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Female work capacity during the menstrual cycle

Physiological and psychological reactions

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GAMBERALE, F., STRINDBERG, L. and WAHLBERG, I. Female work capacity during the menstrual cycle: Physiological and psychological reactions. *Scand. j. work environ. & health* 1 (1975) 120-127. Changes in physical and mental work capacity during the menstrual cycle were studied in 12 healthy women with severe menstrual distress. Physiological and psychological tests were performed before, during, and after menstruation. Heart rate, pulmonary ventilation, oxygen uptake, blood lactate concentration, and perceived exertion were measured during work on a bicycle ergometer at two submaximal work loads corresponding to 40 and 70 %, respectively, of individual maximal oxygen uptake. Mental work capacity was studied with the aid of performance tests of psychological functions such as attention, short-term memory, perceptual speed, perception of time, and reaction time. No change in heart rate or oxygen uptake could be observed over the three phases of the menstrual cycle. However, pulmonary ventilation during work varied significantly. It was highest in the menstrual phase. At the same heart rate exercise on the bicycle ergometer was perceived as more exerting in the menstrual phase than in either the premenstrual or postmenstrual phase. Among the performance tests significant results were obtained only in a test of reaction time, which was slightly impaired during the menstrual phase. The results of the performance tests do not however support the assumption that menstruation affects a woman's mental work capacity.

Key words: menstrual cycle, work capacity, physiological-psychological reactions.

Female physical work capacity during different phases of the menstrual cycle has been the subject of study and discussion. In a study of participants in the Helsinki Olympics, Bausenwein (2) found that most of the female competitors produced their poorest results immediately prior to menstruation. This finding led to the conclusion that women should refrain from hard training a few days before menstruation. Similar results have been obtained in other studies. Thus in exami-

nations of sports performances Erdelyi (8) and Wearing et al. (20) found that poorer results were attained immediately prior to or during menstruation than after menstruation.

However, these studies applied to maximal sports performances in which non-physical factors, such as motivation, may have had an effect on the results attained. Very little is known about the possible fluctuations in the circulatory and ventilatory response at the submaximal work intensities to which people may be exposed during their daily work.

It has long been assumed that a woman's mental performance capacity is impaired prior to and during menstruation. Extensive research has been devoted to studies of emotional changes during the menstrual cycle. Cyclical changes in anxiety, aggression, depression, and sub-

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jective well-being were reported by, e.g., Moos et al. (13) in a recently performed study. However, the assumption of concomitant changes in intellectual capacity has yet to be confirmed (17, 21).

Kopell et al. (11) advanced the hypothesis that the nervous system's arousal level may be altered during the menstrual cycle as a consequence of changes in estrogen and progesterone secretion. In support of this hypothesis the authors reported changes in the perception of time and the two flash fusion (TFF) threshold during the menstruation cycle. A low arousal level before and during the menstrual period has been suggested, in accordance with the aforementioned hypothesis, as the cause of, e.g., the results obtained by Dalton (5), i.e., a higher accident rate during this period of time.

In view of the consequences which any such fluctuations would have on the suitability of women for certain occupations, further research would appear to be greatly justified. However, support for the hypothesis cited has been weak to date. Adrenaline secretion, which has been assumed to be an indicator of arousal level, has not proved to vary systematically during the menstrual cycle (14). DeMarchi and Tong (6) showed that changes in the TFF threshold during the menstrual cycle were the result of a more cautious attitude on the part of subjects and not the result of changes in sensory sensitivity, as Kopell's hypothesis suggested. No systematic change in simple reaction time has yet been linked to the menstrual cycle (11, 15).

The objective of the present study was to examine female physical and mental work capacity during the menstrual cycle. The physical aspects covered the circulatory and ventilatory response to submaximal work loads. Moreover, subjective perception of physical exertion was also examined. The mental aspects covered those components which were believed to be affected by changes in the arousal level of the nervous system.

All subjects chosen for the study suffered from severe menstrual distress. The idea was that no impairment in work capacity during menstruation would be assumed for women in general unless impairment was found in this group before or during menstruation.

PHYSIOLOGICAL REACTIONS

Subjects and methods

Twelve healthy women from 20 to 34 years of age (mean age: 27 years) participated in the study. All had regular menstrual cycles. None used oral contraceptives. All had severe menstrual distress such as nausea, headache, and/or pain leading to the use of analgesics and an occasional absence from work. No analgesics were permitted during the study.

The subjects were carefully examined with conventional clinical examination techniques. All proved to be healthy. Subjects participated in experiments on three different days of the menstrual cycle, i.e., on the first or second day of menstruation, 10 to 18 days after the start of menstruation (postmenstruation) and 6 to 2 days prior to the estimated start of menstruation (premenstruation). Subtrials for each individual subject took place at the same time of day. Subjects were asked not to alter their usual program of physical activity during the course of the examination. In order to counterbalance training effects, four subjects began the series of experiments during the premenstrual phase, four began during the menstrual phase, and four began during the postmenstrual phase.

Body weight and hemoglobin content were measured at each subtrial. Blood pressure, heart rate, pulmonary ventilation, and oxygen uptake at rest were also measured.

Subjects then exercised on a bicycle ergometer for 6 min at each of the two loads calling for 40 % and 70 % of their individual maximal oxygen uptakes, respectively. These work intensities represented the exertion to which a person may be exposed on the job. In order to establish the loads cited, each subject performed a maximal exercise test (1) before the study began. Their maximal oxygen uptakes varied from 1.7 l/min to 2.5 l/min around a mean value of 2.18 l/min. The submaximal work loads varied from 37 to 58 W and 87 and 112 W, respectively, so as to correspond to the demand for 40 and 70 % of individual oxygen uptake, respectively.

Heart rate, oxygen uptake, blood lactate concentration, pulmonary ventilation, and blood pressure were determined in the final two minutes at each load. Heart rate was recorded by means of an ECG. The values used were the mean values for heart rate in the final 2 min.

Expiratory air was collected in Douglas bags in the final minutes at each load, and its volume was measured in a balanced spirometer. The oxygen and carbon dioxide content in expiratory air was analyzed according to the method of Haldane, and oxygen uptake was calculated. Blood samples for lactic acid determinations were taken immediately after the end of work at each load. The analysis was performed according to Ström's modification (18) of the Barker and Summerson technique. Hemoglobin content was determined with a spectrophotometer and the cyanmethemoglobin method.

Results

A two-way analysis of variance (22), in which the individuals and the phases constituted the two dimensions of classification, was used for the statistical testing of the significance of differences between values obtained in the three different phases of the menstrual cycle. There were no significant differences at rest between the three phases of the cycle with respect to body weight, hemoglobin content, blood pressure, heart rate, and oxygen uptake (table 1). However, pulmonary ventilation tended to be somewhat higher during the menstrual phase than during the other two phases [$F(2,22) = 3.00$; $p < 0.10$].

With a 40 and 70 % utilization of maximal oxygen uptake, no differences in heart rate and oxygen uptake were recorded for the three phases. However, blood lactate concentration tended to vary between the three phases (table 2 and 3), the highest concentration being obtained during the postmenstrual phase. At the higher work load pulmonary ventilation varied significantly between the phases [$F(2,22) = 5.64$; $p < 0.05$]. Pulmonary ventilation was higher during the menstrual phase than during either the premenstrual [$F(1,11) = 5.69$; $p < 0.05$] or the postmenstrual phase [$F(1,11) = 10.13$; $p < 0.01$]. The differences between the premenstrual and postmenstrual phases were not statistically significant [$F(1,11) = 0.86$; $p > 0.05$].

PSYCHOLOGICAL REACTIONS

Subjects and methods

The same twelve, healthy subjects were used as in the physiological experiments. Each subject estimated the degree of perceived exertion with the aid of a scale giving ratings of perceived exertion (RPE) according to Borg (3, 4) in the final minute of the two loads on the bicycle ergometer. In previous studies using the RPE scale estimates of perceived exertion displayed a linear relationship to heart rate (4, 9).

Six psychological tests were performed in the following sequence prior to the physical exercise tests.

Choice reaction time (CRT). A stimulus/response panel was placed on a desk in

Table 1. Mean values for body weight, heart rate, blood pressure, hemoglobin content (Hb), oxygen uptake (VO_2), and pulmonary ventilation at rest on the three different measurement occasions, along with F-values for the differences between measurement occasions.

Variables	Pre-menstruation	Menstruation	Post-menstruation	F
Body weight (kg)	59.5	60.1	59.3	0.21
Heart rate (beats/min)	65	66	65	1.13
Blood pressure (mm Hg)	110/73	111/71	110/72	0.75/0.63
Hb (g %)	13.9	13.9	14.2	1.31
VO_2 (l/min)	0.26	0.27	0.26	0.52
Pulmonary ventilation (l/min)	8.3	9.1	8.3	3.00

front of the subject. The subject's fingertips rested 70 mm from three pressure plates, each supplied with a stimulus lamp. The subject was instructed to respond to a signal from any of the lamps by pressing the corresponding pressure plate with her fingertips. She could follow this instruction only by moving her entire hand towards the pressure plate. Stimulus administration followed a random pattern, determined in advance, with the number of visual signals evenly distributed among the lamps. Reaction time was recorded at about 8-s intervals. An acoustic warning signal was emitted 3 s prior to the administration of each stimulus. A total of 30 stimuli were provided in each trial. Performance was measured as the mean reaction time for the last 20 stimuli administered.

Time estimation (T 15 and T 30). The subject was asked to estimate two periods of time, 30 s and 15 s, with the aid of the stimulus response panel described in the preceding section. The start of each time period was indicated by the lighting of a lamp on the panel. This action started an electronic timer. The subject could stop the timer by pressing a pressure plate when she felt a specific time period had elapsed. The subject was instructed

not to count to herself. The first time estimate was for 30 s, and the second for 15 s. The procedure was repeated four times, and the mean value was calculated for an estimation of 30 s and 15 s, respectively.

Serial Color Word Test (SCWT 1 and 2). A perceptual conflict test, the Serial Color Word Test (SCWT) according to Smith et al. (16), was used. SCWT is a modification of the Stroop test (19). It consisted of two parts, SCWT 1 without perceptual conflict and SCWT 2 with perceptual conflict. In SCWT 1 a full sheet of paper (210 × 297 mm) was used on which a number of groups of crosses were printed, each group of crosses being either yellow, blue, red, or green. The subject was instructed to indicate the color of each group of crosses as quickly as possible. In the SCWT 2 the crosses on the sheet were replaced by the letters "yellow," "blue," "red," and "green." However, the words were printed in colors other than the colors indicated by the words. The task of the subject was the same as in SCWT 1, i.e., to indicate as quickly as possible the color in which each word was printed. The time required to accomplish this task was measured.

Table 2. Mean values for heart rate, blood lactate concentration (Hla), oxygen uptake ($\dot{V}O_2$), and pulmonary ventilation at a 40 % work load, along with F-values for the differences between measurement occasions.

Variables	Pre-menstruation	Menstruation	Post-menstruation	F
Heart rate (beats/min)	105	106	105	0.11
Hla (mmol/l)	1.8	1.8	2.1	2.75
$\dot{V}O_2$ (l/min)	0.88	0.86	0.88	0.37
Pulmonary ventilation (l/min)	22.7	22.9	22.2	0.96

Table 3. Mean values for heart rate, blood lactate concentration (Hla), oxygen uptake ($\dot{V}O_2$), and pulmonary ventilation at a 70 % work load, along with F-values for the differences between measurement occasions.

Variables	Pre-menstruation	Menstruation	Post-menstruation	F
Heart rate (beats/min)	148	145	146	2.38
Hla (mmol/l)	4.4	4.1	5.0	3.30
$\dot{V}O_2$ (l/min)	1.51	1.50	1.52	1.11
Pulmonary ventilation (l/min)	42.1	43.5	41.6	5.64 ^a

^ap < 0.05; df = 2,22.

Table 4. The analysis of variance of the rating of perceived exertion in exercise on a bicycle ergometer during premenstrual, menstrual, and postmenstrual phases of the menstrual cycle.

Source of variation	df	MS	F	p
Menstrual cycle (M)	2	6.77	4.57	< 0.05
Work intensity (I)	1	485.68	162.98	< 0.001
Subjects (S)	11	6.62		
M $\times$ I	2	0.03	0.06	
M $\times$ S	22	1.48		
I $\times$ S	11	2.98		
M $\times$ I $\times$ S	22	0.54		

Search test (S 1 and S 2). Two versions of the test were used with differing demands on short-term memory (12). The test material consisted of a matrix (7×7) in which each square contained a letter of the alphabet and a number. In S 1 the subject was shown combinations of letters and numbers which she then had to find in the matrix. The other search task, S 2, consisted of alphameric groups with three combinations of a letter and a number in each group. One of the combinations in each group could be found in the matrix. The subject's task was to identify this combination among the three combinations. Twenty combinations were provided in each version. Performance was measured as the mean time required to locate a combination.

Letter elimination. This test, which was similar in nature to ordinary tests of perceptual speed, imposed severe demands on short-term memory. The test material consisted of a full page (210×297 mm) containing 20 lines with 30 consonants in each line. Six of the consonants were specified as search letters which could be found repeatedly anywhere in the matrix. The task of the subject was to mark as quickly as possible all the letters in the matrix which were identical to any of the search letters. Thus the subject was forced to keep the search letters in mind in order to perform the task efficiently. The time needed to complete the test and the number of errors were recorded.

Perceptual speed: Bourdon-Wiersma. A modified version of the Bourdon-Wiersma Vigilance Test was used (10). The test material consisted of a full page (210×297 mm) with groups of dots arrayed in 20 lines with 25 groups of dots on each line. Each group of dots consisted of

three, four, or five dots. The subject's task was to cross out each group with four dots as quickly as possible, starting from left to right, line by line. The time needed to complete the test and the number of errors made were recorded.

Results

Estimates of perceived exertion in exercise on the bicycle ergometer were subjected to an analysis of variance. The model for the analysis of variance corresponded to a model for a 3^2 factorial design with repeated measurements (22). The two sources of variation in the analysis consisted of the phases in the menstrual cycle and the work loads in the exercise on the bicycle ergometer.

The results from each of the psychological tests were submitted to an analysis of variance. The model for the analysis of variance corresponded to a 3^2 Latin square with repeated measurements (22). The two dimensions in the classification consisted of the phases in the menstrual cycle and the measurement sequences. The latter classification was used in order to analyze the training effect which occurred from the repeated testing.

The results of the analysis of variance of the estimates of perceived physical exertion are shown in table 4. The degree of perceived exertion varied significantly with the phase in the menstrual cycle [$F(2,22) = 4.57$; $p < 0.05$]. Fig. 1 shows that the same exercise intensity was found to be more tiring during the menstrual phase than in the pre- and postmenstrual phases. Fig. 2 shows that lower estimates of perceived exertion at the same heart rate were obtained during the pre-

Fig. 1. Rating of perceived exertion (RPE) at different phases of the menstrual cycle. Ratings obtained after 5 min of work on the bicycle ergometer at two submaximal intensities corresponding to 40 (●-----●) and 70 % (○-----○) of each subject's maximal oxygen uptake, respectively. The circles in the figure indicate mean values for 12 subjects.

and postmenstrual phases than during the menstrual phase.

The results of the analysis of variance of performance on the psychological tests are summarized in table 5. Only the test of choice reaction time varied significantly in the three different phases of the menstrual cycle [$F(2,18) = 5.04$; $p < 0.05$]. Reaction time tended to be longer during the menstrual phase than during the pre- and postmenstrual phases (see table 6). Performance was affected significantly by training on four of the six tests, i.e., choice reaction time, SCWT, Letter elimination and Bourdon-Wiersma. No significant interaction was observed between training and phases of the menstrual cycle.

DISCUSSION

The objective of the physiological part of the study was to examine whether the circulatory and ventilatory response to physical work varied during the menstrual cycle. There were no differences in heart rate or oxygen uptake, either at rest or at the two submaximal work intensities, during the three phases. On the other

Fig. 2. Relation between the rating of perceived exertion (RPE) and heart rate during work on the bicycle ergometer at different phases of the menstrual cycle. The regression lines were calculated for values of two work loads corresponding to 40 and 70 % of each subject's maximal oxygen uptake, respectively. (●-----● = premenstruation, $y = 0.106x - 0.870$, $r = 0.850$; ○-----○ = menstruation, $y = 0.111x - 0.459$, $r = 0.846$; □..... = postmenstruation, $y = 0.098x - 0.217$, $r = 0.785$)

hand, pulmonary ventilation varied. It was at a maximum during menstruation, both at rest and at one submaximal work intensity. The increased ventilation, which was not caused by increased oxygen uptake, may have been due to pain during menstruation. However, this hyperventilation did not appear to have had any major effect on cardiorespiratory adaptation during submaximal work.

Thus no results were obtained pointing to any real differences in cardiorespiratory adaptation during submaximal work, measured on the basis of heart rate and oxygen uptake, during the menstrual cycle, even though the study comprised women with severe menstrual distress. Similar results were obtained by Doolittle & Engebretsen (7) in a study of 16 female university students. As already mentioned, however, Bausenwein (2) and Erdelyi (8) both found that physical work capacity varied during the menstrual cycle. These studies referred to maximal performances by top women athletes. In maximal performances, however, factors such as motivation and perceived exertion are probably very important to results. This view was supported, e.g., by our

results, which indicated that subjectively perceived exertion was greater during menstruation when work was performed at submaximal intensities. Thus our results do not conflict with results obtained in earlier studies.

The results of this study failed to support the hypothesis that a woman's ability to perform mentally demanding tasks is altered during the menstrual cycle. Statistically significant results were obtained for only one of the six tests used, i.e., choice reaction time, which increased during menstruation. The differences be-

tween the three measurement occasions during the menstrual cycles were entirely within the realm of chance for the remaining tests. Thus the present study was unable to confirm the results of Kopell et al. (11) on cyclical changes in the perception of time. The results were unexpected, since we used the same technique in the testing of time perception as these authors. The results from the choice reaction time test should be interpreted with great caution. The training effect in this test was found to be somewhat greater than expected on the basis of results ob-

Table 5. Summary of the analyses of variance of results from different tests performed during the three phases of the menstrual cycle, along with F-values for the effects of the menstrual cycle (M), training (T) and interaction between the two (M x T).

Performance test	Source of variation		
	M	T	M x T
Choice reaction time	5.04 ^a	15.97 ^b	0.78
Time estimation 15 s	1.49	2.12	0.44
Time estimation 30 s	0.05	1.62	1.15
SCWT 1	1.17	20.26 ^b	1.48
SCWT 2	0.40	24.63 ^b	0.17
Search test 1	0.33	2.24	0.52
Search test 2	0.22	1.73	0.05
Letter elimination (time)	0.65	26.87 ^b	1.07
Letter elimination (no of errors)	0.81	11.11 ^b	0.05
Letter elimination (time and no. of errors) ^c	0.86	26.68 ^b	0.23
Bourdon-Wiersma (time)	1.17	28.56 ^b	1.12
Bourdon-Wiersma (no. of errors)	0.01	5.14 ^a	0.50
Bourdon-Wiersma (time and no. of errors)	0.22	25.72 ^b	0.01

^a $p < 0.05$; $df = 2,18$,

^b $p < 0.01$; $df = 2,18$

^c The analysis was performed on a combination of time (speed) and number of errors (accuracy) after transformation into z values.

Table 6. Mean values (M) and standard deviations (SD) for the performance of 12 subjects on different tests performed during the three phases of the menstrual cycle.

Performance test	Premenstruation		Menstruation		Post-menstruation	
	M	SD	M	SD	M	SD
Choice reaction time (m sec)	460	69.4	490	71.9	464	70.4
Time estimation 15 s (sec)	16.0	6.3	16.8	7.7	14.7	5.4
Time estimation 30 s (sec)	26.8	10.2	27.0	12.4	27.5	11.9
SCWT 1 (sec)	50.9	7.7	52.3	5.3	52.0	7.7
SCWT 2 (sec)	79.7	20.3	81.5	14.8	80.4	20.4
Search test 1 (sec)	2.49	0.43	2.44	0.62	2.57	0.42
Search test 2 (sec)	9.33	3.97	9.64	2.78	9.00	2.22
Letter elimination (min)	4.31	1.14	4.52	1.17	4.28	0.92
Letter elimination (no. of errors)	6.32	5.21	9.20	6.39	8.30	8.40
Bourdon-Wiersma (min)	6.22	0.71	6.35	0.40	6.25	0.76
Bourdon-Wiersma (no. of errors)	15.0	11.0	14.6	8.4	15.1	17.7

tained by authors in previous investigations.

Certain limitations should be kept in mind when generalizing these results for the implications to ordinary work situations outside the laboratory. The effect of the menstrual cycle on performance in mentally demanding work was studied in a situation in which the subjects worked with maximal effort during limited periods of time. The tests used, like the instructions and pauses, were especially selected so as to reduce to the greatest possible extent the effect of mental fatigue and fluctuations in motivation. The possibility of cyclical changes in performance capacity, owing to the joint action of adverse factors, such as mental fatigue and declining motivation, can therefore not be precluded. There is every reason to assume that relevant knowledge of the effects of the menstrual cycle on both mental and physical performance capacity can be obtained if attention is devoted to an elucidation of motivational aspects.

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