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BRIEF NOTE

THE INFLUENCE OF THE MENSTRUAL CYCLE ON THE BLOOD FLOW THROUGH MUSCLE DURING ISOMETRIC EXERCISE[1]

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The endurance time for fatiguing isometric contractions is about one-third longer in women than men when contractions are sustained at 40% of each individual's maximum strength (Petrofsky *et al* 1975). Although the endurance in men remains somewhat constant from day to day, we have found that while this endurance is also true for women taking oral contraceptives, it is not the case for women with normal menstrual cycles where there was a sinusoidal variation in endurance throughout the cycle. The longest endurance occurs 7 to 10 days after the onset of bleeding (Petrofsky *et al* 1975). Some of this variation in endurance was considered to be due to fluctuations in the deep muscle temperature of the forearms of these subjects, but a large proportion of the variation remained unexplained. Two principal factors having an important influence on isometric endurance are muscle temperature (Clarke *et al* 1958) and the blood flow through the muscle during contractions (Barcroft and Millen 1939). It has been shown that muscle temperature alone cannot account for this large variation in endurance (Petrofsky *et al* 1975). The purpose of this investigation was to determine whether or not there is a change in muscle blood flow throughout the menstrual cycle that could account for the change in endurance.

The subjects in this study were 4 female volunteers. Two subjects were taking the oral contraceptive, OVULIN 21. We measured isometric strength and endurance on a handgrip dynamometer and assessed the maximal voluntary contraction (MVC) as the strongest of 2 brief (< 3 sec) maximal efforts. Three minutes were allowed between contractions. In each experiment, 30 min following the assessment of isometric strength a tension of 40% MVC was held to fatigue (endurance time.

Subjects' blood pressures were measured by auscultation of the inactive arm before, as often as possible during, and 30 sec and 60 sec after the contractions. Their heart rate was measured from a continuous recording of the ECG at rest and throughout the duration of the 40% MVC contraction. The blood flow through the forearm was measured by venous occlusion plethysmography, using a mercury-in-rubber strain gauge dynamometer. One minute prior to any flow measurements, a wrist cuff was inflated to 300 mmHg to occlude the circulation to the hand. The blood flow was measured 5 times/min at rest, during the isometric contractions, and at various intervals in the post exercise recovery period. The statistical analysis of the data involved calculation of means and standard deviations and related T-tests; the level for significance was $P < 0.05$.

All subjects were trained in the experimental procedures over a 6 week period (Petrofsky *et al* 1975). Following this period in each experiment, isometric strength was determined as described above and 30 min later the duration of 40% MVC contraction was measured. Blood pressure

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and heart rate were measured for 2 min before, during and at 30 sec and 60 sec after the contractions and blood flow 2 min before, during and from 2 to 5 min, 7 to 10 min and 12 to 15 min following the contractions. Each experiment was conducted on Monday, Wednesday and Friday of successive weeks for 2 complete menstrual cycles.

No statistical difference was evident in either the strength or the endurance of the 2 women taking oral contraceptives during the first and second halves of their menstrual cycles (table 1). In contrast, for the 2 subjects with normal menstrual cycles, endurance during the first half of the menstrual cycle was significantly longer than the endurance during the second half of the menstrual cycle.

Prior to the contraction, the average resting forearm blood flow was the same irrespective of the day of the menstrual cycle for the 2 women taking oral contraceptives (table 1). During the contraction, these subjects showed an almost linear rise in the blood flow with time as the contractions continued. The peak blood flow at the end of the contractions, however, showed no significant difference between the first and last halves of the menstrual cycle. Following the contractions, the blood flow recovered to the resting level with 12 min after the end of the exercise. A polynomial evaluation was made of the blood flows during recovery from each experiment to estimate the magnitude of the total blood flow debt incurred during the recovery following isometric exercise (area under the flow curve less resting flow). No significant difference existed in the average blood flow debt (blood flow debt/12 min recovery period) between the first and last halves of the menstrual cycle for the 2 women taking oral contraceptives.

In contrast, the menstrual cycle had a pronounced influence on the resting, exercising, and recovery blood flows in the 2 subjects not taking oral contraceptives. The pre-exercise forearm blood flows measured for the first halves of the mentrual cycle averaged 1.3 and 3.0 ml/100 ml/min respectively. Although the highest resting forearm blood flows were found when the subjects were in the last halves of their menstrual cycles, the average blood flows during the fatiguing contractions were significantly ($P < 0.05$) higher in the first halves of their menstrual cycles, the average peak exercising blood flows averaging 25.3 ml/100 ml/min and 21.2 ml/100 ml/min for the pre and post-ovulatory phases, respectively. The hyperaemia following exercise was complete within 12 min post exercise irrespective of the phase of the menstrual cycle; however, the average blood debt incurred by the exercise was greater in the second half of the menstrual cycle (averaging 7.3 ml/100 ml/min and 10.1 ml/100 ml/min); the difference was statistically significant ($P < 0.01$). No significant difference occurred between the heart rates and blood pressures recorded in the first and last half of the menstrual cycle for any of the subjects.

As reported previously, we found a marked increase in endurance for isometric

TABLE 1

*Blood Flow and Endurance.**

	No Contraceptives		Contraceptives	
	Ovulatory	Luteal	Ovulatory	Luteal
Strength (Kg)	32.5± 2.5	31.8± 2.7	33.1±2.9	33.6±2.3
Endurance (sec)	168 ±17	145 ±15	110 ±7	105 ±6
Blood Flow Rest (ml/100gm/min)	1.3± 1.1	3.0± 1.4	2.1±0.8	2.2±1.0
Blood Flow at End Exercise (ml/100/gm/min)	25.3± 1.8	21.2± 2.1	24.1±1.3	24.2±1.2
Blood Flow in Recovery (ml/100gm/min)	7.3± 1.0	10.1± 1.1	8.5±1.1	8.6±1.2

*All data shown represent the mean ± the S.D.

exercise in the pre-ovulatory phase of the menstrual cycle (Petrofsky *et al* 1976). Since isometric endurance is reduced when the temperature of the exercising muscle is increased toward or above the core temperature (Clarke *et al* 1958), it is not surprising that the post-ovulatory increase in core temperature and the associated increase in forearm deep muscle temperature result in a lower endurance for isometric exercise. Even when muscle temperature is stabilized, we found the endurance for isometric exercise still varies during the menstrual cycle.

Although the effects of progesterone on peripheral blood flow are questionable, there is a marked influence of estrogen on the blood flow through the hand and forearm and especially on venous tone (Nuwayhid *et al* 1975). Under the influence of estrogen, the normal blood flow response to known vasodilators may be reduced or reversed (Lloyd and Pickford 1962). It is possible, then, that the blood flow response to exercise might be reduced due to the action of estrogen during the luteal phase of the menstrual cycle and cause the endurance for isometric exercise to be lower. A curious finding of our results was that the blood flow recorded prior to and during the hyperaemia following the exercise was reduced during the pre-ovulatory phase and enhanced during the luteal phase of the menstrual cycle. The mechanism of this response, like that during exercise, remains vague and requires further investigation.

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