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THE EFFECTS OF AN EIGHT-WEEK NAUTILUS TRAINING PROGRAM ON CARDIOVASCULAR FITNESS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University

By

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* * * *

The Ohio State University

1978

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CHAPTER I

INTRODUCTION

Introduction and Statement of the Problem

It has been a reasonably well accepted fact that participation in a weight training program does little to increase the participant's cardiovascular fitness (4,6,15,41). The West Point study conducted by Dr. James Peterson and representatives of the Nautilus Sports/Medical Industries (41) demonstrated evidence showing that with a properly supervised program on Nautilus equipment, cardiovascular endurance can be improved. The supervision to which this statement refers is a one-to-one ratio between administrator and subject with each administrator driving his subject at each machine to a point of extreme fatigue. Much of the information published by Nautilus is based upon the West Point study inferring that similar results can be achieved when following the Nautilus exercise program as prescribed by Darden (6).

While the West Point study was concerned with strength training, neck strengthening, cardiovascular fitness, flexibility, body composition, and thermographic diagnosis, this investigation isolated solely on cardiovascular fitness. Since the length of the rest interval
between exercises was of extreme importance, the time was closely monitored between each bout of exercise. The training sessions were set up along the guidelines established by Darden and were closely followed. With the one minute rest interval allowed at the beginning of the program, the subjects were able to complete the twelve exercises in under twenty-five minutes. In compliance with Darden, the rest intervals were gradually reduced until, by the end of the eighth week, only a minimum of rest was allowed. The West Point study employed rest intervals of a much shorter duration at the onset. Two factors which may have possibly biased the final results at West Point were the use of subjects who were concurrently involved with spring football training and the use of an unproven method for evaluating maximal aerobic performance. The results, therefore, of the cardiovascular section of Project Total Conditioning is subject to question.

Improving cardiovascular endurance by employing strength training techniques has practical applications to coaches and athletes in all sports. Traditionally, coaches have used two types of fitness programs to increase their athletes' physical performances. One of these programs, conventional strength training, was designed specifically to increase the participant's muscular strength and consisted of a series of free weight exercises. Unfortunately, this did little in improving the athlete's
cardiovascular endurance, and therefore another training program had to be used. Usually the endurance workouts employed interval training techniques with the distances run being dependent upon the athlete's specific sport or event. If a significant increase in cardiovascular fitness can, in fact, occur by using Darden's program as has been suggested by Nautilus advertisements, then further consideration should be given to these methods as a total conditioning program.

**Purpose of the Study**

The purposes of the present investigation were to determine whether or not (a) change in the subjects' performance on a bicycle ergometer test of predicted maximal oxygen consumption would be greater after eight weeks of Nautilus training than after eight weeks of spring soccer practice, or eight weeks of Nautilus work and spring training, or of eight weeks of no athletic training, (b) change would occur in the subjects' resting heart rate and resting blood pressure after eight weeks of Nautilus work, spring practice, Nautilus work and spring practice, or no training, (c) change in the subjects' submaximal heart rate would be greater after Nautilus work, spring practice, Nautilus work and spring training, or no training.
Definitions of Terms

Some of the terms used in the present investigation were defined as follows:

(1) **Cardiovascular fitness**, as stated by Fox (8), is the ability of the heart and lungs to take in and transport adequate amounts of oxygen to the working tissues, allowing activities that involve large muscle masses to be performed over long periods of time.

(2) **Maximal oxygen consumption**, as defined by Saltin (44), is the maximum rate at which oxygen is taken into the body and used by the tissues.

(3) **Aerobic capacity**, as defined by Cooper (4), is the maximum amount of oxygen that can be processed by the body during exhausting work, while Astrand (2) refers to aerobic capacity, aerobic power, and maximal oxygen consumption as measures of maximum oxygen transport. Aerobic capacity, therefore, is concerned with the rate of oxygen intake and the amount of oxygen used by the body.

(4) **Eccentric muscular contraction**, according to DeVries (6), refers to the lengthening of the muscle during contraction.

(5) **Concentric muscular contraction**, on the other hand, is the shortening of the muscle during contraction.

(6) **The Overload Principle** is the physiological principle upon which the development of strength and
endurance depends. Lange (37) explained that strength and endurance of a muscle increases only when that muscle performs against workloads that are above those normally encountered.

Statement of the Hypotheses

The hypotheses were:

1. The subjects in the Nautilus training group would show greater improvement in aerobic capacity than the spring training only group, the Nautilus and spring training group, or the no training group on the bicycle ergometer test of predicted maximal oxygen after eight weeks training.

2. Resting heart rates and resting blood pressure would be lower with the Nautilus training group than with the spring training group, the Nautilus and spring training group, or with the no training group after eight weeks of training.

3. Submaximal heart rates at the end of the fifth minute of the bicycle ergometer test would elicit greater change in the Nautilus training group than with the spring training group, the Nautilus and spring training group or with the no training
group after eight weeks training.

Limitations

One of the limitations of the present study was the factor of motivation among some of the soccer players during the workout sessions. In order for significant achievements to be made using any type of conditioning program, a certain amount of discomfort and pain must be endured. On occasions some of the soccer players were reluctant to experience this. This may have affected the degree of improvement made. A second limitation was the degree of participation in other activities by the subjects. This was beyond the control of the investigator, however, all subjects were encouraged to continue their regular patterns of living and discouraged from embarking on any activities of a developmental nature.
CHAPTER II

REVIEW OF RELATED LITERATURE

The review of literature for the present study was concerned with five major areas. Significance of heart rate in physiological performance, cardiovascular fitness and training, Nautilus, maximal oxygen consumption and testing instruments and test selection are the five topics which will be discussed.

Significance of Heart Rate in Physiological Performance

According to Karpovich (11), a linear relationship exists between work intensity and oxygen consumption. During physical activity, metabolism is increased and consequently the need for oxygen is increased. As a result of this greater need for oxygen by the tissues, the cardiovascular and respiratory systems make adjustments by increasing cardiac output and respiration so that the needed oxygen can be supplied.

Eventually, a state is reached whereby a maximum amount of oxygen is being supplied to and consumed by the working tissues, and any further increase in workload results in no further adjustments of the cardiovascular and respiratory systems. The individual, in reaching this state during exercise, has reached his
aerobic capacity, and the amount of oxygen being consumed during this state is known as his "maximum oxygen consumption." The degree to which this upper limit is adjusted upward reflects the training effect on and the endurance level of the individual. Astrand (2) states that the untrained individual may have a maximum intake of only two liters per minute, whereas the highly-trained athlete may more than triple this amount. Karpovich (11) states the limiting factors of oxygen consumption to be (A) ventilation of the lungs; (B) oxygen carrying capacity of the blood, determined by the hemoglobin content of the blood; (C) unloading oxygen to the tissues; and (D) minute volume of the heart. DeVries (7) states that gas transport can be limited by (A) cardiac output; (B) vascular dynamics; and (C) oxygen carrying capacity of the blood. Astrand (2) indicates there is a high correlation between blood volume and maximal oxygen consumption. The cardiac output is determined by two factors: the heart rate and the stroke volume (7). Carlesten and Grimby (3) state that most investigators, during recent years, agree that the heart rate is the chief factor in this increase of the cardiac output. DeVries (7) gives three reasons why the heart rate is the more important variable:

Stroke volume probably increases very little with an increase in metabolism until a level approximately eight times
the resting level is reached; Heart rate is proportional to the workload imposed; Heart rate is proportional to the oxygen consumption during exercise.

Kurucz, Fox, and Mathews (34) found a linear relationship between heart rate and workload to a heart rate response of 160 BPM. Beyond this point, the degree of relationship decreased.

Cardiovascular Fitness and Training

According to Astrand (1) training is an increase in the organism's possibilities for performing a special task. Karvonen (33) maintains that the aim of training is to better adapt the organism to exercise. Most investigators seem to agree that training does involve repeated exercise which elicits progressive change in the performance of an organism. Brouha (20) summarized the physiological effects of training, which include: 1) greater mechanical efficiency in terms of oxygen consumption for a given amount of work; 2) greater maximum oxygen consumption; 3) quicker return of pulse rate and blood pressure to normal following submaximal exercise; 4) capacity to perform more work aerobically and anaerobically; 5) improvement in neuromuscular coordination; 6) lower blood lactate for a given amount of work; and 7) better pulmonary ventilation during work. Training has proven itself most beneficial to the well-being of the human body in work, sports, and even at rest.
Two questions that arise when planning a training program are the degree of intensity and the duration of the training to be administered. Several different answers to these questions have been offered. Åstrand (1) indicated that since the organs of the body individually adapt as the whole body adapts to the stress of exercise, the rate of work is most important in training, and workloads should be gradually increased to allow for body adaptation. In a study by Sharkey and Holleman (46) involving the use of the Åstrand and Ryhming step test and the Balke treadmill test, sixteen college-aged males were randomly assigned to either a control group or one of three training groups who exercised for six weeks at heart rates of 120, 150, and 180 BPM, respectively. After six weeks of training on a treadmill for ten minutes per day, three days per week, significant improvement was found in both tests at the .01 level (F = 6.79, F = 8.41, respectively). The 180 heart rate group was found to be significantly better on both tests than all other groups, and the 150 heart rate group was significantly better on both tests than the 120 heart rate group or the control group. Results indicated that intensity of the training should include intense activity as opposed to light or moderate activity. The authors suggested a training level of at least 150 BPM and suggested that results may have differed with men of a different age and activity level. In reviewing the
problems of cardiovascular training, Karvonen also
determined that training at high pulse rate levels was
necessary to obtain any of the major effects of training
such as lowering of the exercise pulse rate and increasing
performance capability during hard exercise. Sixty percent
of the maximum heart rate was the critical threshold
value he suggested. Shephard (16) suggested that short,
intensive activity periods induce training and improve
physical efficiency. Shephard's investigation of thirty-
ine inactive subjects who trained for five, ten, or
twenty minutes, one, three, or five times per week,
determined that short, intensive activity periods would
improve physical efficiency, depending upon the subjects'
initial levels of fitness. The twenty minutes per day,
five days per week period improved cardiovascular efficiency
best, but the shorter training periods also significantly
(.05) increased efficiency in sedentary subjects. Shephard,
however, used only one or two subjects per training
program, which may have reduced the practical significance
of the results of the study. Significant improvement on
the Balke treadmill test, the Åstrand-Ryhming test of
physical fitness, and the Taylor, Buskirk, and Henschel
test of maximal oxygen consumption was found by Jackson,
Sharkey, and Johnston (30) after subjects trained for
two, three, and five days at increased workloads and
speeds on the treadmill. Results of the study of twenty
males, seventeen to twenty-three years of age, indicated that all groups significantly improved at the .05 level on the Balke test ($F = 3.14$) and the Astrand-Ryhming test ($F = 7.27$), but the two or three days per week groups were better than the five days per week group. Results of the Taylor, Buskirk, and Henschel test showed a slight improvement in the two and three day groups, but statistically there were no significant differences in any of the groups. The authors concluded that the initial level of fitness of the subjects must be considered, and the five days program was probably too strenuous for the fitness level of the subjects investigated. Possibly, the small number of subjects per group (four) and the various levels of initial fitness influenced the results of the investigation. Pollock, Cureton, and Greninger (42) reported that frequency as well as intensity of training was proportional to changes in endurance and efficiency. A study of nineteen male volunteers, randomly assigned to one of two groups, training thirty minutes, two days per week or four days per week for twenty weeks, resulted in a 17 percent increase in maximal oxygen intake for the two-day group and a 35 percent increase for the four-day group. Both groups improved significantly (.05) on resting, recovery, and exercise heart rates, but only the four-day group significantly (.05) improved in body composition and did not improve on endurance or cardiovascular tests.
The authors noted that the group training the most frequently elicited the greatest improvement.

Duration of the exercise has been found to be of some importance in training. Sharkey (46) defined duration as "the total work done in training and determined that an increase in intensity is directly related to an increase in duration. In Sharkey's investigation, thirty-six college males were randomly assigned to groups training at heart rates of 130, 150, and 170 beats per minute and at levels of duration of 7,500 or 15,000 kilopond meters total work. The training program consisted of riding a bicycle ergometer three days per week for six weeks. No significant intensity, duration, or interaction effects were found between the pre- and post-measures of three cardiovascular tests (Astrand-Ryhming test, Balke treadmill test, and Sjostrand physical work capacity test). Sharkey concluded that neither training intensity nor duration or training significantly influenced training changes when either was held constant. Lack of control group, different initial levels of fitness of the subjects, and the fact that the cardiovascular tests seemed to measure different aspects of fitness, may have influenced the results of the investigation. In a study by Durnen, Brockway, and Witcher (25), the subjects walked 10, 20, or 30 kilometers daily at a heart rate of about 120 to 130 beats per minute. The authors concluded that since the heart rates were moderate and changes in
cardiovascular efficiency did occur, the duration of the work must have been a factor. In a similar study by Yeager and Brynteson (51), eighteen freshman women exercised for ten, twenty, and thirty minutes at a heart rate of 144 beats per minute for three days a week on the bicycle ergometer. Results of the pre- and post-Åstrand predicted maximal oxygen uptake test and PWC-170 work capacity test revealed significant (105) cardiovascular fitness improvements in all groups. Since the heart rates again were moderate and the thirty-minute group increased more consistently in cardiovascular endurance, duration of work seemed important. The small number of subjects per group and the lack of a control group probably biased the results of the study. Cooper (4) has suggested that, based on his and other laboratory investigations of subjects of all ages and activity levels, if the exercise is strenuous enough and long enough, a training effect will occur. Holmes (30), Sharkey and Holleman (46), and Yeager and Brynteson (51) suggested a six-week training period was sufficient for measuring increases in cardiovascular efficiency. Holmes used a six-week training period for boys aged six to fifteen. Divided into four groups, the boys practiced muscular endurance training, steeplechase training, circuit training, and interval training thirty minutes per day, four days per week. All groups improved significantly
on cardiovascular tests at the end of six weeks. Sharkey and Holleman's program of treadmill training for college men and Yeager and Brynteson's bicycle ergometer training program for college women both showed significant improvement (.01 and .05, respectively) on cardiovascular tests following six-week training periods. Brouha (20) has maintained that after a steady level of training has been reached, an increase in the duration of daily training will not bring about improvement, but an increase in work rate at progressive levels will bring improvement up to a maximum state of training.

According to Karvonen (33), the cardiovascular system should be regarded as trained when a large cardiac output and a high maximum oxygen consumption have been developed. As the cardiovascular system is trained, the efficiency of the heart increases, which causes it to circulate more blood without beating as often. The increase in efficiency can be recognized in several different ways. At the resting state, the pulse rate may be reduced between the beginning and the end of a training period. Fletcher (26) reported reductions in resting pulse rates of twelve men, aged twenty to forty-six years, after bench stepping thirty times per minute until exhaustion. The small number of subjects, however, in addition to the wide range in ages, may have increased the possibility of spurious results. Henry (29) studied
resting heart rates of eighteen college athletes participating in various programs and concluded that resting heart rate was a valuable measure of cardiovascular condition. Resting heart rates decreased after training in all subjects with a correlation of 0.76 between the pre- and post-training resting heart rates. Based on a review of several studies, Montoye (13) concluded that although resting heart rate usually decreased with training, low correlations between resting heart rate and performance indicated the resting heart rate was of little value when predicting a subject's cardiovascular fitness. Michael and Gallon (39) found that resting pulse rates decreased significantly in three to six weeks during a basketball training season. In a study with oarsmen, rugby players, and non-trained subjects, Sloan and Keen (46) found significant decreases at the .05 level in resting pulse rates in the athletic groups after two to four months of training. The large number of subjects (100) tested, in addition to repeated observations of the resting heart rates, increased the possibility of reliable results. Sharkey and Holleman (47), however, found that changes in resting pulse rate were not consistent. In the previously mentioned study by Sharkey and Holleman, resting heart rates were measured several times before, during, and after the six-week training period. At the end of the training period, the investigators could find
no distinguishable differences in the groups' resting heart rates. In most of the studies which found a decrease in resting heart rates, the decrease was found after training in conditioned athletes but not in untrained subjects.

Another way that the fitness of the heart may be recognized is by the decrease in pulse rate during exercise. Astrand \(^{(18)}\) maintained that the pulse rate decrease is dependent upon an increased stroke volume. Fox and Mathews \(^{(8)}\) attributed the increased stroke volume to the increased size of the ventricular cavity and increased myocardial contractility promoted by training. In any case, heart rate during exercise is considered a more precise measure of cardiovascular endurance than either pre- or post-exercise heart rates \(^{(25)}\).

A third way that increased fitness of the heart may be recognized is by a change in blood pressure after training. Some studies have shown a significant decrease in systolic and diastolic blood pressure with training. Cogswell, Henderson, and Berryman \(^{(21)}\) in a study of seven male volunteers, indicated a significant decrease in resting diastolic and systolic blood pressure at the .01 level following a twelve-week training program of moderate exercise. Michael and Gallons \(^{(39)}\) determined that a change in blood pressure would occur over a period of training but would do so much slower than a change in
pulse rate. Seventeen male varsity basketball players were studied over a period of sixteen weeks. Significant (.05 level) pulse rate changes were noted in six weeks, while significant (.05 level) changes in blood pressure were not noted until after sixteen weeks. Brouha (20) observed that cardiovascular recovery processes improve with training, and heart rate and blood pressure return to the pre-exercise level sooner in the better-trained individual.

Some factors that may affect the heart rate and blood pressure have been noted in reviews of cardiovascular research by Larson (36) and Montoye (13). Investigations by Suggs and Splinter (48), who studied nineteen college men trained on a bicycle ergometer, and by Brouha, Maxfield, Smith, and Stopps (20), who studied five men and one woman trained on a bicycle ergometer under different conditions, have also brought to light factors which affect heart rate and blood pressure. Exercise, age, sex, season, climate, altitude, air and water movement, loss of sleep, respiration, metabolic activity, changes in body posture, digestion, disease, drugs, and emotions are some of the factors that may influence cardiovascular measures.

To summarize the preceding investigations, training has been shown as a favorable method of increasing cardiovascular fitness. Intensity and duration of the
training program are two questions that have been frequently investigated. Most studies such as those of Sharkey and Holleman (47) and Shephard and Walters (48) favored the longer, more intense training periods as the ones which elicited the most improvement. However, studies such as that of Jackson, Sharkey, and Johnston (30) favored the shorter duration periods because the longer periods may be too strenuous. Sharkey (46) determined that neither duration nor intensity influenced cardiovascular endurance if either of the two were held constant. The question of initial level of fitness presented by Shephard and Walters (48) has proved to be very important. Intensity and duration of the training program must be according to the subject's initial level of fitness to avoid being too strenuous. The training program, therefore, must be of sufficient duration and intensity to elicit a training effect with regard to age, activity, and initial level of fitness of the subjects.

Resting heart rate was listed as a measure of cardiac fitness by several authors (26,29,39). Heart rate during exercise was considered a more precise measure, however (25). Resting blood pressure was supported as an indicator of cardiovascular endurance (21), but the lowering of resting blood pressure has been shown to required longer periods of training.
Most of the studies of cardiovascular fitness and training investigated have employed the use of small numbers of subjects divided into several training groups. Also, the initial level of fitness for subjects within a study has varied considerably. These two factors may have influenced the results of the studies reviewed.

Nautilus

Nautilus training is a type of training which utilizes Nautilus weight training machines. The main characteristic of Nautilus training which separates it from conventional weight training is the fact that each machine provides resistance correlated to the force exerted throughout the full range of motion. This means that the resistance varies directly with the strength of the muscle being exercised. This is accomplished by the means of a cam which compensates for the variations in strength by changing the moment arm. So, even though the weight being moved remains constant, the resistance it provides varies, and these variations are in accordance with the strength curve of the particular muscle group being worked.

Currently, there are twenty-one separate Nautilus machines, each designed to exercise a specific muscle group. According to Riley (15), each machine is designed to provide for "the seven requirements of exercise":

1) full range resistance; 2) direct resistance; 3) balanced resistance; 4) omni-directional resistance; 5) automatically variable resistance; 6) rotary form resistance; and 7) negative work potential.

The present popularity of Nautilus training is due largely to the short duration of the workouts and to the significant gains in strength and flexibility which occur despite the brief exercise periods (31).

Nearly all the research concerning Nautilus training is that which has been conducted at the Nautilus Sports/Medical complex or research which has been supervised by Nautilus personnel. Darden (6), in a review of his investigations, suggested that significant improvement in cardiovascular capacity will result from Nautilus training sessions lasting less than thirty minutes per day, three days a week. The most publicized Nautilus project was entitled Total Conditioning: A Case Study (41) and was conducted at the U. S. Military Academy under the supervision of Nautilus representatives. In this study, twenty-one varsity football players participated in a Nautilus training program three days a week for six weeks. For comparative purposes, a matched control group also consisting of football players was chosen. Pre- and post-training tests were administered to determine, among other things, 1) strength and flexibility gains; 2) cardiovascular improvement; and 3) changes in body composition. The results indicated
a significant improvement in cardiovascular fitness at the .05 level. However, two aspects of this study are subject to question. First, the subjects were concurrently involved with spring football practice while undergoing Nautilus training. Second, the maximal state evaluation was determined by a timed two-mile run which is not a proven test for cardiovascular efficiency. These factors may have had a major influence on the results of the investigation. In addition to the gains in cardiovascular fitness, significant changes in strength and flexibility occurred. The impressive feature of this claim is that the improvements were a result of only eight-and-one-half hours of total training time (41).

**Maximal Oxygen Intake**

Cooper (4) has suggested that oxygen consumption is the key to endurance training. The general agreement has been that maximal oxygen consumption (max VO₂) is the best measure of cardiovascular efficiency, as was stated in a study by Glassford, Baycroft, Sedgwick, and Macnab (28). Twenty-four male subjects, seventeen to twenty-three years of age, were given three direct tests of maximal oxygen uptake (Mitchell, Sproula, and Chapman treadmill test, Taylor, Buskirk, and Henschel treadmill test, and the Åstrand bicycle ergometer test) and one indirect test (Åstrand-Ryhming nomogram bicycle ergometer). All four test results indicated improvement in maximal
oxygen consumption, and intercorrelation between tests showed the predicted test method to be as accurate as the direct test methods. Wilmore (50) and Montoye (13) have reported the usefulness of maximum oxygen consumption as a measure of cardiovascular efficiency. In a study by Wilmore (50), thirty male college students were investigated for a relationship between maximal oxygen consumption and endurance capacity. Maximal oxygen consumption was directly measured during two bicycle ergometer work capacity tests, and results indicated a correlation of .78 when measured in milliliters per kilogram per minute and .64 when measured in milliliters per lean body weight per minute. The author cautioned that body weight must be taken into account in the comparisons. Montoye (13) noted, in an overview of circulatory-respiratory fitness, that maximal oxygen consumption and heart rate are closely related, and maximal oxygen consumption is, therefore, an accepted method of assessing cardiorespiratory fitness. DeVries (7) has stated that maximal oxygen consumption is the best single measure of work capacity, particularly in aerobic work. DeVries was supported by Cooper's (4) observation that maximal oxygen consumption determined in the laboratory is the best indicator of cardiovascular fitness. The preceding fact was noted by Cooper during his investigation of 115
male Air Force officers in which he correlated twelve-minute field test performances with laboratory determination of maximal oxygen consumption \(r = 9.897\). Cooper assumed, therefore, that the twelve-minute test was an accurate predictor of cardiovascular fitness, but age range of the subjects and the fact that they were all Air Force officers may have influenced the results.

Although laboratory determination of maximum oxygen consumption has been established as the best method, time, expense, and excessive physical demands on the subject contribute to the difficulty of using this method with large groups \((4, 28)\). For this reason, many studies have been undertaken to determine indirect methods of measuring maximal oxygen consumption. Probably the most well-known indirect method is that of Astrand and Ryhming \((18)\). Astrand \((1)\) observed that respiration and circulation in aerobic exercise would play a major role in maximal oxygen tests, especially in the engagement of large muscle groups. Therefore, a test procedure utilizing aerobic exercise was required. With the concept of aerobic exercise in mind, Astrand and Ryhming \((18)\) constructed a nomogram for determining maximal oxygen consumption (aerobic power) from heart rates during submaximal work. By determining that 50 percent of the maximum would be reached in about five to six minutes, a nomogram was constructed by Astrand and Ryhming on the
basis of a maximum heart rate of 170 beats per minute in 112 well-trained men and women subjects. Because the maximal oxygen consumption is being predicted rather than being directly measured, a certain amount of error should be expected. In the case of the Astrand-Ryhming, the standard deviation lies at $\pm 15$ percent (18). A more accurate method for prediction has been developed by Fox (27). It is based on a linear equation relating the directly-measured max VO$_2$ to the submaximal heart rate (HR$_{SUB}$) response recorded during the fifth minute of bicycle exercise at 150 watts (900 Kg-METERS per MIN). The equation is:

$$\text{PREDICTED MAX VO}_2 \, (\text{LITERS PER MIN}) = 6.3 - 0.0193 \times \text{HR}_{SUB}$$

The standard deviation for this method, according to Fox (27), is $\pm 0.24$ liters per minute of 7.7 percent. Other popular indirect tests include the Harvard Step Test, the Progressive Pulse Ratio Test, the Delta RQ Test, and the Sjostrand-Wahlund Test. DeVries and Klafs (23) compared these methods with the Astrand-Ryhming and found them to be less accurate in their predictions when compared with actual measurements. All of these tests were based on the premise that the increase in heart rate and oxygen consumption are somewhat linear. A study by Taylor, Buskirk, and Henschel (49) demonstrated the linearity of oxygen consumption and heart rate using
twelve male subjects, aged eighteen to thirty-five years. Subjects were given repeated treadmill tests, which consisted of walking and running on the treadmill at specified grades ten minutes to one hour per day. Reliability of the method was .95. The authors suggested the muscle mass employed in maximal oxygen consumption tests was an important factor in the determination of maximal oxygen uptake. This fact could be important when deciding what kind of testing instrument should be used. Astrand and Saltin (19) determined that a linear relationship existed between heart rate and maximal oxygen consumption in various activities such as leg work, running skiing, swimming, and arm work. The study, however, involved the use of only seven subjects, which may have influenced results. Malhorta, Supta, and Rai (38) studied seven male subjects, aged twenty-eight to thirty-four, during performances at different intensities on the bicycle ergometer and concluded that a linear relationship existed between heart rate and oxygen consumption in all subjects.

In summary, maximal oxygen consumption has been shown to be a useful predictor of cardiorespiratory fitness (28, 13, 50). Although direct determination of maximal oxygen consumption is considered best (4, 7), indirect methods have been employed because of convenience (4, 28, 27). Many techniques of indirect methods have been proposed, but the Astrand test of predicted maximal
oxygen uptake has probably been the most widely used, and the Fox Equation being the most accurate. The fact that indirect methods of measuring Max VO\textsubscript{2} assumes a linear relationship with heart rate has been frequently investigated (49, 38, 19).

Testing Instruments and Test Selection

According to Wells, Balke, and Fossan (50), submaximal work is that work which is performed at an average heart rate of less than 180 beats per minute. Montoye (13) proposed that to effectively test aerobic work capacity, the test must be long enough to minimize the contribution of anaerobic work. Also, with the use of submaximal tests, motivation is minimized and subjects may be tested without severe health risks (23). Several submaximal tests have been reviewed including those of Åstrand (27), and the Harvard Step Test (7). The Harvard Step Test proved to be less accurate than the Åstrand method (23), and the Astrand test, in terms of the standard error of estimate, was less accurate than the Fox Equation (27). In an attempt to validate his method, Fox (27) compared seventy-four predicted and measured VO\textsubscript{2} values before and after physical training and with age. The overall accuracy of the method was a standard deviation of ±0.24 liters per minute of ±7.7 percent. The use of a bicycle ergometer as opposed to a step test or a treadmill has been supported by Åstrand and Saltin (19). Scott and Wilson (46)
also determined, in a study of forty-five college females during fitness testing, that the bicycle ergometer is desirable because it is reliable, work can be directly translated to kilogram-meters, subject motivation is high, and the muscle action is similar to walking or running. Von Dobelin (48) supported Scott and Wilson by stating that the bicycle ergometer is advantageous because physiological measurements, such as heart rate and respiratory rate, are easy to perform, and mechanical work can be measured accurately.

Summary

It appears clear that the Fox Equation is best to fit the needs of the present investigation. Although the Astrand method represents the older, more widely used test, the Fox Equation appears to be more accurate though scarcely reviewed.

The succeeding chapter reveals data analysis, findings of the study, and a discussion of the findings.
CHAPTER III

METHODS AND PROCEDURES

Subjects

A total of thirty-six male college students from The Ohio State University served as subjects. Of the thirty-six, eighteen were recruited from the university's varsity soccer team; nine, from the varsity wrestling team; and nine, from the physical education service program.

From comparative purposes, four groups were formed. One group was made up of nine varsity soccer players who were participating not only in Nautilus training but also in a three-day-a-week off-season soccer practice. This group will be referred to as the Combined Training Group. The remaining nine soccer players were involved only in the off-season practice sessions and made up the Spring Training Only Group. The nine wrestlers were involved solely in the Nautilus program and were referred to as the Nautilus Training Only Group. The control group consisted of nine physical education students who underwent no type of physical training. All groups received the pre- and post-training tests.
Testing Instruments

Several tests of aerobic fitness were reviewed for use in the present study. The five-minute bicycle ergometer test for predicting maximal oxygen uptake and the Fox Equation were selected. Fox's method is fairly new in the cardiovascular field but is an acceptable and accurate method of measuring maximal oxygen consumption and served as the criterion measure of cardiovascular fitness (27). The Monark bicycle ergometer was the instrument chosen for the test and was adjusted for a resistance of 150 watts (900 Kg-METERS PER MINUTE). A speed of 20 MPH, according to the bicycle's speedometer, was maintained throughout the five-minute ride. A Hewlett-Packard Model 1500a electrocardiograph was used to record heart rate during the resting state and during the fifth minute of bicycle exercise. The subject was attached to the electrocardiograph by three surface electrodes, one attached to the skin over the sternum, one on the left sixth rib, and the third attached on the left trapezius. The electrodes were then attached to the amplifier by an input extension cable, and heart rates were monitored continuously during exercise. Prediction of maximal oxygen consumption was accomplished by inserting the fifth minute heart rate into the Fox Equation:

\[
\text{PREDICTED MAX \( VO_2 \) (LITERS PER MINUTE) = } 6.3 - 0.0193 \times HR_{\text{SUB}}
\]
The following instructions were given to all subjects preceding each ergometer test.

1. Keep the speedometer at 20 mph.
2. Keep both hands on the handlebars and focus on the speedometer.
3. Do not start or stop pedalling until told to do so.

In addition to the above test, changes in resting heart rate and blood pressure were measured. Both measurements were taken prior to the ergometer exercise with the subject in a sitting position. A sphymomanometer and stethoscope were used to test blood pressure with measurements being in terms of millimeters of mercury. Heart rate was recorded as beats per minute.

Test Administration

All tests were administered by the investigator in the Work Physiology Research Laboratory, Ohio State University one week prior to and following the training period.

Research Design

For the Nautilus Only Group, the eight-week training sessions were set up along the guidelines established by Darden (6) and were closely followed. A Monday-Wednesday-Friday schedule was chosen with the understanding that more than two absences resulted in expulsion from the
program. One-minute rest intervals were allowed between machines during the first week of training but were reduced by 10 seconds each week thereafter until the subject was allowed only the time to adjust the weight setting before beginning his next exercise. Proper form was required with special attention given to a slow speed of movement, a full range of motion, and a high level of intensity. When the subject was able to perform twelve repetitions on a particular machine, additional resistance was added to that exercise at the next workout. All exercises were performed in the following order:

Station 1

Machine: Duosymmetric-Polycontractile Hip and Back
Muscles used: Buttocks and Lower Back
Repetitions: 8-12
Sets: 1

Station 2

Machine: Leg Curl
Muscles used: Biceps Femoris, Semitendinosus, Semimembranosus
Repetitions: 8-12
Sets: 1

Station 3

Machine: Compound Leg-Leg Press
Muscles used: Quadriceps, Hamstrings, Buttocks
Repetitions: 8-12
Sets: 1
Station 4
Machine: Leg Extension
Muscles used: Quadriceps
Repetitions: 8-12
Sets: 1

Station 5
Machine: Multi-Exercise, Calf Raises
Muscles used: Calf
Repetitions: 8-12
Sets: 1

Station 6
Machine: Double Chest-Decline Press
Muscles used: Pectorals, Deltoids, Triceps
Repetitions: 8-12
Sets: 1

Station 7
Machine: Combination Pullover/Torso Arm-Pullover
Muscles used: Latissimus Dorsi
Repetitions: 8-12
Sets: 1

Station 8
Machine: Tricep Extension
Muscles used: Triceps
Repetitions: 8-12
Sets: 1
Station 9
Machine: Tricep Extension
Muscles used: Triceps
Repetitions: 8-12
Sets: 1

Station 10
Machine: Neck and Shoulder
Muscles used: Trapezius
Repetitions: 8-12
Sets: 1

Station 11
Machine: 4-Way Neck
Muscles used: Front, Sides, Back of Neck
Repetitions: 8-12
Sets: 1

Station 12
Machine: Rotary Neck
Muscles used: Neck Rotators
Repetitions: 8-12
Sets: 1

The Combined Training Group followed the same training regime on a Tuesday-Thursday-Saturday schedule. In addition to the Nautilus workouts, each subject in this group participated three times a week in off-season varsity soccer practice.

The Spring Practice Only Group involved itself solely in the soccer practice which consisted of agility
and conditioning drills.

The Control Group, consisting of nine subjects did not participate in physical education activities during the training period.

During the investigation, one subject from the Nautilus Training Only Group was dropped because of illness.

**Statistical Treatment**

The experimental design was a one-way analysis of covariance in which the F-ratio was used to determine the significance of the variation among four treatment groups' improvement on the cardiovascular tests. The analysis of covariance is based on the following assumptions which were appropriate for this investigation (9,10).

1. The test is most appropriate for intact groups (groups that are not equated experimentally) and where experimental control is not possible. Experimental subjects in the present study were varsity collegiate soccer players and wrestlers and were not equated experimentally.

2. Analysis of covariance usually involves a pre-test and a post-test, and the pre-test score is used as the covariate. The pre-test scores for the Fox
Equation, the submaximal and resting heart rates and the blood pressure measures were used as covariates.

4. The analysis of covariance can be applied to eliminate possible initial bias if significant differences between groups exists in pre-training analysis.

The procedure for the analysis of covariance includes obtaining the sums of squares between groups, within groups, and for the total sample, along with each sum's degrees of freedom. Adjusted sums of squares, mean squares, and degrees of freedom are obtained for the dependent or post-test variable (9). The $F$-ratio is then calculated and compared with tabled values of $F$ for the appropriate degrees of freedom and the desired level of significance. If the calculated $F$-ratio is larger than the tabled $F$, the null hypothesis is not accepted. If the calculated $F$-ratio is smaller than the tabled $F$, the null hypothesis is retained. In the present study, Alpha was .01, and Tukey's studentized range table was used to determine the source of variation.

The $t$-ratio was used to determine if the difference between the mean of the pre-test scores and the mean of
the post-test scores was statistically significant. Since the .01 level of confidence was chosen, then it is correct in assuming that the difference between the pre- and post-test scores, if proven to be significant, occurred by chance only one time out of one hundred.

The appropriateness of the t-ratio depends upon certain requirements such as: 1) making a comparison between two means; 2) using interval data (data at the interval level of measure as opposed to being ranked or nominal); and 3) that the data are normally distributed (13). However, according to Ferguson (9), "...even for quite small samples, say, of the order of 5 or 10, if the distributions do not grossly depart from normality, this deviation will not seriously affect the estimation of probabilities."

The t-ratio is obtained by taking the difference between the pre- and post-test means and dividing by the standard error of the difference. This figure must then be interpreted with reference to degrees of freedom (N - 1). If the obtained t-ratio is found to be greater than the tabled t-ratio, then it can be assumed that the pre- and post-test scores were, in fact, statistically different.
Summary

This chapter has included a description of the subjects tested, the training program used, instructions for administration of the cardiovascular tests, and the statistical treatment of the data. In the following chapter, results of the cardiovascular tests and training program are presented and discussed.
CHAPTER IV

ANALYSIS OF THE DATA

Data secured for the present investigation included pre- and post-test scores for resting heart rates, resting systolic and diastolic blood pressures, submaximal heart rates, and maximal oxygen consumption measures as predicted using the Fox Equation. The $t$-ratio for related samples was used to determine significant improvement of the four groups' performances on the pre- and post-tests. Analysis of covariance was used to determine any statistically significant difference among groups.

Table 1 includes means, standard errors of the means, and $t$-ratios of the resting heart rates on the pre- and post-tests. The groups were, Group I (Spring Training Only), Group II (Nautilus Training Only), Group III (Combined Training), and Group IV (Control).
Table 1
Means, Standard Error of the Mean, and t-Ratios of Resting Heart Rates (Beats per Minute)

<table>
<thead>
<tr>
<th>Group</th>
<th>PRE-TEST M</th>
<th>SEM</th>
<th>POST-TEST M</th>
<th>SEM</th>
<th>DIFF</th>
<th>t RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (N=9)</td>
<td>65.4</td>
<td>2.6</td>
<td>63.6</td>
<td>3.0</td>
<td>1.9</td>
<td>0.5145</td>
</tr>
<tr>
<td>II (N=8)</td>
<td>67.4</td>
<td>2.8</td>
<td>64.3</td>
<td>2.1</td>
<td>3.1</td>
<td>1.5390</td>
</tr>
<tr>
<td>III (N=9)</td>
<td>83.6</td>
<td>4.6</td>
<td>75.7</td>
<td>4.0</td>
<td>7.9</td>
<td>3.7311*</td>
</tr>
<tr>
<td>IV (N=9)</td>
<td>69.8</td>
<td>1.4</td>
<td>69.7</td>
<td>1.0</td>
<td>0.1</td>
<td>0.1512</td>
</tr>
</tbody>
</table>

*p < .01

All of the resting heart rates decreased from pre- to post-tests, but in order to be statistically significant at the .01 level of confidence with 8 degrees of freedom for Groups I, III, and IV and 7 for Group II, t values greater than 3.355 and 3.499, respectively, were needed. Since the t of 3.7311 from Group III was beyond the tabled level, the change in resting heart rate experienced by that group was found to be significant and was a product of combined training.

Table 2 contains the results of the analysis of the resting heart rates by the covariance method.
Table 2
Results of Analysis of Covariance of Resting Heart Rates

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Adjusted Means</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>91.6</td>
<td>3</td>
<td>30.5</td>
<td>1.41</td>
<td>I 68.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II 67.5</td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>650.4</td>
<td>30</td>
<td>21.7</td>
<td></td>
<td>III 66.6</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IV 71.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Total</td>
<td>742.0</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F.01 3/30 df = 4.51

Results of the analysis of covariance verified that no significant difference existed between any of the four groups' resting heart rates.

In Table 3, the means, standard errors of the means, and t-ratios of the submaximal heart rates are shown for the pre- and post-test five-minute bicycle ergometer ride. Although all groups' submaximal heart rates decreased, only Group II and Group III had significant changes. An analysis of covariance for the submaximal heart rates is shown in Table 4.
Table 3

Means, Standard Error of the Mean, and \( t \)-Ratios of Submaximal Heart Rates

<table>
<thead>
<tr>
<th>Group</th>
<th>PRE-TEST</th>
<th>POST-TEST</th>
<th>GROUP DIFF.</th>
<th>( t ) RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SEM</td>
<td>M</td>
<td>SEM</td>
</tr>
<tr>
<td>I (N=9)</td>
<td>132.1</td>
<td>4.2</td>
<td>127.4</td>
<td>3.4</td>
</tr>
<tr>
<td>II (N=8)</td>
<td>146.1</td>
<td>7.7</td>
<td>140.3</td>
<td>7.9</td>
</tr>
<tr>
<td>III (N=9)</td>
<td>156.6</td>
<td>3.5</td>
<td>144.3</td>
<td>3.9</td>
</tr>
<tr>
<td>IV (N=9)</td>
<td>164.6</td>
<td>3.4</td>
<td>163.9</td>
<td>2.8</td>
</tr>
</tbody>
</table>

*\( p < .01 \)

Table 4

Results of Analysis of Covariance of Submaximal Heart Rates (Beats per Minute)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Adjusted Means</th>
<th>Comparison Between Means Using Tukey's Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>624.1</td>
<td>3</td>
<td>214.0</td>
<td>10.32</td>
<td>I 144.0 I-II 0.211</td>
<td>II 143.8 I-III 5.816</td>
</tr>
<tr>
<td>Within</td>
<td>622.5</td>
<td>30</td>
<td>20.8</td>
<td></td>
<td>III 138.2 I-IV 6.309</td>
<td>IV 150.3 II-III 5.605</td>
</tr>
<tr>
<td>Total</td>
<td>1264.6</td>
<td>33</td>
<td></td>
<td></td>
<td>IV 150.3 II-III 5.605</td>
<td>III-IV 12.125*</td>
</tr>
</tbody>
</table>

\( F .01, 3 3/30 df = 4.51 \)

*\( p < .01 \)
The F-ratio of 10.32 was found to be significant beyond the .01 level. Tukey's ratio of 7.2883 was needed for the group comparisons to be statistically significant at the .01 level. A significant difference was found between Group III and the control group. No significant difference, however, existed between any of the other groups. It is interesting to note that at the .05 level, all groups significantly differed from the control group.

Table V includes means, standard error of the mean, and t-ratios for the four groups' pre- and post-test performances on the five-minute bicycle ergometer test in terms of predicted maximal oxygen consumption.

Table 5
Means, Standard Error of the Mean, and t-Ratios of Four Groups' Predicted Maximal Oxygen Consumption (ml-kg-1 • min-1)

<table>
<thead>
<tr>
<th>Group</th>
<th>PRE-TEST M</th>
<th>SEM</th>
<th>POST-TEST M</th>
<th>SEM</th>
<th>GROUP DIFF.</th>
<th>t-RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (N=9)</td>
<td>55.37</td>
<td>1.20</td>
<td>55.46</td>
<td>.94</td>
<td>.09</td>
<td>3.2853</td>
</tr>
<tr>
<td>II (N=8)</td>
<td>50.79</td>
<td>2.18</td>
<td>52.05</td>
<td>2.23</td>
<td>1.26</td>
<td>4.5013*</td>
</tr>
<tr>
<td>III (N=9)</td>
<td>46.91</td>
<td>.96</td>
<td>50.04</td>
<td>1.14</td>
<td>3.14</td>
<td>6.0875*</td>
</tr>
<tr>
<td>IV (N=9)</td>
<td>42.18</td>
<td>.89</td>
<td>42.19</td>
<td>.71</td>
<td>.01</td>
<td>0.5161</td>
</tr>
</tbody>
</table>

*p < .01
Performance scores increased between the pre- and post-tests in all groups, but only Groups II and III showed statistically significant changes.

Table 6 contains the results of the analysis of covariance as applied to the maximal oxygen predictions using the pre-test scores as the covariates. Adjusted means and comparisons among the means using Tukey's studentized range test are also listed.

The $F$-ratio of 7.79 proved significant beyond the .01 level. The Tukey ratio of 3.59 was used to determine if the group comparisons were significantly different at the .01 level. Just as with the sub-maximal heart rate measures, only Groups III and IV differed significantly. When tested at the .05 level, however, Groups II and IV proved different.

Table 6

Results of Analysis of Covariance of Maximal Oxygen Predictions (ml • kg$^{-1}$ • min$^{-1}$)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>$F$</th>
<th>Adjusted Means</th>
<th>Comparison Between Means Using Tukey's Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>53.66</td>
<td>3</td>
<td>17.89</td>
<td>7.79</td>
<td>I 51.01</td>
<td>I-II  .43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II 51.44</td>
<td>I-III .76</td>
</tr>
<tr>
<td>Within</td>
<td>69.03</td>
<td>30</td>
<td>2.3</td>
<td></td>
<td>III 51.77</td>
<td>I-IV 3.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IV 47.96</td>
<td>II-III .33</td>
</tr>
<tr>
<td>Total</td>
<td>122.69</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>II-IV 3.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>III-IV 3.81*</td>
</tr>
</tbody>
</table>

$F_{.01} = 4.51$  
* $p < .01$
Table 7 contains means, standard error of the mean, and t-ratios of the pre- and post-test resting systolic blood pressure measures.

### Table 7

Means, Standard Error of the Mean, and t-Ratios of Resting Systolic Blood Pressure Measurements (mm of Hg)

<table>
<thead>
<tr>
<th>Group</th>
<th>PRE-TEST</th>
<th>POST-TEST</th>
<th>GROUP DIFF.</th>
<th>t RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (N=9)</td>
<td>113.89 2.32</td>
<td>115.56 5.01</td>
<td>1.67</td>
<td>0.1992</td>
</tr>
<tr>
<td>II (N=8)</td>
<td>111.88 5.03</td>
<td>112.25 6.91</td>
<td>.38</td>
<td>0.1492</td>
</tr>
<tr>
<td>III (N=9)</td>
<td>114.56 2.51</td>
<td>114.44 5.27</td>
<td>.33</td>
<td>0.0839</td>
</tr>
<tr>
<td>IV (N=9)</td>
<td>125.33 2.14</td>
<td>124.98 1.98</td>
<td>.45</td>
<td>0.6100</td>
</tr>
</tbody>
</table>

The resting systolic blood pressure measures increased slightly in Groups I and II but slightly decreased in Groups III and IV. According to the results of the t-tests, however, the differences were not statistically significant and therefore could have happened by chance. Table 8 contains the analysis of covariance of the resting systolic blood pressure measures.
Table 8
Results of Analysis of Covariance of Resting Systolic Blood Pressure (MM of Hg)

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Adjusted Means</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>139.11</td>
<td>3</td>
<td>46.37</td>
<td>.63</td>
<td>I 119.08</td>
<td>2.884</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II 118.45</td>
<td>3.123</td>
</tr>
<tr>
<td>Within</td>
<td>2192.54</td>
<td>30</td>
<td>73.08</td>
<td></td>
<td>III 117.07</td>
<td>2.869</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IV 113.21</td>
<td>3.210</td>
</tr>
<tr>
<td>Total</td>
<td>2331.65</td>
<td>33</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

F .01 3/30 df = 4.51

An F-ratio of .63 verified no significant difference between any of the groups resting systolic blood pressure measures. In Table 9 may be found the means, standard error of the mean, and t-ratios for the resting diastolic blood pressure measures.

Table 9
Means, Standard Error of the Mean, and t-Ratios of Resting Diastolic Blood Pressure Measures (MM of Hg)

<table>
<thead>
<tr>
<th>Group</th>
<th>PRE-TEST</th>
<th>POST-TEST</th>
<th>GROUP DIFF.</th>
<th>t RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SEM</td>
<td>M</td>
<td>SEM</td>
</tr>
<tr>
<td>I (N=9)</td>
<td>74.44</td>
<td>4.60</td>
<td>73.89</td>
<td>3.98</td>
</tr>
<tr>
<td>II (N=8)</td>
<td>70.50</td>
<td>2.77</td>
<td>70.38</td>
<td>2.55</td>
</tr>
<tr>
<td>III (N=9)</td>
<td>71.11</td>
<td>3.71</td>
<td>70.89</td>
<td>4.43</td>
</tr>
<tr>
<td>IV (N=9)</td>
<td>83.44</td>
<td>2.38</td>
<td>83.56</td>
<td>2.17</td>
</tr>
</tbody>
</table>
No significant difference was found in any of the groups' resting diastolic blood pressure measures between the pre- and post-tests. Table 10 contains results of the analysis of covariance of the resting diastolic blood pressure measures.

Again, the analysis verified that no statistically significant difference was found between the groups' resting diastolic blood pressure measures during the pre- and post-tests.

Table 10

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Adjusted Means</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between</td>
<td>11.30</td>
<td>3</td>
<td>3.77</td>
<td>.23</td>
<td>I 74.39</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II 74.47</td>
<td>1.46</td>
</tr>
<tr>
<td>Within</td>
<td>490.02</td>
<td>30</td>
<td>16.33</td>
<td></td>
<td>III 74.43</td>
<td>1.37</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IV 75.88</td>
<td>1.47</td>
</tr>
<tr>
<td>Total</td>
<td>501.32</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F .01, 3/30 df = 4.51

Of the four groups involved in this investigation, only the Combined Training Group significantly lowered resting heart rates. A possible explanation was offered by Karvonen (33) who indicated that resting pulse rates are likely related to cardiovascular training, but different results of training are measured than those
determined by the rise in pulse rate from a resting to a working state. DeVries (7) maintained that heart rates are more affected by work done during the aerobic state. Since the Combined Training Group probably had more aerobic training than the other groups, their heart rates were more affected. Furthermore, initial levels of fitness have been shown to affect responses to cardiovascular tests (46). Resting blood pressure was not affected by the training program probably because the subjects' blood pressures were lower than normal, 113/72 as compared with 120/80, before the training program began. DeVries (7) implied that a training regime may not affect normal or below normal blood pressure.

In both the submaximal and predicted maximal state, only the Combined Training Group differed from the Control Group at the .01 level, although when tested at the .05 level, the Nautilus Only Group also showed a significant difference with the Control Group. Both the Combined Training and the Nautilus Only Groups improved significantly between pre- and post-testing. Evidently, the duration and intensity of the workouts used by these two groups were sufficient enough to provide improved aerobic efficiency. The Spring Training Only Group performed most of the drills and exercises during workouts anaerobically, probably indicating why no significant improvement occurred.
A summary of the present investigation, conclusions, and suggestions for further study are presented in Chapter V.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Purpose and Procedures

The purpose of the present investigation was to determine if changes in cardiovascular efficiency would occur following an eight-week training program.

Subjects were thirty-six male college students, eighteen of which were recruited from The Ohio State University varsity soccer team, nine from the varsity wrestling team, and nine from The Ohio State University physical education service program. The physical education students, acting as a control group, were not currently engaged in physical activity courses. The wrestlers were assigned to the Nautilus Training Only Group, and nine of the soccer players made up the Combined Training Group which consisted of Nautilus training in addition to off-season soccer practice. The remaining nine soccer players were involved solely in the soccer practice and formed the Spring Training Only Group. The cardiovascular measures administered to all of the subjects before and following the eight-week training program were resting heart rates and blood pressures, submaximal heart rates from a five-minute
bicycle ergometer ride, and predicted maximal oxygen consumption measures from the Fox Equation. The analysis of covariance was used to determine significant differences between groups' performances on the cardiovascular post-tests. The t-ratio was computed for all measures to determine if significant differences existed between pre- and post-test performances. Alpha was .01.

Results

The following are the results of the present investigation:

1. The subjects in the Combined Training and Nautilus Training Only groups showed greater improvement in aerobic capacity than the Spring Training Only or Control groups after eight weeks of training.

2. Resting blood pressures were not significantly lowered in any of the groups.

3. Resting heart rates were significantly lowered in the Combined Training Group. A change did not occur in the other three groups.

4. Submaximal heart rates were significantly lowered in the Combined Training and Nautilus Training Only groups with the greatest change occurring in the Combined Training Group. No
noticeable change was found in the other two groups.

Conclusions

Concerning the effects of an eight-week program of Nautilus training, the following conclusions would seem warranted:

1. A program of Nautilus weight training for three days per week over an eight-week period would be beneficial in increasing cardiovascular efficiency in college athletes.

2. An off-season training program supplemented with Nautilus weight training would produce even greater results in cardiovascular fitness.

3. Changes in resting heart rates and resting blood pressures are largely affected by subjects' initial levels of fitness.

4. Submaximal heart rates at a given workload can be significantly lowered with the eight-week Nautilus training program as prescribed by Darden.
Observation

An interesting aspect of this study deals with the different levels of motivation which existed between the soccer players and the wrestlers. As a group, the soccer players needed constant supervision and encouragement during workouts to maintain the desired level of intensity. Without this supervision, the workouts would surely have deteriorated to uselessness. The wrestlers, however, seemed to thrive on the exercise sessions, and, without exception, each wrestler pushed himself to exhaustion. This degree of high motivation and the willingness to undergo the pain and fatigue associated with proper training no doubt had an effect on the overall results of this study. The amount of effort put into this program or any program is directly related to the amount of improvement achieved. It should be made clear that gains similar to the cardiovascular improvements made by the wrestlers should not be expected unless similar effort is put into each exercise of each workout session.

Recommendations

The following recommendations are offered:

1. Direct measurements of oxygen consumption, substituted for the predicted measures in the present study, might be used to obtain more precise results.
2. A similar investigation might be carried out using non-athletes as subjects to determine if Nautilus training would have an even greater value for cardiovascular conditioning.

3. A similar investigation involving a larger sampling of subjects may provide more accurate results.

4. A physical fitness test administered before the investigation might be of value in determining the subjects' initial levels of fitness.

5. Heart rates taken at various times during actual workout sessions could better indicate the subjects' levels of intensity during exercise.
APPENDIX A

BODY COMPOSITION CHANGES
One of the anticipated results of the West Point study was to have been a significant decrease in the percentage of body fat with a complimentary increase in lean body weight after the six weeks of Nautilus training. This did not occur. In fact, the experimental group as a whole averaged a slight increase in the amount of body fat. Body compositions were determined by skinfold measurements and by a potassium Whole Body Counter. In the present investigation, each subject underwent hydrostatic weighing prior to and immediately following the Nautilus Training program to determine if, in fact, any change in body composition would occur. The results, as indicated below show no appreciable gain in total body weight or lean body weight and no significant reduction in body fat (lbs.) or percentage of body fat.

Table 11

Mean, Mean Difference and t-Ratios for Weight, Lean Body Weight, Fat Weight, and Fat Percentage of Nautilus Only Group

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Lean Body Weight</th>
<th>Fat Weight</th>
<th>% Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Training X</td>
<td>151.34</td>
<td>136.69</td>
<td>12.46</td>
<td>8.12</td>
</tr>
<tr>
<td>Post-Training X</td>
<td>151.80</td>
<td>137.15</td>
<td>12.28</td>
<td>8.04</td>
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<tr>
<td>Mean Diff.</td>
<td>.41</td>
<td>.46</td>
<td>.18</td>
<td>.08</td>
</tr>
<tr>
<td>t-Ratio</td>
<td>.3313</td>
<td>.4112</td>
<td>.7279</td>
<td>.1884</td>
</tr>
</tbody>
</table>

$t .01 = 3.50$
APPENDIX B

VITAL DATA OF SUBJECTS
Table 12

Height, Weight, Age, % Fat, and Lean Body Weight of Group I (Spring Practice Only)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height (inches)</th>
<th>Weight (lbs.)</th>
<th>Age</th>
<th>% Fat</th>
<th>LBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>70.5</td>
<td>151.75</td>
<td>19</td>
<td>12.0</td>
<td>133.5</td>
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<tr>
<td>B</td>
<td>70.75</td>
<td>154</td>
<td>18</td>
<td>11.5</td>
<td>136.29</td>
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<td>C</td>
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<td>152.25</td>
<td>19</td>
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<td>133.83</td>
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</table>
Table 13

Height, Weight, Age, % Fat, and Lean Body Weight of Group II (Nautilus Only)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height (inches)</th>
<th>Weight (lbs.)</th>
<th>Age</th>
<th>% Fat</th>
<th>LBW</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>68</td>
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<td>129.77</td>
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<td>19.37</td>
<td>8.1</td>
<td>136.69</td>
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Table 14

Height, Weight, Age, % Fat, and Lean Body Weight of Group III (Combined Training)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height (inches)</th>
<th>Weight (lbs.)</th>
<th>Age</th>
<th>% Fat</th>
<th>LBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>156</td>
<td>18</td>
<td>11.6</td>
<td>137.91</td>
</tr>
<tr>
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<td>71</td>
<td>160.5</td>
<td>18</td>
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<td>155.75</td>
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<td>136.9</td>
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<td>21</td>
<td>12.6</td>
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<td>139.5</td>
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<td>6.1</td>
<td>130.99</td>
</tr>
<tr>
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<td>133.75</td>
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</table>
Table 15

Height, Weight, Age, % Fat, and Lean Body Weight of Group IV (Control)

<table>
<thead>
<tr>
<th>Subject</th>
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<th>Weight (lbs.)</th>
<th>Age</th>
<th>% Fat</th>
<th>LBW</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<td>14.1</td>
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<tr>
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</tr>
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</table>
APPENDIX C

SUBJECT CONSENT FORM
RESEARCH INVOLVING HUMAN SUBJECTS
CONSENT TO SERVE AS A SUBJECT IN RESEARCH

BEHAVIORAL AND SURVEY RESEARCH FORM

I consent to serve as a subject in the research
investigation entitled: ________________________________

The nature and general purpose of the research
procedure have been explained to me. This research is to
be performed by or under the direction of Dr. ____________,
who is authorized to use the services of others in the
performance of the research.

I understand that any further inquiries I make
concerning this procedure will be answered. I understand
my identity will not be revealed in any publication,
document, recording, video-tape, photograph, computer
data storage, or in any other way which relates to this
research. Finally, I understand that I am free to withdraw
my consent and discontinue participation at any time
following the notification of the Project Director.

Signed ____________________________

Witness - (Auditor) ____________________________ Date ____________________________

Investigator 

PA-027
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BIBLIOGRAPHY

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