A STUDY OF THE EFFECTS OF ISOTONIC AND ISOMETRIC EXERCISE ON SELECTED PHYSIOLOGICAL VARIABLES

by

Martha Stephens

7081

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Greensboro
June, 1965

Approved by

Celeste Ulrich
Director

APPROVAL SHEET

This thesis has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro, Greensboro, North Carolina.

Thesis Director: Celeste Ulrich

Oral Examination Committee Members: Ethel Martus

Rosemary McGee

Laura G. Anderton

March 29, 1965

Date of Examination

STEPHENS, MARTHA. A Study of the Effects of Isotonic and Isometric Exercise on Selected Physiological Variables. (1965) Directed by: Dr. Celeste Ulrich. pp. 75.

The purpose of this study was to compare the effects of isotonic and isometric exercise on the physiological variables of oxygen consumption, hemoglobin concentration, systolic blood pressure, diastolic blood pressure, and pulse rate. Conditions of the experiment were base homeostatic level, isotonic exercise level, and isometric exercise level. Under each of these conditions, measures were taken for each of the physiological variables. The basis for comparing the two exercise series was specified as a one-minute duration of exercise with a weight load of approximately ten pounds.

Ten members of the graduate class in physical education of the University of North Carolina at Greensboro were randomly selected to be subjects for the experiment. All subjects had normal hemoglobin counts; none of them had donated blood within six weeks prior to the experiment.

A one-group method was the basic design of the study. Measures taken on the physiological variables were compared among the three conditions of the experiment. Fisher's "t" test of significance for small, correlated groups was the statistical tool used in this study.

The results of this study enabled the investigator to conclude the following points:

1. Both exercise conditions did elicit physiological changes over the base condition.

2. In relation to the cardio-respiratory systems, the isotonic condition placed a greater exercise stress on the body.

3. Under the exercise conditions, the build-up of the hemoglobin concentration was not indicated.

4. Second order differences indicated that the isotonic condition resulted in a greater hemoconcentration than did the isometric condition; the isometric condition increased systolic blood pressure to a greater extent than did the isotonic condition.

ACKNOWLEDGEMENT

The writer wishes to express her sincere appreciation to Dr. Celeste Ulrich, of the Department of Health, Physical Education and Recreation, for her guidance during this study.

To the assistants and students who participated in this study, the writer expresses her thanks for their willingness to help.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Throughout history, the values of exercise have had many implications to man. Very early, the need for survival implied the need for physical fitness for man. In this century, physical fitness has been stressed as its relationships with growth, health, and aging are explored. The value of exercise in theraputic work--professional or nonprofessional--is being recognized. Therapists in mental institutions are using movement patterns to help patients release tensions. Children, youths, adults often find that certain activities give them a sense of accomplishment. Recreational activities are important to many people; they provide an opportunity for people to meet and interact. International sport events are providing a channel of communication between peoples of different nations. Exercise in some form has progressed with man throughout history; in all probability, exercise will continue to be an important part of the future, and fitness will be an important concomitant of that future.

Exercise tends to cause changes in the physiological functionings of man's body; to a certain extent these changes and subsequent homeostatic adjustments can be measured and predicted. Measuring these changes and recognizing relationships between changes are basic to research which ultimately hopes to predict behavior of cells, tissues, organs, and organisms.

The two types of exercise--isotonic and isometric--result in changes in the physiological systems of man. Isotonic or dynamic exercise places an overload stressor on many systems of the body. Isometric or static exercise recently has been noted for its strength development potential. As the body systems are interdependent, overload of the muscular system also causes changes in other systems. It would seem profitable to impose both types of exercise on a group of people and to compare their effect on certain variables representing selected physiological systems.

In order to compare effects, a basis for comparison must be established. If a satisfactory method describing isometric exercise as a force moving through a distance could be found, one might use comparable work loads as a basis for comparison. If an equal work load concept could not be used for a basis of comparison, the elements of time and weight load might be found satisfactory.

Many comparisons of the effects of isotonic and isometric exercise on selected physiological variables might eventually provide evidence for use in predictive purposes. These predictions would probably be based on demonstrated relationships among various variables within an exercise syndrome. One advantage of having predictive formulas would be that types of exercise could be balanced to achieve maximum results for any purpose.

Before a prediction formula can be established a basis of comparison must be selected. Therefore, information relative to the effects of the two types of exercise on certain physiological variables must be obtained. Finally, the validity of this information should be repeatedly demonstrated before a prediction formula is derived.

This present study is designed to measure the effects of the two types of exercise on selected physiological variables after the selection of a basis for comparison.

STATEMENT OF PROBLEM

The purpose of this study was to compare the effects of isotonic and isometric exercise on the physiological variables of oxygen consumption, hemoglobin concentration, systolic blood pressure, diastolic blood pressure, and pulse rate.

Conditions of the experiment were base, isotonic, and isometric. Under each of these conditions, measures were taken for each of the physiological variables. The basis for comparing the two exercise series was specified as a one-minute duration of exercise with a weight load of approximately ten pounds.

Ten members of the graduate class in physical education of the University of North Carolina at Greensboro were randomly selected to be subjects for the experiment. All subjects had normal hemoglobin counts; none of them had donated blood within six weeks prior to the experiment.

CHAPTER II

REVIEW OF LITERATURE

Work may be viewed in a number of different ways. Karpovich (8:65) stated that physicists define work "as a product of force and the distance through which this force acts." But this definition of work does not take into account the varying degrees of physiological work which must be accomplished by the human organism in order to complete the physical work task. For example, performing an isometric task of holding weights in a stationary position requires no work by definition, yet physiologists (8;15) prefer to classify work tasks by their energy requirements.

Starr (36:28) derived a mathematical method of estimating work done with relation to an established load so that static and dynamic work can be expressed in the same units. He took into account the work done in supporting as well as starting, moving, and stopping the load. This is not to say that because "physical work loads" for static and dynamic tasks are equal that the physiological work done will be equal; physiological work includes other factors such as movement of limbs, leverage, internal friction, circulatory impediments, and/or facilitations (36:27-28). But this system of deduction does permit the researcher to equate static and dynamic work relative to a specified load for the purposes of comparing the physiological changes which take place. Therefore, for this paper the term "physical work load" is defined as the work performed by the muscles relative to an established load. According to Hubbard (7:18) the terms "isotonic" and "isometric" have become associated with tension development during shortening of the muscle and tension development with no shortening of the muscle respectively. Therefore, the term "isotonic" could be substituted for dynamic and "isometric", for static.

The physiological variables chosen for investigation in this study are oxygen consumption, pulse rate, total blood volume, and blood pressure. These variables were chosen because they reflect the inter-relativeness of the cardio-respiratory systems whose functionings determine to a great extent the efficiency of the human body in performing work tasks.

Upon considering a common function of both the circulatory and respiratory systems, that of supplying oxygen to be utilized by muscle tissue and eliminating waste products, one is impressed by the various mechanisms which regulate and determine this function. Brouha and Radford (2:183-185) have suggested the following steps in the process of oxygen utilization: (1) respiration and inspiration, (2) the diffusion of oxygen and carbon dioxide in the lungs, (3) the velocity of the blood flow, and (4) the diffusion of gases from the blood to the muscles and from the muscles to the blood. Some of the regulators of oxygen utilization and carbon dioxide removal are nervous stimulation, chemicals, blood temperature, blood composition, and the vasomotor system. These regulators and their regulatory processes are discussed below.

Impulses from the respiratory center of the brain result in ispiration, and it is believed that these impulses follow an automatic rhythm (10:149). These respiratory center impulses also cause the minute-volume of breathing to be stepped up and the bronchial tubes to be expanded (8: 213). Impulses also flow from the cardiac center of the brain, and these may accelerate the heart rate. These centers work together to facilitate the expiration of carbon dioxide, the inspiration of oxygen, the velocity of the blood flow, and the diffusion of oxygen and carbon dioxide in the lungs.

Some metabolites will cause a dilation of the capillaries and arterioles which in turn favor a better blood supply to the muscles, thereby making more oxygen available. An increase in carbon dioxide also facilitates the dissociation of oxyhemoglobin (8:213) which makes available more oxygen for the muscle tissues.

A rise in blood temperature facilitates the dissociation of oxyhemoglobin as well as increasing the rate of breathing.

The amount of circulating hemoglobin in the blood is one factor determining the oxygen carrying capacity of the blood. With all other factors being conducive to oxygen transfer, the more hemoglobin available in the blood, the greater the amount of oxygen picked up in the lungs.

By action of the vasomotor system, constriction of the blood vessels in unused areas of the body results in a greater volume of oxygenated blood supply to the working muscles (8:213).

It can be seen readily that the cardio-respiratory systems work together to enable the body to utilize oxygen. Measures of pulse rate, oxygen consumption, total blood volume, and blood pressure indicate the interactions of these regulators. The quantity and the quality of these interactions depend both upon the types of work tasks as well as other influencing factors.

The investigator has reviewed pertinent information concerning each physiological measure to be used in this study. Factors which influence the normal variations in the measures will be noted. Methods of measuring each of the physiological variables will be indicated.

PULSE RATE

Pulse rate may be defined as the rate of beating of the heart which is the rate of systolic ejection of blood into the aorta. Many factors have been found to effect the pulse rate; therefore, a review of the effects of pertinent factors on pulse rate has been included so that the investigator might have a basis for setting up experimental controls.

Karpovich (8:176) and Morehouse (10:101) both cited the study done by Schneider and Truesdell which indicated that pulse rate is affected by body position. The pulse rate is generally highest when one is standing and lowest when one is reclining. Obviously, if valid conclusions are to be drawn, a standard procedure concerning posture and pulse rate must be included in the experimental design.

Age is another factor which causes normal variations in the pulse rate. The foetus's average resting pulse rate is 150, which descends to 70 at ages 25-40 and ascends to 75 at 80 years of age (13:60). These variations indicate that any reported information relative to pulse rate must be interpreted in the light of the ages of the subjects.

Environmental temperature is yet another factor influencing the pulse rate. Loss of heat from the body may occur through the channels of conduction, convection, and radiation (10:218). With an increase in skin temperature, heat receptors in the skin are stimulated to the point that nervous impulses via the hypothalmus inhibit the vaso-constriction of the skin vessels thereby facilitating heat loss. In order to pump more blood through the dilated vessels, the pulse rate may rise.

Epinephrine, a product of the adrenal medulla, tends to accelerate the heart rate under emotional conditions. This is yet another reason for the difficulty encountered in an attempt to obtain reliable resting heart rates.

Karpovich (8:177) stated that digestion of food raises pulse rate for several hours. This factor must not be overlooked when measuring exercise pulse rate after a meal.

Activity of the muscles tends to raise heart rate. But different types of exercise investigated have indicated that the pulse rate rise is evidenced at varying times. With regard to isometric work, Brouha and Radford (2:199) stated that pulse rate may accelerate slightly, remain unchanged, or even slow down during the effort but accelerate afterwards and stay elevated for an amount of time determined by the magnitude of the effort and the muscles involved. McCurdy, in a study reported by Karpovich (8:181), found no significant change in the heart rate when a maximum pull was exerted on a back and leg dynamometer; these results, as explained by Karpovich, indicated that the hindrance of the return of venous blood to the heart is a factor in the pulse rate not being increased during the experiment. But studies dealing with isotonic work have indicated that pulse rate increases at the beginning of the exercise and shows linear relationships with oxygen consumed for the work period and with the work load up to a certain limit (8:180-181). If the work load is submaximal, a steady state condition may be reached gradually. It is suggested by some investigators (20:975) that when studying respiratory and circulatory functions during submaximal work that at least five minutes should be spent on the work task to allow time for adaptations in the systems. Le Blanc stated that a measure of pulse rate taken fifteen seconds after an exercise period is considered by some authorities to represent the exercise pulse rate (4:394). Both intermittent long-term training and short-term training decreased the pulse rate in a reclining position (28:72-73); this finding agrees with a statement by Morehouse that training makes a small but consistent reduction in the resting heart rate (10:260).

OXYGEN CONSUMPTION

A measure of oxygen consumption for a given work task includes the oxygen used during the task, plus the oxygen needed for recovery. At rest the body normally requires from two to three hundred cubic centimeters per minute (8:53). Deviations from this average required amount have been accounted for by such factors as the hemoglobin count, pulmonary ventilation, oxygen concentration in the air, the respiratory rate, the cardiovascular rate, the oxygen dissociation curve, and exercise. Some findings relative to these deviations are discussed below.

Because one of the main functions of hemoglobin is that of transporting oxygen, one would assume that the hemoglobin count would correlate highly with oxygen intake. Astrand, as reported by Taylor, found a high correlation coefficient between maximal oxygen intake and total circulatory hemoglobin (15:147).

At rest the lung ventilation per minute, the minute volume, averages eight liters (8:113). Riley stated that pulmonary ventilation was not a factor limiting an oxygen supply to working muscles (12:169). Neither, as Consolazio (4:356) has stated, is the ability to maintain a high pulmonary ventilation a factor involved in limiting the oxygen supply to working muscles. Riley also stated that the oxygen cost of breathing varies with body size and also between people of the same approximate size (12:165). Taylor (15:144) stated that the diffusion capacity of the lungs is generally believed to be great enough to oxygenate the arterial blood even during high levels of work; he reported a study done by Mitchell, and others, in which even at maximal oxygen intake the arterial saturation of the blood was well over ninety per cent.

With a decreased oxygen content of the air, the oxygen tension of the blood falls and this decrease activates the carotid body, which in turn stimulates the respiratory center to increase the rate of breathing, thereby compensating for the lack of oxygen in the air (10:149-150).

The respiratory rate governs, to an extent, the amount of time available for the diffusion of gases in the lungs. The mechanisms which speed up the rate of breathing also augment the depth of breathing so that more oxygen is available to the circulating blood.

With an increase in the circulatory rate the blood picks up more oxygen in a given unit of time if the pulmonary ventilation is adequate.

Taylor stated that tasks requiring ten to fifteen times the basal oxygen consumption are unable to be met as the cardio-respiratory systems cannot supply the necessary oxygen (15:124). Astrand and Saltin, in an experiment involving seven subjects performing maximal work of various types, found that the capacity of the heart may limit oxygen uptake (19:981).

The oxygen dissociation curve expresses the relation between oxygen tension and per cent hemoglobin saturation (6:301). With a decrease in oxygen tension the hemoglobin per cent saturation falls; if oxygen tension is increased the per cent hemoglobin saturation is increased. Two factors influence this relationship--temperature and acidity. DeLanne, and others, found that the degree of change in oxygen and carbon dioxide levels in venous blood from the resting values was influenced by intensity and duration of exercise and by environmental temperature (22: 332). Both temperature and acidity tend to affect the dissociation process in a similar manner. With a rise in either factor, the dissociation of oxyhemoglobin is facilitated and a fall in either factor has the opposite effect. The rate at which this dissociation takes place in the tissues affects the quantity of hemoglobin available for receiving oxygen in the lungs.

Activity causes a rise in oxygen consumption relative to the work load. Clarke (25), Anrep (17), von Sallfeld (17), Barcroft (22), Millen (22), and Royce (34) are a few of the investigators who have studied the relationships involved between oxygen consumption and isometric work. David Clarke (25:3-6) tested an hypothesis that "static" exercise, holding weights in the hands, would increase muscle tension resulting in a limiting of oxygen transport and a build up in oxygen debt to a greater extent than dynamic exercise. His results supported his hypothesis. Other studies which support Clarke's evidence of smaller oxygen income during isometric work because of occlusion of blood vessels are a study done by Anrep and von Sallfeld (17) and a study by Barcroft and Millen (22). Barcroft and Millen found that potentially dilated blood vessels, due to liberation of vasodilators by active muscle tissue, would not dilate because of compression of the blood vessels resulting from strong contractions. Anrep and von Sallfeld concluded, "A comparison of the venous outflow and of the arterial inflow of blood into a contracting skeletal muscle shows that muscular contraction is accompanied by a compression of the intramuscular blood vessels." (17:398) Royce stated, "Maximal isometric contraction, however, brings about fatigue which in turn diminishes the amount of tension produced. Consequently, the tension will decrease to a point where it no longer impairs the circulation." (24:205) After reviewing the literature relating oxygen consumption and isotonic work, the investigator found that, generally, this relationship is expressed as energy costs of various activities (8:79-110; 10:194-196).

TOTAL BLOOD VOLUME

According to Short (13:22), "Blood is a complex physico-chemical system comprising <u>formed elements</u> (red blood-corpuscles, white blood cells, and platelets) suspended in a fluid matrix, the <u>plasma</u>, a saline solution of proteins and other organic substances." Best and Taylor (1:19) stated that in normal subjects, blood makes up about seven per cent of the body weight, with plasma volume being about four per cent and red cell volume, about three per cent. The total blood volume is therefore affected by any factors which have an influence on its components--the plasma volume and the red cell volume.

Orten and Orten found that a low protein diet produced mild chronic anemia in rats; this condition can be prevented or cured by an adequate protein intake (32:29-30). Whipple and his associates, as reported by Best and Taylor (1:71), found that the lack of the protein globin may be a factor in the synthesis of hemoglobin. The heme (porphyrin and iron) part of the hemoglobin molecule is synthesized by the human body provided iron is available, because the pyrrole groups can readily be synthesized from simpler compounds found in the body (1:71).

The quantity of red cells would also affect the total blood volume. Short (13:28-29) stated that circulating mature erythrocytes are non-nucleated, bi-convex disks which are thirty-four per cent by weight composed of hemoglobin. There is a normal variation in the quantity of hemoglobin found in the red blood cells between the sexes. Short (13:30) indicated that adult men have 16.0 ± 2.0 hemoglobin grams per one hundred milliliters of blood, whereas women's blood contains 14.0 ± 2.0 grams per one hundred milliliters of blood. The average red blood cell count in a resting man is five million per cubic centimeter of blood (8:148). The red blood cell count supposedly would be altered by the menstrual process and hemorrhaging.

Sinclair (35:32-37) did an experiment comparing the effects of varying degrees of physical activities during the menstrual cycle on red blood count. She found that the decrease or increase in red blood count during menstrual flow depended upon the characteristics of the individual.

Leverton and Roberts (31) stated that the generally common acceptance of low hemoglobin count for women during menses is probably more a reflection of the iron-deficient diets than excessive iron losses in the menses. This study is supported by another study done by the same authors (30) in which four women were kept on a constant diet and no definite measurable effects of the menstrual cycle on red cell count or hemoglobin count were found.

Moore and Buskirk (9:227-230) stated that the immediate effects of loss of five hundred cubic centimeters of blood are a decrease in the circulating bood volume, an alteration in the blood transport, stroke volume, heart rate, and venous return at a given exercise level. The plasma volume is restored within twenty-four to forty-eight hours, but the red cell volume takes from three to six weeks for restoration. These authors made an interesting comment that the maximal oxygen intakes in the hemorrhage experiments reported by Balke, and others, are well below the levels commonly measured by a test assessing maximal oxygen intake. Ebert, Stead, and Gibson (27) reported some interesting results of an acute hemorrhage experiment: (1) with a loss of 15.5 to 19.7 per cent of total blood volume within six to thirteen minutes, five of the six subjects showed sign of cardiac collapse; (2) at the end of seventy-two hours after hemorrhage, the plasma volume equaled the original plasma plus the volume of the red cells removed; (3) for the first two hours after hemorrhaging, the serum protein concentration decreased but thereafter both fluid and protein were added to the plasma at the same time. Balke, and others (21), in a work capacity test before and after removal of five hundred cubic centimeters of blood found that test results obtained forty-eight and seventy-two hours after hemorrhaging did not show significant differences from the pre-hemorrhage test results.

It would seem logical that body size and total blood volume would be highly correlated. Astrand, as reported by Brouha and Radford (2:192), stated that total blood hemoglobin and maximum oxygen intake are highly correlated but blood volume and maximum oxygen intake seem to be indices of general body size.

Exercise is another factor which has a marked effect on the total blood volume. This investigator was unable to find any material relating isometric exercise and total blood volume; therefore, the following studies discuss findings related to isotonic exercise and training. Moore and Buskirk (9:215) stated that in acute exercise, hemoconcentration is a result of temporary water loss and not a result of an increase in red cell volume. Cassels and Morse (24) stated that the normal subject exercised to exhaustion has a gain in red cells from spleenic activity of five to twenty cubic centimeters. The intensity of the work also seems to play a part in the hemoconcentration, as severe exercise results in considerable hemoconcentration and plasma volume reduction; but, moderate work may allow the increased hemoconcentration occurring at the beginning of the work to gradually return to the initial values unless dehydration occurs (9:215). At the beginning of intensive training, the red cell count may be reduced because of an increase in the rate of destruction of red cells (9:219). But the physically trained individual is reported to have a greater total hemoglobin count than nontrained individuals (28;29). Of course in interpreting this data, one must remember that when the carbon monoxide method is used to assess red cell count, both myoglobin and circulating hemoglobin are indicated (23).

BLOOD PRESSURE

Blood pressure is defined by Morehouse (10:300) as, "The force with which the blood distends the walls of the blood vessels." This paper will be concerned with the measure of arterial blood pressure. Systolic pressure is defined as the maximal level of arterial blood pressure (10:114) and diastolic pressure, as the lowest level of arterial blood pressure prior to the next systolic ejection (10:114). Factors affecting the blood pressure are the pumping action of the heart, the capacity of the vascular system, the age of the individual, the individual's emotional state, posture, and exercise.

The ultimate source of energy for maintaining arterial pressure is the heart beat (10:113). As the heart frequency is accelerated, the heart empties more completely thereby yielding a greater stroke volume which adds to the arterial flow and a subsequent rise in the arterial pressure (18:797).

The capacity of the vascular system is altered by the amount of vasoconstriction of the vessels in different areas of the body. The greater the vasoconstriction, the greater must be the arterial pressure to overcome the resistance.

With aging, the arterial walls tend to lose their elasticity thereby becoming a resistance to blood flow and becoming a cause of higher arterial pressure (10:115). The normal systolic pressure in young males is about 120 millimeters of mercury, and the average diastolic pressure is about eighty millimeters of mercury (10:116).

Emotional states tend to increase arterial pressure (10:117); this increase is partially explained by the action of the secreted epinephrine from the adrenal glands.

The effect of different postures on blood pressure is related to changes in blood flow due to gravitational force. When going from a reclining to a standing position, gravitational force causes a momentary drop in blood pressure resulting in a diminished venous return (10:117).

Elevation of systolic blood pressure during exercise is a resultant of a greater stroke volume which overcomes the activity of the vasomotor system. The blood vessels in skeletal muscles receive vasomotor fibers from the sympathetic nervous system. But vasoconstriction of the vessels remains even after the vasomotor nerve is cut; also vasodilator activity does not seem to be a significant factor in increasing the blood supply to the working muscle. Therefore it would appear that the increased blood flow to muscles during activity must result from factors which overcome the normal constricted state (10:118-119).

During isotonic exercise, the systolic pressure tends to rise because of the greater stroke volume during exercise; diastolic pressure may or may not rise depending upon the elevation of the heart rate. With a highly elevated heart rate, the time for available diastolic fall in pressure is decreased, but the greater stroke volume aids in a faster diastolic recoil (10:115).

A study (37) reviewed by the investigator stated that isometric exercise results in a rise in both systolic and diastolic blood pressure. The isometric work consisted of squeezing a grip dynamometer for one minute of maximum effort.

METHODS OF MEASURING VARIABLES

There are three common ways of measuring the pulse rate. First, counting the radial pulse is an inexpensive, quick, easy method of determining pulse rate. One can feel the pulsations of the radial artery by placing one's index and second fingers over the artery at the wrist. Second, the use of a stethoscope amplifies the heart sounds and is probably more accurate than the touch method. Third, the cardiotachometer takes a continuous record of the heart rate and is useful in experiments where pulse rate during activity is a consideration.

Karpovich (8:67-68) reviewed three methods of measuring oxygen consumption. In the closed circuit spirometer method, the subject inhales pure oxygen from a special spirometer which contains a carbon dioxide absorbent for the exhaled air going back into the spirometer. The investigator then subtracts the amount of oxygen left in the spirometer from the original amount to determine the amount used during the experiment. In the open circuit spirometer method, the subject inhales atmospheric air and exhales into a measured spirometer. Gas analysis of samples from the spirometer are run to determine the oxygen used. In the Douglas bag method, the subject's exhalation is deposited into rubber bags and the content is later measured and analyzed. This method is commonly used in studies requiring mobility of the subject.

Reeve said, "Blood volume is usually calculated from an estimation of either plasma or red cell volume and the hematocrit." (33:812) Short (13:23) stated that the dilution method is based on the assumptions that the foreign matter injected to be distributed through the blood is non-toxic and that it does not readily leave the blood stream. The principle, involved in the dye method, as stated by Consolazio, and others (4:265), is that the plasma volume is calculated from the concentration of the dye in the plasma after complete mixing of the plasma with a known quantity of dye. The hematocrit yields the percentage of red cells to plasma and this data plus the estimated plasma volume is used to compute the total blood volume. In using this method, all necessary precautions to eliminate hemolysis must be observed. Consolazio, and others (4:273), stated that the principle involved in the carbon monoxide method is "...a measured volume of carbon monoxide is introduced into the blood by inhalation. The increase in carbon monoxide content of the blood, divided into the total quantity of carbon monoxide administered, represents the blood volume." Again the hematocrit value is taken and this data plus data derived from the carbon monoxide method are used in calculating the blood volume. In using this method, the investigator must be careful to avoid the toxic effects of carbon monoxide gas on the subject. Because the investigator did not have the necessary technique for performing venous punctures, the physiological variable of hemoglobin concentration was substituted for the variable of blood volume. A measure of hemoglobin level is an indicator of blood volume for a particular instant in a particular vessel.

Both direct and indirect methods of measuring blood pressure are discussed by Morehouse (10:115-116). With the direct method, a needle is inserted into the artery. With the indirect method, a sphygmomanometer is used to measure the systolic and the diastolic pressures. This method is based on the measurement of the pressure which is just sufficient to collapse an artery.

This presentation of information relative to the physiological variables to be measured in this study has been for the purpose of reviewing relative studies and of indicating factors which might cause variations in the measurements to be used. The investigator's experimental design attempts to control as many of these factors as possible. From this review, one will note that an experiment involving equating isotonic and isometric exercise on the basis of work done relative to a specified load and taking measurements of various cardio-respiratory variables for comparative purposes has not been attempted. It is hoped that this review has pointed out the possibilities for such a study.

CHAPTER III

EXPERIMENTAL PROCEDURE

The purpose of this study was to compare the effects of isotonic and isometric exercise on the physiological variables of oxygen consumption, hemoglobin concentration, systolic and diastolic blood pressure, and pulse rate under the specification of equal time and load for the exercises involved. The investigator's original plan was to compare the effects of <u>equated</u> isotonic and isometric work loads. It was thought that the work loads could be equated by a method derived by Starr (36); however, the method was not possible for utilization because the mathematical description was too nebulous. Consultation with a physicist confirmed this point. Therefore, it was decided that work load would be specified as to duration of exercise and weight of the load. In this chapter the following headings are discussed: Subjects, Controls, Measurement Techniques, Experimental Design and Procedure, and Treatment of Data.

I. SUBJECTS

The subjects participating in this study were graduate students in physical education at the University of North Carolina at Greensboro during the fall semester of 1964-65. Their ages ranged from twenty-one to twenty-seven years of age. Twelve graduates were randomly selected and asked to participate in the experiment. The procedure for randomly selecting the subjects was taken from Ray's book, <u>Statistics in</u>

Psychological Research (11), and the random numbers were obtained from a book published by the Rand Corporation (16:10). Four of the original twelve subjects were unable to participate and subsequently, replacements were randomly selected from the remaining members of the class. Of the twelve subjects selected to participate in the experiment, two became ill and were unable to be subjects; the final number of subjects was ten.

II. EXPERIMENTAL CONTROLS

All of the subjects were considered to have normal hemoglobin counts as the averages of the subjects' counts taken on two separate days ranged from 12 to 14.5 hemoglobin grams per one hundred cubic centimeters of blood (13:30).

The range for the averages of the subjects' systolic blood pressures, measured on four different days after at least thirty minutes of rest, was from 118.5 to 131 millimeters of mercury as read visually on the aneroid sphygmomanometer of a Stoelting deceptograph (14). The range for the averages of the subjects' diastolic blood pressures measured under the same conditions was from 78 to 89.5 millimeters of mercury.

As loss of blood through hemorrhaging results in a decreased red cell volume which is not restored for three to six weeks (9), each of the subjects was asked if she had donated blood within six weeks prior to participation in the experiment. None of the subjects had donated blood within this time period.

Several studies (32;19) noted that diet may be a factor in the concentration of hemoglobin found in the body. Under emotional conditions, the pulse rate may be accelerated. For these reasons, the subjects were asked to eat a balanced diet and to attempt to avoid emotional duress as much as possible for the duration of the experiment.

As body position also affects several of the physiological variables, the subjects were instructed to remain seated while measures were being taken.

Environmental temperature was kept as comfortable as possible, but no particular room temperature was set for the experiment.

Each subject had a specific time of day in which she was tested; this time was the same for each of the four days of the experiment.

III. MEASUREMENT TECHNIQUES

Oxygen Consumption Technique

A Collins 13.5 Liter Respirometer (3), a closed circuit spirometer, was the instrument used to record the oxygen consumed during the practice, exercise, and recovery periods. This apparatus consisted of a bell-shaped container, a carbon-dioxide absorber, and a kymograph with a pen attachment for recording oxygen uptake. The rotational speed of the kymograph was set at 32 millimeters per minute. After each day of the experiment, the absorber was replaced, and the bell was refilled with water. For each subject's trial on the spiromenter, a barometric pressure reading was taken from a Taylor Stormoscope Barometer, an aneroid barometer. A temperature reading was taken from the centigrade thermometer attached to the spirometer. These readings enabled the investigator to correct the oxygen consumed to standard pressure, standard temperature and dry (6:2475; 3:27). In interpreting the recordings on the kymograph, the investigator followed the procedure indicated in the spirometer manual (3:9). The operator of the spirometer was responsible for replenishing the oxygen supply after each subject had finished her trial, for recording the temperature and barometric readings for each trial, for replenishing the ink supply and attaching the graph paper after each trial, for marking the different phases of the experiment during each trial and numbering the graph, and for changing the mouthpiece after each subject's trial.

Pulse Rate and Blood Pressure Technique

The Stoelting Deceptograph was the instrument used to record the subject's pulse rate and systolic and diastolic blood pressure. The cardio-sphygmographic component of the deceptograph was used in this experiment. This component consists of an aneroid sphygomomanometer gauge, a rubber hand pump, an upper arm cuff, a recording pen, and a connecting manifold with a resonance control and a pump shut-off valve (14:6). The recording pen was used to indicate the pulse rate for specific phases of the experiment during each trial. The operator of the deceptograph visually noted the systolic and diastolic readings by observing the action of the pointer in the aneroid gauge. Her reliability was established prior to the experiment by a procedure of continuous readings until two consecutive readings yielded the same results. During the trials of the experiment, the operator was responsible for recording the pulse rate, systolic blood pressure, and diastolic blood pressure for each subject, and replenishing the ink and paper supply of the deceptograph. She also marked on the graph paper the different phases of each trial, counted and recorded the pulse rates, and indicated the subject's number on the graph for each subject in the experiment.

Hemoglobin Concentration Technique

The Haden-Hausser Hemoglobinometer was the instrument used to determine the subject's hemoglobin concentration during the trials of the experiment. This instrument consists of a pipette with a 1:20 dilution ratio, a comparator slide with cover glass, a housing container with a magnifier, and a light filter (5). A dilution fluid of a 1/10 normal hydrochloric acid solution was used with the sample of blood which was converted to acid hematin over a minimum time period of thirty minutes (5). The hemoglobin level was then determined. The investigator was then responsible for cleaning the pipette by washing it with water, then alcohol, and finally acetone. She also cleaned the comparator slide and cover glass with a sodium bicarbonate solution and recorded the hemoglobin level for each subject for each trial during the experiment.

IV. EXPERIMENTAL DESIGN AND PROCEDURES

The basic design for this experiment involved four days and the same hour of each day for each subject. All of the subjects were tested on each of the four days with the exception of one subject who was required to return on another day because of an error made during the experiment. Wednesday and Friday of one week and Monday and Wednesday of the following week were the days used in this experiment. Subjects entered the laboratory at thirty minute intervals to be measured.

The scores for the base condition were taken after the subjects had rested at least thirty minutes in a sitting position. Scores at rest were averaged to obtain a base score for each of the physiological variables. As the first day was considered a practice period, the oxygen consumption base scores were averages of the second, third, and fourth days of the experiment. This was done because the procedure of breathing through a mouthpiece was unusual for the subjects and it was believed that certain psychic components might influence oxygen consumption. The base scores for the physiological variables of pulse rate, systolic blood pressure, and diastolic blood pressure were the averages of all four days of the experiment. Upon consideration of the subjects' comfort, the investigator decided to average the hemoglobin level of the first two days of the experiment to establish the base scores for that particular variable.

The isotonic exercise scores for the subjects on the physiological variables were taken during and after the exercise series. The isotonic exercises performed were the alternating actions of extending the left leg at the knee and the returning from this extension. This series was performed for one minute with the same ten pound weight, weighed to the nearest pound, tied around the left ankle of each of the subjects. Each subject was instructed to extend her left leg as fully as possible and to hesitate upon return from extension so that the momentum built up from her leg hitting the back of the table would not be used in extending the leg on the next cycle. The subjects were asked to perform as many of these exercises cycles as possible in the one minute time limit. Oxygen consumption and pulse rate scores were recorded during the exercise series. Systolic and diastolic blood pressure readings were taken immediately after the exercise series and at the same time that oxygen consumption was being recorded for a recovery period of two minutes. Immediately after the completion of recovery, the subject's finger was pricked and a blood sample was taken for later analysis of the hemoglobin level after exercise.

The isometric exercise consisted of the subject holding her left leg extended for one minute with the same weight which was used for the isotonic series. Her left leg was placed into the completely extended position and supported until a signal was given to start the exercise. The subject was instructed to hold her left leg as straight as possible until the signal was given to stop, at which signal she should lower her leg. Measures on the physiological variables for this series were taken at comparable times as those for the isotonic series.

The isotonic and isometric measures were taken on the third and fourth days respectively of the experiment. Because a one-group method was used in this experiment, the possibility of a training effect from the isotonic exercise to the isometric exercise scores must be recognized. However, in view of the duration of the exercise bout and the load lifted, probably no lasting training effect was present to influence the isometric scores on the physiological variables.

The measures taken during this experiment required the use of a particular type of chair and arm rest. In order that the subjects with different lengths of the upper leg could be seated with support for the total length of the upper leg, the seat length of the chair had to be adjustable. Also, an adjustable arm rest was needed so that each subject's arm would rest at her heart level. As any two subjects had overlapping hours to be tested and a condition of the experiment being that once seated no subject was to get up, the chair had to be made so that both subjects had access to the measuring instruments. The height of the chair had to be high enough to allow swinging freedom for the varying lengths of leg. For the reasons given, the seat frames, made of pipe, could be screwed into floor flanges arranged on a board which was padded between the two rows of flanges to form a seat. Two seats were so arranged on a board; this board was set on top of a table, and supports were provided for the subjects' feet. The arm rest was made adjustable through the use of telescoping poles with two wing-nut screws to lock the pole into place. The board for the arm rest was attached to the top pole with a flange, and the arm rest was padded. This arm rest was attached to a wooden base which could be moved from subject to subject. A photograph of the chair and arm rest is found in the Appendix, page 65.

The equipment was arranged so that each subject tested during any one hour was accessible to the operators of the measuring instruments. A photograph of the equipment set-up appears in the Appendix, page 66.

Two different work sheets were used during the experiment; an instruction sheet, and an information form. Both of these forms appear in the Appendix, Tables I and II. The information taken from the second form is summarized in Tables III-IX.

Three assistants and the investigator were needed to operate the measuring instruments during the experimental trials of isotonic and isometric exercise. For the other two days of the experiment, two assistants and the investigator were needed. One assistant operated the deceptograph, another operated the respirometer, and the third operated a stop watch, aided in attaching and removing the weight, and helped in cleaning the hemoglobinometer slides and pipettes. The investigator was responsible for obtaining and reading the hemoglobin levels, for aiding any of the assistants when they required aid, for computing the oxygen consumed in the different phases of each trial, and for instructing the subjects as to the procedures to be followed on each trial.

The procedures for the total experiment were as follows:

1. The subjects were randomly selected.

2. Each subject was assigned to the same hour for each day of the experiment. These subjects were tested from two o'clock p.m. until nine o'clock p.m.

3. The instruction form was given to each subject.

4. The base condition was imposed on all subjects. This condition is defined as the situation under which the physiological measures taken yielded base scores. This condition was a part of each of the four days of the experiment and the first two days of the experiment were used to measure base scores only.

5. The isotonic condition was imposed on all subjects. This condition is defined as the situation under which the physiological measures taken yielded isotonic scores for each of the variables. This condition was imposed after the base condition on the third day of the experiment.

6. The isometric condition was imposed on all subjects. This condition is defined as the situation under which the physiological measures taken yielded isometric scores for each of the variables. This condition was imposed after the base condition on the fourth day of the experiment.

7. The data was analyzed statistically to locate the differences, if any, among the three conditions for each of the physiological variables involved.

The procedures which each of the instrument operators used with their particular measuring instrument are as follows:

Deceptograph (14)

1. The procedure involved in inflation of the arm cuff follows:
   a. The cardio-vent component of the deceptograph was turned counterclockwise.
   b. The hand pump valve was turned clockwise.
2. The procedure involved in reading the systolic and diastolic blood pressure follows:
   a. The air pressure in the cuff was slowly released by turning the hand pump valve counterclockwise.
   b. The aneroid guage was watched and the systolic pressure was noted.
   c. The pressure was then allowed to drop more rapidly for fifteen to twenty millimeters and then the dropping rate was again slowed down.

d. The diastolic point was visually noted during the slow release of the air pressure.

e. The cuff was deflated as the operator depressed the cardio-vent.

3. The procedure involved in recording the subject's pulse rate follows:

a. The cuff was inflated and the clamp on the rubber tube was clicked into the lock position.

b. The resonance control knob was turned counter-clockwise to engage the writing mechanism.

c. The pen was centered on the paper by manipulation of the cardio-pen-centering knob.

d. The paper feed was turned on and the pulse rate was recorded.

4. The procedure involved in disengaging the pen mechanism follows:

a. The paper feed switch was turned to the <u>off</u> position.

b. The resonance control knob was turned clockwise.

<u>Respirometer</u> (3)

1. The procedure involved in preparing the respirometer for each subject follows:

a. The paper was attached to the kymograph with tape and the horizontal lines denoting minutes were numbered consecutively beginning with number one.

b. A clean mouthpiece was fitted to the respirometer.

c. The air tubes on the respirometer were adjusted so that the subject was as comfortable as possible.

2. The procedure involved in readying the subject for use of the respirometer follows:

a. The subject was instructed to breathe normally into the machine.

b. A noseclip was attached to the subject's nose to prevent escape of air.

c. The subject was instructed to take the mouthpiece into her mouth so that the rubber edges were between her lips and her teeth.

Hemoglobinometer (5)

1. The procedure involved in the withdrawal of blood follows:

a. The subject's finger was sponged with alcohol.

b. The finger was punctured and .5ml of blood was removed by drawing it into a pipette.

c. The end of the pipette was cleaned with an alcohol swab and immersed into a 1/10 normal hydrochloric acid solution which was freshly made for each day of the experiment.

d. The acid solution was drawn into the pipette up to the calibrated mark above the bulb of the pipette.

e. The pipette was shaken several times until the brownish acid hematin color appeared.

f. Both ends of the pipette were capped with a rubber closure.

2. The procedure involved in the determination of the hemoglobin level follows:

   a. Each pipette containing the acid solution was allowed to set for a minimum of thirty minutes.

   b. Then the blood sample was transferred by capillary action to the comparator slide.

   c. The slide was slipped into the housing and the hemoglobin level was determined by comparing the color of the sample solution to the color standards of known concentrations.

Each of the procedures given for each of the measuring instruments was followed whenever that particular situation took place in the experiment.

The procedures followed in obtaining scores under the base condition and the base-exercise conditions are as follows:

Base condition

1. The subject rested quietly in a sitting position for a minimum of thirty minutes.

2. The blood pressure was taken to determine the diastolic pressure.

3. A blood sample was taken to determine hemoglobin level. This sample was placed on a card numbered with the subject's number, and the time when the blood was placed in the acid solution was recorded.

4. The subject breathed into the respirometer and as the recording pen approached the number thirteen, the operator of the respirometer informed the operator of the deceptograph.

5. The operator of the deceptograph prepared the machine for recording pulse rate. The cuff was inflated to a pressure ranging from six to twenty millimeters below the diastolic pressure determined after a minimum of thirty minutes of rest.

7. The systolic and diastolic blood pressures were then taken and recorded.

<u>Base-exercise condition</u>

1. The subject rested quietly in a sitting position for a minimum of thirty minutes.

2. The blood pressure was taken to determine the diastolic pressure.

3. The subject was given instructions as to the type of exercise to be performed that day.

4. The subject breathed into the respirometer and as the recording pen approached the number thirteen, the operator of the respirometer informed the operator of the deceptograph.

5. The operator of the deceptograph prepared the machine for recording pulse rate. The cuff was inflated to a pressure ranging from six to fourteen millimeters below the diastolic pressure determined after a minimum of thirty minutes of rest.

6. When the recording pen reached the number fourteen on the kymograph, the paper feed on the deceptograph was turned on and the pulse rate was recorded for one minute.

7. The switch controlling the movement of the kymograph was turned to the off position.

8. The systolic and diastolic blood pressures were then taken and recorded.

9. The investigator and an assistant tied the weight on the subject's foot around the ankle while the operator of the deceptograph prepared her machine.

10. On the signal go from the deceptograph operator, the respirometer operator turned the kymograph drum on, the deceptograph operator turned on the paper feed to record the pulse rate, and the subject started her one minute exercise bout.

11. At the end of one minute of exercise, the deceptograph operator gave a verbal signal to stop and the subject lowered her leg onto a box support. This stop command was the signal to an assistant to start a stop watch timing the length of time the deceptograph operator took in reading the final systolic and diastolic blood pressures.

12. The deceptograph operator took the blood pressures within a time range of 25.4 to 44.5 seconds after the exercise bout. The assistant stopped the stop watch when the deceptograph operator started to deflate the cuff.

13. The respirometer operator continued taking a graphic record of the oxygen consumed for a two minute recovery period after exercise.

14. After the recovery period was completed, the investigator withdrew a blood sample for the purpose of determining hemoglobin level. This sample was compared with the color standard after at least thirty minutes had elapsed.

V. TREATMENT OF DATA

The scores for each of the physiological variables under each of the imposed conditions are summarized in Tables III-IX, pages 69-75.

Each score for the oxygen consumption variable was actually an average of the amount of oxygen consumed over a three minute time period. The oxygen consumption scores for the exercise series were computed from the minute of exercise and the two minutes of recovery.

Each score for the other physiological variables were the actual measures rather than averages.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

A one-group method experimental design involving ten subjects was used to determine the effects of two types of exercise on the physiological variables of oxygen consumption, hemoglobin level, systolic blood pressure, diastolic blood pressure, and pulse rate. The three conditions of the design were base, isotonic, and isometric situations; corresponding measures for each of the physiological variables were taken during the four day duration of the experiment. For the first two testing days only base measures were taken, but for the third and fourth days both base measures and isotonic or isometric measures were taken respectively. A Collins 13.5 Liter Respirometer, a Stoeling Deceptograph, and a Haden-Hausser Hemoglobinometer were the instruments used in obtaining measures of the dependent variables.

The raw data for each subject for each physiological variable is summarized in the Appendix, Tables III-IX.

ANALYSIS

The investigator wished to determine if any differences, attributable to treatment effects, existed among the three conditions involving the five variables. Realizing that one can never be certain that favorable appearing differences are the result of a treatment effect, the investigator believed that within the limitations of the research design certain assumptions might be drawn. As is conventional, the five per cent level of significance was chosen to define the class of error outcome for rejecting the null hypothesis of no difference between the conditions. A test of significance of mean differences for small correlated groups was used to determine the ratio of apparent treatment effects to an estimate of the error. The formula for computing a value embodying this ratio and an explanation of the symbols are given below:

$$t = \frac{MD}{\sqrt{\frac{\sum d^2}{n(n-1)}}}$$

1. MD was computed by summing the difference scores between any two of the conditions for any one of the variables and dividing the sum by ten.
2. $\sum d^2$ signifies that the mean of the difference scores was subtracted from each of the difference scores and these deviations were squared and summed.
3. n(n-1) signifies the number of degrees of freedom involved in this computation; n equals ten.

A first order difference score was the difference between any two conditions of the experiment for any one subject. A second order difference score was the difference between the differences of any two conditions for any one subject. These second order difference scores were analyzed in the same test of significance as the first order difference scores. The analysis for both first and second order difference scores resulted in four "t" values for each physiological variable.

Null Hypotheses

Four assumptions stated as null hypotheses were tested for each of the five variables.

1. There is no difference between the isotonic and the base conditions.

2. There is no difference between the isometric and the base conditions.

3. There is no difference between the isotonic and the isometric conditions.

4. There is no difference between the differences of the isometric and base and the isotonic and isometric conditions. This comparison is referred to as a second order comparison.

STATISTICAL ANALYSIS OF NULL HYPOTHESES

Oxygen Consumption

Data regarding the oxygen consumption variable is summarized in Table X.

1. With regard to the first null hypothesis that there is no difference between the isotonic and the base conditions, the value of "t" was significant beyond the one per cent level. There was statistically significant evidence to assume the null hypothesis was not tenable and to announce a difference between the two conditions in favor of the isotonic condition.

2. With regard to the second null hypothesis that there is no difference between the isometric and the base conditions, the value

TABLE X

"t" VALUES FOR OXYGEN CONSUMPTION

	Mean	"t"	Level of Significance
Isotonic-Base	556.503	4.681	1%
Isometric-Base	157.179	2.224	--
Isotonic-Isometric	403.823	2.526	5%
Isometric:Base Isotonic:Isometric	-242.180	-1.117	--

of "t" was not significant at the five per cent level. Therefore the null hypothesis was found tenable.

3. With regard to the third null hypothesis that there is no difference between the isotonic and isometric conditions, the value of "t" was significant beyond the five per cent level. There was statistically significant evidence to assume the null hypothesis was not tenable and to announce a difference between the two conditions in favor of the isotonic condition.

4. With regard to the fourth null hypothesis that there is no difference between the differences of isometric and base and isotonic and isometric conditions, the value of "t" was not significant at the five per cent level. Therefore, the null hypothesis was found tenable.

Hemoglobin Level

Data regarding the hemoglobin level variable is summarized in Table XI.

1. The value of "t" for the relationship between the isotonic and base conditions was significant beyond the five per cent level. This relationship was in favor of the base condition.

2. With regard to the second null hypothesis that there is no difference between the isometric and base conditions, the value of "t" was significant beyond the one-tenth per cent level; this difference was in favor of the base condition.

3. The value of "t" for the relationship between the isotonic and isometric conditions was not significant at the five per cent level. The null hypothesis was found tenable.

TABLE XI

"t" VALUES FOR HEMOGLOBIN LEVEL

	Mean	"t"	Level of Significance
Isotonic-Base	-.725	-2.627	5%
Isometric-Base	-1.175	-5.543	.1%
Isotonic-Isometric	.45	1.867	--
Isometric:Base Isotonic:Isometric	-1.525	-3.900	1%

4. The value of "t" for the relationship stated in the fourth null hypothesis of no difference between the isometric and base and the isotonic and isometric conditions was significant beyond the one per cent level. This difference was in favor of the differences between the isotonic and isometric conditions.

Systolic Blood Pressure

The data regarding the systolic blood pressure variable is summarized in Table XII.

1. The difference between the isotonic and the base conditions was significant beyond the one-tenth per cent level; this difference was in favor of the isotonic condition.

2. The difference between the isometric and the base conditions was significant beyond the one-tenth per cent level; this difference was in favor of the isometric condition.

3. The difference between the isotonic and the isometric conditions was not significant at the five per cent level; therefore, the null hypothesis was found tenable.

4. The value of "t" for the relationship existing between the differences of the isometric and base conditions and the differences of the isotonic and isometric conditions was significant beyond the one per cent level. This difference was in favor of the differences between the isometric and the base conditions.

TABLE XII

"t" VALUES FOR SYSTOLIC BLOOD PRESSURE

	Mean	"t"	Level of Significance
Isotonic-Base	9.7	5.679	.1%
Isometric-Base	11.3	9.843	.1%
Isotonic-Isometric	-1.6	-.719	--
Isometric:Base Isotonic:Isometric	12.8	4.082	1%

Diastolic Blood Pressure

The data regarding the diastolic blood pressure variable is summarized in Table XIII.

1. The difference between the isotonic and the base conditions was not significant at the five per cent level; therefore, the null hypothesis was found tenable.

2. The difference between the isometric and the base conditions was not significant at the five per cent level; therefore, the null hypothesis was found tenable.

3. The difference between the isotonic and the isometric conditions was not significant at the five per cent level; therefore, the null hypothesis was found tenable.

4. The second order difference between the isometric-base conditions and the isotonic-isometric conditions was not significant at the conventional level of significance; therefore, the null hypothesis was found tenable.

Pulse Rate

The data regarding the pulse rate variable is summarized in Table XIV.

1. The value of "t" for the relationship of the difference existing between the isotonic and the base conditions was significant beyond the one-tenth per cent level. This relationship was in favor of the isotonic condition.

2. The difference between the isometric and the base conditions was significant beyond the one-tenth per cent level. This difference was in favor of the isometric condition.

TABLE XIII

"t" VALUES FOR DIASTOLIC BLOOD PRESSURE

	Mean	"t"	Level of Significance
Isotonic-Base	1.5	1.090	--
Isometric-Base	-.1	-.073	--
Isotonic-Isometric	1.6	.643	--
Isometric:Base Isotonic:Isometric	-1.7	-.451	--

TABLE XIV

"t" VALUES FOR PULSE RATE

	Mean	"t"	Level of Significance
Isotonic-Base	30.475	6.527	.1%
Isometric-Base	14.975	6.911	.1%
Isotonic-Isometric	16.5	3.265	1%
Isometric:Base-Isotonic:Isometric	-1.525	-.245	--

3. With regard to the third null hypothesis of no difference between the isotonic and the isometric conditions, the value of "t" was significant beyond the one per cent level. This difference was in favor of the isotonic condition.

4. The second order difference between the isometric-base condition and the isotonic-isometric condition was not significant at the five per cent level; therefore, the null hypothesis was found tenable.

SUMMARY REGARDING STATISTICAL ANALYSIS

Statistically significant differences were noted:

1. from isotonic to base conditions for the variables of oxygen consumption, systolic blood pressure, and pulse rate.

2. from base to isotonic conditions for the variable of hemoglobin level.

3. from isometric to base conditions for the variables of systolic blood pressure and pulse rate.

4. from base to isometric conditions for the variable of hemoglobin level.

5. from isotonic to isometric conditions for the variables of oxygen consumption and pulse.

6. from the difference between the isometric and base conditions to the difference between the isotonic and the isometric conditions for the variable of systolic blood pressure.

7. from the difference between the isotonic and isometric conditions to the difference between the isometric and base conditions for the variable of hemoglobin level.

INTERPRETATION

Statistical differences found are only significant in terms of the physiological interpretations which can be accorded.

The consumption of oxygen by the subjects was greater under the isotonic condition than with the isometric and base conditions. The difference between the oxygen consumed during the isotonic exercise condition and the base condition was significant. Also the difference between the isotonic and isometric conditions was significant and in favor of the isotonic condition. Upon examining the second order difference between the isometric-base and the isotonic-isometric condition, one notes that the oxygen consumed is in favor of the situation involving the isotonic condition. These results indicated that in this study, the isotonic condition resulted in a greater consumption of oxygen by the subjects. In descending order, the conditions resulting in the greatest amount of oxygen consumed by the subjects were isotonic, isometric, and base. Because oxygen consumed is related to oxygen utilization, the investigator concluded that the three conditions utilized oxygen in the order given above. Also for the specifications of equal time and equal load used in this study, the isotonic condition placed the greater work load on the body.

This interpretation is in accord with a conclusion reported by Astrand and Saltin (20), in a study involving work on a bicycle ergometer, that the greater the work load, the more rapid is the increase in oxygen consumption. In any exercise, oxygen is not only consumed by the muscle tissue moving the load, but it is also used to supply the heart, respiratory muscles, endocrine glands, and other body organs with oxygen to enable them to meet the new demands placed upon the body. Astrand and Saltin also stated that in cardio-respiratory studies a certain amount of time is necessary before the cardio-respiratory systems are adjusted to the work load. In the present study, the isotonic exercise series was of such short duration that probably the cardio-respiratory systems were not adjusted and were subsequently inefficient in providing oxygen to the tissues. That the isometric exercise condition, under the equal specifications of time and weight, resulted in less oxygen consumption than the isotonic condition possibly indicated that the isometric series required a smaller degree of adjustment of the cardio-respiratory systems. Clarke (25) reported a study in which the oxygen debt build-up of an isometric exercise was greater than that built up during an isotonic exercise of comparable metabolic loads. The present study combined the oxygen consumed during work with that consumed during a two minute recovery to provide an estimate of the total oxygen consumed. Possibly because of different degrees of adjustment made by the body in meeting the different exercise conditions, the metabolic loads between the two conditions were not comparable and no attempt was made to compare the oxygen consumed during the recovery periods. When the results, in terms of hemoglobin level, of the isotonic-base and the isometric-base comparisons are evaluated, the differences are in favor of the base condition. In one sense, these findings are in agreement with those stated by Moore and Buskirk (9) that moderate work may allow the increased hemoconcentration occurring at the beginning of the work to return gradually to the initial values.

If one takes into consideration that the hemoglobin level base scores were actually average scores of the hemoglobin level taken on the first and second days of the study, the fact that the hemoglobin level after exercise tended to go below the level of the base score might be explained. In the comparison between the isotonic and isometric hemoglobin level scores, the differences tended to be in favor of the isotonic series; however, these differences were not significant. This trend probably indicated that the isotonic condition resulted in more hemoconcentration than did the isometric condition. In noting the second order differences of the comparison of the differences between the isometric-base and the differences between the isotonic-isometric conditions, the difference is significant and in favor of the isotonic-isometric conditions. Again this difference probably indicated the greater effect of the isotonic condition on hemoconcentration. This might have been explained by the relationship existing between intensity of work and rise in hemoconcentration. Oxygen consumed during an exercise is an indication of the intensity of that exercise. Physiologically, the stress of the isotonic condition on the body was greater than the stress of the isometric condition as evidenced by the significant difference between them in the measure of oxygen consumption. Therefore, the trend for the difference in hemoconcentration to be in favor of the isotonic condition was logical even though the difference was not significant.

When the results, in terms of the systolic blood pressure, of the isotonic-base and the isometric-base comparisons are evaluated, the differences are in favor of the exercise conditions. This rise in systolic blood pressure after exercise is a common occurrence in athletics. For the group, the isometric condition tended to raise the systolic blood pressure more than the isotonic condition. This result is consistent with the relationship existing between peripheral resistance and blood pressure rise. The difference for the comparison of the differences of the isometric-base and isotonic-isometric conditions was in favor of the isometric-base conditions. This finding was consistent with the previous computations in which the differences between the isotonic and the isometric conditions were less than the differences between the isometric and the base condition. In circulation, the static contraction of the quadricep muscles probably resulted in occluded blood vessels which raised the peripheral resistance to the blood flow and subsequently resulted in a raised systolic blood pressure. That muscular contraction is accompanied by occlusion of the blood vessels is supported by Anrep and von Sallfeld (17). Of course isotonic contraction also occludes the intramuscular vessels, but theoretically the alternating contraction and relaxation of the muscle fibers in an isotonic movement tend to increase and to decrease the peripheral resistance respectively; the number of fibers participating in this cycle determine the amount of peripheral resistance. Royce (34) reported that maximal isometric contractions would bring about fatigue which would decrease the tension to a point at which the circulation would no longer be impaired. In the present study, the difference between the isometric and the isotonic conditions was not significant, but the trend was favorable to the isometric condition. For these reasons, the investigator supports the concept that fatigue was a factor resulting in a lessening of the impairment to the circulatory system during the isometric contraction. Also, the investigator points out that both exercise conditions resulted in significant differences over the base condition; this is probably explained by the relationship between muscle contraction and occlusion of the intramuscular blood vessels.

None of the comparisons embodying the diastolic blood pressure scores were significant. But the trend was such that the isotonic condition resulted in a rise in diastolic blood pressure, and the isometric conditions resulted in a fall in diastolic blood pressure. The comparison of the second order difference indicated that the isotonic-isometric differences were greater than the isometric-base differences.

Both of the exercise conditions, relative to the variable of pulse rate, resulted in significant differences between the respective conditions and the base scores. These differences were in favor of the exercise conditions. In descending order, the conditions causing a significant rise in pulse rate over the base condition were isotonic and isometric conditions. This finding is consistent with the concept that the isotonic condition probably placed a greater exercise stress on the cardio-respiratory systems than did the isometric condition. The second order difference was not significant but the trend was in favor of the differences between the isotonic-isometric conditions.

In summarizing, the effects of the isotonic and isometric conditions on the physiological variables were consistent with the current information relating these various variables. This information includes such direct relationships as the correspondence between intensity of work and oxygen consumption, between hemoconcentration and intensity of work, between degree of muscular contractions and systolic blood pressure, and between pulse rate and intensity of work. Although the weight load and the duration of the exercise were equal for both conditions, the evidence substantiates the viewpoint that the isotonic condition placed a greater exercise stress upon the body on all variables except in relation to the diastolic blood pressure.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of the experiment was to determine the effects of two types of exercise, under the specifications of equal weight load and time, on the physiological variables of oxygen consumption, hemoglobin concentration, systolic blood pressure, diastolic blood pressure, and pulse rate.

Measures on the physiological variables were taken on the following instruments: a Collins 13.5 Liter Respirometer, a Stoeling Deceptograph, and a Haden-Hausser Hemoglobinometer.

Isotonic and isometric exercise conditions were performed by each subject; equal in both conditions were a ten-pound weight and a one minute time limit. The isotonic condition consisted of an alternate lifting and lowering action of the left leg when the weight was tied to the ankle. With the same weight attached to the ankle, the isometric condition consisted of a holding of the left leg in complete extension at the knee. The measures taken during the exercise conditions were compared with each other and to measures taken during the base condition. Measures for the base condition were taken after each subject had rested for a minimum of thirty minutes.

The subjects were ten graduate students in physical education who were randomly selected from the graduate class in physical education at the University of North Carolina at Greensboro. All subjects had normal hemoglobin counts. None of the subjects had donated blood within six weeks prior to the experiment.

FINDINGS

The statistical tool used to indicate the significance of the mean of the differences between any two conditions was a Fisher's "t" test of significance for small, correlated groups. The conventional five per cent level of significance was used as a basis for assuming the null hypotheses to be tenable or untenable. Values for "t" indicated that:

1. There were significant differences between the isotonic and the base conditions on the variables of oxygen consumption, systolic blood pressure, and pulse rate. These differences were in favor of the isotonic condition.

2. There were significant differences between the isometric and the base conditions on the variables of systolic blood pressure and pulse rate. These differences were in favor of the isometric condition.

3. The second order difference relative to the hemoglobin level was significant for the isotonic-isometric and the isometric-base conditions. This difference was in favor of the isotonic-isometric conditions.

4. The differences between the two exercise conditions were significant with regard to oxygen consumption and pulse rate. These differences were in favor of the isotonic condition.

5. Both exercise conditions were significantly different from the base condition with regard to the variable of hemoglobin level. This difference was in favor of the base condition in both cases.

6. The second order difference relative to the systolic blood pressure was significant for the isotonic-isometric and the isometric-base conditions. This difference was in favor of the isotonic-isometric conditions.

CONCLUSIONS

The exercise conditions were stressful enough to elicit significant physiological changes over the base condition for the variables of systolic blood pressure and pulse rate. The isotonic condition resulted in a significant difference over the base condition for the variable of oxygen consumption. The results enabled the investigator to conclude that the two types of exercise conditions did elicit physiological changes over a base condition.

A comparison of the significant differences between the two exercise conditions indicated that they elicited different physiological changes relative to oxygen consumption and pulse rate. These differences were in favor of the isotonic condition. As oxygen consumption and pulse rate are indicators of intensity of work, the investigator concluded that the evidence supported the concept that the isotonic condition placed a greater exercise stress on the body in relation to the cardio-respiratory systems.

Any hemoconcentration that occurred at the onset of the exercise conditions was eliminated by the end of the recovery period. This conclusion is based on the significant differences between the exercise conditions and the base conditions in which the differences are in favor of the base condition. In these exercises of short durations, the build-up of the hemoglobin concentration was not indicated.

No conclusions can be stated regarding the effects of the exercise conditions on the variable of diastolic blood pressure.

The second order differences were significant with respect to hemoglobin level and systolic blood pressure. The difference relative to the systolic blood pressure was in favor of the isometric-base conditions; the difference relative to the hemoglobin level was in favor of the isotonic-isometric conditions. This evidence indicated that the isotonic condition resulted in a greater hemoconcentration than did the isometric condition. Also, the investigator concluded that the isometric condition increased systolic blood pressure to a greater extent than did the isotonic condition.

All of the above conclusions have meaning only when certain basic assumptions relative to statistical theory have been met. The assumption of randomness was only partially met in this experiment; the subjects were randomly selected but were not randomly assigned to occasions of measurement, as a time factor made that procedure unfeasible. Further research, using a completely randomized design, could meet these assumptions.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

1. Best, Charles H., and Norman B. Taylor. The Physiological Basis of Medical Practice. Seventh edition. Baltimore: The Williams & Wilkins Company, 1961. 1554 pp.

2. Brouha, Lucien, and Edward P. Radford, Jr. "The Cardiovascular System in Muscular Activity," Science and Medicine of Exercise and Sports, Warren Johnson, editor. New York: Harper and Brothers Publishers, 1960. Pp. 178-206.

3. Clinical Spirometry. 555 Huntington Avenue, Boston 15, Massachusetts: Warren E. Collins, Inc., (n.d.). 35 pp.

4. Consolazio, C.F., Robert E. Johnson, and Louis J. Pecora. Physiological Measurements of Metabolic Functions in Man. New York: McGraw-Hill Book Company, Inc., 1963. 505 pp.

5. Haden-Hausser Hemoglobinometer. 6040 Belfield Avenue, Philadelphia: C.A. Hausser and Son, (n.d.).

6. Hodgman, Charles D. (ed.). Handbook of Chemistry and Physics. Fortieth edition. 2310 Superior Avenue, Cleveland, Ohio: Chemical Rubber Publishing Company, 1959. 3456 pp.

7. Hubbard, Alfred W. "Homokinetics: Muscular Function in Human Movement," Science and Medicine of Exercise and Sports, Warren Johnson, editor. New York: Harper and Brothers Publishers, 1960. Pp. 7-39.

8. Karpovich, Peter. Physiology of Muscular Activity. Fourth edition. Philadelphia: W.B. Saunders Company, 1953. 340 pp.

9. Moore, Richard, and Elsworth R. Buskirk. "Exercise and Body Fluids," Science and Medicine of Exercise and Sports. Warren Johnson, editor. New York: Harper and Brothers Publishers, 1960. Pp. 207-235.

10. Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. Fourth edition. Saint Louis: The C.V. Mobsy Company, 1963. 323 pp.

11. Ray, William S. Statistics in Psychological Research. New York: The Macmillan Company, 1962. 303 pp.

12. Riley, Richard L. "Pulmonary Functions in Relation to Exercise," Science and Medicine of Exercise and Sports, Warren Johnson, editor. New York: Harper and Brothers Publishers, 1960. Pp. 162-177.

13. Short, Rendle. A Synopsis of Physiology. Fifth edition. Baltimore: The Williams and Wilkins Company, 1961. 348 pp.

14. Stoelting Deceptograph: Instruction and Service Manual. 424 North Homan Avenue, Chicago 24, Illinois: C.H. Stoelting Company, (n.d.). 39 pp.

15. Taylor, Henry Longstreet. "Exercise and Metabolism," Science and Medicine of Exercise and Sports, Warren Johnson, editor. New York: Harper and Brothers Publishers, 1960. Pp. 123-161.

16. The Rand Corporation. A Million Random Digits with 100,000 Normal Deviates. Glencoe, Illinois: The Free Press, Publishers, 1955. 600 pp.

B. PERIODICALS

17. Anrep, C.V., and E. von Sallfeld. "The Blood Flow through Skeletal Muscle in Relation to Its Contraction," Journal of Physiology, 85: 375-399, 1935.

18. Asmussen, E., and M. Nielsen. "Cardiac Output during Muscular Work and Its Regulation," Physiological Reviews, 35: 778-800, 1955.

19. Astrand, P.O., and B. Saltin. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16: 977-981, 1961.

20. Astrand, P.O., and B. Saltin. "Oxygen Uptake during the First Minutes of Heavy Muscular Exercise," Journal of Applied Physiology, 16: 971-976, November, 1961.

21. Balke, B., G.P. Grillo, E.B. Konecci, and U.C. Luft. "Work Capacity after Blood Donation," Journal of Applied Physiology, 7: 231-238, 1954.

22. Barcroft, H., and J.L.E. Millen. "The Blood Flow through Muscle during Sustained Contraction," Journal of Physiology, 97: 17-31, 1939.

23. Bass, David E., and others. "Comparison of Blood Volume during Physical Conditioning, Heat Acclimatization, and Sedentary Living," Journal of Applied Physiology, 12: 186-188, March, 1958.

24. Cassels, D.E., and M. Morse. "Blood Volume and Exercise," Journal of Pediatrics, 20: 352-364, 1942.

25. Clarke, David H. "Energy Cost of Isometric Exercise," Research Quarterly, 31: 3-6, March, 1960.

26. DeLanne, R., and others. "Changes in Acid-Base Balance and Blood Gases during Muscular Activity and Recovery," Journal of Applied Physiology, 14: 328-332, May, 1959.

27. Ebert, R.V., E.A. Stead, and J.G. Gibson. "Response of Normal Subjects to Acute Blood Loss," Archives of Internal Medicine, 68: 578-590, 1941.

28. Holmagren, A., and others. "Effect of Training on Work Capacity, Total Hemoglobin, Blood Volume, Heart Volume and Pulse Rate in Recumbent and Upright Positions," Acta Physiologica Scandinavica, 50: 72-83, September, 1960.

29. Kjellberg, S.R., U. Rudhe, and T. Sjostrand. "Increase in the Amount of Hemoglobin and Blood Volume in Connection with Physical Training," Acta Physiologica Scandinavica, 19: 146-151, 1949.

30. Leverton, R.M., and L.J. Roberts. "Hemoglobin and Red Cell Content of the Blood of Normal Women during Successive Menstrual Cycles," Journal of the American Medical Association, 106: 1459-1463, 1936.

31. Leverton, R.M., and L.J. Roberts. "The Iron Metabolism of Normal Young Women during Consecutive Menstrual Cycles," Journal of Nutrition, 13: 65-95, January, 1937.

32. Orten, A.U., and J.M. Orten. "Role of Dietary Protein in Hemoglobin Formation," Journal of Nutrition, 26: 21-31, July, 1943.

33. Reeve, E.B. "Methods of Estimating Plasma and Total Red Cell Volume," Nutrition Abstracts and Reviews, 17: 811-834, 1948.

34. Royce, Joseph. "Isometric Fatigue Curves in Human Muscle with Normal and Occluded Circulation," Research Quarterly, 29: 204-212, May, 1958.

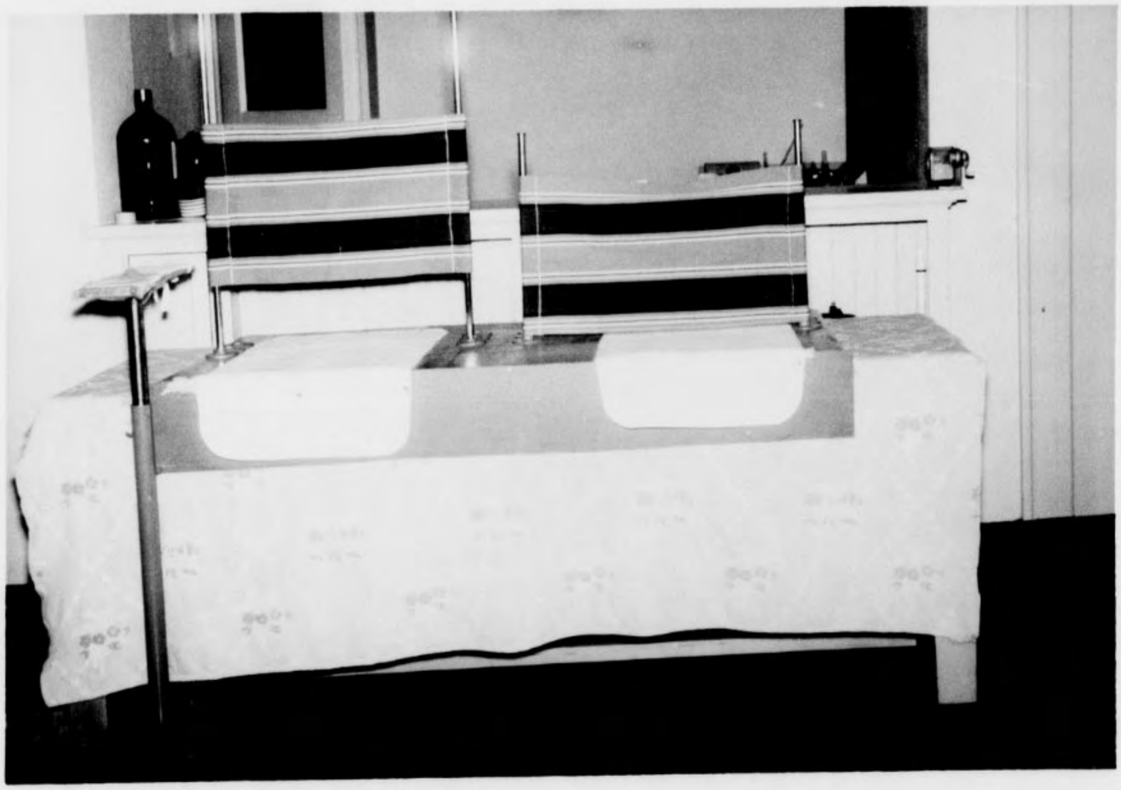
35. Sinclair, C.B. "Abstract of a Study of the Effects of Varying Degrees of Physical Activity during the Menstrual Period upon the Red Blood Cell Count," Research Quarterly, 8: 32-37, December, 1937.

36. Starr, I. "Units for the Expression of Both Static and Dynamic Work in Similar Terms, and Their Application to Weight-Lifting Experiments," Journal of Applied Physiology, 4: 21-29, 1951.

37. Thompson, Clem W. "Some Physiologic Effects of Isometric and Isotonic Work in Man," Research Quarterly, 25: 476-482, December, 1954.

A P P E N D I X

CHAIR AND ARM REST



EQUIPMENT SET UP

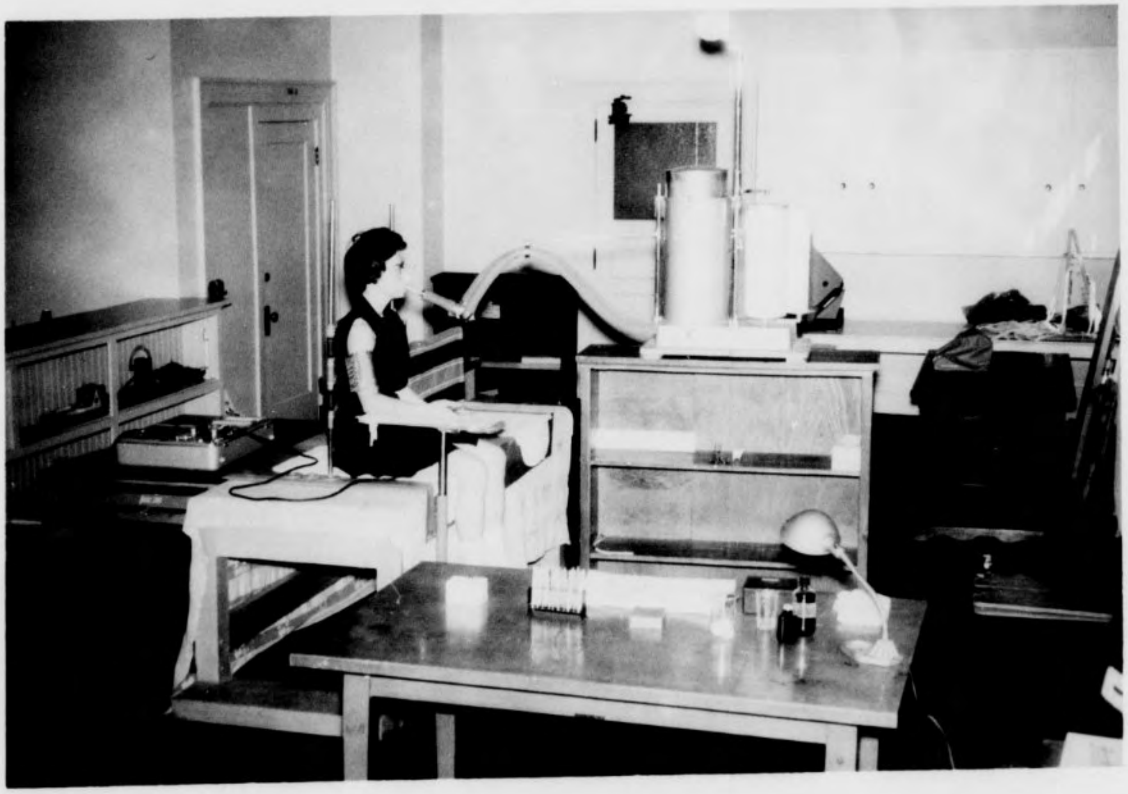


TABLE I

INFORMATION SHEET FOR EACH SUBJECT

Name: Dates: Time:

Procedure for Each Subject:

1. Please come dressed in your gymsuit.

2. Weigh in on the scales in Coleman before reporting to the Rosenthal lab.; note your weight to the nearest pound; do not wear shoes but do weigh in while wearing your gymsuit.

3. When you enter the lab., please come in quietly as measurements are being taken and silence is a condition of the experiment.

4. Sit quietly, in a special chair which we'll have ready for you, for thirty minutes; you may read but please do not talk.

5. After thirty minutes of sitting quietly, measurements of your hemoglobin count, pulse rate, oxygen consumption, and blood pressure will be taken during a fifteen minute time period. These measurements will be used as your base scores.

6. You will then perform an isotonic or isometric task for a minute during and after which the above measurements will be repeated to determine an exercise score.

7. You may then leave and we'll expect to see you on the next date listed above. Please report to the lab. on time as you are part of a tight schedule.

It is important that you realize that your diet habits and your emotional state can influence the results of this experiment. Please try to eat a balanced diet, and forget those end of semester "blues" when you enter the laboratory.

Thank you,

TABLE II

FORM FOR EACH SUBJECT FOR EACH DAY OF THE EXPERIMENT

Name: Age: Height: Weight:

Temp.: Pressure: Date:

Time of Last Menses:

<u>Time</u>	<u>Measures</u>	Pre:	Post:
	Heme Count:		
	Oxygen Cons.:		
	Pulse Rate:		
	Blood Press.:		
	Systolic		
	Diastolic		

Work Conditions: check the series

Base Scores:

Isotonic: ;Wt. Used: ;Time:

Isometric: ;Wt. Used: ;Time:

TABLE III

CHARACTERISTICS OF SUBJECTS

Subjects	Age	Height	Weight	Time of Last Menses
1	22	5'6"	122	1/6/65
2	23	5'6"	135	12/20/64
3	27	5'7"	129	1/2/65
4	21	5'5"	129	12/28/64
5	25	5'6.5"	117	12/12/64
6	24	5'4"	124	12/21/64
7	22	5'8"	126	1/6/65
8	25	5'3"	116	12/22/64
9	22	5'7"	126	12/19/64
10	25	5'7"	125	12/24/64

TABLE IV

BASE CONDITION SCORES FOR SUBJECTS ON FIRST DAY OF EXPERIMENT

Subjects	Heme g/cc	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	12	257.833	79	112	70
2	12.5	364	80	124	84
3	13.5	151.666	76	118	78
4	14.5	364	90	122	84
5	12.5	242.666	81	122	80
6	11.5	176.600	84	118	78
7	12.5	319.200	84	118	78
8	12.5	410.400	89	126	84
9	12	273.600	66	124	86
10	13.5	380.009	90	126	84

TABLE V

BASE CONDITION FOR SUBJECTS ON
SECOND DAY OF EXPERIMENT

Subjects	Heme g/cc	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	12.5	379.166	67	118	80
2	14.5	591.500	85	126	88
3	13.5	273.000	60	122	84
4	14.5	348.833	113	132	90
5	12.5	212.333	75	124	86
6	12.5	192.333	86	122	86
7	11.5	288.166	76	122	82
8	12.5	424.666	82	122	86
9	12	333.666	66	122	86
10	12.5	394.333	87	124	86

TABLE VI

BASE CONDITION FOR SUBJECTS ON
THIRD DAY OF EXPERIMENT

Subjects	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	258.400	63	122	80
2	395.200	88	132	90
3	288.799	78	116	78
4	304	92	132	90
5	238.133	69	122	80
6	273.600	94	130	88
7	440.800	92	132	94
8	699.199	89	132	88
9	288.799	75	130	92
10	577.600	98	132	92

TABLE VII

ISOTONIC CONDITION FOR SUBJECTS
ON THIRD DAY OF EXPERIMENT

Subjects	Heme g/cc	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	12	653.599	93	122	78
2	12.5	653.599	100	134	86
3	13.5	820.800	108	124	78
4	11.5	942.399	104	134	88
5	12	625.100	110	138	78
6	12	501.600	107	134	92
7	11	699.199	132	136	90
8	12	1003.200	135	140	92
9	11.5	1808.800	110	140	90
10	12.5	1276.800	132	144	90

TABLE VIII

BASE CONDITION FOR SUBJECTS ON
FOURTH DAY OF EXPERIMENT

Subjects	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	312.550	71	122	82
2	297.666	74	128	88
3	223.250	65	130	88
4	238.133	108	138	94
5	242.666	74	122	82
6	267.900	87	126	82
7	282.783	86	122	82
8	520.916	92	128	88
9	357.200	66	128	84
10	312.550	88	128	86

TABLE IX

ISOMETRIC CONDITION FOR SUBJECTS
ON FOURTH DAY OF EXPERIMENT

Subjects	Heme g/cc	Oxy. cons. cc/min.	Pulse rate beat/min.	Systolic mm/Hg	Diastolic mm/Hg
1	12	327.433	82	130	80
2	12	1116.250	93	136	90
3	12.5	282.783	78	132	86
4	12.5	416.733	123	146	96
5	11.5	318.500	86	128	84
6	11	520.916	101	136	84
7	10.5	282.783	103	134	80
8	12.5	893	115	146	82
9	10.5	372.083	89	136	80
10	11	461.383	96	138	84