************CYCLE 1*************			CYCLE MEAN	*************CYCLE 2*************			CYCLE MEAN	DECILE MEAN
	GROUP 1	GROUP 2	GROUP 3		GROUP 1	GROUP 2	GROUP 3		
DECILE									
1	2.1180	2.0655	1.8305	2.0047	2.0325	1.8515	2.0015	1.9618	1.9833
2	2.1710	1.9285	1.8442	1.9815	2.0987	1.7580	1.8462	1.9010	1.9412
3	2.2000	1.8193	1.7433	1.9208	2.0208	1.9862	1.9680	1.9917	1.9563
4	2.0978	2.0240	1.6180	1.9132	2.0250	1.7760	1.8405	1.8805	1.8969
5	2.0415	1.8628	1.7033	1.8958	2.2468	2.1287	2.0148	2.1301	2.0130
6	2.0500	1.7043	1.7048	1.8197	2.2140	1.8293	1.9818	2.0093	1.9140
7	1.8073	1.9100	1.6485	1.7886	2.2133	1.9420	1.9350	2.0301	1.9093
8	1.9470	1.6207	1.7530	1.7736	2.1725	1.7495	2.0967	2.0063	1.8899
9	1.8868	1.8360	1.8178	1.8468	2.2483	1.9422	2.0400	2.0768	1.9618
10	1.9923	1.8028	1.6778	1.8242	2.4488	2.0695	1.9393	2.1525	1.9884
MEAN	2.0312	1.8574	1.7421	1.8769	2.1720	1.9033	1.9664	2.0139	

TABLE OF STANDARD DEVIATIONS

1	0.5285	0.3153	0.3258	0.3864	0.4363	0.2141	0.4403	0.3523	0.3622
2	0.5080	0.3909	0.3771	0.4146	0.4236	0.2991	0.0938	0.3138	0.3619
3	0.3454	0.3199	0.1728	0.3349	0.2975	0.3748	0.1166	0.2582	0.2947
4	0.3442	0.4409	0.1492	0.3741	0.1727	0.1845	0.2114	0.2043	0.2952
5	0.3493	0.1785	0.1958	0.2552	0.4328	0.5070	0.1378	0.3690	0.3326
6	0.2932	0.2035	0.0550	0.2540	0.3415	0.2496	0.1970	0.2944	0.2856
7	0.2815	0.3457	0.1737	0.2740	0.1659	0.1349	0.2695	0.2249	0.2744
8	0.1546	0.2480	0.3134	0.2639	0.2281	0.1930	0.0269	0.2481	0.2773
9	0.2921	0.1071	0.2527	0.2115	0.5819	0.2469	0.1340	0.3628	0.3133
10	0.1877	0.2235	0.2445	0.2403	0.3397	0.3338	0.1952	0.3510	0.3386
MEAN	0.3274	0.2885	0.2267	0.3058	0.3442	0.2865	0.2011	0.3037	

SUMMARY DATA FOR MEASURE # 41 RATINGS OF CARDIOVASCULAR EXERTION--SLOPE

TABLE OF MEANS

	**************CYCLE 1**************			CYCLE	**************CYCLE 2**************			CYCLE	DECILE
	GROUP 1	GROUP 2	GROUP 3	MEAN	GROUP 1	GROUP 2	GROUP 3	MEAN	MEAN
DECILE									
1	1.7558	1.7943	1.5007	1.6836	1.5410	1.5220	1.8168	1.6266	1.6551
2	1.7820	1.6305	1.4855	1.6327	1.8313	1.4215	1.8133	1.6887	1.6607
3	1.8550	1.6410	1.6205	1.7058	1.8320	1.6817	1.8193	1.7777	1.7417
4	1.8453	1.7480	1.4340	1.6758	1.7017	1.3830	1.7483	1.6110	1.6434
5	1.4720	1.7665	1.6785	1.6390	2.0603	1.8003	1.9700	1.9435	1.7912
6	1.4593	1.5387	1.5485	1.5155	2.0563	1.4655	1.8255	1.7824	1.6490
7	1.4955	1.7565	1.4922	1.5814	2.1245	1.7230	1.7950	1.8808	1.7311
8	1.6390	1.3595	1.6123	1.5369	2.0732	1.3973	1.9640	1.8115	1.6742
9	1.5840	1.4838	1.6360	1.5679	2.1655	1.6382	1.9238	1.9092	1.7385
10	1.7230	1.4788	1.5972	1.5997	1.9525	1.7330	1.8362	1.8406	1.7201
MEAN	1.6611	1.6198	1.5606	1.6138	1.9338	1.5766	1.8512	1.7872	
TABLE OF STANDARD DEVIATIONS									
1	0.4876	0.5214	0.0822	0.3992	0.4660	0.3325	0.2211	0.3500	0.3683
2	0.3509	0.6570	0.1852	0.4203	0.4504	0.1193	0.1134	0.3189	0.3660
3	0.2447	0.3764	0.2140	0.2823	0.4101	0.1835	0.1258	0.2538	0.2651
4	0.2290	0.6080	0.2531	0.4077	0.5188	0.3847	0.1605	0.3867	0.3900
5	0.7065	0.2835	0.2158	0.4328	0.5340	0.3127	0.1009	0.3462	0.4137
6	0.4730	0.2130	0.1228	0.2815	0.5378	0.5060	0.2381	0.4782	0.4072
7	0.4600	0.3874	0.1914	0.3541	0.4982	0.2447	0.2947	0.3756	0.3883
8	0.3414	0.2870	0.1827	0.2840	0.2649	0.3837	0.0822	0.3961	0.3651
9	0.4029	0.3299	0.1205	0.2868	0.5171	0.3335	0.1058	0.3962	0.3805
10	0.2102	0.2633	0.3083	0.2602	0.2756	0.2628	0.2592	0.2581	0.2818
MEAN	0.3932	0.3940	0.1898	0.3392	0.4461	0.3211	0.1775	0.3645	

SUMMARY DATA FOR MEASURE # 5: HEART RATE--SLOPE

TABLE OF MEANS

	*************CYCLE 1*************			CYCLE	*************CYCLE 2*************			CYCLE	DECILE
	GROUP 1	GROUP 2	GROUP 3	MEAN	GROUP 1	GROUP 2	GROUP 3	MEAN	MEAN
DECILE									
1	18.6690	15.7458	13.9318	16.1155	16.9177	14.9338	14.4090	15.4202	15.7678
2	17.4660	15.9480	12.4305	15.2815	15.8077	16.6762	15.0173	15.8338	15.5576
3	17.4450	15.3933	11.8295	14.8893	18.7588	16.1335	13.9377	16.2767	15.5830
4	16.8593	15.5878	12.9718	15.1396	16.1090	15.9063	15.7565	15.9239	15.5318
5	15.3353	15.2070	13.5780	14.7067	15.5060	17.8060	17.0058	16.7726	15.7397
6	14.5828	14.6025	13.3660	14.1838	18.0608	16.7765	15.8780	16.9051	15.5444
7	15.3898	14.3368	13.4232	14.3833	18.6337	17.0003	15.7663	17.1334	15.7583
8	16.7013	16.0682	13.2193	15.3296	18.8810	18.0788	15.8495	17.6031	16.4663
9	14.9327	15.7720	12.9593	14.5547	18.3105	17.6697	15.0525	17.0109	15.7828
10	17.2115	15.6145	14.0488	15.6249	19.6667	18.2860	15.4023	17.7850	16.7050
MEAN	16.4592	15.4276	13.1758	15.0209	17.6652	16.9267	15.4075	16.6665	

TABLE OF STANDARD DEVIATIONS

1	6.0885	3.5518	1.7674	4.3078	4.7616	3.4586	3.1087	3.6544	3.9228
2	5.0779	2.0738	4.1624	4.2170	5.3551	4.3724	1.3580	3.7468	3.9113
3	5.8558	2.8645	2.0185	4.3096	4.2086	4.2520	2.0890	3.8972	4.0803
4	4.5323	2.1564	1.3100	3.1931	3.8498	4.9410	1.1841	3.3325	3.2168
5	4.9150	2.6550	2.5527	3.3145	4.3811	4.1349	4.1166	3.9384	3.7129
6	3.7236	3.7920	2.1867	3.0614	4.3040	3.8414	2.5872	3.4318	3.4709
7	4.3499	2.9172	1.5360	2.9714	4.7871	3.5557	1.5982	3.4495	3.4477
8	4.5391	2.8950	1.2757	3.2940	3.9535	4.1004	2.8216	3.5797	3.5590
9	4.8468	3.5871	1.9031	3.5242	4.1103	2.2555	3.4684	3.3827	3.6437
10	4.5876	3.7856	2.0997	3.5594	5.0837	3.4870	3.8363	4.2216	3.9749
MEAN	4.4806	2.7614	2.0561	3.5156	4.1934	3.5710	2.5878	3.6094	

SUMMARY DATA FOR MEASURE # 6: RATINGS OF PERCEIVED MUSCULAR EXERTION--AVERAGE

TABLE OF MEANS

	CYCLE 1			CYCLE	CYCLE 2			CYCLE	DECILE
	GROUP 1	GROUP 2	GROUP 3	MEAN	GROUP 1	GROUP 2	GROUP 3	MEAN	MEAN
DECILE									
1	12.5625	12.6655	12.6892	12.6388	12.0957	12.4355	12.9193	12.4835	12.5611
2	12.9200	12.5953	12.2405	12.5853	11.9922	11.5470	12.7797	12.1063	12.3458
3	12.6003	12.1870	12.7678	12.5183	11.7743	12.8670	13.1668	12.6027	12.5605
4	12.6375	12.1555	12.1383	12.3104	11.4550	12.0285	12.5872	12.0236	12.1670
5	12.6295	12.5833	13.1073	12.7733	11.4063	12.5685	12.8875	12.2874	12.5304
6	12.5918	12.3708	12.8952	12.6192	11.5625	12.1608	13.0142	12.2458	12.4325
7	12.1898	12.7135	12.2855	12.3963	11.3188	12.4498	13.0293	12.2659	12.3311
8	12.1173	11.9600	12.8142	12.2972	11.8925	11.3710	13.2125	12.1587	12.2279
9	12.0382	12.6600	12.9005	12.5329	11.7192	11.8060	12.9315	12.1522	12.3426
10	11.8750	12.5347	12.6608	12.3568	11.9583	12.3017	12.9168	12.3923	12.3745
MEAN	12.4162	12.4425	12.6498	12.5029	11.7175	12.1536	12.9445	12.2718	

TABLE OF STANDARD DEVIATIONS

1	2.1244	0.6145	1.5773	1.4197	1.9325	1.3128	1.0446	1.3823	1.3726
2	1.7371	0.8673	0.5662	1.0952	1.6169	1.2680	0.5213	1.2284	1.1641
3	1.0838	0.9927	0.5216	0.8534	1.3088	0.9842	0.5500	1.0975	0.9624
4	1.2726	0.3987	1.1499	0.9508	1.4401	1.8750	0.9821	1.4215	1.1917
5	1.4709	1.4926	1.3521	1.3257	0.9756	0.7606	0.7215	1.0007	1.1752
6	1.5236	2.1055	1.7843	1.6616	1.3388	2.0212	0.8221	1.4746	1.5481
7	1.9141	1.1349	1.1661	1.3334	1.3939	1.1407	1.3123	1.3802	1.3288
8	1.5687	1.7947	0.9719	1.3991	1.3369	1.0879	0.7131	1.2666	1.3071
9	2.1458	1.4364	0.6507	1.4415	1.1357	0.8928	0.5312	0.9893	1.2246
10	0.5992	1.2416	0.1696	0.8098	0.6615	0.9710	1.1982	0.9693	0.8737
MEAN	1.4477	1.1721	1.0160	1.2192	1.2158	1.2201	0.7925	1.1993	

SUMMARY DATA FOR MEASURE # 7: RATINGS OF PERCEIVED CARDIOVASCULAR EXERTION--AVERAGE

TABLE OF MEANS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
DECILE									
1	10.6942	11.6630	11.3257	11.2277	10.4498	11.4055	12.1785	11.3446	11.2861
2	10.9143	11.5368	11.1202	11.1904	10.8585	10.8135	12.0838	11.2519	11.2212
3	10.7600	11.1087	11.7690	11.2126	10.7480	11.6963	12.4455	11.6299	11.4212
4	10.4840	11.0158	11.0655	10.8551	10.2200	10.9060	11.9542	11.0267	10.9409
5	10.3798	11.9197	11.8572	11.3856	10.8188	11.2915	12.3918	11.5007	11.4431
6	10.3000	11.3953	11.7920	11.1624	11.0875	10.8902	12.5360	11.5046	11.3335
7	10.9668	11.9305	11.4212	11.4395	10.8800	11.0545	12.5250	11.4865	11.4630
8	10.9120	11.1488	11.8950	11.3186	11.2625	9.8375	12.6398	11.2466	11.2826
9	10.9445	11.5420	12.0800	11.5222	11.1107	10.4288	12.2400	11.2598	11.3910
10	10.8750	11.1028	11.9225	11.3001	10.6043	11.0328	12.5000	11.3790	11.3395
MEAN	10.7231	11.4363	11.6248	11.2614	10.8040	10.9357	12.3494	11.3630	

TABLE OF STANDARD DEVIATIONS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
1	2.0494	1.1075	1.7620	1.5819	2.3164	2.1527	0.7043	1.8460	1.6823
2	1.4411	1.0785	1.4298	1.2306	2.0442	2.0342	1.1140	1.7275	1.4671
3	0.9533	1.0508	0.8211	0.9612	2.1457	1.8091	0.8703	1.6974	1.3657
4	1.7626	0.7577	1.4064	1.2724	2.2243	2.6391	1.0453	2.0252	1.6564
5	2.5828	1.7502	0.7467	1.8328	1.4994	1.3767	0.7679	1.3284	1.5665
6	2.4842	2.3407	1.0897	1.9838	1.9876	2.7614	1.1646	2.0284	1.9699
7	3.5601	0.9664	1.4298	2.1066	1.9111	1.7718	1.5716	1.7662	1.9013
8	2.4453	2.3109	1.1454	1.9069	1.8572	1.8062	0.3795	1.7373	1.7844
9	2.9090	2.4982	1.0132	2.1271	1.5076	1.5617	0.8365	1.4437	1.7829
10	1.3150	1.9536	1.2230	1.4632	1.5596	1.6680	1.2323	1.5985	1.4992
MEAN	2.0139	1.5271	1.1430	1.6352	1.6934	1.8270	0.9185	1.6744	

SUMMARY DATA FOR MEASURE # 8: HEART RATE--AVERAGE

TABLE OF MEANS

DECILE	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
1	145.1408	147.5498	144.2343	145.6416	132.2000	136.8735	143.1947	137.4228	141.5322
2	140.5165	143.9095	145.0650	143.1637	135.6685	139.6085	141.3610	138.8793	141.0215
3	135.5835	141.4185	146.1570	141.0530	131.5150	142.3578	141.5735	138.4821	139.7675
4	133.7262	140.3735	139.3633	137.8210	130.7100	137.3085	138.7458	135.5881	136.7045
5	136.0417	139.5165	142.0000	139.1861	133.3918	137.7048	143.9168	138.3378	138.7619
6	134.8000	137.1083	140.4525	137.4536	134.0000	135.2518	141.3968	136.9828	137.1682
7	137.2875	141.9315	140.4093	139.8761	130.5088	134.9515	148.4433	137.9678	138.9220
8	139.7323	140.4573	142.8857	141.0251	132.2125	135.6168	150.4032	139.4108	140.2180
9	137.1233	140.5390	146.7085	141.4569	126.3868	137.1378	144.8403	136.1216	138.7893
10	135.9165	138.4215	144.5715	139.6365	122.3333	135.5240	142.8335	133.5636	136.6000
MEAN	137.5868	141.1225	143.1847	140.6314	130.8927	137.2335	143.6709	137.2657	

TABLE OF STANDARD DEVIATIONS

DECILE	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
1	17.8021	11.5755	10.1920	12.3871	21.8542	11.9726	4.8194	14.0651	13.6242
2	21.7640	10.9374	6.9839	13.3856	17.4802	8.4982	2.4077	10.5258	11.9779
3	21.7871	8.2149	10.6100	14.1055	20.8555	7.2610	7.0533	13.1590	13.4051
4	18.0198	5.7259	7.9649	11.1415	15.1656	10.3881	0.8485	10.2814	10.5463
5	17.4569	8.1585	10.2488	11.6802	22.8253	4.6041	5.2219	13.2540	12.2249
6	16.8315	8.7611	5.2136	10.5587	20.3516	9.4338	3.2844	12.3115	11.2203
7	18.2709	9.6024	4.2776	11.1918	21.5949	7.4483	7.1089	14.8169	12.8784
8	16.5668	8.5611	10.0731	11.1579	19.8887	4.0420	9.6782	14.3491	12.5974
9	15.4420	9.4289	10.8892	11.7806	21.8133	1.8100	6.9096	14.3583	13.1301
10	16.8048	10.7023	5.3166	11.4189	15.3260	5.2270	12.0044	13.7593	12.7486
MEAN	16.2758	8.6337	7.8752	11.7029	17.8404	7.0786	6.7923	12.7787	

SUMMARY DATA FOR MEASURE # 9: WORK PERFORMED

TABLE OF MEANS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
DECILE									
1	1695.9790	2117.2083	2272.3750	2028.5208	1798.7498	2551.5833	2281.6670	2210.6667	2119.5937
2	1898.1665	2324.7915	2795.2083	2339.3888	1706.0830	2434.1665	2262.3335	2134.1943	2236.7915
3	1809.9373	2348.8125	2847.0836	2335.2777	1598.1665	2399.8335	2244.7918	2080.9306	2208.1042
4	2006.3748	2285.3750	2986.6253	2426.1250	1551.5833	2233.4165	2223.4167	2002.8055	2214.4652
5	1996.6248	2367.9793	2957.6665	2440.7568	1432.6670	1941.0000	1904.9585	1759.5419	2100.1493
6	1813.9997	2606.5000	2856.1667	2425.5555	1140.2912	2108.3750	1959.7500	1736.1387	2080.8471
7	1987.3750	2712.7290	3156.8333	2618.9791	1105.8960	2059.8753	2116.1250	1760.6321	2189.8056
8	2005.4583	2702.2500	2942.0000	2549.9027	1349.9165	1764.3750	1949.7500	1688.0138	2118.9583
9	1977.1875	2376.0208	2738.6667	2363.9583	1131.8335	1849.3750	1886.4167	1622.5418	1993.2501
10	1704.5418	2527.6667	2768.9165	2333.7083	1013.5000	1922.6665	1811.8333	1582.6666	1958.1875
MEAN	1889.5645	2436.9333	2832.1542	2386.2175	1382.8687	2126.4666	2064.1043	1857.8133	

TABLE OF STANDARD DEVIATIONS

	CYCLE 1 GROUP 1	CYCLE 1 GROUP 2	CYCLE 1 GROUP 3	CYCLE MEAN	CYCLE 2 GROUP 1	CYCLE 2 GROUP 2	CYCLE 2 GROUP 3	CYCLE MEAN	DECILE MEAN
1	747.2710	646.3853	661.1330	670.9309	628.4565	1093.8287	630.2283	805.0738	730.7018
2	853.0344	527.5909	546.9288	708.7825	611.9995	1406.9923	334.7538	882.0133	789.5004
3	725.8881	850.4088	474.7772	773.3640	484.4186	1171.2267	166.7600	759.7350	760.9015
4	872.7368	902.4789	434.9904	816.6845	506.9779	978.6878	314.8197	685.1485	768.2736
5	721.6281	889.1698	318.5387	745.7451	528.8564	851.1726	261.9156	592.5316	744.9496
6	573.9741	1191.4381	228.4175	840.5683	368.5307	973.2980	289.4424	718.2736	841.8139
7	658.8531	909.5696	129.6224	775.9228	297.6369	658.0614	173.2585	620.3633	814.9828
8	626.8603	1114.8129	480.6958	825.3907	328.3880	514.3852	336.7591	448.4417	784.7233
9	628.6788	927.4368	469.5897	712.7568	227.0538	602.9618	487.6325	556.4675	731.0699
10	620.5754	1106.0364	550.0594	864.6856	271.2709	761.7839	611.7410	677.7410	851.1255
MEAN	633.5738	834.2422	457.6350	760.8550	473.8834	863.1732	385.6206	693.4700	

APPENDIX B

Summary of Analysis of Variance of Heart Rate Measures

Table 1

Resting Heart Rate

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	3150.38	1575.189	.6760
Cycle (C)	1	50.05	50.050	1.1316
Deciles (D)	9	289.65	32.183	.8010
Subjects w/in Groups	9	20972.24	2330.249	------
G X C	2	69.29	34.645	------
G X D	18	1407.77	78.209	1.9465*
C X D	9	233.82	25.980	.6381
C X S (G)	9	398.07	44.230	------
D X S (G)	81	3254.52	40.179	------
G X C X D	18	831.68	46.204	1.1348
C X D X S (G)	81	3298.05	40.717	------

* $p < .05$

Table 2

Final Heart Rate

Source of Variation	df	Sum of Squares	Mean Square	*F*
Group (G)	2	9375.78	4687.888	2.1648
Cycle (C)	1	637.00	637.002	10.0305*
Deciles (D)	9	516.86	57.429	1.3314
Subjects w/in Groups	9	19489.93	2165.547	------
G X C	2	405.90	202.949	3.1957
G X D	18	681.49	37.861	.8777
C X D	9	169.72	18.858	.3831
C X S (G)	9	571.56	63.507	------
D X S (G)	81	3493.98	43.136	------
G X C X D	18	254.59	14.144	.2873
C X D X S (G)	81	3986.93	49.221	------

* $p < .05$

Table 3

Heart Rate (slope)

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	320.39	160.195	.6809
Cycle (C)	1	162.48	162.477	28.6107**
Deciles (D)	9	35.85	3.983	2.8742**
Subjects w/in Groups	9	2117.41	235.268	------
G X C	2	11.16	5.582	.9830
G X D	18	85.99	4.777	3.4472**
C X D	9	68.12	7.569	3.5510**
C X S (G)	9	51.11	5.679	------
D X S (G)	81	112.26	1.386	------
G X C X D	18	46.11	2.562	1.2018
C X D X S (G)	81	172.66	2.132	------

** $p < .01$

Table 4

Heart Rate (average)

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	3383.13	1691.566	.6340
Cycle (C)	1	679.67	679.671	10.3548*
Deciles (D)	9	648.86	72.096	2.3387*
Subjects w/in Groups	9	23013.10	2668.122	------
G X C	2	523.79	261.895	3.9900
G X D	18	607.61	33.756	1.0950
C X D	9	341.16	37.907	1.1826
C X S (G)	9	590.74	65.683	------
D X S (G)	81	2497.04	30.828	------
G X C X D	18	528.34	29.352	.9157
C X D X S (G)	81	2596.48	32.055	------

* $p < .05$

APPENDIX C

Summary of Analysis of Variance of Ratings of Perceived Exertion

Table 1

Ratings of Perceived Muscular Exertion (slope

Source of Variation	df	Sum of Squares	Mean Square	*F*
Group (G)	2	2.95631	1.47816	1.9542
Cycle (C)	1	1.12628	1.12628	8.0634*
Deciles (D)	9	.38324	.04259	.8061
Subjects w/in Groups	0	6.80769	.75641	------
G X C	2	.31852	.15926	1.1402
G X D	18	.79939	.04441	.8407
C X D	9	1.14159	.12684	2.8989*
C X S (G)	9	1.25710	.13968	------
D X S (G)	81	4.27882	.05282	------
G X C X D	18	.61790	.03433	.7845
C X D X S (G)	81	3.54422	.43756	------

* $p < .05$

Table 2

Ratings of Perceived Muscular Exertion (average)

Source of Variation	df	Sum of Squares	Mean Square	*F*
Group (G)	2	22.2916	11.14578	.4746
Cycle (C)	1	3.2019	3.20190	8.2392*
Deciles (D)	9	3.9291	.43656	.8353
Subjects w/in Groups	9	211.3452	23.48280	------
G X C	2	9.9682	4.98412	12.8252**
G X D	18	9.1132	.50629	.9687
C X D	9	2.2025	.24472	.5412
C X S (G)	9	3.4976	.38862	------
D X S (G)	81	42.3335	.52264	------
G X C X D	18	6.7334	.37408	.8273
C X D X S (G)	81	36.6268	.45218	------

* $p < .05$

** $p < .01$

Table 3

Ratings of Perceived Cardiovascular Exertion (slope)

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	1.59169	.79584	.5513
Cycle (C)	1	1.80353	1.80353	13.5742**
Deciles (D)	9	.55114	.06124	1.1009
Subjects w/in Groups	9	12.99309	1.44368	------
G X C	2	1.41132	.70566	5.3111*
G X D	18	1.17184	.06510	1.1703
C X D	9	1.31199	.14578	3.4964
C X S (G)	9	1.19579	.13287	------
D X S (G)	81	4.50586	.05563	------
G X C X D	18	1.39290	.07738	1.8560
C X D X S (G)	81	3.37717	.04169	------

* $p < .05$

** $p < .01$

Table 4

Ratings of Perceived Cardiovascular Exertion (average)

Source of Variation	df	Sum of Squares	Mean Square	F
Group (G)	2	61.8025	30.90125	.6336
Cycle (C)	1	.6197	.61966	.3356
Deciles (D)	9	4.9651	.55168	1.0877
Subjects w/in Groups	9	438.9344	48.77049	------
G X C	2	15.0258	7.51290	4.0686
G X D	18	12.1041	.67245	1.3258
C X D	9	1.9834	.22038	.3421
C X S (G)	9	16.6189	1.84654	------
D X S (G)	81	41.0833	.50720	------
G X C X D	18	7.1281	.39601	.6147
C X D X S (G)	81	52.1833	.63324	------