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ABSTRACT

Effects of different training intensities on oxygen intake were determined in this study. Sixteen male subjects aged 16-18 were randomly assigned to one of three training groups or a control group. The training groups trained 3 days per week on bicycle ergometers at different intensities (85 percent, 75 percent, or 65 percent of heart rate maximum) with all groups doing the same total mechanical work (12,000 KPM per training session). Analysis of covariance revealed a significant difference between the groups. Significant differences were found between both the 85 percent and 75 percent groups and the control. No significant differences were found between the 65 percent group and the control or between the 75 percent and the 85 percent group. Within the limitations of the study, it was concluded that when comparing between training intensities while holding mechanical work constant, it is necessary to work at a minimum of 75 percent of heart rate maximum to elicit significant changes in oxygen intake maximum. (Author)

CHANGES IN $\dot{V}O_2$ MAX. RESULTING FROM BICYCLE TRAINING AT DIFFERENT INTENSITIES HOLDING TOTAL MECHANICAL WORK CONSTANT

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Introduction

There now exists an abundance of information to indicate that systematic, prudent exercise will cause a number of beneficial physiological effects in the individual collectively referred to as the "training effect" (1, 2, 3, 9). It is commonly accepted that a good measure of these physiological events is the $\dot{V}O_2$ max. test (1, 2, 9, 10). In recent years a commonly reoccuring question appearing in the literature has been: "Are there optimal means of obtaining the training effect?" The factors effecting optimal achievement of the training effect most often studied are those of intensity, duration, frequency and modality of training.

While there have been a number of studies which have systematically investigated the factors cited above, the possibility exists that the conclusions drawn from these studies may have been biased by their inability to control for total work done between experimental groups (5, 6, 7, 8, 12, 16). Another possible source of error in previous studies was the lack of control for intensity. Two individuals working at a heart rate of 150 are not necessarily working at the same intensity if they have different maximal heart rates. Pollack et al. (13) demonstrated a means of controlling for intensity by having their subjects work at a given percentage of their HR max.

Review of Literature

In a multi-factor study, Sharkey (15) controlled for total work, using bicycle ergometers. The subjects trained at heart rates of 130, 150, and 170 at two different work levels. He found no significant differences in the training effect resulting from the three submaximal cardio-vascular tests.

Faria (5) compared the effects of bench stepping at heart rates of 125, 145, and 165, finding significant advantages as measured by PWC 180 for the groups training at the two higher intensities. Comparing various heart rate intensities, Sharkey and Holleman (16) found that it was necessary to work at a heart rate of 150 to obtain a training effect. Similarly, Karvonen et al. (8) found that training at heart rates less than 150 did not increase working performance as measured by heart rate elicited at a given work load.

Roskamm (14) compared the effects of steady state and two forms of interval training holding total mechanical work constant by means of bicycle ergometers. He found that steady state training was best for improving resting heart rate while interval training was best for improving maximal working capacity .

Parr (12) showed similar improvements in $\dot{V}O_2$ max. from six weeks of treadmill training at heart rates of 140, 160, and 180.

Shepard (17) studied the effects of training at varying percentages of aerobic power in untrained subjects. He found some training effects at a low intensity (39% of aerobic power) but the most effective system involved a higher intensity (96%).

Cureton (4) indicated that a HR of 150 is essential for a training effect to occur while Cooper (2) has indicated by his point system that an inverse linear relationship exists between intensity and duration of training.

Purpose of the Study

The purpose of the present study was to determine the effect of different training intensities on $\dot{V}O_2$ max. when total mechanical work is held constant.

Method

Sixteen male high school students, ages 16-18 years served as subjects. These young men were non-athletes and were cautioned to simply maintain their normal exercise habits throughout the study. The subjects were receiving released time from their normal physical education classes and all subjects were volunteers.

Initially a pre-test of $\dot{V}O_2$ max. was determined using an adaptation of the procedures recommended by Mitchel et al. (10) as follows: All subjects were given two days to become acquainted with bicycle ergometer work. Prior to measurement of $\dot{V}O_2$ max. each subject was fitted with bipolar chest electrodes connected to a NARCO physiograph chart recorder in order that heart rate could be accurately determined.

During the test of maximal oxygen consumption and during all work measurement throughout the study, the subjects pedalled on a Monark bicycle ergometer at a rate of 50 rpm synocronous with a metronome, the seat having been adjusted to provide for nearly full extension of the legs with the feet firmly on the pedals.

Each subject was given an initial 10-minute warmup period during which the resistance on the ergometer was adjusted so that the subject would achieve a steady state heart rate between 120 and 130 beats per minute.

Following a ten-minute rest period the subject began a series of 3-minute work bouts followed by 10-minute rest intervals with the work increased by 150 kpm with each work bout. The resistance for the first work bout was determined from the resistance needed in the warmup period with the intent being to obtain maximal O_2 consumption in 2-3 trials. Expired air was collected in 30 second samples during the last minute of each trial.

During all gas collection periods, the subject was fitted with a spring-type nose clip, a rubber mouth piece and a Collins high-speed respiratory triple "j" valve. Expired air was collected in 100 - liter plastic Douglas bags. Ventilation was measured using a Parkinson-Cowan dry gas meter calibrated throughout the study using a Tissot gasometer. Expired air was analyzed using a Beckman Oxygen Analyzer Type F-3 and a Beckman Carbon Dioxide Analyzer Type LB-1. Gas analyzers were calibrated using certified gas samples checked for accuracy during the study by the Scholander method. Expired air temperature was measured with a thermometer fixed in the Parkinson Cowan mixing chamber. A NOVA mercurial barometer was used to measure air pressure. All measurements were subsequently corrected to STPD.

The oxygen consumption during the trial in which there was less than a 150 ml. increment or when the subject could no longer continue due to fatigue was defined as the subject's $\dot{V}O_2$ max. Heart rate during the last minute of the last work load was defined as HR max.

Following the initial testing period the subjects were randomly assigned to one of three training groups or a control group. The training groups worked three days per week on bicycle ergometers at different intensities i.e. at 85, 75, and 65% of each individual's HR max. All subjects did the same total work (12,000 KPM) during each training session. This was accomplished by adjusting the length of the work bout every two weeks according to the resistance needed to maintain the required heart rate intensity. Following 10 weeks of training, the subjects were retested for $\dot{V}O_2$ max. using the same procedure as in the pre-test.

Results and Discussion

The subjects involved in the study had a mean age of 16.8 years with a range of 16 - 18 years; a mean height of 171.45 cm. with a range of 163 - 183 cm.; a mean weight of 66.31 kg. with a range of 50.9 - 108.2 kg.

Table 1 presents means and standard deviation of training parameters including HR max., training heart rates, duration of exercise and training work load for each of the experimental groups. Table 2 presents means and standard deviations for pre and post test scores of $\dot{V}O_2$ max. and body weight.

A one-way Analysis of Covariance was employed to test the presence of a significant difference between groups. The difference between the postraining value and the pretraining value was the dependent variable and the pretraining value for each of the variables was the covariate. Results of the Analysis of

Covariance for $\dot{V}O_2$ max. and body weight are shown in Table 2. The adjusted mean changes in $\dot{V}O_2$ max. expressed both in L./min. and Ml./kg./Min. were significantly different ($P < .01$). The Duncan New - Multiple Range test indicated significant differences ($P < .01$) in the adjusted mean changes between both the 85% and 75% group and the control. No significant differences ($P > .05$) were found between the 85% group and the 75% group or between the 65% group and the control.

It was clear from this study that working at 75% of HR max. was necessary to elicit a significant training effect as measured by $\dot{V}O_2$ max. Furthermore it didn't seem to matter whether the subject worked at 85% or 75% of HR max. These findings are in general agreement with the conclusions of Faria (5), Sharkey and Holleman (16), Karvonen (8), Shepard (17) and Cureton (4).

The findings of this study along with those of earlier studies seem to give rise to a theory that working around 75% of HR max. is the most efficient means of training for "average" individuals. This however, should not preclude the possibility that activity carried out for long enough periods of time at lower intensities such as walking may indeed yield a training effect as supported by Cooper (2). It may mean that an individual need do more total work, spread out over a longer time frame in order to overcome the diminishing training effects consistent with a lower intensity work load.

Following the post - test of $\dot{V}O_2$ max. a series of experiments were conducted, measuring $\dot{V}O_2$ continuously throughout and 15 minutes following each of the three intensities in two subjects with similar age, height and weight. As shown in Table 3, these two subjects required similar amounts of O_2 to accomplish each of the work tasks. Thus, not only was total mechanical work held constant throughout the study but apparently so was $\dot{V}O_2$, at least for these two subjects.

It may be inferred from these experiments that the training effect is dependent not merely upon the magnitude of $\dot{V}O_2$ but also upon the $\dot{V}O_2$ intensity. One may hypothesize, for instance, that while the 65% group was using just as much

O_2 in a training period as did the higher intensity groups that this level of O_2 consumption was not intense enough to open up new capillaries, increase Hb level or any of the myriad of specific physiological training effects.

Further work is needed in this area - comparing the training effect of varying intensities of $\dot{V}O_2$ while maintaining total $\dot{V}O_2$ constant between subjects using length of training period, and varying exercise modalities as other independent variables.

Conclusions

Within the limitations of the present study the following conclusions were drawn:

1. When comparing between training intensities while holding total mechanical work constant at 12,000 KPM per training session, it is necessary to work at a minimum of 75% of max. HR to elicit a significant change in $\dot{V}O_2$ max.

2. There is no difference in the training effect between working at 75% and 85% of max. HR if total mechanical work is held constant at 12,000 KPM per training session.

TABLE 1
MEANS AND STANDARD DEVIATIONS FOR TRAINING PARAMETERS

Intensity (% HR max.)	HR max.		Training HR		Duration of Exercise (Min.)		Work Load (KPM/Min.)	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
85%	189.0	7.57	160.50	6.61	2.89	2.89	853.75	177.07
75%	190.0	9.52	142.50	7.14	10.34	10.34	562.50	248.75
65%	187.5	6.61	121.75	4.11	8.45	8.45	362.50	94.65
Control	186.0	4.43	------	----	-----	-----	------	-------

TABLE 2
MEAN CHANGES IN $\dot{V}O_2$ MAX. AND WEIGHT FOLLOWING
10 WEEKS OF TRAINING

Variable	Group	Premean	SD	Postmean	SD	Mean Diff	F ratio	Adjusted mean diff.
$\dot{V}O_2$ Max. (Ml./Kg./Min.)	85%	44.69	15.60	54.08	18.71	9.39		9.39[d]
	75%	44.14	5.26	52.84	3.46	8.70		8.70[d]
	65%	41.38	13.70	44.75	12.55	3.38	6.31[a]	3.37
	Control	46.53	12.95	46.27	13.07	-.26		-.25[b,c]
$\dot{V}O_2$ Max. (L./Min.)	85%	3.06	.31	3.72	.26	.66		.20[d]
	75%	2.61	.55	3.15	.40	.54		.51[d]
	65%	2.77	.74	2.94	.53	.17	14.04[a]	.16
	Control	2.87	.82	2.89	.81	.02		.03[b,c]
Body Weight (Kg.)	85%	74.65	23.75	74.67	24.18	.02		-.12
	75%	58.85	7.85	59.52	7.76	.67		.80
	65%	70.10	21.89	69.52	22.35	-.58	3.82	-.64
	Control	61.63	1.82	62.50	1.99	.87		.95

[a]F ratio is significant at .01 level, DF(3,11)
[b]Significantly different from the 85% group at .01 level, Duncan's New-Multiple Range Test
[c]Significantly different from the 75% group at .01 level, Duncan's New-Multiple Range Test
[d]Significantly different from the control group at .01 level, Duncan's New-Multiple Range Test

TABLE 3

$\dot{V}O_2$ (LITERS) DURING EACH OF THE THREE INTENSITIES IN 2 SUBJECTS WITH SIMILAR AGE, HEIGHT, WEIGHT

Subject	85%	75%	65%
G.A. Ht. 168 cm. Wt. 116 lbs. 52.7 Kg. Age 16 years	29.93L.	28.02L.	27.64L.
L.M. Ht. 168 cm. Wt. 51.7 Kg. Age 16 years	28.44L.	29.95L.	27.94L.

REFERENCES

1. ASTRAND, P.O. and RODAHL, K. Textbook of work physiology. New York, N. Y.: McGraw-Hill, 1970.

2. COOPER, K. H. Aerobics. New York, N. Y.: Evans and Company, 1968.

3. CURETON, T. K. The physiological effects of exercise programs on adults. Springfield, Illinois: Charles Thomas Company, 1969.

4. CURETON, T. K. "Relationship of physical fitness to athletic performance and sports." Journal of the American Medical Association 162:1139-49, November 1956.

5. FARIA, I. "Cardiovascular response to exercise as influenced by training of various intensities," Research Quarterly 41:44-50, March 1970.

6. FOX, E. L., BARTELS, R. L., BILLINGS, C., MATTHEWS, D. K., BASON, R. and WEBBS, W. "Intensity and distance of interval training programs and changes in aerobic power." Medicine and Science in Sports 5:18-22, 1973.

7. HARPER,DONALD D., BILLINGS,CHARLES, and MATTHEWS, DONALD K. "Comparative effects of two physical conditioning programs on cardiovascular fitness in man." Research Quarterly 40:293-98, May 1969.

8. KARVONEN, M. J., KENTALA, E. and MUSTALS, D. "The effects of training on heart rate: a longitudinal study." Annales Medicenal Experimentales et Biologiae Fenniae 35:307-315, 1957.

9. MATTHEWS, D. K. and FOX, I. "The physiological basis of physical education and athletics. Philadelphia, Pennsylvania: W.B. Saunders Company, 1971.

10. MITCHELL, JERE, SPROULE, B. J. and CHAPMAN, C. "The physiological meaning of the maximal oxygen consumption test." Journal of Clinical Investigation 37:538-45, 1958.

11. NUPP, W.F. The relative effectiveness of four cardio-respiratory conditioning programs. Journal of Sports Medicine and Physical Fitness 10:84-89, June 1970.

12. PARR, RICHARD. Cardiovascular-respiratory adaptation to manipulated cardiac acceleration. Paper presented at American College of Sports Medicine Annual Convention, May 1972.

13. POLLACK, MICHAEL, BROIOA, J., KENDRICK, Z., MILLER, H., JANEWAY, R. and A.C. LINNERUD. "Effects of training two days per week at different intensities on middle aged men." Medicine and Science in Sports 4:192-197, 1972.

14. ROSKAMM, H. "Optimum patterns of exercise for healthy adults." Canadian Medical Association Journal 22:899-900, 1967.

15. SHARKEY, BRIAN J. "Intensity and duration of training and the development of cardiorespiratory endurance." Medicine and Science in Sports 2: 197-202, 1970.

16. SHARKEY, B. J. and HOLLEMAN, J. P. "Cardiorespiratory adaptations to training at specific intensities." Research Quarterly 38:698-701, December 1967.

17. SHEPARD, ROY. "Intensity, duration and frequency of training." Internationale Zeitschrift fur Angewandte Physiologies 26:272, September 1968.