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EFFECTS OF TRAINING ONCE *VS.* TWICE PER DAY AND IMPROVEMENT IN MAXIMAL AEROBIC POWER[1]

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Abstract. This study was designed to determine the effects of once *vs.* twice daily workouts with respect to changes in maximal aerobic power ($\dot{V}_{O_2}{}^{max}$). Thirteen varsity track men were divided into two groups for participation in interval training, once (1/day) and twice (2/day). The intensity of each workout was based primarily on maximal heart rates (max HR). After 4 weeks of training, there was no change in $\dot{V}_{O_2}{}^{submax}$ within either of the groups, while submax heart rate (HR) was significantly lower for both groups. There were no differences between the groups for $\dot{V}_{O_2}{}^{submax}$ or submax HR. $\dot{V}_{O_2}{}^{max}$ improved significantly for both groups while max HR was significantly lower for the 1/day group following four weeks of training. Between group differences existed for max HR. Blood glucose (colori-metric) was significantly lower for the 2/day but not for the 1/day after 4 weeks of training. The data suggest that training 2 times per day is not associated with improvements in $\dot{V}_{O_2}{}^{max}$ over training one time per day.

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The ability of man to perform exhaustive endurance exercise has been of considerable interest in the recent literature. Shephard (1968) found the main factors influencing improvement in maximal aerobic capacity ($\dot{V}_{O_2}{}^{max}$) were training intensity, training frequency, and the initial level of physical fitness. Pollock *et al* (1969) found that both frequency and duration of training affected levels of $\dot{V}_{O_2}{}^{max}$. Work by Davies and Knibbs (1968) showed that the two most important factors that determined improvement in $\dot{V}_{O_2}{}^{max}$ were training intensity and duration of the training sessions. In our study, and contrary to the work of Shephard (1968) and Pollock *et al* (1969), frequency had little effect on the improvement of $\dot{V}_{O_2}{}^{max}$.

Knuttgen *et al* (1973) found no differences between training 3 and 5 times per week, and Jackson *et al* (1968) found no differences while training 1, 2, 3, and 5 times per week. Recently, Fox *et al* (1975) found that neither frequency nor duration had any effect on the improvement of $\dot{V}_{O_2}{}^{max}$. The majority of evidence seems to indicate that the frequency of training has little effect on overall improvement of maximal aerobic capacity. A recent trend in intercollegiate track work, however, has been to increase the frequency of training from 1 to 2 or even 3 times per day in an attempt to improve performance. To our knowledge, only one study by Watt *et al* (1973) relates multiple daily training to mile run times, showing no improvement when subjects trained either 1 or 2 times per day.

Due to the lack of comprehensive, descriptive data related to the frequency of training per day, our study was designed to determine the influence of increasing the frequency of training from 1 to 2 times per day upon the improvement of $\dot{V}_{O_2}{}^{max}$ and several other physiological parameters.

METHODS AND MATERIALS

Subjects. Thirteen varsity track men volunteered as subjects for this study. Prior to this study, they were engaged in a low level, non-supervised conditioning program for the indoor track season involving an outdoor running program consisting of a 10.6 Km run each day. The intensity of these runs

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was dependent on the weather conditions and on the desire of the subject. During this program, the men merely maintained an adequate level of conditioning. All subjects gave their informed consent prior to participating in the project and their vital data appear in table 1.

TABLE 1

Vital data of the subjects.

Group	n	Wt(kg)	Ht(cm)	Age
1/day	7	69.4±4.1*	179.3±6.9	19.2±1.6
2/day	6	65.9±6.5	176.6±9.2	19.1±2.2

*$\bar{X}$±SD.

Laboratory Procedures. Prior to the initiation of the experiment, each subject reported to the laboratory at least twice for preliminary evaluation. This evaluation served a two-fold purpose:

1. To familiarize each subject with the bicycle ergometer and respiratory equipment and to explain the procedure to be followed during the actual data collecting sessions;
2. To collect data at a number of submaximal workloads which would permit the estimation of each subject's maximal aerobic capacity using the familiar power output ($\dot{V}_{O_2}$) oxygen uptake heart rate (HR) relationship as described by Astrand and Rhyming (1954).

After the preliminary data collection periods, the following procedures were employed every time the subjects reported to the laboratory. Attired in shorts and tennis shoes, each man had his height and weight recorded and had 5 ml of blood withdrawn from the anticubital vein. With the aid of the preliminary power output-($\dot{V}_{O_2}$) and HR data, a submaximal workload that would elicit about 90% of the subject's maximal aerobic capacity and a second maximal workload calculated to be 5% to 10% greater than the predicted maximal were determined. Each subject pedaled the ergometer for 5 min at the submaximal level and as long as possible to a maximum of 5 min at the maximal level at 60 rpm with a 10 min rest between the rides. If the 5 min ride was completed, another 5% to 10% greater power output test was carried out.

During the last minute of the submaximal exercise ride and 30 seconds prior to exhaustion during the supermaximal exercise rides, $\dot{V}_{O_2}$, ventilation ($\dot{V}_E$), and HR were determined. Oxygen consumption was calculated using the open circuit method by collecting expired air in Douglas bags for subsequent analysis. A Beckman E-2 Oxygen Analyzer and a Beckman-Spinco LB-1 Analyzer were utilized to determine expired oxygen and carbon dioxide, respectively. Both instruments were calibrated with gases that had previously been verified on a Lloyd-Haldane chemical analyzer. Inspired ventilation volumes were measured by a Parkinson-Cowan CD-4 gas meter previously calibrated utilizing a Collins 120 liter spirometer. Heart rate was recorded on electrocardiograph Lead I. We considered maximal oxygen consumption achieved when for two different maximal workloads the $\dot{V}_{O_2}$ did not differ by more than 2% (leveling off). This work-rest sequence was repeated during the second week and at the termination of the conditioning program using the identical submaximal workload but additional maximal workloads as needed to achieve leveling off of $\dot{V}_{O_2}{}^{max}$. Extreme care was taken to duplicate the time of day, diet prior to the data collection, and the ride sequence procedure for each subject throughout the experiment. We analyzed blood samples for hematocrit, hemoglobin and plasma glucose.

Training Procedures. The athletes were divided into 2 training groups. One group participated in 1 work session per day (1/day), and a second group in 2 sessions per day (2/day). The number of athletes assigned to each group was determined primarily by the amount of time available to each subject, as many were carrying a full academic load, and on their willingness to condition 2 times a day.

The training sessions were conducted at 6:30 a.m. and 4:00 p.m. four days a week beginning on Monday. Generally, the work session included a 10.6 km run each morning for the 2/day. The afternoon session involved both the groups, and consisted of middle distance intervals with distances ranging from 400 m to 1.6 km. Each of the subjects worked at a pace commensurate to his best time on the track for a given distance. This pace was set at 75% of the optimal time, and the times for each interval were taken from a training manual designed specifically for this purpose (Gardner and Purdy 1970). Additionally, the number of intervals or the total distance covered in each workout was equated as closely as possible so that each of the workouts had a similar degree of difficulty.

Prior to the beginning of the afternoon workout, resting blood pressure was taken. Once a week HR values were determined by each subject after each of the intervals. Additionally, during the first and fourth weeks, each of the subjects ran a competitive mile for time. Between and within group differences were statistically examined using unpaired and paired *t* ratios.

RESULTS AND DISCUSSION

Maximal values. Data for maximal bicycle exercise showed very consistent trends. Both groups displayed week by week improvement in $\dot{V}_{O_2}{}^{max}$L/min, but the 1/day group had the greatest overall increases and the most consistent week by week improvement (see table 2).

When expressed as $\dot{V}_{O_2}{}^{max}$ml/kg-min, both the groups showed significant improvement between the preconditioning evaluation and the fourth week evaluation.

TABLE 2

Data from maximal bicycle ergometer rides for all subjects.

Variable	Group	n	Pre	2nd	4th	Δ Pre-4th
$\dot{V}_{O_2}$ max (L/min)	1/day	7	3.6± .84	3.8± .50	3.9±0.3	0.32±0.10*
	2/day	6	3.6± .27	3.8± .33	3.9±0.3	0.26±0.05*
$\dot{V}_{O_2}$ max (ml/kg-min)	1/day	7	52.3±3.1	55.1±2.6	57.2±2.6	4.9±1.6*
	2/day	6	54.7±1.8	58.1±2.8	59.4±1.1	4.7±0.7*
Max Heart Rate	1/day	7	185.7±6.3	182.0±7.5	180.0±7.5	−5.7±3.8*
	2/day	6	181.1±4.7	181.1±5.5	181.6±6.7	−1.5±2.8 ns

*Significant difference between preconditioning and 4th week ($P<.01$). $\bar{X}\pm SD$; ns=not significant.

Of particular significance was the fact that the 1/day group showed consistent week by week improvement, while the 2/day had the greatest improvement during the first two weeks. There were no significant differences between groups for $\dot{V}_{O_2}{}^{max}$ml/kg-min before or after conditioning.

The average workload for the groups was about the same before conditioning 1,500 kilopoundmeters/minute (kpm/min), while after conditioning, the mean workloads were 1,650 kpm/min and 1,700 kpm/min for 2/day and 1/day, respectively.

Maximal HR values generally showed a consistent decreasing trend for 1/day. This trend was not seen for 2/day. The 1/day group showed the most consistent week by week decreases in HR and also had the greatest overall difference when expressed as the difference between precondition and fourth week. The difference in maximal HR was significantly different ($P<0.05$) between the two groups.

Submaximal values. These submaximal rides represented 85% of maximal aerobic power in the 1/day group and 92% for the 2/day group. The $\dot{V}_{O_2}{}^{submax}$ showed no significant within or between group differences (see table 3). Within group submaximal HR values were decreased after 4 weeks of conditioning for the 1/day and 2/day groups. There were no significant differences between the 1/day and the 2/day groups.

Blood data. The trends for the blood variables were consistent over the 4 week period. Overall, hematocrit determinations showed no significant differences, but both groups had a slight decrease between weeks 2 and 4. Blood glucose was the one measure that showed changes over the conditioning period. As seen in table 4, the 2/day group had a significant decrease after 4 weeks of training. For the 1/day group, there was a decline from the preconditioning to second week, then the trend reversed, and at the

TABLE 3

Data from submaximal bicycle ergometer rides for all subjects.

Variable	Group	n	Pre	2nd	4th	Δ Pre-4th
$\dot{V}_{O_2}$ submax (L/min)	1/day	7	3.2±0.1	3.1±0.2	3.3±0.2	0.06±0.08*
	2/day	6	3.3±0.2	3.3±0.2	3.4±0.2	0.04±0.06*
$\dot{V}_{O_2}$ submax (ml/kg-min)	1/day	7	46.2±2.9	45.7±3.8	47.0±3.6	0.8±1.8*
	2/day	6	50.7±2.9	50.4±2.5	51.6±3.4	0.9±1.2*
Submax Heart Rate	1/day	7	171.2±7.3	166.0±6.8	161.8±5.2	−9.4±4.1**
	2/day	6	170.1±7.2	164.1±3.6	161.6±4.1	−8.5±4.7†

*Not significant; $\bar{X}\pm SD$.
**Significant difference between preconditioning and 4th week ($P<.01$).
†Significant difference between preconditioning and 4th week ($P<.05$).

TABLE 4

Hematocrit, hemoglobin, and plasma glucose values for all subjects during 4 weeks of training.

Variable	Group	n	Pre	2nd	4th	Δ Pre-4th
Hematocrit	1/day	6	44.1±	44.8±2.6	43.7±2.7	−0.40±0.34*
	2/day	6	41.5±2.8	42.4±3.0	41.7±2.2	0.20±0.66*
Hemoglobin (gm/100 ml)	1/day	6	16.1±0.5	15.8±0.8	15.7±1.0	−0.40±0.55*
	2/day	6	15.7±1.0	15.4±0.5	15.4±0.5	−0.30±0.64*
Glucose (mg/100 ml)	1/day	6	92.2±7.2	86.5±6.8	90.8±9.7	−1.4±5.53*
	2/day	6	90.3±6.8	82.5±2.5	79.1±4.7	−11.1±6.8**

*Not significant; $\bar{X}\pm SD$.
**Significant difference between preconditioning and 4th week ($P<.01$).

4th week blood glucose approached the precondition values. These decreases were significantly greater ($P<0.05$) in the 2/day than in the 1/day.

Track Data. Blood pressure taken at approximately 4:00 p.m. during the first and fourth weeks showed a marked decrease for both groups (see table 5). There were significant differences from preconditioning to the fourth week for the 2/day as well as the 1/day group. Mile run times also showed a significant difference from preconditioning to the 4th week for the 1 and 2/day groups. There were no differences for either BP or mile times.

The data reported for the conditioning parameters are within the normal range and are similar to other reported studies (Ekblom *et al* 1968, Saltin 1968, Skinner 1964): there was an improvement in $\dot{V}_{O_2}{}^{max}$, no change in $\dot{V}_{O_2}{}^{submax}$, and decreases in maximal and submaximal HR. These changes showed some variability, however, and depended on the daily frequency of training. To our knowledge, such changes in conditioning parameters attributable to an alteration in the daily training frequency have not been reported previously.

An important aspect of particular interest is the reduced blood glucose values for the 2/day group. In this study, it is difficult to state with certainty whether or not the reduced plasma glucose levels are indicative of reduced liver or muscle glycogen levels. Costill *et al* (1971a, b) showed that after 3 consecutive days of 10 mile runs plasma glucose levels were fairly constant while muscle glycogen dropped to very low levels. Apparently, Costill's subjects were not able to replenish muscle glycogen from day to day under these strenuous conditions. Costill's study was similar to ours in work intensity for a given training period, but lasted only 3 days as compared to the 4 weeks in our study. If the levels of muscle

TABLE 5

Mile time track data and blood pressure values (Mean±SD).

Variable	Group	n	pre	4th	Δ Pre-4th
Systolic P (mmHg)	1/day	7	134.7± 3.5	128.1± 3.6	−6.6 ±4.7*
	2/day	6	136.1± 5.2	132.0± 8.8	−4.11±3.8**
Diastolic P (mmHg)	1/day	7	82.8± 3.6	82.8± 3.6	0.00±0.9 ns
	2/day	6	81.1± 4.3	81.3± 5.0	0.20±0.1 ns
Mile Time (min:sec)	1/day	7	5:07±17	4:40±10	−0:27±9.5*
	2/day	6	5:06±16	4:45±16	−0:21±7.9*

*Significant difference between preconditioning and 4th week ($P<.01$); ns=not significant.
**Significant difference between preconditioning and 4th week ($P<.05$).

glycogen were depleted with 3 consecutive daily 10 mile runs, it seems likely that the 2/day subjects in our study would have similar trends relative to muscle glycogen. The decreased plasma glucose levels measured could be indicative of a gradual long term decrease in glucose-glycogen pools mediated by the chronic stress and fatigue due to the excessive exercise regimen.

Bergstrom and Hultman (1967) and Hermansen *et al* (1967) showed that vigorous training similar to those encountered by our subjects, when combined with uncompensated carbohydrate consumption, depletes liver glycogen, which then contributes to a reduction in blood glucose.

Within the limits of our study, there is no certain way to determine if the lowered blood glucose values reflect reduced levels of liver or muscle carbohydrate; however, under conditions of severe exercise such as those encountered by our subjects, carbohydrate levels do show a tendency to decrease. We suggest that reduced carbohydrate levels could affect the levels of performance in long distance competitive events and/or in the successful completion of a lengthy series of conditioning intervals. These points relate to the observation in our study that improvement in mile run times after 4 weeks of conditioning tended to decrease more in the 1/day group.

It appears that increasing daily workouts from 1 to 2 days was not associated with any significant improvement in $\dot{V}_{O_2}{}^{max}$. These observations and data from other studies show that 4 or 5 workouts per week produce produce maximal improvements in $\dot{V}_{O_2}{}^{max}$. Because levels of plasma glucose decreased significantly in the groups working 2/day, this factor can be interpreted as being involved in the reduced levels of conditioning observed.

LITERATURE CITED

Astrand, P. O. and I. Rhyming 1954 A nomogram for calculation of aerobic capacity. J. Appl. Physiol. 7: 218-221.

Bergstrom J. and E. Hultman 1967 A study of the glycogen metabolism during exercise in mm. Scand. J. Clin. Lab. Invest. 19: 218-228.

Costill, David L., R. Bowers, G. Branam, and K. Sparks 1971a. Muscle glycogen utilization during prolonged exercise on successive days. J. Appl. Physiol. 31: 834-838.

———, K. Sparks, R. Gregor, C. Turner 1971b Muscle glycogen utilization during exhaustive running. J. Appl. Physiol. 31: 353-356.

Davies, C. T. M. and A. V. Knibbs 1968 The training stimulus: The effects of intensity, duration, and frequency of effort on maximum aerobic power output. Int. Z. Angew. Physiol. 26: 272-278.

Ekblom, B., P. O. Astrand, B. Saltin, J. Stenberg, and B. Wallstrom 1968 Effects of training on circulatory response to exercise. J. Appl. Physiol. 24: 518-528.

Fox, E. L., R. L. Bartels, C. E. Billings, R. O'Brian, R. Bason, and D. K. Mathews 1975 Frequency and duration of internal training programs and changes in aerobic power. J. Appl. Physiol. 38: 481-484.

Gardner, James B. and J. Gerry Purdy 1970 Computerized Running Training Programs, Tafnews Press, Los Altos CA.

Hermansen, L., H. Hultman, and B. Saltin 1967 Muscle glycogen during prolonged severe exercise. Acta. Physiol. Scand. 71: 129-139.

Jackson, J. H., B. J. Shorkey, L. P. Johnston 1968 Cardiorespiratory adaptations to training at specified frequencies. Res. Quart. 39; 295-300.

Knuttgen, H. G., L. O. Nordesjo, B. Ollander, and B. Saltin 1973 Physical conditioning through interval training with young male adults. Med. Sci. Sports. 5: 220-226.

Pollock, J. L., T. K. Cureton, and L. Greninger 1967 Effects of frequency of training on working capacity, cardiovascular function and body composition of adult men. Med. Sci. Sports. 1: 70-74.

Saltin, B. 1968 Response to submaximal and maximal exercise after bed rest and straining. Circulation. 38 (Supplement 7).

Shephard, R. J. 1968 Intensity, duration, and frequency of exercise as determinants of the response to a training regime. Int. Z. Angew. Physiol. 26: 272-278.

Skinner, J. S. 1964 Effects of a program of endurance exercises on physical work. Am. J. Cardiol. 14: 747.

Watt, Edward, W., E. R. Buskirk, and B. A. Plotnicki 1973 A comparison of single vs. multiple daily training regimens: some physiological considerations. Res. Quart. 44: 119-123.