1963

The Effect of Immersion in a Heated Whirlpool Bath Upon Reaction Time, Arm and Shoulder Girdle Strength, and General Endurance

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THE EFFECT OF IMMERSION IN A HEATED WHIRLPOOL BATH UPON REACTION TIME, ARM AND SHOULDER GIRDLE STRENGTH, AND GENERAL ENDURANCE

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Physical Education, South Dakota
State College of Agriculture
and Mechanic Arts

August, 1963

THE EFFECT OF IMMERSION IN A HEATED WHIRLPOOL BATH

UPON REACTION TIME, ARM AND SHOULDER GIRDLE

STRENGTH, AND GENERAL ENDURANCE

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Thesis Adviser

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Head of the Major Department

ACKNOWLEDGMENTS

The author wishes to express his most sincere appreciation to Dr. M. Thomas Woodall for his valuable guidance, supervision, and assistance in the completion of this research study.

The author also expresses his gratitude to the members of the faculty and to the students who took part in the investigation for their interest and cooperation in making it possible for this study to be conducted.

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CHAPTER I

INTRODUCTION

Justification of Study

The use of hydrotherapy as a relief against such common minor discomforts as muscle stiffness or muscle soreness has long been advocated by athletic trainers and physical therapists. It is known to have gotten its start as early as World War I in France where it was used as a therapeutic agent for war casualties suffering from gunshot wounds (1).

In athletic training, a question which very often arises is whether or not the whirlpool method of therapy should be used on an individual within a few hours prior to participation in physical activities requiring muscular strength, endurance and quick muscular response. In many cases where whirlpool treatment was indicated, it was withheld because of the possible draining effect it is considered to have on a person's muscular strength, endurance and reaction time (2).

The author has found within the span of his experience with the use of the whirlpool that athletes, coaches, and athletic trainers offer considerable opposition to its use just before competitive sports participation.

In reviewing many sources, the author was unable to locate any research supporting the concept that hydrotherapy should not be used immediately before athletic competition.

Wickstrom and Polk indicated "there appears to be no research substantiating the idea that hydro-therapy is contraindicated when the subject would have to participate in physical activity requiring muscular strength-endurance within a few hours after treatment" (3).

In a letter concerning the author's request for information relating to his study, Art Dickinson, Jr., athletic trainer, Arizona State College, Tempe, Arizona, and associate editor of the National Athletic Trainers Association Journal, said: "I know of practically no previous investigations in this area," but, that in opposition, he knew of no one who advocated this "technique" of whirlpool therapy before athletic performance (4).

In an additional attempt by the author to locate pertinent material, a letter was written to the Research Department, Section of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, Minnesota. Dr. Earl C. Elkins, Associate Consultant, in his reply did not mention an awareness of any studies opposing water therapy of this type before athletic activity. He specifically pointed out that "we have not done anything in this area" (5).

It is hoped that this study will help provide suitable evidence upon which to base a more definite view in regard to this concept of "contraindication" (6) of whirlpool therapy prior to athletic participation.

Statement of the Problem

The purpose of this study was to investigate the effect of immersion in a heated whirlpool bath on muscular strength, general

endurance and reaction time.

Limitations and Assumptions of Study

The procedures used and the results of this study were limited by the following conditions: (1) Ten, nonathlete, male freshmen students in the physical education service program at South Dakota State College volunteered as subjects. (2) The personal habits and outside activities of each subject could not be controlled; however, definite instructions were given regarding sleeping, eating, drinking, smoking and exercise habits. (3) Arm strength was the only measure of muscular strength.

The findings in this study were based on the following assumptions: (1) The measuring devices used in this study were assumed to be valid in the measurement of arm and shoulder girdle strength, general endurance and reaction time. (2) The temperature of the water and the time of immersion in the whirlpool for each subject in this study were assumed to be the most often used temperature and time variation in therapy of this type.

Definition of Terms

For purposes of this study the following definitions will be used.

1. Muscular strength--the maximum amount of strength applied in one muscular contraction.

2. Muscular endurance--the ability to repeat muscular contractions for extended time periods.

3. General endurance--a combination of three factors including strength of the body in relation to body size, total muscular endurance and circulorespiratory endurance.

4. Circulorespiratory endurance--"Circulorespiratory endurance as a quality is a combination of muscular strength, muscular endurance, and strength and endurance of the heart" (7).

5. Reaction time--time between the application of a stimulus and muscular response.

6. Hydrotherapy--the treatment of disease or ailments by use of water either externally or internally.

7. Immersion--in this study will refer to the immersion of a subject in a whirlpool up to and including the acromion process of the scapula.

8. Nonathlete--student who is not a member of a college athletic team.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The author has found a definite lack of material pertaining to the effect of the whirlpool bath on muscular strength, endurance and reaction time. Others have made similar statements regarding the absence of information concerning hydrotherapy and its apparent effect on human muscle.

Badgley stated, "A comprehensive search of recently published scientific periodicals and related materials did not reveal any studies reporting the effects of hot baths on the injury free, normally functioning limb" (8).

In 1961, Wickstrom and Polk said: "There is a dearth of information relative to the effect of whirlpool treatments on participation in physical activity which requires muscular strength and endurance" (9).

Various studies have been made pertaining to the function and value of the whirlpool. As early as 1930, it was concluded by Benson (10) that this method of therapy had a definite value in the recovery of athletic injuries. Hueston and Nolan (11) studied the effect of the whirlpool bath on body temperatures, pulse rate and blood pressure. In 1956, Hellebrandt, Hautz, and Eubank (12) reported on the measurement of whirlpool temperatures, pressures, and turbulence. One year later, Badgley (13) studied the effect of the whirlpool on

the flexibility of the ankle joint.

Though the literature reveals practically no research concerning the effect of the heated whirlpool bath on the performance of various physical tasks, studies have been done pertaining to the effects of other forms of moist heat on muscular performance.

Hot Baths and Showers

Performances in several different experimental work conditions have been studied with attention focused on hot showers and hot baths. The effect that these forms of moist heat have on various muscular activities varies in view of the conclusions drawn by different experimenters.

Robbins (14) studied the effect of hot showers on strength. Twenty-five boys participated in a regular one-half hour physical education class. At the end of the period a ten-minute shower (115 degrees Fahrenheit) was given to some of the class members. The effect of the hot shower, according to Robbins, produced a decrease in grip strength which was significant at the .01 level.

In agreement with this conclusion, Reidman said: "Hot showers have been found to be distinctly detrimental to performance and least effective in relieving fatigue" (15).

Asmussen and Boje (16) found from a study made in 1945 that 12- to 15-second performances on a bicycle ergometer were improved from 5.0 to 7.2 per cent after a ten-minute shower at 47 degrees centigrade.

Carlile stated, "The general opinion among swimmers, other athletes, and coaches would appear to be that hot water is enervating.

Pre-race passive heating is generally considered to be detrimental" (17). However, in his study of the effect of preliminary passive warming on swimming performances, it was found that his group of subjects, ten swimmers, showed an average improvement of approximately one per cent in 230 trials of 40 yards when given an eight-minute shower at 105 degrees Fahrenheit before the swimming trials. The results of the group proved to be significant at the .001 level.

Muido concluded from his paper on the influence of body temperature on performances in swimming that "a given distance could be swum in a shorter time when the organism was warmed previously" (18). His experiment on the effects of passive warming before swimming 50 meters showed that hot baths of 40 to 43 degrees centigrade for 15 to 18 minutes improved the swimming times as much as two per cent. A subsequent experiment which included swimming a 400-meter crawl and a 200-meter breast-stroke indicated that the performances were improved in time by 2.1 to 3.9 per cent after the hot baths.

All research cited previously in this chapter has dealt with the passive warming of the entire body through hot showers or hot baths.

Immersion

Nukada (19), in 1955, studied the effects of immersing the arm only. In his experiment, the arm was immersed up to the shoulder in water of approximately 20, 30, and 40 degrees centigrade for 15 minutes. It was weighted with 5 kilograms and held in a position with the elbow at a 90 degree angle and with the forearm on a horizontal

plane. His results showed that as the temperature of the hot water bath increased, a decrease in the time the arm could maintain this position occurred.

Grose (20) conducted research on the lowering of muscle fatigue curves by heat. In his study, 12 subjects were studied in regard to the effect of the immersion of the arm in a hot water bath of 48 degrees centigrade for eight minutes. The water was kept at a constant level just above the elbow. Each subject was required to produce repeated maximum contractions of the forearm muscles on an ergometer for six minutes; a total of 180 contractions in the six-minute period. The experiment concluded that the application of moist heat to the forearm did not affect initial strength, but that a 34 per cent increase in the rapidity of fatigue was produced.

The work of the whirlpool bath, as it normally functions, on the human body under selected conditions of bath time and bath temperature has been studied. In 1961, an investigation was conducted by Wickstrom and Polk regarding the apparent effect of the whirlpool on the strength and endurance of the quadricep muscle group. Twenty high school athletes were used as subjects in four experimental conditions. Each subject was seated in a whirlpool bath submerged up to the crest of the ilium during each of the experimental conditions. A twenty-minute bath of 104 and 110 degrees Fahrenheit was given. After each bath treatment a strength-endurance test given at one- and two-hour intervals on different days was applied to the quadriceps muscle. The strength-endurance test, used by the experimenters, demanded

continued contraction of the quadriceps muscle through a complete 90 degree extension of the lower leg with a weight attached to the foot. The number of complete extensions without interruption of a definite predetermined rhythm constituted the score in the test. In summary, Wickstrom and Polk stated:

> Time is the significant variable in the recovery of trained athletes from the physiological effects of a whirlpool bath. When water temperature is 104 or 110 degrees Fahrenheit, recovery from a 20-minute whirlpool bath can be expected within a period of two hours. As water temperature of a whirlpool bath increases, the amount of time required for recovery increases. Water temperature of 110 degrees Fahrenheit produces more profound and lasting physiological effects upon performance than water temperature of 104 degrees Fahrenheit (21).

The conclusions drawn by Wickstrom and Polk appear to be somewhat controversial. Dr. Earl C. Elkins, Associate Consultant, Section of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, Minnesota, said:

> The study by Wickstrom and Polk does not appear to be a very well controlled study and, as they have indicated, should be redone. One criticism of the study is that some of the increase in performances that they did obtain may have been on a training basis rather than actual improvement (22).

In addition, he expressed doubt that ordinary whirlpool immersion would have any great effect upon the strength and endurance of muscles.

In attempting to form a generalization concerning the literature related to the effect of the whirlpool bath on muscular strength, endurance, and reaction time, this investigator finds inconsistency and a definite lack of completed research.

CHAPTER III

PROCEDURE

Introduction

The effect of body immersion in a heated whirlpool on arm and shoulder strength, general endurance of the body, and reaction time was selected by the author to be investigated. The aforementioned factors were chosen as the variables to be tested in this experiment in view of their acceptance as essential qualities in athletic activities of all types (23, 24, 25, 26).

Subjects

The subjects in this investigation were nonathlete, freshmen students in the men's physical education service program at South Dakota State College. The entire group consisted of ten men who volunteered for the study. They ranged in age from 18 to 19 years and varied in body type from the ectomorph (one subject measured 6 feet tall and weighed 127 pounds), to the athletically built mesomorph, and the heavier endomorphic type. Only one subject approached the endomorphic build. He measured 5 feet 9 inches in height and weighed 185 pounds.

Certain criteria were chosen as necessary prerequisites in order to provide normal, healthy, and somewhat physically fit individuals for the study. It was essential that each subject possess a fairly high level of physical fitness on the basis of subjective and objective evaluation by the author and other physical education

instructors at South Dakota State College. It was also important that all subjects had completely passed a comprehensive physical examination required by all college entrants and were allowed to participate in all types of physical activity.

Upon being selected as participants in the study, the subjects met twice with the author to receive verbal and written instructions regarding the procedure to be followed while being treated in the whirlpool, during testing, and also during the interim between scheduled treatments. (See Appendix A).

The subjects were instructed to maintain their eating, sleeping, drinking, and smoking habits for the duration of the study. They were asked to refrain from participation in any form of a physical fitness improvement program, such as a self-directed weight training program or daily tennis or track workouts. The subjects did not participate in any freshmen physical education service course for the spring quarter of 1963, and were also instructed to abstain from intramural participation for the duration of the investigation.

Experimental Treatment

The whirlpool bath used in the study was a Hydro Massage, Subaqua, Therapy Tank manufactured by the Ille Electric Corporation of Long Island City, New York. (See Figure I).

Each subject was seated in the whirlpool bath so that the level of the water came just above the acromion process of the scapula. An overflow device on the whirlpool and a manually operated water hose were used to regulate the amount of water in the tank. The level of

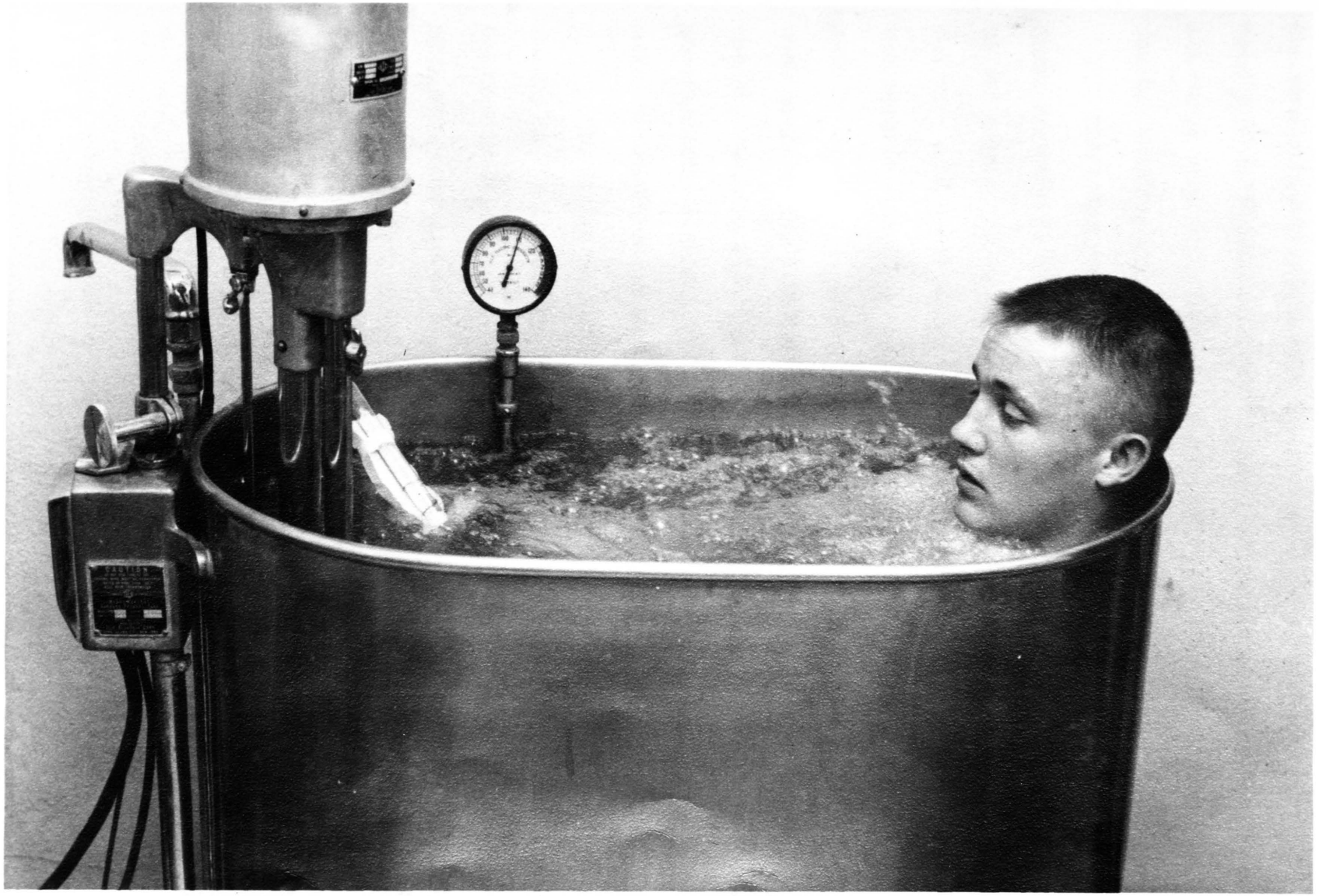

Figure I. Subject immersed in whirlpool

the nozzle creating the water agitation was maintained at approximately 12 to 18 inches below the level of the water for each subject. All vents were fully opened, allowing the greatest turbulence possible for the whirlpool.

The temperature of the water was kept between 104 and 106 degrees Fahrenheit, and was measured by a dairy thermometer in addition to the regular thermometer attached to the side of the whirlpool tank. The time of immersion for each subject was ten minutes. The time and temperature factors used in this experiment were based on suggestions made by Dr. Earl C. Elkins of the Physical Medicine and Rehabilitation staff at the Mayo Clinic, and by several athletic trainers of the Big Ten, Big Eight, and Western Athletic Conferences to whom a questionnaire was sent asking their opinion regarding the average water temperature and immersion time. (See Appendix B).

Dr. Elkins concluded: "Temperature of 104 degrees Fahrenheit should be the maximum used" (27). Dean Nesmith (28), Head Trainer, University of Kansas, Lawrence, Kansas, was one of a majority of nine who, in response to the author's questionnaire, recommended an average temperature of 105 degrees Fahrenheit. Mr. Warren Arial (29), Head Trainer, University of Indiana, Bloomington, Indiana, was one of the majority who recommended an average immersion time of ten minutes.

The treatment took place in the small therapy room off the regular training room in the gymnasium at South Dakota State College. Room temperature was kept as comfortable as possible, considering the type of heating system in use in the building, and one window was

kept open to insure a constant supply of fresh air. To avoid interference with the use of the training room by varsity athletic teams, whirlpool treatment for each subject was scheduled after 4:00 P.M., unless a make-up treatment was necessary.

Measurements

The strength of the arm and shoulder girdle, reaction time, and general body endurance were the qualities measured in this study. The testing of these qualities took place in the research laboratory room of the South Dakota State College Gymnasium. Here also, the temperature was kept as comfortable as possible with one window open. All outside interferences were kept to a minimum. Only the experimenter and the subjects waiting to be tested were present in the room at any one time. Those in the room during the testing of a subject were instructed to refrain from any disturbance disconcerting to the person being tested.

A definite order for the completion of the tests during each testing situation was established at the outset and followed for the duration of the study. The reaction time of each subject was measured first, followed by an arm and shoulder girdle strength measurement, and then a test of general body endurance was given.

Each subject was told that he was competing only against himself and that he was to perform every test to the best of his capabilities. In addition, he was given verbal encouragement in the actual performance of the tests.

Arm and Shoulder Girdle Strength

A push-pull attachment to a hand dynamometer was used to measure arm and shoulder girdle strength.

Jebens (30), in a study of the push and pull test as an indication of arm and shoulder strength for high school boys, found, on the basis of a +.864 correlation between arm strength and push-pull tests, that push and pull tests are valuable in determining the strength of an individual's arm. He also concluded in his study that the sum of a push-pull test was reliable in predicting arm strength.

McCloy and Young (31) direct attention to the fact that coefficients of correlation of about +.95 have been obtained between arm strength for boys, measured by a dynamometer and the McCloy pull-up and dip tests.

In using the push-pull attachment to the hand dynamometer, each subject was given three trials in a pushing direction and three trials in a pulling direction. The best of the three trials for each type of contraction was added together to give the individual's total arm and shoulder strength score.

For the measurement of pulling strength on the dynamometer, each subject was instructed to hold the push-pull attachment chest high, with the palms of the hands facing each other and with the forearms parallel to the floor. With one sustained effort he was told to pull on the handles away from the midline of the body with as much force as possible (32). (See Figure II).

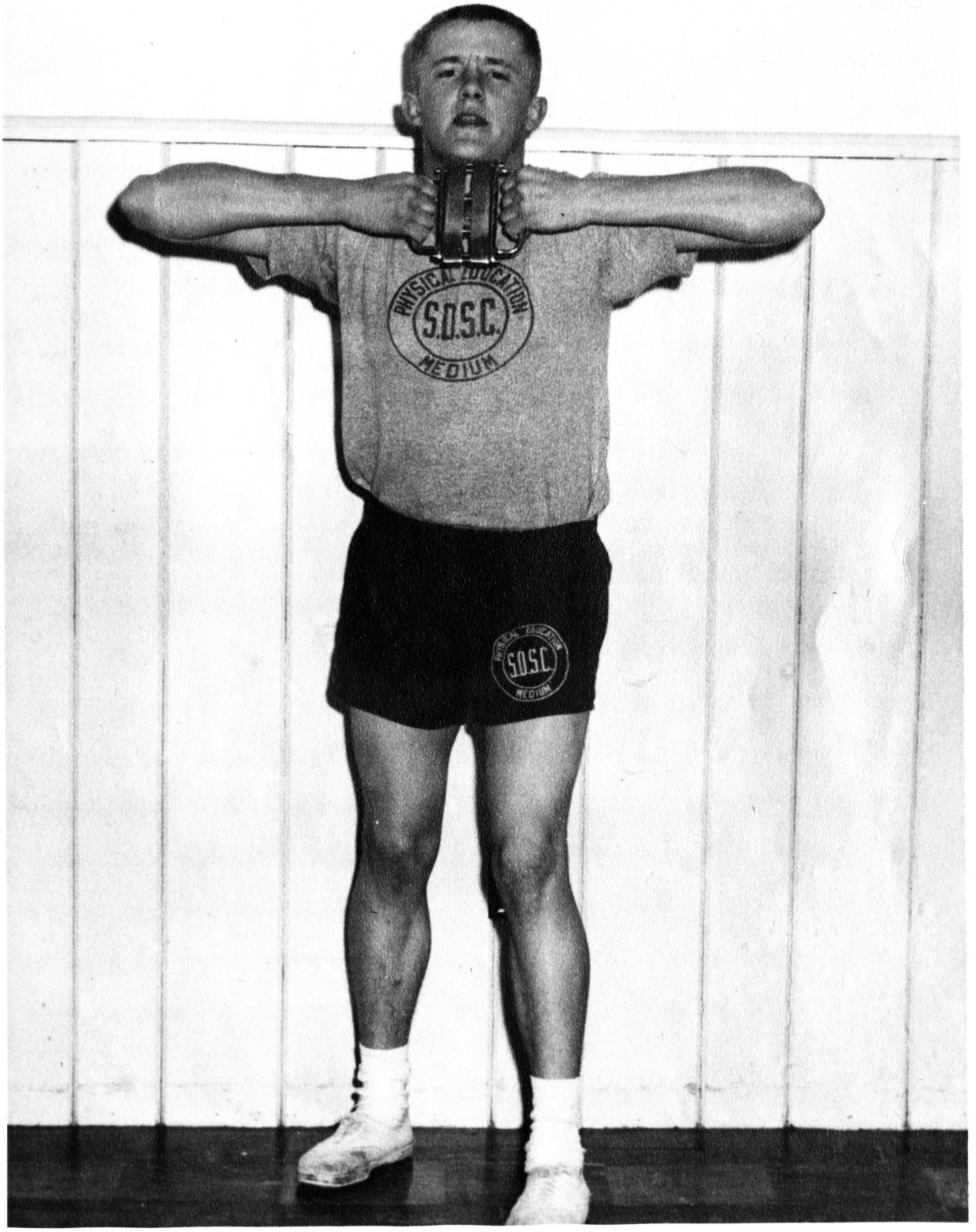

Figure II. Pulling strength test

In measuring pushing strength, the same position was maintained, with the exception that he was allowed to touch his body with the top part of the attachment to prevent loss of control in exerting a maximum contraction. (See Figure III).

General Endurance

In an attempt to provide one test which would measure a combination of muscular strength, endurance, and circulorespiratory condition, the author selected the Harvard Step Test. In reference to the step test, McCloy and Young state:

> The Harvard Step Tests have been well validated, and measure a sort of general endurance; that is, they do not measure strength, or muscular endurance, or circulorespiratory endurance in any special way. The tests seem to measure a combination of types of endurance (33).

Each subject was given the step test over a five-minute period. (See Figure IV). At the end of the test or when he could no longer maintain the pace, 30 steps each minute, his pulse was recorded from pulsations of the right carotid artery on a level even with the hyoid bone. The pulse was taken from one to one and one-half minutes, from two to two and one-half minutes, and from three to three and one-half minutes after the stepping ceased. A physical efficiency index was then computed as his score from the following formula (34):

$$PEI = \frac{\text{Duration of Exercise in Seconds X 100}}{\text{2 X Sum of Pulse Counts in Recovery}}$$

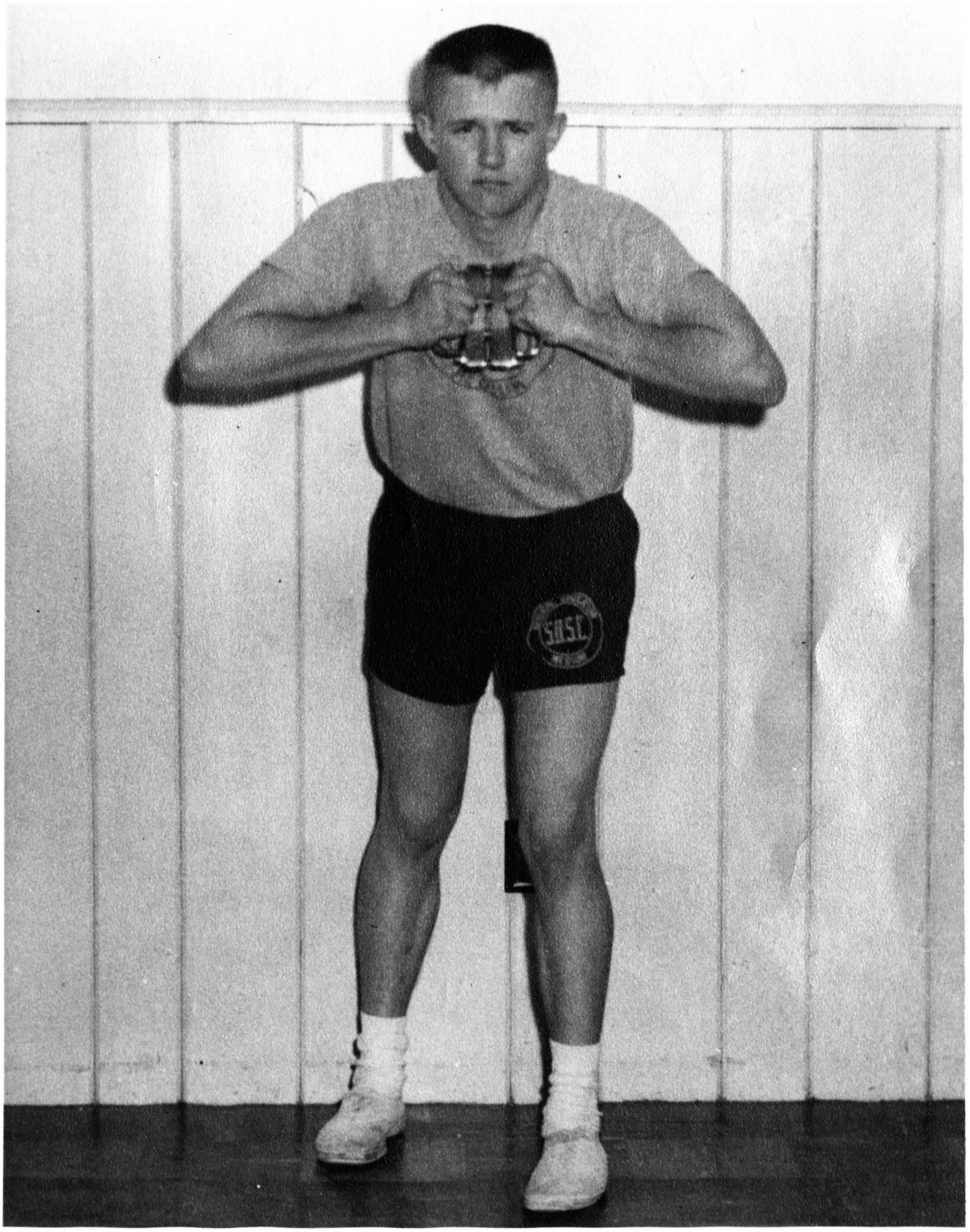

Figure III. Pushing strength test

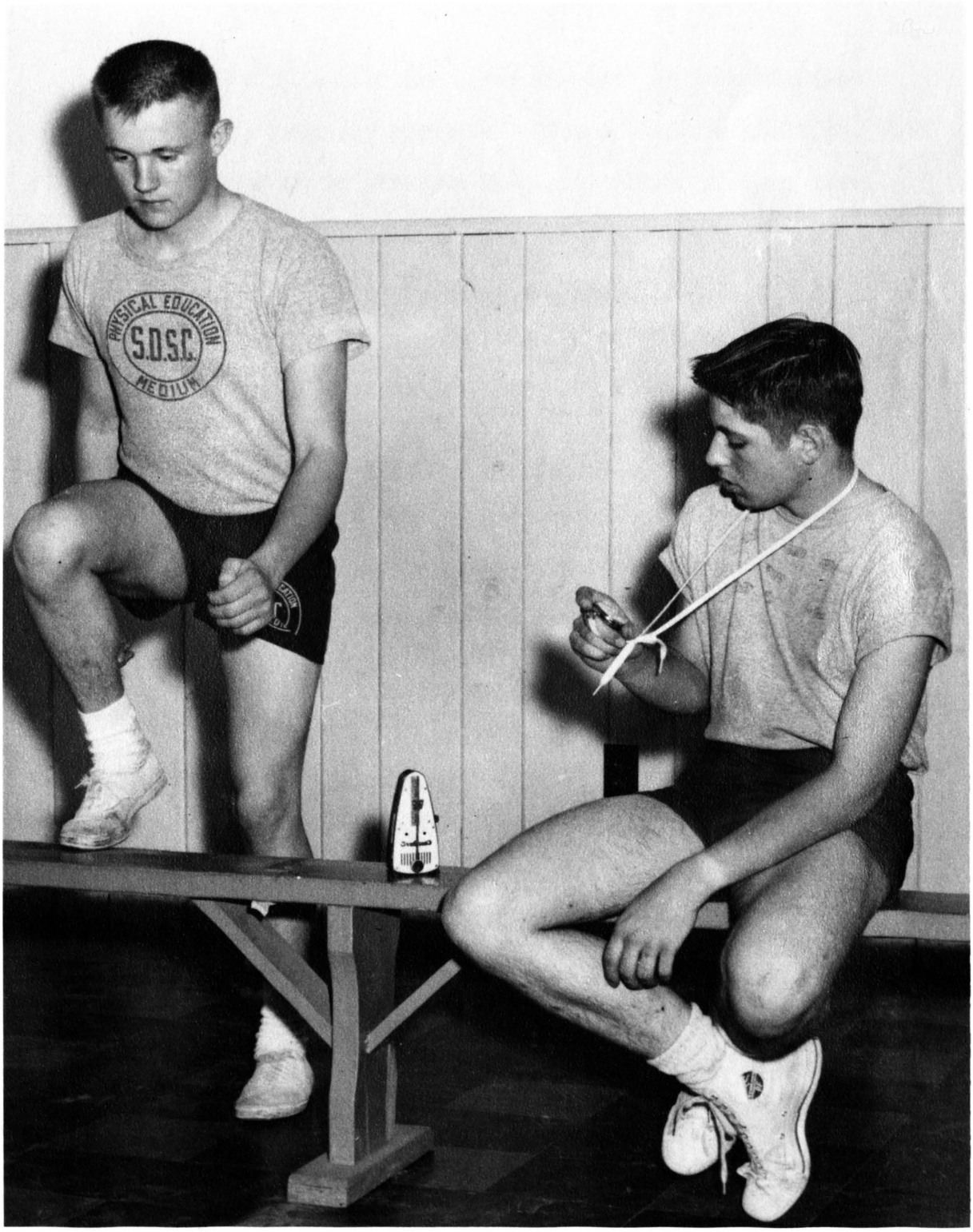

Figure IV. Harvard step test

Reaction Time

A Creighton Hale Reaction Timer was used to test the time required for quick muscular response. From a standing position, each subject was instructed to withdraw his hand, which had been previously placed on a contact switch, as rapidly as possible when a light stimulus was received. (See Figure V). Twenty trials were provided during each testing situation. The results of the trials were totaled, and the mean score for each subject was calculated.

Experimental Design

The purpose of this study was to determine the effect of immersion in a heated whirlpool at four different time intervals, (30, 60, 90, and 120 minutes), upon arm and shoulder strength, reaction time, and general endurance of the body.

Each of the ten participants in the study was subjected to twenty 10-minute whirlpool baths at 104-106 degrees Fahrenheit during the 9-weeks experimental period. After each whirlpool treatment, at 1 of the 4 time intervals, the subjects were given tests of arm and shoulder strength, reaction time, and general endurance.

On five periodically scheduled days during the study, each subject, without a whirlpool treatment, performed the previously mentioned tests, thereby providing control sessions throughout the study. These sessions are referred to as the "0" time interval.

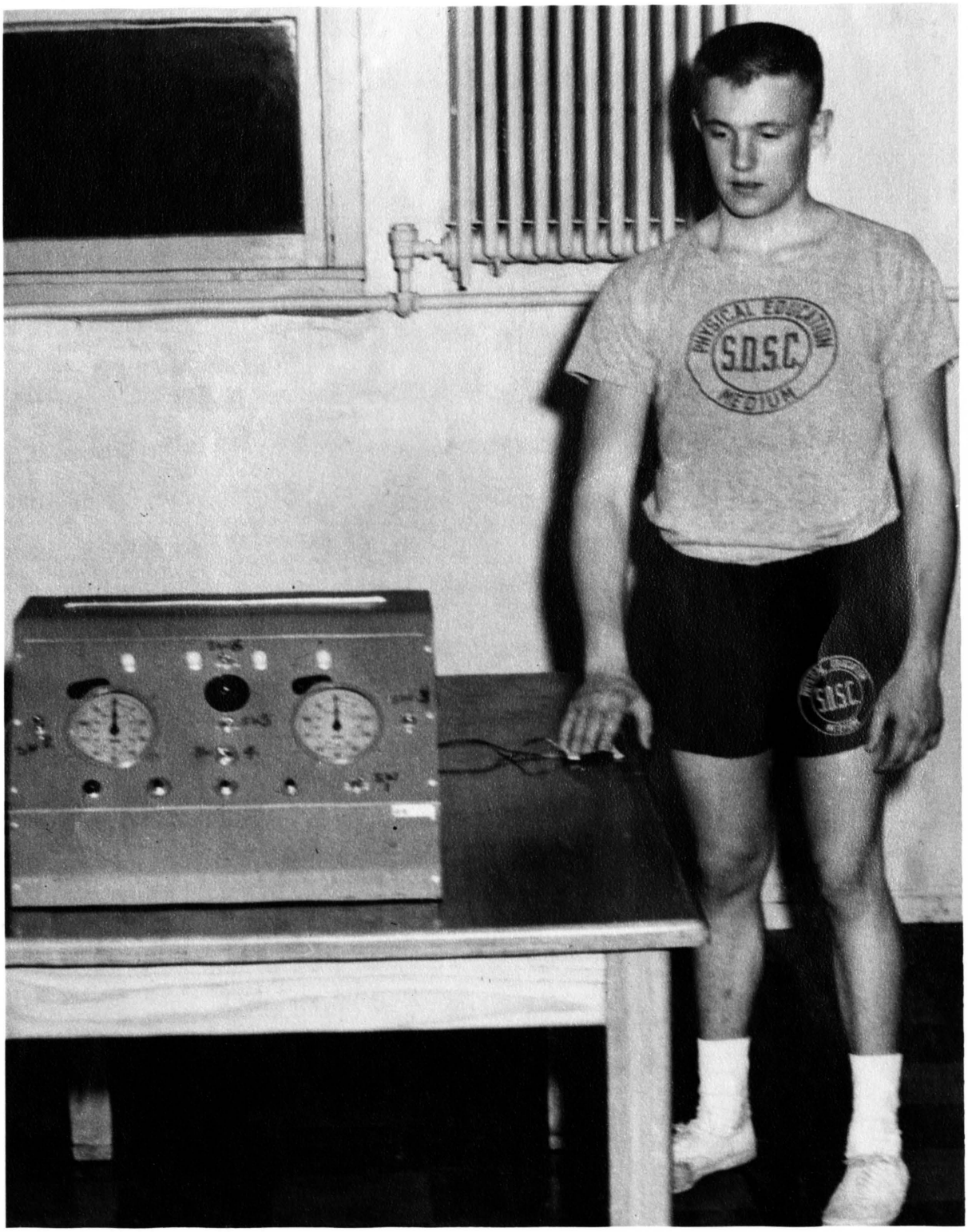

Figure V. Position of subject prior to measuring reaction time by the Creighton Hale Reaction Timer

Subjects were randomly assigned to a pattern of treatments. Reading horizontally, the following schedule reveals one complete cycle of five treatments for each subject.

Subject's Number	Time Intervals (minutes)				
1 and 10	0	30	60	90	120
2 and 9	30	60	90	120	0
3 and 8	60	90	120	0	30
4 and 7	90	120	0	30	60
5 and 6	120	0	30	60	90

This rotating pattern of treatments distributed the practice or training effect of the numerous treatments on the results of this investigation.

CHAPTER IV

ANALYSIS OF DATA

Introduction

This chapter concerns the statistical analysis of the data (see Appendix C through E) collected for each of 10 subjects during 25 testing sessions. Scores on each of the three items under investigation, reaction time, arm and shoulder girdle strength, and general endurance, were grouped according to the time interval following whirlpool immersion at which they were recorded. For example, the scores for five trials for each of the ten subjects at the 30-minute interval on the general endurance test were averaged together. This mean was then compared with the general endurance means of the 60, 90, 120, and 0 minutes, or control interval, by the analysis of variance technique (35). An F ratio of greater than 3.77 was needed to designate statistically significant differences at the .01 level of confidence between the means for the various time intervals.

Reliability

Using the retest method, a Pearson-r of .83 was computed as a coefficient of correlation in determining the reliability of the reaction time measurements used in this study. Arm and shoulder girdle strength measurements were also tested for reliability using the Pearson Product Moment method. A coefficient of correlation of .89 was computed for this test.

Converting the Data

In measuring general endurance, it was necessary to convert the heart rate recorded after exercise into a physical efficiency index which was used in this study as an indicator of general endurance. A formula adopted from Clarke (36) was used for this purpose. The average of 20 reaction time trials, given to a subject during each testing session, was recorded as his reaction time. Arm and shoulder girdle strength was determined by combining the best of three pulls and the best of three pushes on a push-pull attachment to a hand dynamometer.

Findings

Reaction Time

Table 1 indicates the individual subjects' mean reaction scores for each of the five different time intervals. It was noted that six subjects experienced reactions at the 30-minute interval that were slower or equal to what they had recorded at the 0-minute interval. In contrast, seven subjects showed an improvement from the 0-minute interval to the 60-minute interval, and six showed an improvement from the 0- to the 90-minute interval. None of the subjects measured showed any variation in reaction time (increase or decrease) greater than .033 seconds.

Table 1. Individual Mean Scores (Seconds) for Reaction Time

Subject number	Time Intervals				
	0-Minute	30-Minute	60-Minute	90-Minute	120-Minute
1	.191	.182	.184	.174	.164
2	.204	.234	.210	.215	.228
3	.177	.183	.201	.190	.181
4	.196	.195	.191	.216	.203
5	.203	.207	.200	.195	.199
6	.198	.198	.189	.191	.191
7	.202	.191	.196	.201	.192
8	.165	.165	.184	.180	.175
9	.201	.210	.192	.186	.188
10	.209	.203	.191	.199	.189

Figure VI represents the gain or loss of the subjects in reaction time as determined by the series of reaction tests administered to each subject using the Creighton Hale Reaction Timer. The highest bar level indicates a decreased ability to react quickly to a visual stimulus. In comparison to the control, the tests administered to the subjects 30 minutes following whirlpool treatment illustrated a decrease in the ability of the group to respond with as much speed as before. However, in each of the three remaining time intervals, a performance was recorded which was equal to or showed an improvement over the control measure.

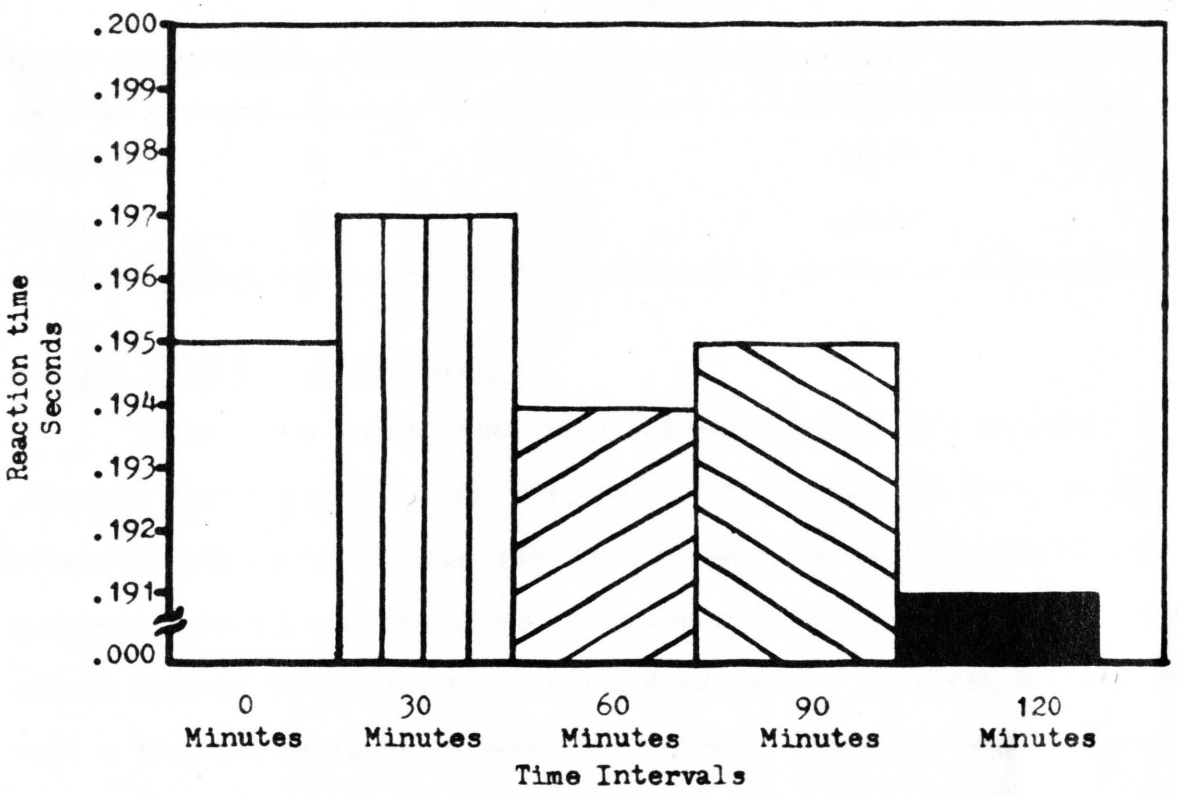

Figure VI. Comparison of reaction time means

Though the graph illustrates a noticeable difference between the mean performances at the intervals shown, it was noted that these extreme differences were, for the most part, due to the finely graduated scale on the vertical axis of the graph.

The F ratio obtained for reaction time between the five means representing the various time intervals was .0000 (Table 2). No statistically significant differences occurred among the means.

Table 2. Summary of Analysis of Variance for Reaction Test Performances

Source	df	Sum of squares	Mean of squares	F
Treatments	4	.000	.00000	.0
Within	45	.006	.00013	

Arm and Shoulder Girdle Strength

Table 3 reveals the mean scores for each subject's arm and shoulder girdle strength. On the basis of the push-pull test, it was observed that the difference between arm and shoulder strength at the 0-minute interval and the 30-minute interval did not vary to any great extent in 9 of the subjects. Subject 9 showed the greatest variation with a 12.8 lb. decrease in strength. Five of the experimentees were found to exhibit a slight decrease in arm and shoulder girdle strength, while at the same time five indicated either an increase or no difference at all.

In comparing the differences in the mean scores for arm and shoulder strength between the 0-minute interval and 60 minutes after whirlpool treatment, it was noted that 6 of the subjects were able to show an increase in strength at the 60-minute interval, while four made a small decrease. Subject 9 continued to show a decrease, with the difference widening to 15.6 lbs.

When making a comparison between the control measurement of the subjects' arm and shoulder girdle strength and the measurements taken at the 90- and 120-minute intervals, the author found the greatest

Table 3. Individual Mean Scores (Pounds) for Arm and Shoulder Girdle Strength

Subject number	Time Intervals				
	0-Minute	30-Minute	60-Minute	90-Minute	120-Minute
1	292.0	288.4	290.0	291.8	300.4
2	197.6	196.4	196.0	198.0	196.8
3	207.8	206.4	205.6	212.4	208.8
4	250.2	250.2	253.6	250.0	254.8
5	261.8	264.6	263.6	269.8	266.0
6	222.8	224.6	226.0	220.4	222.2
7	269.2	273.6	272.0	273.6	273.2
8	168.0	172.2	172.0	161.8	169.2
9	219.2	206.4	203.6	206.6	208.8
10	223.4	220.6	225.2	232.5	231.5

differences. In 7 out of 10 cases, the differences proved to be an increase in strength. Subject 1 improved to the greatest extent, with an 8.4 lb. increase from the 0-minute interval to 120 minutes after whirlpool treatment. Subject 9 again showed a decrease in his mean strength score when comparing these intervals with the control; however, 120 minutes after whirlpool treatment, there was less reduction in strength than at any other selected time. Subject 8 showed his greatest variation at the 90-minute interval with a 6.2 lb. reduction in arm and shoulder girdle strength as compared to the control measurement. However, 120 minutes after whirlpool treatment, his mean strength score improved over his control score by 1.2 lbs.

Figure VII displays arm and shoulder girdle strength means for the various time intervals. The means recorded for the group 30 minutes and 60 minutes following whirlpool treatment showed a loss in strength in comparison to the control. However, 90 minutes after whirlpool treatment and 120 minutes after, a gain in strength over the control measure was noted with the greatest improvement observed at the 120-minute interval.

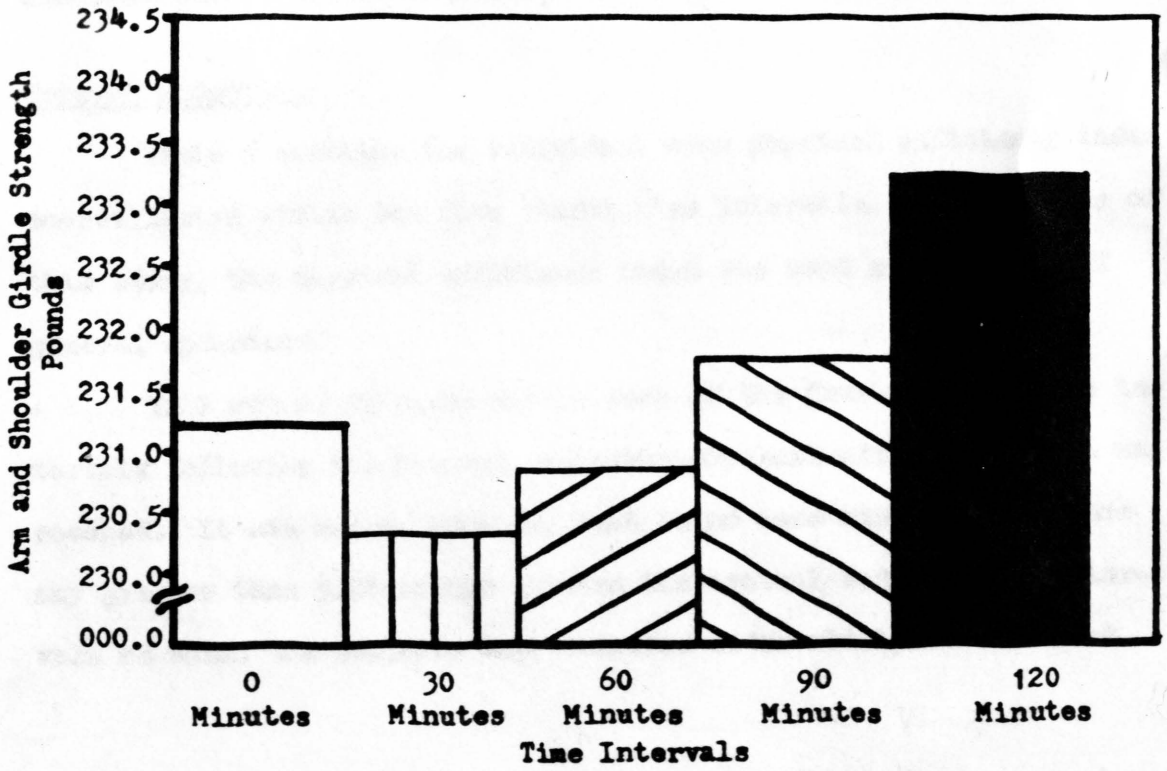

Figure VII. Comparison of arm and shoulder girdle strength means

The F ratio obtained for arm and shoulder girdle strength on the basis of five group means representing the time intervals was .0081 (Table 4). This F ratio was not statistically significant at the .01 level of confidence.

Table 4. Summary of Analysis of Variance for Arm and Shoulder Girdle Strength Test Performances

Source	df	Sum of squares	Mean of squares	F
Treatments	4	47.86	11.96	.0081
Within	45	66,596.92	1,479.93	

General Endurance

Table 5 contains the individual mean physical efficiency index scores listed within the five chosen time intervals. For purposes of this study, the physical efficiency index was used as a measure of general endurance.

In 7 out of 10 cases within each of the four selected time intervals following the control, a higher physical efficiency index was reached. It was noted, however, that in no case was the difference any greater than 5.76 points between the control and the time intervals at which the subjects were measured after whirlpool treatment.

Table 5. Individual Mean Physical Efficiency Scores Measuring General Endurance

Subject number	Time Intervals				
	0-Minute	30-Minute	60-Minute	90-Minute	120-Minute
1	81.46	79.70	81.54	84.00	82.94
2	89.04	86.20	92.52	91.70	94.80
3	86.82	85.56	85.56	85.70	87.26
4	83.32	84.68	85.70	88.34	85.16
5	81.78	83.32	83.46	82.56	83.06
6	81.08	81.54	78.92	82.56	79.58
7	80.86	81.32	83.46	80.68	80.58
8	76.12	78.38	79.72	78.42	81.00
9	76.60	76.92	75.32	75.82	75.14
10	78.54	83.28	84.02	83.86	81.68

In using the Harvard Step Test Physical Efficiency Index as a measurement of general endurance, it was indicated by Figure VIII that performances of the test improved over the control interval at each interval following whirlpool treatment. Ninety minutes after whirlpool treatment, the group exhibited its highest mean score on this particular test.

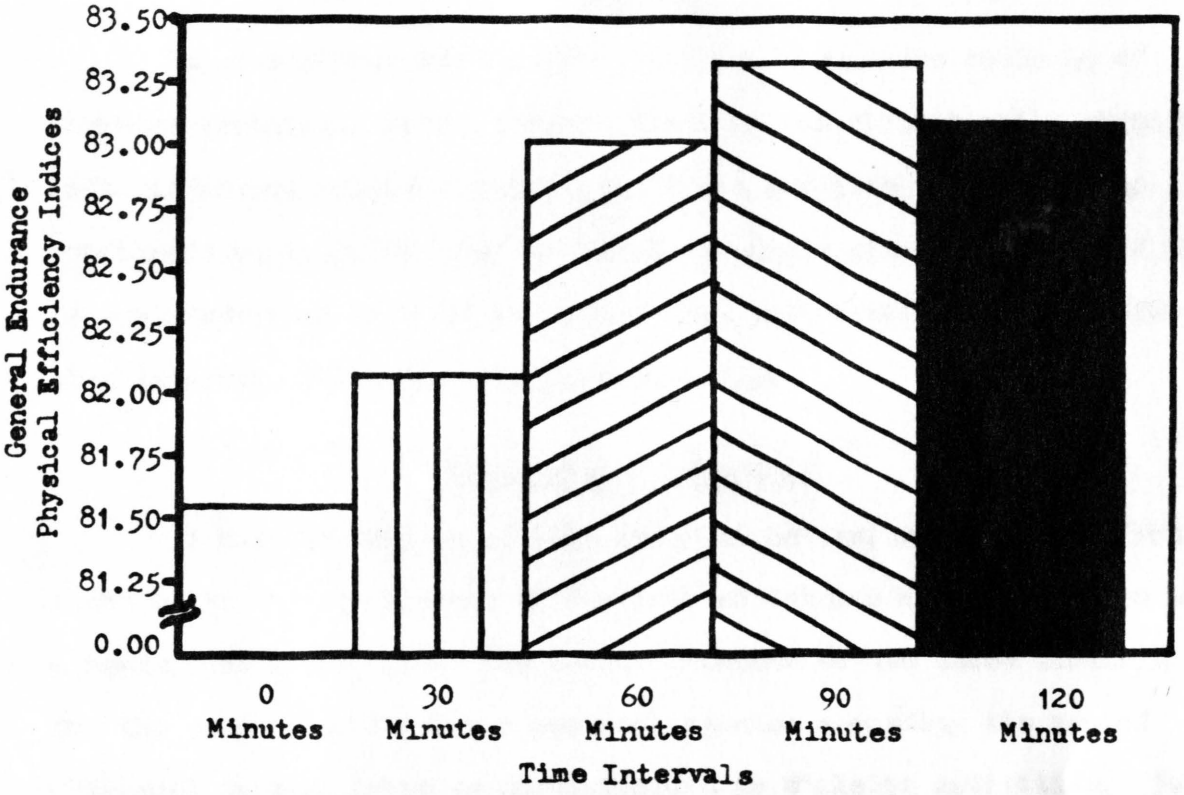

Figure VIII. Comparison of general endurance means

The F ratio obtained for general endurance on the basis of the means representing the five time intervals was .3067 (Table 6). This F ratio was not statistically significant.

Table 6. Summary of Analysis of Variance for Performances of General Endurance Test

Source	df	Sum of squares	Mean of squares	F
Treatments	4	23.64	5.91	.3067
Within	45	868.12	19.29	

Summary

In summarizing the results obtained through the analysis of variance technique, it was evident there was no statistically significant difference between the ability of the subjects to perform the reaction time test, the arm and shoulder girdle strength test, and the general endurance test without prior whirlpool treatment or at various time intervals following whirlpool treatment.

Discussion of Findings

It was the purpose of this study to determine what the effect might be on the performance of physical activities after immersion in a heated whirlpool bath. The author intended to use these findings for the purpose of forming a personal opinion regarding the use of whirlpool therapy prior to participation in athletic activities. For this reason, the temperature of the whirlpool bath and the time of immersion selected in this study were based on the opinions and suggestions of various athletic trainers and medical personnel.

From the results of this experiment, it is the opinion of the author that when whirlpool immersion therapy, similar in nature to that described and used in this study, is indicated for aiding the recovery of athletic injuries, it need not be withheld prior to participation in an athletic event.

Though the subjects were not questioned as to how they felt whirlpool immersion affected their ability to perform the tests administered, two subjects volunteered their opinion. Subject 2, when performing the strength tests following a 90-minute wait after whirlpool

treatment, indicated that it didn't seem to make much difference to him how long he waited after the whirlpool treatment. Just after performing the reaction test and the arm and shoulder girdle strength test, subject 5 mentioned that even though he felt weak on many occasions immediately after the whirlpool treatment, he still seemed to be able to do as well on the tests as at any other time.

CHAPTER V

SUMMARY

The primary purpose of this study was to determine what effect immersion in a heated whirlpool bath had on arm and shoulder girdle strength, general endurance, and reaction time at four different time intervals (30, 60, 90, and 120 minutes).

Subjects for the study were 10 nonathlete, freshmen students in the physical education service program at South Dakota State College.

During the 9-week experimental period, each of the 10 participants in the study was subjected to twenty 10-minute whirlpool baths at 104-106 degrees Fahrenheit. At the conclusion of each whirlpool treatment, at 1 of the 4 time intervals, the reaction time, arm and shoulder girdle strength, and general endurance of the subjects were tested. Five times during the study each subject performed these same tests without prior whirlpool treatment for the purpose of establishing a control. These sessions were referred to as the 0-minute interval.

The scores for each subject on the tests given, reaction time, arm and shoulder girdle strength, and general endurance, were grouped according to the time interval at which they were collected. The means of all subjects for each item under investigation were then compared at the five different time intervals (0 minutes or control, 30, 60, 90, and 120 minutes) by the analysis of variance technique to determine if there were any statistically significant differences.

Findings

Reaction Time

1. None of the subjects measured showed a difference in reaction time greater than .033 seconds between the tests administered without whirlpool treatment, or at various intervals following whirlpool treatment.

2. Only at the 30-minute interval was there any reduction in the speed of reaction, and this was not statistically significant.

3. The differences that occurred in the reaction time of the subjects at the various time intervals were not statistically significant.

Arm and Shoulder Girdle Strength

On the basis of a push-pull measurement, the differences that occurred among the means of the subjects' arm and shoulder girdle strength at the time intervals were not statistically significant.

General Endurance

1. At every interval following whirlpool treatment, the physical efficiency index, used in this study as a measure of general endurance, showed an improvement over the control interval.

2. The differences that occurred among the means of the subjects' general endurance measurement at the various time intervals were not statistically significant.

Conclusion

In view of the findings in this study, the author concludes: when whirlpool immersion therapy, similar to that used in this study, is indicated as an aid to the recovery of an athletic injury it need not be withheld immediately prior to participation in an athletic event.

Recommendations

From the results experienced in this study, the following generalizations and recommendations are made:

1. It is recommended that a similar study be conducted, using a larger sample over a longer period of time.

2. A similar study of the effect of whirlpool treatment on the qualities present in competing athletes could include other additional measuring procedures. For example, the use of regular athletes and actual performances in well-controlled athletic activities might be adopted as a method of measurement. A treadmill or a bicycle ergometer could be used also to measure more accurately the ability of an individual to maintain a given activity over an extended period of time.

3. At no time immediately prior to any testing session, (0-minute interval included), was an individual allowed to go through a preliminary warm-up. Additional research should be conducted which would include a pretest warm-up, in addition to the whirlpool, to determine if this type of therapy affects any differently the performance of an individual in athletic activities.

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APPENDIX A

INSTRUCTIONS TO SUBJECTS PARTICIPATING IN STUDY

1. When you miss due to illness or injury, that scheduled treatment will have to be made up before the others can be continued. It is imperative that you contact me as soon as possible in order to re-schedule the date missed.

2. When you are scheduled for a treatment you must be here and ready (dressed appropriately) five minutes before treatment.

3. Your activity will be limited to a certain extent after the whirlpool treatment and before the tests. Bring books to study during this time. Do not eat anything, drink anything during this period between treatment and tests.

4. You will not be permitted to participate in the intramural program or any other recreational program requiring physical activity for the duration of the study. Do not work out on your own. (weight training, running, etc.)

5. Limit your physical activity considerably one hour before each scheduled treatment.

6. Maintain the following personal habits just as they are now.
   a. If you smoke, continue to do so. Do not quit due to the study. (Do not smoke within one hour before whirlpool treatment)
   b. If you drink alcoholic beverages, you needn't abstain completely. However, excessive drinking on a continuous basis will render the testing invalid.
   c. Maintain normal eating habits. (Do not eat within one hour before treatment)
   d. Maintain the sleeping habits you have now.
   e. In short, do not try to break the pattern of living that you have adopted for yourself while in college or at home.

7. You are competing only against yourself so just continue to do your best on the tests given to you.

APPENDIX B

QUESTIONNAIRE LETTER SENT TO ATHLETIC TRAINERS FROM THE BIG TEN, BIG EIGHT, AND WESTERN ATHLETIC CONFERENCES

Brookings, South Dakota
_____, 1963

Dear Mr. _____

I am in the process of beginning a master's study on the effect of complete immersion in a whirlpool on strength, endurance, and reaction time. Your opinion as to the optimum average temperature and the average time limit to use for complete immersion is important to my study.

Please enclose this letter upon which your opinion has been indicated in the stamped self-addressed envelope provided. Your reply to the following two questions is of utmost importance to me and will be greatly appreciated.

Which of the following average temperatures would you use when immersing a subject in the whirlpool up to and including the acromion process. (Circle your answer)

1. 98.6 F
2. 100 F
3. 105 F
4. 110 F
5. 115 F
6. None of the above, I would suggest _____

Which of the following average time limits would you use when completely immersing a subject in the whirlpool. (Circle your answer)

1. 5 minutes
2. 10 minutes
3. 15 minutes
4. 20 minutes
5. 30 minutes
6. None of the above, I would suggest _____

If you should desire an abstract of the results of this study, please indicate and I will be most happy to send a copy when the study has been completed. Yes_____ No_____

Signature_____

Yours truly,

Dennis L. Hegle

APPENDIX C

Raw Data: Reaction Time (sec.)

Time Int.	Subject Number 1	2	3	4	5	6	7	8	9	10
0	.243	.192	.175	.220	.242	.215	.220	.170	.241	.270
	.208	.199	.180	.191	.205	.205	.193	.162	.194	.210
	.166	.193	.171	.177	.193	.177	.210	.163	.185	.192
	.184	.234	.181	.204	.187	.212	.188	.162	.198	.188
	.156	.200	.180	.187	.188	.182	.201	.166	.188	.187
30	.221	.274	.181	.215	.266	.206	.194	.186	.267	.228
	.184	.197	.187	.194	.197	.218	.189	.162	.219	.198
	.181	.206	.174	.185	.185	.191	.201	.164	.189	.193
	.162	.279	.197	.192	.192	.184	.193	.165	.189	.207
	.162	.212	.174	.188	.193	.190	.180	.150	.186	.190
60	.226	.214	.235	.211	.229	.202	.212	.209	.209	.206
	.185	.199	.190	.187	.196	.215	.179	.173	.182	.188
	.165	.215	.195	.179	.191	.164	.226	.165	.191	.173
	.180	.209	.189	.195	.197	.183	.185	.203	.180	.190
	.163	.215	.197	.185	.188	.180	.179	.171	.198	.196
90	.232	.229	.202	.232	.221	.210	.220	.238	.194	.217
	.152	.211	.189	.245	.197	.212	.182	.154	.182	.184
	.171	.207	.199	.192	.180	.174	.190	.173	.187	.189
	.171	.225	.171	.205	.199	.178	.226	.170	.178	.211
	.162	.204	.191	.205	.177	.183	.186	.163	.189	.194
120	.181	.281	.193	.237	.212	.203	.205	.206	.191	.196
	.162	.205	.178	.212	.215	.207	.166	.170	.182	.170
	.153	.202	.179	.176	.192	.178	.202	.164	.199	.189
	.164	.252	.179	.189	.184	.191	.201	.167	.187	.196
	.160	.200	.178	.199	.190	.178	.187	.167	.184	.196

APPENDIX D

Raw Data: Arm and Shoulder Girdle Strength (pounds)

Time Int.	Sub. No.	Pulling Test 1st Trial	Pulling Test 2nd Trial	Pulling Test 3rd Trial	Pushing Test 1st Trial	Pushing Test 2nd Trial	Pushing Test 3rd Trial	Combined Score
0 min.	1	108	104	120	156	126	104	276
		130	128	126	138	140	134	270
		150	146	148	132	130	136	286
		170	162	160	134	120	132	304
		176	164	160	148	144	138	324
	2	92	90	76	104	112	106	204
		80	82	54	108	102	102	190
		92	84	72	110	108	106	202
		84	78	80	114	118	100	202
		70	70	74	116	116	114	190
	3	100	102	88	100	107	107	209
		74	76	86	104	102	84	190
		102	102	96	116	100	106	218
		98	96	92	112	108	106	210
		100	100	86	106	112	102	212
	4	105	98	102	130	106	138	243
		120	106	108	116	108	120	240
		120	116	114	142	138	134	262
		110	110	106	138	136	140	250
		116	114	112	130	136	140	256
	5	110	105	102	140	145	144	255
		124	118	90	142	130	128	266
		130	126	116	128	124	124	258
		112	100	122	134	134	134	256
		138	128	124	136	132	128	274
	6	94	94	90	120	128	94	222
		50	94	84	122	118	116	216
		78	92	86	114	106	106	206
		72	86	98	126	108	94	224
		110	104	100	136	118	114	246
	7	128	97	100	138	122	126	266
		120	114	114	136	128	124	256
		130	120	116	132	132	126	262
		142	106	132	138	130	126	280
		136	130	128	146	142	128	282

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
	8	66	60	64	68	80	94	160
		56	32	32	92	80	92	148
		68	72	64	108	88	100	180
		68	60	60	108	98	100	176
		58	56	64	112	108	96	176
	9	106	90	92	100	102	90	208
		116	110	106	110	102	106	226
		102	90	84	120	110	102	222
		112	100	92	110	100	100	222
		104	96	90	114	104	104	218
	10	94	90	102	90	92	105	207
		62	96	88	126	122	124	222
		100	112	110	128	122	118	240
		106	104	96	120	124	96	230
		110	100	100	104	108	100	218
30 min.	1	124	120	124	120	150	140	274
		130	128	120	138	142	150	280
		146	136	128	132	134	132	280
		146	128	148	144	140	146	294
		168	166	168	136	144	134	304
	2	66	70	62	108	100	108	178
		88	86	86	126	115	112	214
		68	70	86	112	112	102	198
		84	80	80	104	106	112	196
		82	80	76	114	108	110	196
	3	104	94	94	106	93	100	210
		88	100	98	106	100	98	206
		104	104	98	104	102	104	208
		96	98	96	110	104	100	208
		80	94	94	106	106	106	200
	4	111	102	96	114	110	116	227
		128	110	100	110	106	100	238
		112	114	106	140	136	150	262
		114	104	110	148	130	120	262
		118	116	108	144	140	140	262

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
	5	105	102	108	138	141	142	250
		130	126	126	141	134	124	271
		130	126	118	136	132	120	266
		100	140	138	130	120	126	270
		130	130	120	136	130	130	266
	6	95	90	90	110	114	120	215
		90	88	84	128	128	120	218
		96	82	78	124	114	96	220
		96	96	98	124	118	110	222
		112	106	96	136	136	118	248
	7	130	122	104	134	126	128	264
		114	124	124	138	128	134	262
		138	130	124	132	136	136	274
		144	138	130	140	134	134	284
		140	130	128	144	134	134	284
	8	66	38	58	72	105	84	171
		50	48	50	104	106	102	156
		68	64	60	112	104	98	180
		70	62	52	108	92	100	178
		68	50	48	108	108	102	176
	9	100	92	94	110	110	100	210
		96	82	82	98	90	100	196
		105	92	96	110	114	104	220
		76	84	88	110	110	104	198
		108	100	90	100	96	96	208
	10	86	93	94	104	120	108	213
		76	78	100	128	120	122	228
		116	96	108	112	114	112	230
		96	70	98	116	110	108	214
		112	110	100	106	100	96	218
60 min.	1	118	112	122	128	84	104	250
		140	132	130	142	140	136	282
		144	144	134	136	126	144	288
		178	176	164	144	128	124	322
		178	148	166	122	130	130	308
	2	86	76	74	106	110	110	196
		92	90	86	96	86	92	188
		60	88	84	110	94	96	198
		86	86	80	110	112	114	200
		82	74	72	116	114	110	198

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
	3	78	98	100	104	106	104	206
		96	96	82	94	82	80	190
		106	100	100	106	110	106	216
		98	96	90	112	100	106	210
		100	98	100	104	106	100	206
	4	100	90	106	122	96	126	232
		120	106	104	122	124	116	244
		116	114	106	140	144	130	260
		128	126	106	142	120	126	270
		116	94	118	144	142	138	262
	5	88	120	100	142	144	148	268
		128	126	90	132	130	124	260
		130	126	126	128	120	118	258
		126	128	130	130	130	126	260
		140	138	140	132	132	132	272
	6	92	84	80	122	112	114	214
		86	68	90	120	112	110	210
		84	80	94	124	112	114	218
		94	110	102	124	124	118	234
		116	104	106	138	132	124	254
	7	128	114	114	120	116	118	248
		134	116	110	142	130	128	276
		134	130	110	136	130	120	270
		138	144	120	142	134	132	286
		132	138	136	142	136	130	280
	8	74	72	68	90	105	106	180
		54	40	60	94	70	94	154
		42	44	64	98	102	106	170
		74	68	64	106	104	100	180
		58	66	66	110	100	96	176
	9	90	98	102	98	104	100	206
		100	94	82	104	100	100	204
		102	94	74	106	104	102	208
		90	88	88	106	100	96	214
		88	98	96	104	100	96	204
	10	88	82	88	118	122	104	210
		104	102	104	114	114	120	224
		116	116	120	130	108	116	250
		98	94	70	126	106	116	224
		106	90	100	106	112	108	218

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
90 min.	1	127	120	120	118	102	104	245
		130	142	126	144	140	139	286
		160	158	158	140	136	126	300
		176	166	172	142	114	116	328
		170	168	160	138	130	140	310
	2	86	82	70	114	109	116	202
		86	84	80	110	94	104	196
		88	86	84	114	110	98	202
		88	82	70	110	110	104	198
		84	80	76	106	106	108	192
	3	94	96	98	96	106	108	206
		104	102	100	99	76	100	204
		114	108	100	110	100	96	224
		86	102	96	108	114	110	216
		100	90	94	112	108	100	212
	4	80	82	114	124	132	124	246
		114	104	94	112	140	130	254
		108	112	100	136	130	126	248
		114	108	106	124	132	132	246
		120	116	106	136	132	112	256
	5	90	104	124	144	148	146	272
		132	128	128	133	128	130	265
		124	114	114	120	128	120	252
		146	138	130	140	126	126	286
		144	130	106	128	130	126	274
	6	84	66	82	126	118	120	210
		74	86	70	130	118	110	216
		82	84	78	114	104	104	196
		110	106	94	136	126	112	246
		104	104	86	130	124	114	234
	7	126	114	112	136	118	130	262
		132	124	114	136	132	130	268
		136	128	124	140	132	133	276
		142	132	126	138	126	132	280
		140	134	118	142	140	130	282
	8	54	54	50	95	84	85	149
		52	48	38	84	80	90	142
		52	46	64	102	110	104	174
		74	68	68	98	98	94	172
		62	62	64	108	108	106	172

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
	9	99	98	98	106	110	106	209
		84	86	86	90	104	90	190
		104	86	82	112	108	104	216
		104	98	88	106	100	104	210
		98	92	90	110	92	92	208
	10	*	*	*	*	*	*	*
		114	108	108	130	128	118	244
		94	110	86	126	110	116	236
		98	78	94	128	110	116	226
		112	86	92	106	112	104	224
120 min.	1	128	125	124	144	120	142	272
		154	144	134	130	130	122	284
		164	158	154	136	140	140	304
		178	166	168	118	148	116	326
		174	166	164	136	142	130	316
	2	82	84	72	114	106	100	198
		84	84	76	112	106	98	196
		88	84	80	98	104	110	198
		86	74	72	110	108	112	198
		76	78	72	116	108	112	194
	3	98	92	98	98	104	92	202
		74	102	98	104	96	88	206
		108	94	96	108	104	98	216
		104	94	90	106	106	108	212
		94	84	98	104	106	110	208
	4	110	110	100	100	132	128	242
		118	118	112	120	106	126	244
		118	114	116	132	124	132	250
		114	114	116	144	146	146	262
		126	122	112	150	136	124	276
	5	114	110	114	134	143	144	258
		126	106	122	144	142	136	270
		112	126	128	126	130	118	258
		126	120	122	134	130	124	260
		148	126	130	136	136	128	284

* Not recorded.

Time Int.	Sub. No.	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial	Combined Score
	6	94	104	104	104	118	108	222
		96	88	82	120	114	114	216
		86	72	78	128	116	108	214
		92	92	94	122	118	112	216
		110	102	82	132	126	116	242
	7	126	110	104	132	130	122	258
		130	112	102	140	132	122	270
		132	130	120	140	134	124	272
		130	134	130	140	132	130	274
		140	134	124	152	140	134	292
	8	52	54	60	92	102	102	162
		30	46	30	96	96	96	142
		68	60	64	110	104	96	178
		74	72	64	108	96	96	182
		74	74	60	108	104	98	182
	9	106	95	90	100	100	88	206
		110	104	90	106	98	102	216
		80	94	86	114	106	102	208
		104	96	90	104	96	90	208
		100	90	86	106	104	96	206
	10	*	*	*	*	*	*	*
		80	108	98	132	124	120	240
		120	110	112	126	114	108	246
		112	104	100	116	104	100	228
		104	96	96	104	108	108	212

* Not recorded.

APPENDIX E

Raw Data: General Endurance (Harvard Step Test)

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
0 min.	1	70	66	61	76.1
		67	60	60	80.2
		66	60	55	82.9
		63	57	55	85.7
		68	59	55	82.4
	2	65	57	53	85.7
		66	57	54	84.7
		63	57	54	86.2
		60	52	48	93.7
		60	51	47	94.9
	3	75	62	58	76.9
		64	57	53	86.2
		61	56	52	88.8
		59	49	49	95.5
		63	57	53	86.7
	4	66	57	51	86.2
		65	56	53	86.2
		67	59	57	82.0
		70	61	57	79.8
		67	60	55	82.4
	5	73	66	61	75.0
		67	61	56	81.5
		67	60	55	82.4
		64	58	53	85.7
		66	58	54	84.3
	6	71	64	60	76.9
		69	62	59	78.9
		66	59	55	83.3
		69	60	56	81.1
		66	57	53	85.2
	7	72	64	61	76.1
		67	59	54	83.3
		66	57	52	85.7
		67	61	57	81.1
		71	64	57	78.1

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
0	8	78	72	68	68.8
		73	64	61	75.8
		70	63	61	77.3
		67	58	56	82.9
		73	65	60	75.8
	9	71	62	59	78.1
		70	64	59	77.7
		73	63	59	76.9
		73	64	60	76.1
		77	65	60	74.2
	10	72	69	65	72.8
		67	57	55	83.7
		71	62	59	78.1
		67	59	56	82.4
		72	64	62	75.7
30 min.	1	73	66	63	74.2
		72	63	60	76.9
		67	59	57	82.0
		68	60	59	82.0
		63	57	56	85.2
	2	66	59	55	83.3
		65	58	55	84.3
		66	57	55	84.3
		63	53	55	85.7
		62	56	51	88.7
	3	70	63	60	77.7
		66	58	56	83.3
		64	57	53	86.2
		66	58	55	83.8
		59	49	47	96.8
	4	65	56	51	87.2
		66	55	52	86.2
		67	58	52	84.7
		64	56	53	86.7
		70	63	59	78.1

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
30 min.	5	73	63	58	77.3
		66	57	53	85.2
		69	60	54	82.0
		64	54	51	88.8
		67	58	55	83.3
	6	68	62	61	78.5
		67	59	57	82.0
		68	60	56	81.5
		68	60	57	81.1
		64	58	55	84.7
	7	68	61	59	79.8
		68	59	54	82.9
		68	60	57	81.1
		67	58	53	84.3
		70	62	59	78.5
	8	75	67	64	72.8
		68	60	57	81.1
		66	58	55	83.8
		72	64	59	76.9
		70	64	60	77.3
	9	76	67	64	74.6
		71	62	58	78.5
		71	62	60	77.7
		73	63	61	76.1
		70	64	59	77.7
	10	71	62	60	77.7
		63	57	55	85.7
		67	60	58	81.1
		66	58	51	85.7
		63	56	55	86.2
60 min.	1	71	62	61	77.3
		68	61	60	79.4
		63	59	54	85.2
		63	58	56	84.7
		67	61	57	81.1
	2	65	59	53	84.7
		56	47	44	102.
		60	54	51	90.9
		62	56	52	88.2
		57	50	48	96.8

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
60 min.	3	70	64	62	76.5
		63	57	53	86.7
		66	57	55	84.3
		60	54	48	92.6
		64	54	53	87.7
	4	68	60	54	82.4
		66	57	52	85.0
		68	61	53	82.4
		61	54	49	91.5
		64	56	52	87.2
	5	69	61	57	80.2
		69	58	56	82.0
		66	58	53	84.7
		62	55	50	89.8
		69	61	58	81.5
	6	71	65	62	75.8
		67	59	57	82.0
		69	62	60	78.5
		70	62	59	78.5
		69	61	58	79.8
	7	63	56	53	87.2
		68	62	58	79.8
		63	56	52	87.7
		69	61	56	80.6
		67	60	56	82.0
	8	76	68	64	72.5
		72	64	60	76.5
		67	59	57	82.0
		63	56	51	88.2
		69	62	58	79.4
	9	78	70	65	70.4
		72	65	62	75.4
		74	64	60	75.8
		72	63	61	76.5
		71	62	58	78.5
	10	67	59	58	81.5
		65	58	54	84.7
		68	63	56	80.2
		62	51	49	92.6
		70	58	57	81.1

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
90 min.	1	67	61	60	79.8
		64	57	55	85.2
		65	62	57	81.5
		59	55	49	92.0
		65	61	58	81.5
	2	62	51	49	92.6
		62	54	49	90.9
		60	52	50	92.6
		61	54	50	90.9
		62	52	50	91.5
	3	66	58	55	83.8
		67	61	57	81.1
		67	60	56	82.0
		65	55	53	86.7
		59	51	48	94.9
	4	68	58	57	82.0
		68	57	53	84.2
		62	54	50	90.4
		60	52	50	92.6
		61	52	49	92.5
	5	67	58	56	82.8
		67	58	53	84.2
		72	63	58	77.7
		66	55	54	85.7
		69	58	55	82.4
	6	65	59	58	82.4
		64	57	54	85.7
		68	60	57	81.1
		67	58	53	84.3
		70	61	58	79.3
	7	71	64	59	77.3
		72	60	55	80.2
		68	60	54	82.4
		69	61	57	80.2
		66	60	54	83.3
	8	74	69	65	72.1
		73	65	62	75.0
		68	61	56	81.1
		67	61	50	80.6
		66	59	55	83.3

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
90	9	76	68	64	72.1
		72	63	59	77.3
		72	61	58	78.5
		71	63	60	77.3
		74	67	62	73.9
	10	69	61	58	79.8
		62	57	55	86.2
		65	57	53	85.7
		66	57	53	85.2
		68	59	55	82.4
120 min.	1	69	64	59	78.1
		69	62	61	78.1
		64	58	55	84.7
		66	59	58	81.9
		62	56	54	87.2
	2	60	56	51	89.8
		54	47	43	102.7
		61	53	50	91.5
		61	52	48	93.2
		58	50	47	96.0
	3	65	57	52	86.2
		64	57	53	86.2
		65	58	54	84.7
		61	55	50	90.4
		62	55	52	88.8
	4	63	55	53	87.7
		65	58	56	83.8
		65	56	53	86.2
		71	62	56	79.3
		64	54	51	88.8
	5	76	67	63	72.8
		66	58	55	83.7
		66	59	55	83.3
		62	55	51	89.3
		64	57	53	86.2
	6	73	67	63	73.9
		66	58	56	83.3
		67	60	57	81.5
		70	60	59	79.4
		69	62	57	79.8

Time Int.	Sub. No.	Pulse Counts 1st	2nd	3rd	PEI
120 min.	7	74	65	61	75.0
		69	60	58	80.2
		66	56	55	84.7
		68	58	56	82.4
		69	60	57	80.6
	8	77	68	65	71.4
		66	59	56	82.9
		64	57	53	86.2
		68	61	58	80.2
		66	59	53	84.3
	9	78	68	65	71.1
		74	64	62	75.0
		71	66	61	75.8
		72	64	61	76.1
		73	62	58	77.7
	10	66	60	59	80.6
		71	66	63	75.0
		68	60	56	81.5
		67	60	56	82.0
		63	54	51	89.3