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Abstract. The degree of fitness as ascertained by performance of a modified Harvard Step Test did not increase over controls for isometrically trained individuals. However, improvement over a prior training period was apparent. The breathing rate is probably a satisfactory index of measurement for the Harvard Step Test but needs further elucidation.

INTRODUCTION

The Harvard "Step Test" has been used to assess the physical fitness of individuals since 1942. Basically it involves stepping up and down from an exercise platform for five minutes or until exhaustion at a constant rate and measuring the pulse rate for a period of time after the cessation of the exercise. The rationale is that since the exercise involves large muscle groups, the cardiovascular and respiratory systems are placed under definite stress (Hoff & Geddes, 1962). The test itself evolved in the Harvard Fatigue Laboratory; and, as mentioned, has been used since 1942 (Brouha, Graybiel, & Heath, 1943). In the last decade much attention has been given to benefits derived from isometric exercising. However, benefits claimed are in the strength of muscles and little work has been done on the effects of isometric contraction on the performance of the cardiovascular and respiratory systems. The primary purpose of this investigation was to determine whether a controlled period of isometric training had an effect on the physical-fitness index as measured by pulse rate after the performance of a three minute "Step Test". A secondary purpose was to ascertain whether, in isometrically trained individuals and in non-trained individuals, the measurement of breathing rates after exercise could be used as an index of physical fitness.

METHOD

Ten college males, age 19-22, were used in this study. None of the ten participated in any form of intercollegiate or intramural athletics nor did they exercise regularly. Five of the subjects volunteered for participation in an isometric exercising program and the other five acted as a control group. Eleven

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standard isometric exercises were selected and were performed daily for six weeks. The exercises selected were designed to increase both leg and upper body strength.

Subjects reported to the laboratory during the week prior to the beginning of the isometric training program for the experimental group and approximately in the middle of each of the subsequent weeks. Upon reporting, a bellows pneumograph, crystal pulse pick-up, and photo-electric pulse pick-up transducers of a polygraph[2] were positioned on the subject. The pneumograph was placed at about the level of the xiphoid process and thus recorded excursions of the thoracic cage. The crystal pulse pick-up was placed on the radial artery of the right arm and the photoelectric pulse pick-up on the end of the right middle finger. Thus two methods of measuring pulse rates were used. No measurements were taken prior to the performance of the Harvard Step Test since it has been shown that, in general, the pulse before the test does not have any significant relation to an individual's performance capacity nor to his physical-fitness index (Gallagher & Brouha, 1943; Brouha & Heath, 1943).

After hook up was complete, the subject was asked to hold the cables and wires of the transducers which were later to be connected to the recording channels of the physiograph. Then under the direction of the investigator the subject performed a modified Step Test according to the procedure outlined by Consolazio, Johnson & Marek (1951). This involved placing one foot on the platform, stepping up placing both feet on the platform, straightening the legs and back, and immediately stepping down again, bringing down first the same foot placed up first. This was done every two seconds for three minutes. At the end of the 3-minute period, the subject sat in a straight-back chair, and cables and wires were connected to the appropriate recording channels of the physiograph. Exactly one minute after exercise had ceased the recording devices were activated and measurements taken for a period of 3½ minutes. A fourth recording channel which indicated timing marks every 30 seconds was also activated. The following diagram shows the time relationships of the entire procedure.

TIME IN MINUTES

START 0 Exercise Period	0	1	1½	2	2½	3	3½
	Rest	No. of Pulses X	Wait	No. of Pulses Y	Wait	No. of Pulses Z	

(Hoff & Geddes, 1962)

[2] Physiograph "Six", E & M Instrument Company, Inc., Houston, Texas.

The index of physical fitness involving the use of the pulse rate was obtained by using the following equation.

$$\text{Physical Fitness Index} = \frac{\text{Duration of Exercise in Sec. x 100}}{\text{2 (Sum of pulse counts)}}$$

(Hoff & Geddes, 1962)

The criteria for establishing degrees of fitness were taken from the same reference.

Below 55	= Poor physical condition
From 55 to 64	= Low average
From 65 to 79	= Average
From 80 to 89	= Good
Above 90	= Excellent

An index of physical fitness involving the use of breathing rates was modified from that used with pulse rates and was established as follows.

$$\text{Index} = \frac{\text{Duration of Exercise in Sec. x 10}}{\text{2 (Sum of Breaths)}}$$

Results

Individual physical-fitness indices as measured by pulse rates are shown in Table 1 for subjects during each of the seven weeks of the experiment. Only three subjects ever reached an index judged average on the basis of many thousands of tests.

Table 1. Physical fitness indices of individual subjects as measured by pulse rates.

	Control Group — Time in Weeks						
Subject	1	2	3	4	5	6	7
R.F.	59.2	61.2	53.6	57.3	60.0	62.1	60.0
S. M.	46.4	46.9	50.6	50.6		51.1	50.6
V.L.	41.1	47.4	50.0	51.1	55.6	58.8	47.8
S.B.	50.0	52.6	54.5	60.0	53.6	60.0	60.0
N.K.	47.9	50.0	50.0	52.6	56.6	54.2	
Average	48.9	51.6	51.7	54.3	56.4	57.4	54.6
% Increase Over First Week		5.5	5.7	11.0	13.7*	17.3	11.0*
	Isometric Training-Group — Time in Weeks						
Subject	1	2	3	4	5	6	7
E.B.	47.9	47.1	50.0	47.4	44.1	48.4	51.4
D.K.	43.9	53.6	70.9	58.8	57.3	56.6	54.5
H.B.	51.5	47.4	65.7	57.7		61.2	52.0
B.Y.	38.3	45.7	67.1	60.0	63.4	63.4	62.1
R.S.	36.0	35.7	38.3	36.0	38.5	37.7	41.1
Average	43.5	46.3	58.4	52.0	50.8	53.5	52.2
% Increase Over First Week		6.4	34.2	19.5	22.4*	23.0	20.0

* Compared against first-week average of four subjects only

Average values for all weeks and the percent increase of the

average values during the second through the seventh weeks over the first-week value are also given in Table 1.

The average values for the control group are higher than those of the experimental group with the exception of the third week. However, although both groups showed increases in indices with time, it can be seen that the isometric training group had a greater percent increase in the index over the first week for each of the six weeks of training when compared to the control group. The higher value was insignificant during the first week of training but was quite apparent during each of the other five weeks, especially during the second week of training. The overall patterns for the two groups were very similar the last four weeks of the experiment. The average percent increase during the last three weeks for the isometric training group was 21.8% as compared to 14% for the control group.

Individual physical-fitness indices as measured by breathing rates are shown in Table 2 for all subjects during each of the seven weeks of the experiment, as well as averages for both groups.

Table 2. Physical-fitness indices of individual subjects as measured by breathing rates.

	Control Group — Time in weeks						
Subject	1	2	3	4	5	6	7
R.F.	23.1	17.3	17.3	15.0	20.5	18.4	20.5
S.M.	19.5	22.8	25.7	28.1		27.3	23.7
V.L.	25.5	26.1	26.5	22.8	24.0	24.7	32.7
S.B.	25.4	28.1	31.6	29.0	34.6	29.5	30.5
N.K.	40.9	31.0	23.1	23.4	26.5	25.7	
Average	26.9	25.1	24.8	23.7	26.4	25.1	25.5
% Decrease From First Week		-6.7	-7.8	-11.9	-1.9*	-6.7	-5.2*
	Isometric Training-Group — Time in Weeks						
Subject	1	2	3	4	5	6	7
E.B.	27.7	26.5	26.9	28.1	23.7	28.1	31.0
D.K.	28.1	35.3	37.5	31.6	31.0	31.6	37.5
H.B.	33.3	40.9	40.0	38.3		36.0	32.7
B.Y.	36.7	47.4	43.9	42.9	40.9	23.7	45.0
R.S.	22.2	24.3	21.7	21.4	20.5	17.9	19.6
Average	29.6	34.9	34.0	32.5	29.0	27.4	33.2
% Increase or Decrease from First Week		+17.9	+14.9	+9.8	-2.1*	-7.5	+12.1

* Compared against first-week average of four subjects only.

As seen, the control-group averages after the first week are less than the first-week value, whereas the values of the isometric training group are higher except during the fifth and sixth weeks. Percent increase or decrease values in comparison to the first week are tabulated beneath the averages in Table 2.

Discussion

Physiological fitness for exertion is dependent for the most part upon nervous system coordination of metabolism, respiration, circulation, and temperature regulation (Morehouse and Miller, 1963). This coordination is dependent upon effective functioning of homestatic mechanisms which adapt to stress situations. This study endeavored to establish a stress condition of three-minutes duration which would not exceed or even encroach upon the capacity of any one individual as evidenced by exhaustion or even minor distress, and to ascertain the effect of isometric training upon ability to perform the task. The ability to establish and maintain a steady state at elevated levels of physical activity is a measure of a person's homeokinetic fitness, whereas the highest level of activity at which a person can maintain a steady state represents his homeokinetic capacity (Morehouse and Miller, 1963). Thus the study aimed at fitness and not capacity.

Although isometric training did not result in above-average physical-fitness indices as determined by pulse rates nor even in higher indices than the non-isometric training groups with the exception of one week, the results do indicate some effect of the training on the basis of the percent increases over the index for the prior training period. One individual, R. S., in the isometric group had unusually low indices for all seven weeks. Without his results, average values would have been slightly higher for the experimental group during most of the weeks of the training period. Also, the percent increases over the first week would have been slightly higher than those shown in Table 1. However, nothing about the performance of the isometric exercises or the Harvard Step Test indicated R. S. was in extremely poor physical condition or unable to perform satisfactory.

Breathing-rate indices of physical fitness are interesting but not conclusive. It would seem on the basis of the uniformity of the average values for the control group throughout seven weeks that breathing rates could be used as a means of measuring physical fitness. However, pulse rates are no doubt better criteria. The percent decrease in indices with time for the control group as compared to mainly percent increases in indices for the experimental group is probably a reflection of faster breathing rather than deeper breathing but needs futher elucidation.

In summary, then, the particular isometric training program used seemed to have some effect on physical fitness. There was a large increase in the physical fitness index during the second

week of isometrics, and even though the index dropped in subsequent weeks the percent improvement was always greater than the control groups. The control groups did not show a great increase in performance at any time such as the experimental group did; but, nonetheless, there was an overall increase in indices. The overall increase was probably a reflection of familiarity with the test procedure. Of course, the experimental group had the same degree of familiarity. The sudden large increase in index of the isometric group, but subsequent drop, might well indicate a short gain of fitness and not a lasting phenomenon.

More subjects are definitely needed for a better evaluation of the effects of isometric training on pulse rates and breathing rates. Also, other factors have to be considered. Eating and sleeping habits could have had some effect on the results since the tests were run early in the afternoon. Also, smoking habits are of concern. Another point worthy of mention is that with longer periods of isometric training, performance by vascular and respiratory systems might be increased. Also, it should be remembered the 3-minute rather than the 5-minute test endeavored to measure fitness and not capacity. Thus, whereas isometric training did not result in larger absolute values for fitness indices, it is possible training of such a nature has an effect on capacity levels.

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