# ADAPTIVE EFFECTS OF STATIC MUSCULAR STRENGTH TRAINING

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## ABSTRACT

The trend towards mechanization of tasks involving manual labor has increased the importance of static muscular activity (isometric contractions). Information about the physiological reaction to static muscular activity has been increasing rapidly over the last few decades, but little information has been developed on the adaptive responses to chronic exposure to static muscular activity. This paper reports the results of an experiment on adaptive cardiovascular changes to a five week training program in which the % MVC was maintained at 50% for the entire program, i.e., weekly adjustments were made for increases in strength. The only significant change in the cardiovascular response to the training program was an increase in the rate at which the heart rate increased during periods of contraction. The average level of heart rate, systolic blood pressure and diastolic blood pressure did not change with training. Neither the systolic or diastolic blood pressure modified their rates of change due to training. Significant changes in strength and endurance hold capacity were also noted.

## INTRODUCTION

Muscular activity has been actively studied for many years. But most of the research has been concerned with dynamic muscular activity. With the trend towards allocation of simple manual activities to machines, static muscular activity (isometric contractions) is becoming relatively more important in industry. In recent years, the information on the physiological effects of static muscular activity has increased rapidly to explain many of the characteristics of the physiological responses. Included in the literature is little information on the adaptive responses to chronic exposure to tasks involving static loading. Possible adaptive responses on a macro level include: changes in endurance hold capacity, recovery from fatigue, changes in cardiovascular responses and changes in muscle strength. Of these possible responses, only changes in muscle strength have been extensively studied. This paper reports the results of a study of the adaptive cardiovascular changes to a five week training program.

## BACKGROUND

Mundale (1970) experimented with intermittent isometric exercises using a hand grip mechanism. His subjects exercised for ten minutes using work rest cycles of one second isometric contractions alternated with one second rest periods. He found a definite trend that stronger subjects were able to exert a smaller proportion of their maximal strength for the ten minutes of exercise than were individuals with low grip strength. In his experiment, the tension which a subject overcomes appears to be a more important factor in producing fatigue than variation in the length of contraction time.

Singh and Karpovich (1967) exercised their subjects four times per week for eight weeks using twenty maximal contractions. The antagonists muscles of the same arm were tested before and after training for maximal strength during concentric, eccentric, and isometric contractions. Respectively, they found increases in strength of 43 percent for the agonist's muscle, and 31 percent, 17 percent, and 26 percent for the antagonists. They explained the considerable improvement in antagonistic muscles by the fact that during maximal contractions of agonists the antagonistic muscles also contracted. Moore (1971) conducted a similar study between active resistance and isometrics for ten days but found no difference in strength gained.

Ramos, et al. (1973) conducted a test to find out the effects of expectation and anticipation to a muscular effort. They told the subject that this last test was ". . . a big one (so) concentrate and get ready." The subject anticipated for 50 seconds before a ten second maximum hold. The mean arterial blood pressure prior to the exercise rose to levels as high as those observed during heavy exercise. The blood pressure steadily increased from the time of the initial encouragement until the contraction was released. The contraction did not alter the slope of the blood pressure curve.

Laycue and Marteniak (1971) concluded there are at least two factors responsible for increases in strength. One is the physiological changes in the muscle that occur through the inducement of tension, and the other is the development of neuromotor patterns which enable an individual to coordinate his



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muscles effectively to exert maximum tension. Moreover, since these neuromotor patterns are specific to the type of contraction performed, it is expected that the ability to produce tension will be specific to the situation in which it is utilized.

Clarke and Stull (1970) found the literature in weight training contained a number of references that said that intensive endurance exercise will do little to enhance strength and strength training is of questionable value in promoting muscular endurance. To test this assumption they ran a seven week training program of ten pounds of resistance for forty repetitions. They concluded that this type of training increases strength (13 percent) and absolute endurance, but does nothing for relative endurance. Stull and Clarke (1970) ran a similar experiment except they used high-resistance, low-repetition training. The results were the same.

Muller (1965) found that by preventing the skin from getting too warm, a higher work level could be reached. He explains that with a warmer extremity more blood is sent to the skin for cooling purposes at the expense of the working muscle. The effects of massage, interruption of blood supply and cooling were all highly significant. In experiments by Clarke, Hellon and Lind (1958) contractions could be held longest when the muscle temperature was 27° C. They obtained this temperature by immersing the arm in water at 18° C for 30 minutes.

Since no one has shown a difference in the pressor response to static loading at a given percentage of strength due to sex, four females were used to represent the lower and four males to represent the higher strength group. Table 1 presents a description of each subject.

TABLE 1

SUBJECT DESCRIPTIONS

| Subj. | Sex | Age | Weight | Height |
|---|---|---|---|---|
| 1 | F | 28 | 120 | 67" |
| 2 | F | 22 | 135 | 69" |
| 3 | F | 23 | 114 | 61" |
| 4 | F | 28 | 143 | 67" |
| 5 | M | 31 | 175 | 74" |
| 6 | M | 21 | 177 | 71" |
| 7 | M | 21 | 135 | 69" |
| 8 | M | 25 | 140 | 72" |

In this experiment it was decided that five weeks was an adequate training period based upon previous work. For example, Byrd and Hills (1971) trained subjects daily for four weeks using one maximum contraction until a 50% strength decrement occurred. These bouts lasted from 60 to 90 seconds. Hand grip strength was increased 14% and the blood flow during exercise increased 39%.

To facilitate testing, a cycle of 30 seconds work followed by 30 seconds rest was chosen. In order to avoid confusion with initial rest, this 30 second rest period will be called recovery period. To facilitate training and to expand the knowledge of information, ten cycles per session were used, and 50% of the maximum voluntary contraction was used as the resistance load. This load has been mentioned by Muller (1965) as an acceptable level for work.

Caldwell, et al. (1974) have proposed a standard procedure for maximum isometric strength. The instructions to the subject are "increase to maximum exertion (without jerk) in about one second and maintain this effort during a four second count." One second before and after the steady exertion are disregarded and the score is taken from the mean of the first three seconds of the steady exertion. This later method was used to record the maximum voluntary contraction and 50 percent of this was used for the exercise.

Some of the subjects did their exercises at home, but all the subjects were tested in the lab. Each subject had their own exercise stand which allowed them to support their elbow during the work part of the exercise and to support the load during the resting part. This minimized the contraction of other muscles and whole body movement. The device for testing and exercise was the same except a bar with a spring scale attached was used for testing as opposed to a dumbell used for the training exercise. Each stand is adjustable for use with different subjects. For testing purposes, an adjustable chair was used to help ensure the same posture for each test. All subjects were instructed to adjust the stand height so that the forearm is parallel to the ground when the elbow rests on the stand and the body is in a normal and comfortable position. Once started the position of the body remained constant until the exercise was completed.

## FAMILIARIZATION

Prior to training, each subject visited the laboratory for familiarization and pretesting. Each person assumed a comfortable position and using the support stand exerted a maximum contraction of the bicep against a round bar gripped in the upturned hand. The subjects were cautioned to use a relaxed grip for all exercises. Three readings were taken from each arm and each arm rested at least three minutes before being retested. Then chest electrodes were attached to the subjects to record heart rate and the ausculation cuff was placed on the right arm to record blood pressure. Each subject did three repetitions of the planned exercise using 50% MVC.

## EXPERIMENTAL ROUTINE

At the beginning of each week the subject made two attempts at maximum contraction. After resting 15 minutes the subject performed ten work-rest cycles with an adjusted 50% MVC while being monitored for heart rate and blood pressure. Heart rate was recorded continuously and blood pressure was recorded during the last 12 seconds of each work and recovery period. To simulate the common five day work week each subject performed the exercise Tuesday through Friday at home or in the laboratory using weights instead of the spring scale equipped stand. This routine was followed for five weeks. A log was given to each subject to record the time of day the



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exercise was performed at home. Most of the training was conducted at the same time each day.

All testing was done between 0900 and 1200 hours and 1400 and 1700 hours. Each subject was tested about the same time each day. The laboratory temperature was around 75 degrees and did not pose a factor.

In addition, the subjects observed the following rules during the five week period of the experiment:

1. Do not consume any calories for two hours before testing.
2. Minimize smoking one hour before each test.
3. Maintain proper sleeping habits during the training period, especially before testing.
4. Record any heavy exercise on the log sheet.

## RESULTS

The results of the experiment will be analyzed by dividing into sections based on the physiological variable. For each variable, the average as a function of the training period and the average rate of change (slope) during the work phase of the cycle are presented.

### Heart Rate

The average heart rate for all subjects during the work phase is shown in Figure 1. There appears to be an increase with training. Statistically this increase is not significant until $\alpha \geq 0.485$. The rate of change of heart rate during the 30 seconds of work as a function of the weeks of training are presented in Figure 2. This rate of change is a measure of the acceleration of the heart rate which

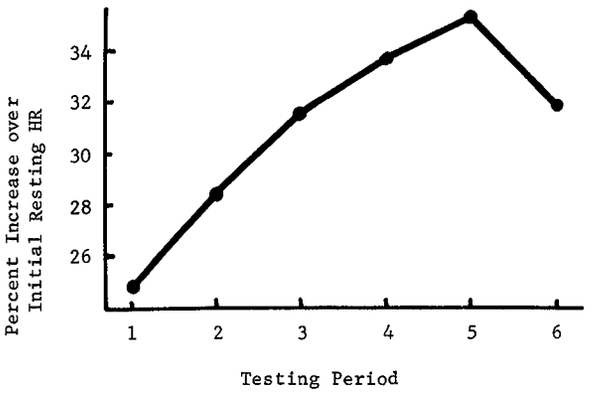


Figure 1. Average heart rate during work as a percent of the basic resting heart rate.

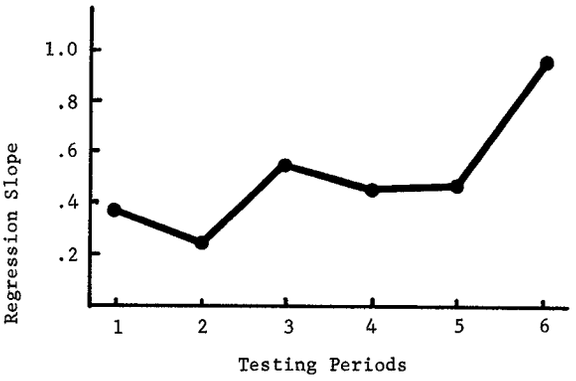


Figure 2. Heart rate regression slope during work.

is called slope, since it was obtained from the simple regression line through the heart rate readings obtained during the 30 second work period. This factor is significantly affected by training for $\alpha \geq 0.064$. Although the average heart during the work period does not appear to be increasing, the rate of change increases with training.

During the recovery period the average heart rate did not change with training ($\alpha \geq 0.835$ for significance of training effect) nor was the rate of change (decrease) of heart rate influenced by training ($\alpha \geq 0.875$ for significance of training effect).

### Systolic Blood Pressure

The average systolic blood pressure as a function of training is shown in Figure 3. Except for the third testing period (after two weeks of training) there is no apparent systematic increase or decrease. Statistically the training effect is not significant until $\alpha \geq 0.87$. The rate of change (slope) of systolic pressure during the work periods was highly variable as shown in Figure 4. Training does not have a significant effect on the slope until $\alpha \geq 0.31$. Therefore, it appears unlikely that either the level or rate of increase of systolic blood pressure is influenced by the training.

During the recovery periods the average systolic pressure was not influenced by training ($\alpha \geq 0.34$ for significant training effect) nor was the rate of change during recovery periods affected by duration of training ($\alpha \geq 0.31$ for significant training effect).



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Diastolic Pressure

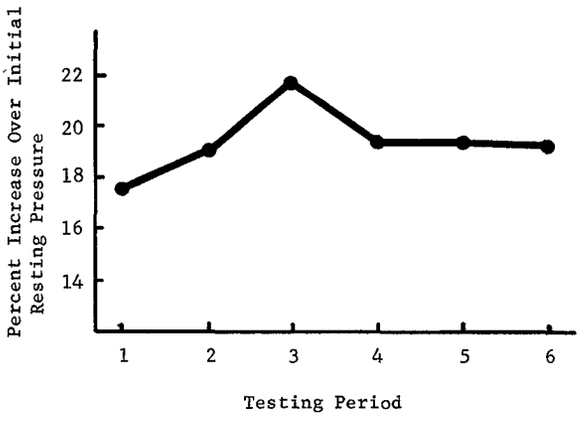


Figure 3. Average systolic pressure during work as a percentage of the basic resting pressure.

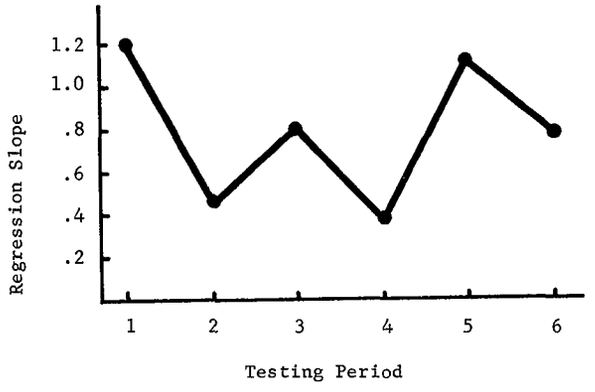


Figure 4. Systolic pressure regression slope during work.

The average diastolic pressure and the rate of change of blood pressure are shown in Figures 5 and 6 respectively. Niether the average pressure $\alpha \geq 0.97$) or the rate of change ($\alpha \geq 0.376$) showed a training effect that was significantly different from zero.

Neither of the variables measure during recovery periods were significantly affected by training duration. A probability of a type I error greater than 0.24 is required for average diastolic pressure and a probability greater than 0.38 is required for the rate of change, before the training effect is significantly different than zero.

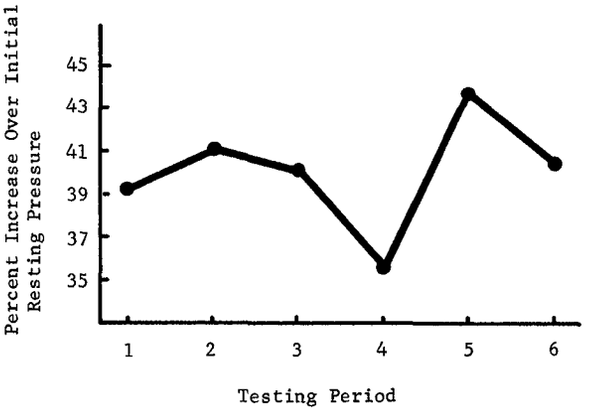


Figure 5. Average diastolic pressure during work as a percentage of the basic resting pressure

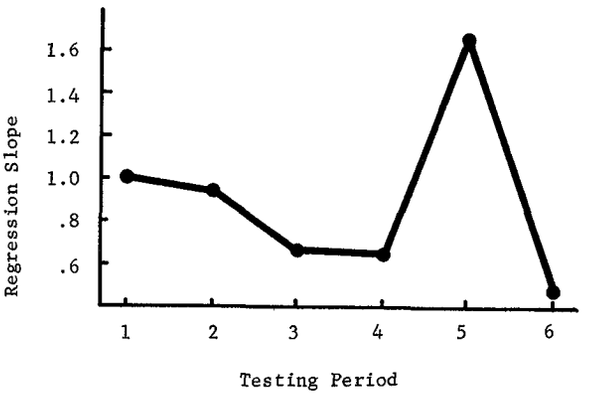


Figure 6. Diastolic pressure regression slope during work.



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Increases in Strength and Endurance

Table 2 presents the 50% MVC strengths and the endurance hold capacities for each subject's left and right arm for both the before training and after training condition. All subjects tested for strength showed increases with the weaker subjects showing the largest increases. The overall increase in strength of the left arm was 49%, while the untrained right arm showed an increase of 33%. The increase in the right arm strength suggests that the mechanism involved is peripheral to the muscle itself. Endurance hold capacity increased for only half the subjects tested.

TABLE 2

STRENGTH AND ENDURANCE BEFORE AND AFTER TRAINING

| Subj. | Arm | 50% MVC Before Training (lbs.) | Endurance (sec.) | 50% MVC After Training (lbs.) | Endurance (sec.) |
|---|---|---|---|---|---|
| 1 | LT | 5 | 90 | 10 | 120 |
| | RT | 5 | 115 | 10 | 70 |
| 3 | LT | 6 | 170 | 9.6 | 170 |
| | RT | 6 | 240 | 8.8 | 110 |
| 4 | LT | 6 | 105 | 10.5 | 80 |
| | RT | 6 | 120 | 9.5 | 60 |
| 5 | LT | 20 | 95 | 21.5 | 160 |
| | RT | 20 | 125 | 21.5 | 160 |
| 7 | LT | 12 | 315 | 14.4 | 210 |
| | RT | 15 | 240 | 14.6 | 180 |

DISCUSSION AND CONCLUSIONS

One reason that stronger persons fatigue earlier and show a greater response in heart rate and blood pressure is that the stronger person has better control over his voluntary muscles. Given a certain size of muscle he will make more demands on that muscle than a weak person would. A weak person could also be called an untrained person. Probably the person who is trained can also tolerate pain more, especially if he pushes himself to even low levels of pain in work and play. All this would cause the stronger or better trained person to exert more of his potential power during the strength testing phase.

In Figures 1 and 2, the trend in heart rate is to increase with training. According to the literature surveyed, the heart rate usually goes down with training. In the conduct of this experiment the percentage of maximum strength was maintained at a constant level of 50%. Since the subjects increased in strength, the amount of weight with which they exercised increased. This increase in load could have caused the increase in the cardiovascular responses.

As the training progressed the subjects probably were able to exert a maximum contraction that was closer to their capabilities. This may explain the large increases in strength. It is interesting to note that the sixth testing period reversed the trend (strength decreased) of the first five testing periods. Since this was the last exercise period there may have been a psychological factor that caused the deviation. Although an end point phenomenon was not mentioned in any of the literature examined it might be prudent to take one more data point than needed and then ignore the last one in the calculations.

The primary goal of this study was to identify the effects of isometric training on heart rate and blood pressure. The only statistically significant value that changed was the rate of change of heart rate during work. The heart rate increased at a faster rate during the exercise for the better trained person. No conclusion can be reached about the other measured quantities. The trend of most of the measures of performance increased. The average diastolic pressure during recovery decreased and the values for rate of change of diastolic pressure during work and recovery, gave no clear trend.

Twelve of the qualities measured were significantly ($\alpha$ = .1) affected by the initial resting value of heart rate or blood pressure (the covariate). The higher the initial value the higher will be the average values for work and recovery for heart rate, systolic and diastolic pressure. The lower the initial value the higher will be the heart rate and systolic slope during work and recovery and systolic and diastolic jump. The quantity not affected by the initial value are diastolic slope during work and recovery.

When the subjects are divided into two groups according to strength, the following variables are statistically significant with the stronger group always having the larger value: average heart rate during work, heart rate slope during work, heart rate jump, average systolic pressure during work and recovery, systolic slope during rest and recovery, and diastolic slope during work.

During training all eight subjects increased in strength. Two of five subjects increased their relative endurance while the other three decrease their endurance at 50% MVC.

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