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Surface Temperature, Body Temperature, and Heart Rate as Affected by Immersing the Feet of Conditioned Basketball Players in Cold Water Bath

Farrel Leroy Jacobsen

SURFACE TEMPERATURE, BODY TEMPERATURE, AND HEART RATE AS AFFECTED BY IMMERSING THE FEET OF CONDITIONED BASKETBALL PLAYERS IN A COLD WATER BATH

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FARREL LEROY JACOBSEN

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This thesis is approved as a creditable and 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.

Thesis Adviser /Date

Head, Physical Education Department Date

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Abstract

FARREL LEROY JACOBSEN

Under the supervision of Professor Glenn E. Robinson

The purpose of this study was to determine whether surface temperature of the feet, body temperature, and heart rate are affected by immersing the subjects' feet in a cold water bath of 34° - 40°Fahrenheit before and after basketball practice sessions.

Twelve male freshman basketball members at South Dakota State University participated in the study conducted over a period of four weeks and four days during the last part of the 1967-1968 basketball season. Each subject was tested six times during this period.

The paired t comparison was used to divide the subjects into pairs. Each pair was divided randomly into experimental and control groups. Surface temperature of the feet, body temperature, and heart rate was taken for each subject before practice, immediately after practice, five minutes after practice, and ten minutes after practice. The experimental group immersed their feet in a cold water bath before practice and three minutes after practice. The members of the control group rested during this period.

The investigator was concerned with the mean gain or loss between the groups. As a result of the statistical analysis of the

data obtained, the investigator found that surface temperature of the feet showed a statistical significance during the short recovery period. Body temperature and heart rate showed no statistical significance, but were lower for group using the cold water bath than for the group observing the rest period.

ACKNOWLEDGMENTS

The writer wishes to express his most sincere appreciation to his adviser, Glenn E. Robinson, Associate Professor, Peter D. Torino, and Dr. W. Lee Tucker for their valuable guidance, supervision, and assistance in the completion of this thesis.

The writer also expresses his gratitude to the members of the freshman basketball squad who gave of their time and effort in making this study possible, and to his wife for her support, patience, and sincere encouragement throughout the study.

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CHAPTER I

THE PROBLEM, LIMITATIONS, AND DEFINITIONS OF TERMS USED

One of the problems plaguing the athletic coach of sports which involve running, quick starts, stops, and fast changes in direction is the effect of such activity upon the surface temperature of the feet, body temperature changes, and resulting changes in heart rate as related to the recovery time of a competitor. Rapid recovery is essential if a competitor, because of the nature of the activity, is required to return to initial competing physical conditions in a short period of time.

Recently, studies have been completed in which researchers employed cold-water applications and observed the relative physiological effects of cold water on the body before and after exercises. The results of such studies have created varying opinions as to the relative effectiveness of such application. The majority of the studies completed by investigators have been based on a cool environment or immersing part or all of the body in a cold water solution above 60° Fahrenheit.

This study was undertaken in an attempt to determine whether surface temperature of the feet, body temperature, and heart rate will return to pre-exercise conditions within ten minutes by immersing only the feet in a cold-water bath of 34° to 40° Fahrenheit for one minute immediately prior to the practice sessions and three minutes after practice sessions.

I. THE PROBLEM

Statement of the problem. The purpose of this study was to determine whether surface temperature of the feet, body temperature, and heart rate are affected by immersing the subject's feet in a cold water bath of 34° - 40° Fahrenheit before and after basketball practice sessions.

Importance of the study. Coaches are ever searching for a method to solve the problem of excess surface temperature on the feet of athletes so that athletes can practice and participate to their capability each day. The effects of fatigue and excess surface temperature on the feet, with resulting blisters, have become an increasingly serious problem to be considered since the pace of the game has increased at both the intercollegiate and interscholastic level.

Coaches are also searching for ways to reduce body temperature and heart rate back to pre-exercise conditions or near pre-exercise conditions in the shortest period of time in order to get maximum effort from each individual in the second half of a game or in a second game, a tournament series, several races, or matches in a short period of rest.

II. LIMITATIONS OF STUDY

1. The study was limited to twelve members of the freshman basketball team at South Dakota State University.

2. The study was initiated fifteen weeks after basketball practice began on October 16, 1967.

3. High-top shoes were worn for practice and games.

4. Only the right foot was checked in measuring surface temperature for uniform testing procedures.

III. DEFINITIONS OF TERMS USED

Surface temperature. Surface temperature of the epidermis was taken for approximately six to eight seconds. Surface temperature is related to the ability of the skin to dispose heat to the surroundings.

Body temperature. The temperature of the internal body was taken for two minutes. Body temperature is a result of the balance between heat products and heat loss.

Heart rate. The number of complete cardiac cycles per thirty seconds.

Recovery time. The time required for altered physiological parameter to return to pre-exercise form. (Example: Respiration and heart rate to return to pre-exercise condition following a bout of work).

Immersion. Placement of the feet in a cold-water bath to a depth of about four inches for one minute.

Cold-water bath. Cold water run from the faucet into a steel tank, five feet long, two and one-half feet wide and one foot high, to a depth of approximately eight inches. The water temperature

was maintained between 34° and 40° Fahrenheit by placing ice cubes in the bath.

Dermalor skin temperature unit. A commercial instrument which is guaranteed to measure surface temperature in about six seconds to an accuracy greater than two percent.

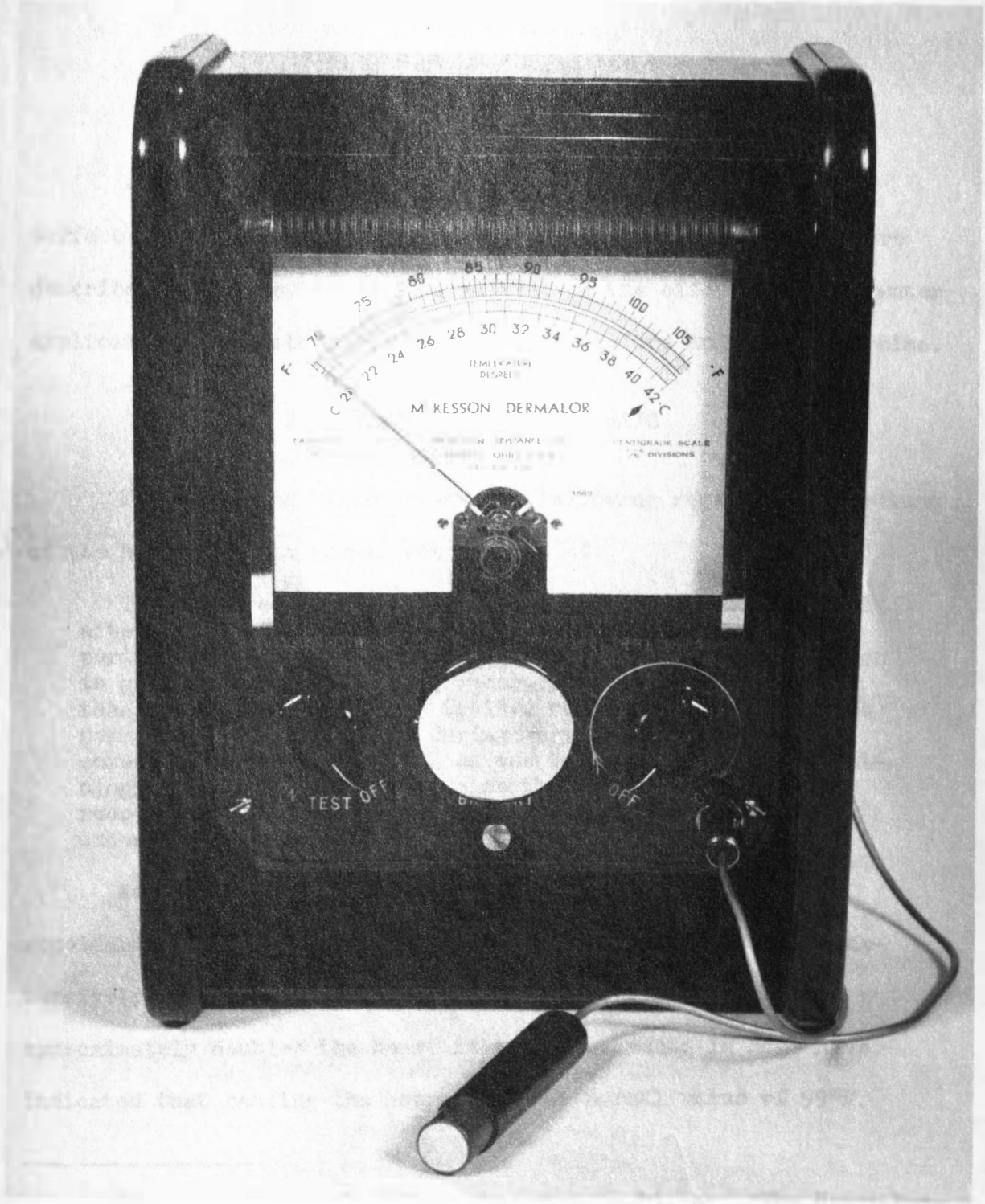

Figure 1. Dermalor skin temperature unit

CHAPTER II

REVIEW OF THE LITERATURE

Readings pertaining to heart rate, body temperature and surface temperature are reported in this chapter. The literature describes the normal conditions as well as the effects of cold water applications on certain parts of the body before and after exercise.

I. LITERATURE ON HEART RATE

Morehouse and Miller state the following regarding the return of the heart rate to normal after exercise:

> The time required for the heart rate to return to normal after exercise depends on the work load of the exercise period and on the physical condition of the subject. In men in good physical condition, recovery occurs more rapidly than in fatigued or poorly trained subjects. The return to normal occurs more slowly during very exhausting exercise, sometimes requiring as long as one to two hours. The physiological factors which determine the time course of the recovery of the heart rate after exercise are not clearly understood.[1]

According to Guyton, increased temperature produces a considerably increased heart rate, but decreased temperature extensively diminishes the rate. A 10°F. ascent in temperature approximately doubles the heart rate. Experiments in dogs have indicated that cooling the heart from the normal value of 99°F.

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[1]Laurence E. Morehouse and Augustus T. Miller, "The Heart Rate During Exercise," Physiology of Exercise (New York: The C. V. Mosby Company, 1959), p. 112.

down to approximately 85°F. actually increased the stroke volume output of the heart. This increase partially makes up for the diminished heart rate, permitting the heart to maintain adequate quantities of blood needed for various parts of the body. However, at still lower temperatures, the cardiac output eventually becomes insufficient to sustain existence. The stroke volume output decreases slightly at higher than normal temperature; however, the greatly increased rate of beat still gradually increases the total cardiac output up to a body temperature of approximately 106°F.[2]

Falls and Weiber investigated the effects of pre-exercise conditions (cold water, hot shower, excessive warm-up) on heart rate and oxygen. Five subjects rode a bicycle ergometer at 1080 kgm/min. for five minutes. Falls and Weiber hypothesized that the cold water shower caused vasoconstriction of the peripheral blood vessels and diverted blood from the skin to the working muscles, thereby reducing the cardiovascular load during the five-minute exercise. Falls and Weiber feel that there are definite physiological effects during exercise and recovery which are related to heating and cooling the body before exercise. Exercise heart rates are significantly lower after a cold shower than after a hot shower or an exercise warm-up.[3]

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[2]C. Guyton, Medical Physiology (Philadelphia: W. B. Saunders Company, 1961), p. 288.

[3]Harold B. Falls and Jacob E. Weibers, "The Effects of Pre-Exercise Conditions on Heart Rate and Oxygen Uptake During Exercise and Recovery," Research Quarterly, XXXVI (October, 1965), 243-253.

Michael investigated the effects of a 60°F. cold shower for two minutes on the circulation of conditioned and non-conditioned men while taking three step bench tests. The subjects either rested or took cold showers between the tests. The exercise consisted of three consecutive one-minute step tests on a seventeen-inch bench at the rate of thirty steps per minute. Pulse rate measurements were taken before, immediately after, and at each minute for five minutes after the tests. The author discovered that the conditioned group was affected more by the cold shower than the non-conditioned group. Both groups had an increase in pulse rate after the step tests and a decrease after showers were taken. However, the conditioned group decreased significantly, but the non-conditioned group failed to reach significance.[4]

Steinhaus and Wendhut state that they found that the effects of a hip bath on pulse rate, blood pressure, and on circulatory adjustments from reclining and standing positions were significant. The cold hip bath showed a slowing of the resting pulse rate in reclining and in standing position. They also found a reduction of the increase of pulse rate that normally occurs when a reclining person resumes the standing position. Together, these findings

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[4]Ernest D. Michael, Jr., "Effects of Cold Showers on Circulation of Conditioned and Non-Conditioned Men," Research Quarterly, I (March, 1957), 38-49.

indicate that the bath temporarily includes changes that relieve the heart somewhat of the burden of maintaining blood pressure.[5]

Happ experimented with a control and an experimental group doing short bouts of strenuous exercise on a bicycle ergometer. Happ used two conditions; the work output experiment consisted of a one-minute all-out ride, a ten-minute rest period followed by an additional one-minute all-out ride on the bicycle ergometer. On alternate days the same subject repeated the work experiment but applied an ice pack to the abdomen during the ten-minute rest period. The author found that the pulse rate during recovery from a bout of moderate exercise diminished when the ice pack was applied during the rest period. Happ also found that a higher percentage of work was done in the second run if the ice pack was applied than if the ice was not used.[6]

Hill and Flack found that by using both hot and cold showers, heart rate decreased with the use of cold water, but that hot water increased heart rate.[7]

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[5]A. H. Steinhaus and G. Wendhut, "Pulse Rate, Blood Pressure, and Vision after a Cold Water Hip Bath," Journal of Applied Physiology, V (December, 1952), 677-685.

[6]William Peter Happ, Jr., "The Physiological Effects of Cold Abdominal Packs," Unpublished Ph.D. Thesis, State University of Iowa, Ames, 1948), pp. 1-82.

[7]A. V. Hill and W. Flack, "Four Phases of Heat Production of Muscle," Journal of Physiology, LIV (March, 1920), 84-128.

II. LITERATURE ON RECOVERY

The literature indicates that cold showers, cold applications, or cool environments have been a widespread means of recovering or refreshing after exercise.

Girdano states that previous studies indicated that a cool environment before work delayed the onset of fatigue and hastened recovery after work. Nineteen subjects were tested four times on different days. The test consisted of an all-out treadmill run in extreme heat, a twelve-minute recovery period, and a second all-out run. The subjects performed completely or partially clothed on two tests and with a hot or cool recovery period on two tests in a balanced rotation. Recovering in a cool environment had no significant effect on the second all-out run, nor on the heart rate, blood pressure, respiration rate, or rectal temperature, although seventeen subjects reported that they felt more refreshed and recovered to a greater extent in cool environment.[8]

Sills and O'Riley used a Sills electric contractor to register the number of steps the right foot took in the initial and final bouts of exercise. The authors found a significant reduction in the final bout of exercise with the use of cold spray. They also found

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[8]Daniel A. Girdano, "The Physiological Effects of Cooling upon Recovery from Fatigue," (Unpublished Master's Thesis, Kent University, Kent, Ohio, 1966), pp. 1-175.

that cold spray on spot-running improved recovery from fatigue more than either a preliminary rest or exercise.[9]

Falls and Richardson investigated the recovery procedure of complete rest, light activity, and cold showers on circulatory recovery from a standardized bicycle ergometer exercise, performance in a second standardized bicycle ergometer exercise, and circulatory recovery from the second exercise. Falls and Richardson found that recovery from excessive stress may be speeded up significantly by taking a cold shower at an average temperature of 68°F. and that this speed recovery will allow for a significantly better performance in a second bout plus significantly better recovery therefrom when compared with either complete rest or light exercise as a recovery procedure.[10]

Happ, Tuttle, and Wilson state that recovery is facilitated by the application of abdominal ice packs after a strenuous exercise. The authors found that the loss in work output in the second of two work periods was reduced when ice packs were applied to the abdomen

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[9]Frank Sills and Vernon O'Riley, "Comparative Effects of Rest, Exercise, and Cold Spray Upon Performance in Spot-Running," Research Quarterly, XXVII (May, 1956), 217-219.

[10]Harold B. Falls and Robert D. Richardson, "Comparison of Recovery Procedure for the Reduction of Exercise Stress," Research Quarterly, XXXVIII (December, 1967), 550-555.

of the subject during the rest phase between the work periods and that ice applications increased work output the following day.[11]

Talich states in his unpublished master's thesis that on the same day after the initial treadmill run, rest appeared to be as beneficial as a cold sitz bath (68° to 72°F.) in a second performance on the treadmill. Each subject participated in two treadmill runs of two minutes duration at seven miles per hour with a ten-minute sitz bath or a rest period between each treadmill run. Talich feels according to the analyzed data that a cold sitz bath would help improve recovery for a second or additional bout of work.[12]

Rosen found that some runners in the 440-yard run could improve their time significantly with the application of cold spray, but that other runners exhibited slower times. The author feels that the effects of the application of cold abdominal spray may depend on each individual.[13]

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[11]W. P. Happ, W. W. Tuttle, and Majorie Wilson, "The Physiological Effects of Cold Abdominal Packs," Research Quarterly, II (March-December, 1949), 153-164.

[12]William Charles Talich, "The Effects of a Cold Sitz Bath on Various Measures of Circulorespiratory Recovery from Vigorous Exercise" (Unpublished Master of Science Thesis, South Dakota State University, Brookings, South Dakota, 1965), pp. 1-47.

[13]M. Rosen, "The Effects of a Cold Abdominal Spray on a Repeat Performance in the 440-Yard Run," Research Quarterly, XXIII (August, 1955), 226-230.

III. LITERATURE ON TEMPERATURE

Although the body is subject to a wide range of environmental temperatures, humidities, pressures, and compositions, an extremely narrow temperature range must be maintained in order for man to exist. Most of the body's vital processes and functions will perform only in this narrow temperature range.[14]

According to Hardy, the body's core temperature is 98°F. (37°C.) and the average skin temperature is 94°F. (33.9°C.). These temperatures are most easily maintained when the surrounding environmental temperature is 86°F. (30°C.) and air movement is kept a minimal.[15]

Mackle and Hatch state that the balance between heat production and heat loss represents the body temperature. This balance is essential to the optimal functions of the body and remains relatively uniform over a wide range of different heat productions and environmental temperature.[16]

Consolazo and associates found that during exercise the temperature of the environment is one of the most important factors

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[14]N. Kleitman, S. Titilblum, and H. Hoffman, "Establishment of Diurnal Temperature Cycle," American Journal of Physiology, CXIX (May, 1937), 48-55.

[15]J. D. Hardy, "Physical Responses to Heat and Cold," Annual Review of Physiology, XII (June, 1950), 119-125.

[16]W. Mackle, and E. F. Hatch, "Heat: Man's Exchange and Physiological Responses," Physiology Review, XXVII (September, 1947), 200-210.

regulating body temperatures. This factor is important because thermal equilibrium is only attainable if the environment is capable of accepting the heat generated by the body without necessitating a rise in body temperature above physiological limits.[17]

Burton states that it is assumed that the temperature of body tissue is generally 37°C. It is known, however, that the surface of the body is at a temperature considerably lower than this. In normal surroundings, for instance, at 25°C., the average temperature for the whole skin surface of a lightly clothed man will be in the neighborhood of 33°C., the average being a mean of widely different temperature at different parts of the body. At the feet the temperature may be as low as 27°C.[18]

Goff, Brubach, Smith and Specht found that a considerable variation was observed in individual responses to submersion. In all but one subject, shivering was regularly encountered within twenty minutes at water temperature below 29.5°C. Immersion at temperatures above 37°C. produced extreme discomfort resulting from high temperature and humidity in the air. To avoid these problems, the water temperature was generally limited to the range 29.5°C.-36.5°C.

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[17]C. F. Consolazo, et al., "Environmental Temperatures and Energy Expenditure," Journal of Applied Physiology, XVIII (January, 1963), 65-74.

[18]Alan Burton, "The Average Temperature of the Tissues of the Body," The Journal of Nutrition, August 2, 1934.

The authors believed that the heart rate is more directly influenced by average skin temperature than by immersion per se.[19]

Margaret Knott, the director at the Kaiser Foundation Rehabilitation Center in Vallejo, California, states that cold water applications for rheumatoid arthritis should be kept below 58° Fahrenheit.[20]

Moore and his associates found that when they used shaved ice and water mixture, the temperature ranging from 34° to 40° Fahrenheit seemed to achieve the best clinical results for rehabilitation of athletic injuries. They recommend that short periods of immersion be used before each exercise bout because of the painful discomfort.[21]

IV. SUMMARY

The evidence presented by the research reviewed seems to indicate that the method of cooling areas of the body influenced by artificial means, for the purpose of speeding up recovery and improving performance, is generally accepted. The best method or

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[19]L. G. Goff, H. F. Brubach, J. Specht, and N. Smith, "Effects of Total Immersion at Various Temperatures on Oxygen Uptake at Rest and During Exercise," Journal of Applied Physiology, IX (July, 1956), 59-61.

[20]Margaret Knott, "Neuromuscular Facilitations in the Treatment of Rheumatoid Arthritis," Journal of the American Physical Therapy Association, XLIV (August, 1964), 737-739.

[21]Robert J. Moore, Jr., Robert L. Nicolette, and Robert S. Behnke, "The Therapeutic Use of Gold (Cryotherapy) in the Care of Athletic Injuries," The Journal of the National Athletic Trainers Association, II (Summer, 1967), 7.

process to use--cold water baths, hand immersion, ice packs, cold spray, cold showers, or cool environment--appears to be a personal opinion or preference. The literature reviewed tends to indicate that a cold application to any part of the body would benefit recovery.

The research completed up to this date also seems to indicate that pre-body cooling prior to bouts of work or cooling during the recovery period facilitates recovery.

CHAPTER III

PROCEDURE FOR OBTAINING DATA

I. INTRODUCTION

This chapter provides a description of the subjects and the procedures used for testing and recording measurements. Measurements considered involved the changes in heart rate, body temperature, and surface temperature of the feet.

II. SUBJECTS

The subjects were twelve male athletes who were members of the freshman basketball team at South Dakota State University. The subjects varied in height, weight, and body build.

Prior to beginning the program, the subjects met with the investigator for orientation on the procedures to be followed throughout the study. During January, 1968, testing was completed in order to separate the subjects into experimental and control groups. The paired "t" comparison was used to divide the subjects into pairs according to playing positions and the results of the pre-test on heart rate. Cold water application on the feet was not employed in equating the pre-test. Each pair was divided randomly into an experimental and a control group. Groups were designated by employing the track pillbox method.

The experimental study was conducted over a period of four weeks and four days, with testing sessions on Monday through Friday except on game days. The initial testing began on January 30, 1968, fifteen weeks after basketball practice started, and ended March 1, 1968.

Before the daily practice on each testing day, four of the twelve subjects reported to the testing laboratory which was kept at a temperature between 68° to 73° Fahrenheit. Two of the four subjects were in the experimental group and two were in the control group.

On arrival to the testing laboratory the four subjects rested in a sitting position for a five-minute period. Following the rest period, heart rate, body temperature, and surface temperature of the feet on all four subjects were recorded. Each pair was tested concurrently at each testing session. Immediately after recording the data, the members of experimental group immersed their feet in a cold water bath (34° to 40° F.). The water was approximately four inches in depth, and the time of immersion was for one minute. The subjects in the experimental groups reported immediately for practice. The two members of the control group did not immerse their feet in the cold water bath and reported for practice after testing was completed.

Both groups participated in a regular basketball practice session approximately one hour and fifteen minutes each day. Each practice session ended with a three to seven-minute passing and running drill called the "three-man weave."

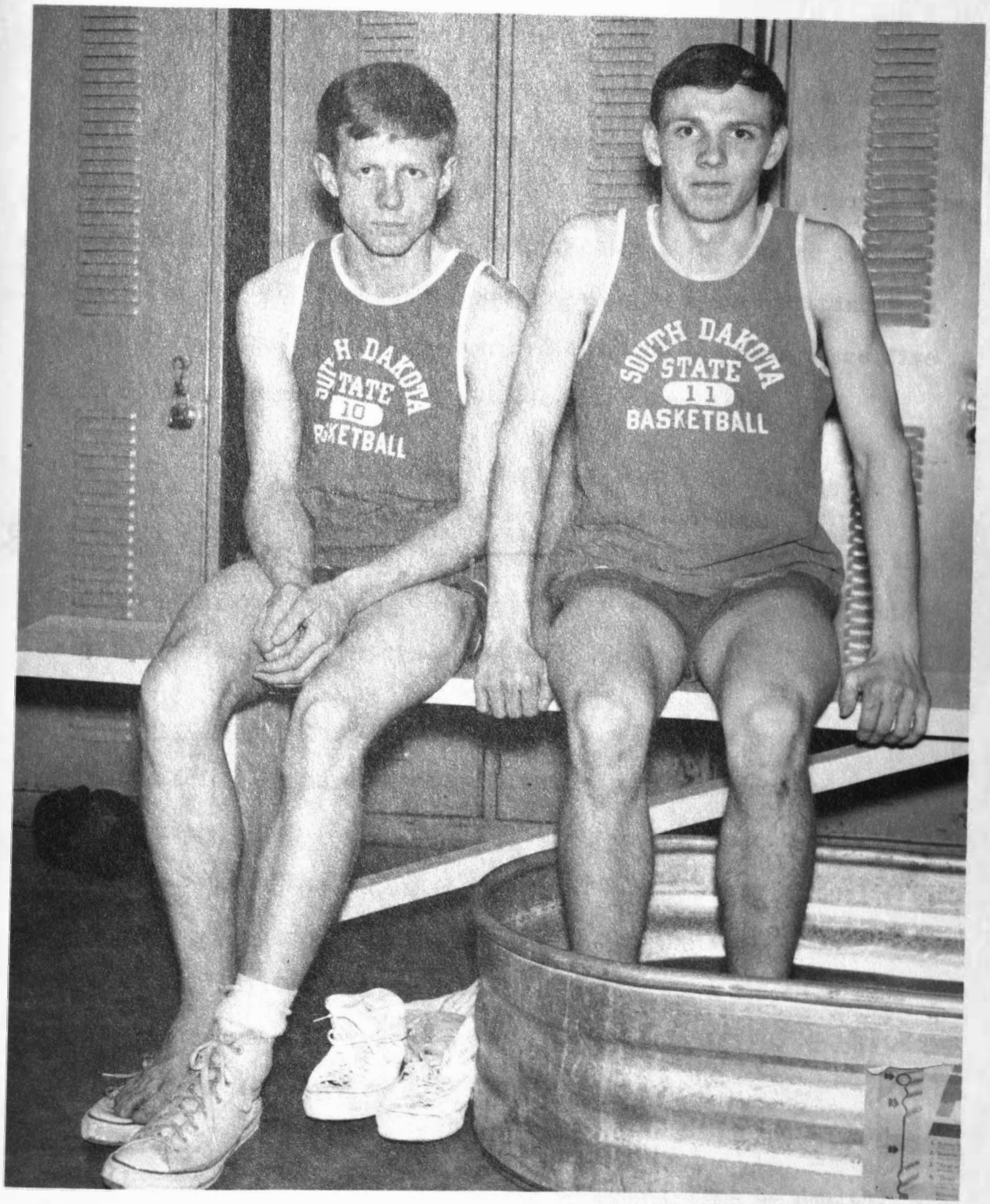

Figure 2. Rest period and immersion

Immediately after practice the subjects reported directly to the testing laboratory, where the subjects were retested on the same items (heart rate, body temperature, and surface temperature of the feet) in the same order as the pre-test. Three minutes after practice the experimental group immersed their feet in a cold water bath (34° to 40° F.) for one minute while the control group were resting in a sitting position. Both groups were retested on the same items five minutes after practice and ten minutes after practice.

III. INSTRUMENTS FOR OBTAINING DATA

Heart rate, body temperature, and surface temperature of the feet were measured to determine the effects of immersing the feet in a cold water bath upon the selected measures.

Heart rate. Heart rate was taken for thirty seconds by the subject placing the three middle fingers of his left hand on the cartoid artery below the right ear at the base of the neck.[1]

Accuracy in the taking of heart rate was checked by qualified testers who were members of the physical education staff. This procedure was followed three of the six testing days in which each subject participated in order to check on the reliability of the subjects in taking heart rate.

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[1]H. Harrison Clarke, Application of Measurement to Health, and Physical Education (Englewood Cliffs: Prentice-Hall, Inc., 1967), p. 199.

Heart rate was taken after the five-minute rest period before practice, immediately after practice, five minutes after practice, and ten minutes after practice.

Body temperature. Body temperature was taken by placing an oral thermometer under each subject's tongue. Body temperature was measured to the nearest tenth of a degree. Each reading was taken for two minutes after the five-minute rest period before practice, immediately after practice, five minutes after practice, and ten minutes after practice.

Surface temperature of the feet. Surface temperature of the feet was taken for approximately six to eight seconds with a Dermalor Skin Temperature Unit which is guaranteed to read surface temperature in about six seconds to an accuracy greater than two percent. Surface temperature was measured to the nearest tenth of a degree. Surface temperature was taken at the following three points on the right foot: (a) on the ball of the foot directly below the sesamoid of the first metatarsal, (b) on the arch at a point on the inner component of the longitudinal arch directly below the navicular bone, and (c) at a point directly behind the calcaneus bone and approximately three-fourths of an inch up from the bottom of the foot.[2]

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[2]Katharine F. Wells, Kinesiology (Philadelphia: W. B. Saunders Company, 1966), pp. 353-359.

Figure 3. Measuring surface temperature, body temperature, and heart rate

The subjects were tested after the five-minute rest period, immediately after practice, five minutes after practice, and ten minutes after practice.

IV. TESTING PERSONNEL

The investigator felt it was necessary to employ four assistants in order to test a subject accurately. Surface temperature of the feet was taken by the investigator employing the Dermalor Skin Temperature Unit. The first assistant started the universal clock at seven minutes when the subjects took their resting positions in the testing laboratory. At the end of the five-minute resting period, the first assistant made certain that each subject took his heart rate for a thirty-second interval. He also made certain that an oral thermometer was placed in each subject's mouth at the end of the five-minute resting period and read at the end of two minutes. The second and third assistants read the oral thermometers and dried the subjects' feet after the immersion in the cold water bath. The fourth assistant recorded all measurements on heart rate, body temperature, and surface temperature of the feet.

CHAPTER IV

ANALYSIS OF DATA

I. INTRODUCTION

Presented in this chapter is the statistical analysis of the data collected before practice, immediately after practice, five minutes after practice, and ten minutes after practice on heart rate, body temperature, and surface temperature of the feet for twelve male freshman basketball players at South Dakota State University. The experimental group immersed their feet in the cold water application of 34° - 40°F. immediately before practice and three minutes after practice for a period of one minute.

II. SCORING OF DATA

Heart rate, body temperature, surface temperature of the feet were analyzed from the raw data. No conversion of raw score was necessary as each pair participated under the same conditions on each testing day.

III. RELIABILITY OF DATA

No reliability coefficients were computed for heart rate, body temperature, and surface temperature of the feet. However, the oral thermometers were checked daily for uniformity at a specific temperature, and the Dermalor Skin Temperature Unit is

guaranteed to read surface temperature to an accuracy greater than two percent. The investigator was aware of the factors which influence pulse rate, such as emotional stresses, body size, and body temperature. Room temperature of the testing laboratory was kept between 68° and 73°F. The barometric pressure ranged from 28.0 to 28.6. Standard procedure, such as a set schedule for taking heart rate, body temperature and surface temperature of the feet, were strictly followed during the pilot study and during the experiment in order to obtain reliable data for the study.

IV. ANALYSIS OF DATA

The investigator employed the paired *t* comparison technique, as outlined by Steel and Torrie,[1] to compare the following mean gain or loss difference between pairs of the experimental and control groups: pre-test to immediately after practice, pre-test to five minutes after practice, pre-test to ten minutes after practice, and from five minutes after to ten minutes after practice. The .01 level of significance was chosen to denote the statistically significant difference between paired groups, but the .05 level of significance was also recorded. A statistical coefficient at or beyond the .01 level necessitated a rejection of the null hypothesis. Five degrees of freedom were used in this investigation, and a *t* value equal to

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[1]Robert G. D. Steel and James H. Torrie, Principles and Procedures of Statistics (New York: McGraw-Hill Book Company, Inc., 1960), pp. 78-79.

or greater than 4.03 at the one percent level was necessary to reject the null hypothesis. In order to report the .05 level of significance the t value had to be equal to or greater than 2.57.

V. FINDINGS

The data from this investigation were analyzed statistically and reported in this section. The three tests investigated were surface temperature of the feet, body temperature, and heart rate.

VI. SURFACE TEMPERATURE ON THE BALL OF THE FOOT

Immediately after practice to five minutes after practice. The t value of the data obtained on the ball of the foot from immediately after practice to five minutes after practice was statistically significant on all tests except tests two and three which were significant at the .05 level. Therefore, the null hypothesis was rejected. (Table I)

Immediately after practice to ten minutes after practice. The t value of the data collected on the ball of the foot from immediately after practice to ten minutes after practice was not statistically significant. Test one was significant at the .05 percent level. The null hypothesis was not rejected. (Table II)

TABLE I

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO FIVE MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	10.1	1.8	8.3	1.19	6.97**
2	7.1	1.6	5.6	1.99	2.80*
3	8.0	0.8	7.2	2.36	3.05*
4	6.4	0.9	5.5	0.86	6.39**
5	6.4	1.0	5.4	0.28	19.29**
6	8.3	1.2	7.1	0.85	8.37**

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

TABLE II

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	2.8	0.3	2.5	0.69	3.62*
2	2.3	0.6	1.7	1.51	1.13
3	1.4	0.7	0.7	1.73	0.41
4	1.7	0.1	1.6	0.92	1.73
5	-1.1	0.1	1.2	1.03	1.17
6	2.3	1.3	1.0	1.04	.96

*Statistical significance at five percent level of significance.

Five minutes to ten minutes after practice. The subjects in the experimental group from five minutes after practice to ten minutes after practice showed an increase in surface temperature of the ball of the foot, but the control group showed a decrease. There was a statistical significance between the groups at the .01 level, but the experimental group's surface temperature was still cooler. The null hypothesis was then rejected. (Table III)

TABLE III

SUMMARY OF t COMPARISON FOR FIVE MINUTES AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	7.4	-1.5	8.9	1.59	5.60**
2	4.8	-0.9	5.7	1.13	5.04**
3	6.4	-0.2	6.6	1.39	4.75**
4	4.6	-0.5	5.1	0.67	7.61**
5	5.3	-6.1	11.4	1.02	11.18**
6	6.0	+0.1	6.1	0.72	8.47**

**Statistical significance at one percent level of significance.

VII. SURFACE TEMPERATURE ON THE ARCH OF THE FOOT

Immediately after practice to five minutes after practice.

The data obtained on the arch of the foot shows that the t value from immediately after practice to five minutes after practice was statistically significant at the .01 level of significance. The null hypothesis was rejected. (Table IV)

TABLE IV

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO FIVE MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	14.2	2.1	12.1	2.65	4.57**
2	13.4	0.6	12.8	1.47	8.78**
3	12.7	1.2	11.5	0.85	13.41**
4	11.1	1.0	10.1	1.39	7.27**
5	12.3	1.0	11.3	0.49	23.06**
6	12.3	1.5	10.8	1.79	6.03**

**Statistical significance at one percent level of significance.

Immediately after practice to ten minutes after practice. Test five, taken on the arch of the foot from immediately after practice to ten minutes after practice, was the only test that was statistically significant at the .01 level. The null hypothesis was therefore not rejected. (Table V)

TABLE V

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	7.0	2.0	5.0	3.70	1.35
2	3.9	0.5	3.4	1.35	2.59
3	3.3	1.5	1.8	1.31	1.37
4	3.7	1.1	2.6	1.22	2.13
5	3.2	0.7	2.5	0.53	4.53**
6	5.1	1.1	4.0	2.13	1.88

**Statistical significance at one percent level of significance.

Five minutes after practice to ten minutes after practice.

The t value of the data collected on the arch of the foot from five minutes after practice to ten minutes after practice showed a decrease in surface temperature for the control group, but the experimental group showed an increase. The experimental group was still cooler after ten minutes. There was a statistical significance between groups at the .01 level on all tests except tests one and three, which were statistically significant at the .05 level. The null hypothesis was therefore rejected. (Table VI)

TABLE VI

SUMMARY OF t COMPARISON FOR FIVE MINUTES AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	7.6	0.1	7.5	2.79	2.69*
2	9.5	0.1	9.4	1.18	7.97**
3	7.7	-0.3	8.0	2.22	3.60*
4	7.4	1.4	7.2	1.03	6.99**
5	8.6	1.2	8.4	0.74	11.35**
6	7.1	-0.7	7.8	1.25	6.24**

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

VIII. SURFACE TEMPERATURE ON THE HEEL OF THE FOOT

Immediately after practice to five minutes after practice.

The t value on the data obtained on the heel of the foot from immediately after practice to five minutes after practice was statistically significant on all tests at the .01 level, except test one, which was statistically significant at the .05 level. Therefore, the null hypothesis was rejected. (Table VII)

TABLE VII

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO FIVE MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	11.5	2.5	9.0	3.04	2.96*
2	12.6	0.2	12.4	2.03	6.11**
3	14.3	0.2	14.1	2.11	6.68**
4	11.9	0.1	11.8	1.61	7.33**
5	12.5	0.7	11.8	1.61	7.33**
6	14.2	2.1	12.1	2.04	5.93**

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

Immediately after practice to ten minutes after practice.

On the heel of the foot the t value of the data collected from immediately after practice to ten minutes after practice was not statistically significant at the .01 level. Tests two and four were statistically significant at the .05 level. The null hypothesis was then not rejected. (Table VIII)

TABLE VIII

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	4.8	1.0	3.8	1.58	2.41
2	5.6	-0.5	6.1	2.04	2.99*
3	6.7	0.2	6.5	3.25	2.00
4	4.2	0.5	3.7	1.01	3.66*
5	2.5	0.8	1.7	0.95	1.79
6	5.8	1.8	4.0	2.70	1.48

*Statistical significance at five percent level of significance.

Five minutes after practice to ten minutes after practice.

The t value of the data obtained on the heel of the foot from five minutes after practice to ten minutes after practice showed a decrease in surface temperature in the control group, but the experimental group increased in surface temperature and was still cooler than the control group. There was statistical significance between groups on all tests at the .01 level, except test one, which was statistically significant at the .05 level. The null hypothesis was then rejected. (Table IX)

TABLE IX

SUMMARY OF t COMPARISON FOR FIVE MINUTES AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	8.4	1.6	6.8	1.79	3.80*
2	6.4	0.7	5.7	0.99	5.76**
3	7.7	0.0	7.7	1.53	5.03**
4	7.6	-0.4	8.0	1.36	5.88**
5	8.8	-0.1	8.9	1.37	6.50**
6	8.6	0.2	8.4	1.29	6.51**

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

IX. BODY TEMPERATURE

Pre-test to five minutes after practice. The t value of the data collected on body temperature from the pre-test to five minutes after practice was not statistically significant at the .01 level. The null hypothesis was not rejected. (Table X)

TABLE X

SUMMARY OF t COMPARISON FOR PRE-TEST TO FIVE MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	0.2	0.9	0.7	0.80	0.88
2	-0.2	0.7	0.9	0.88	1.02
3	0.2	0.8	0.6	0.52	1.15
4	0.3	0.8	0.5	0.42	1.19
5	0.0	0.6	0.6	0.61	0.98
6	0.3	0.3	0.0	0.60	0.00

Pre-test to ten minutes after practice. From pre-test to ten minutes after practice the t value of the data obtained was not statistically significant at the .01 level. The null hypothesis was not rejected. (Table XI)

TABLE XI

SUMMARY OF t COMPARISON FOR PRE-TEST TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	1.0	3.5	2.5	1.51	1.66
2	1.1	3.5	2.4	1.52	1.58
3	0.7	2.2	1.5	0.99	1.52
4	0.9	2.9	2.0	1.07	1.87
5	1.4	2.9	1.5	1.23	1.22
6	0.9	1.2	0.3	0.38	0.79

Five minutes to ten minutes after practice. The t value of the data obtained on body temperature from five minutes after to ten minutes after practice was not statistically significant at the .01 level. Tests three and four were significant at the .05 level. The null hypothesis was not rejected. (Table XII)

TABLE XII

SUMMARY OF t COMPARISON FOR FIVE MINUTES AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean temperature		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	0.7	1.3	0.6	0.24	2.50
2	1.3	1.2	0.1	0.25	0.40
3	0.6	0.9	0.3	0.10	3.00*
4	1.4	0.8	0.6	0.15	4.00*
5	1.1	1.0	0.1	0.25	0.40
6	1.4	0.9	0.5	0.26	1.92

*Statistical significance at five percent level of significance.

X. HEART RATE

Pre-test to immediately after practice. The data obtained on heart rate indicated that the t value from pre-test to immediately after practice was not statistically significant at the .01 level. Tests one and three were significant at the .05 level. The null hypothesis was not rejected. (Table XIII)

TABLE XIII

SUMMARY OF t COMPARISON FOR PRE-TEST TO IMMEDIATELY AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	19.5	28.3	8.8	2.50	3.52*
2	24.3	27.7	3.4	3.53	0.96
3	22.3	30.5	8.2	2.54	3.23*
4	26.8	26.8	0.0	4.05	0.00
5	23.8	27.3	3.5	3.07	1.14
6	24.8	28.8	4.0	3.10	1.29

*Statistical significance at five percent level of significance.

Pre-test to five minutes after practice. The t value on the data collected on heart rate from pre-test to five minutes after practice was not statistically significant at the .01 level, except for test one, which was significant. Tests one, two, and five were significant at the .05 level. The null hypothesis was not rejected. (Table XIV)

TABLE XIV

SUMMARY OF t COMPARISON FOR PRE-TEST TO FIVE MINUTES AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	11.5	18.5	7.0	1.19	5.88**
2	13.2	19.0	5.8	2.04	2.84*
3	15.7	17.8	2.1	2.23	0.94
4	14.0	17.0	3.0	2.94	1.02
5	13.0	16.7	3.7	1.12	3.30*
6	16.5	19.5	3.0	3.31	0.91

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

Pre-test to ten minutes after practice. The t value on the data obtained on heart rate from pre-test to ten minutes after practice was statistically significant at the .01 level for tests two and six. All the tests were significant at the .05 level except test four. The null hypothesis was not rejected. (Table XV)

TABLE XV

SUMMARY OF t COMPARISON FOR PRE-TEST TO TEN MINUTES AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	9.5	12.8	3.3	0.89	3.71*
2	10.7	15.0	4.3	1.06	4.06**
3	10.0	13.7	3.7	1.29	2.87*
4	10.8	12.8	2.0	1.39	1.44
5	9.8	13.3	3.5	1.18	2.97*
6	8.8	15.0	6.2	1.25	4.96**

*Statistical significance at five percent level of significance.

**Statistical significance at one percent level of significance.

Immediately after practice to five minutes after practice.

There was no statistical significance from immediately after practice to five minutes after practice on heart rate at the .01 level. Therefore, the null hypothesis was not rejected. (Table XVI)

TABLE XVI

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO FIVE MINUTES AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	8.2	9.8	1.6	1.67	0.96
2	11.7	8.7	3.0	1.78	1.69
3	8.3	12.7	4.4	2.54	1.73
4	12.8	9.8	3.0	2.15	1.40
5	10.8	10.7	0.1	2.22	0.05
6	11.2	9.3	1.9	0.80	2.38

Immediately after practice to ten minutes after practice.

Heart rate from immediately after practice to ten minutes after practice was not statistically significant at the .01 level as indicated by the t value on the data collected. The null hypothesis was not rejected. (Table XVII)

TABLE XVII

SUMMARY OF t COMPARISON FOR IMMEDIATELY AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	10.0	13.5	3.5	1.74	2.01
2	14.2	12.7	1.5	2.40	0.63
3	12.3	17.0	4.7	2.42	1.94
4	13.7	12.7	1.0	1.64	0.61
5	15.7	14.0	1.7	2.40	0.71
6	16.0	13.8	2.2	2.02	1.09

Five minutes to ten minutes after practice. The t value on the data obtained on heart rate from five minutes after practice to ten minutes after practice was not statistically significant at the .01 level. Test one was significant at the .05 level. Therefore the null hypothesis was not rejected. (Table XVIII)

TABLE XVIII

SUMMARY OF t COMPARISON FOR FIVE MINUTES AFTER PRACTICE TO TEN MINUTES AFTER PRACTICE

Test	Mean heart rate		$\bar{d}$	$s_{\bar{d}}$	t
	Experimental	Control			
1	2.0	5.0	3.0	0.86	3.49*
2	2.5	4.0	1.5	1.37	1.09
3	4.0	4.3	0.3	1.31	0.23
4	3.5	4.5	1.0	1.24	0.81
5	3.2	3.3	0.1	1.28	0.08
6	4.8	4.5	0.3	1.50	0.22

*Statistical significance at five percent level of significance.

XI. SUMMARY OF FINDINGS

The findings of this study showed that the use of a cold water application (34° - 40°F.) was statistically significant at the .01 level for surface temperature on the ball of the foot, the arch of the foot, and the heel of the foot immediately after practice to five minutes after practice and from five minutes after practice to ten minutes after practice. Surface temperature of the experimental group decreased and increased during the ten-minute recovery period, but the control group decreased during the ten-minute recovery period. Surface temperature of the experimental group was still cooler after the ten-minute recovery period when compared with that of the control group.

A statistically significant difference was not found in any other application of the cold water bath (34° - 40°F.) as compared to the control group employing a rest period in this investigation.

XII. DISCUSSION OF FINDINGS

The statistically significant difference, as found between the cold water application (34° to 40°F.) and rest period on surface temperature, indicated the results that would be expected. Similar results have been reported in literature using a cold water application.

Although no statistical significance for body temperature and heart rate was noted, the subjects using the cold water application

(34° - 40°F.) had lower readings than those in the control group using the rest period.

The subjects were not questioned but stated that they felt better during practice and more refreshed after practice with the use of the cold water application of 34° to 40°F.

CHAPTER V

SUMMARY

I. PROBLEM

The purpose of this study was to determine whether surface temperature of the feet, body temperature, and heart rate are affected by immersing the subjects' feet in a cold water bath of 34° - 40° Fahrenheit before and after basketball practice sessions.

II. DATA

Subjects who participated in this study were members of the freshman basketball team at South Dakota State University during the 1967-1968 school year. The subjects were divided into pairs according to playing position and the results of a pre-test on heart rate. Each pair was randomly divided into an experimental and a control group.

The participants were tested six times over a period of four weeks and four days before practice, immediately after practice, five minutes after practice, and ten minutes after practice. The tests employed measured changes in heart rate, body temperature, and surface temperature of the feet.

Data obtained during the testing period were analyzed by employing the paired t comparison.

III. FINDINGS

The use of a cold water application of 34° - 40°F. on the surface temperature of the feet was statistically significant at the .01 level from immediately after practice to five minutes after practice and from five minutes after practice to ten minutes after practice. There was no statistical significance for surface temperature from immediately after practice to ten minutes after practice. Surface temperature of the experimental group decreased and increased during the ten-minute recovery period, but the control group decreased throughout this same period. Surface temperature of the experimental group was still cooler after the ten-minute recovery period when compared with the temperature of the control group.

A statistically significant difference was not found in any other application of the cold water bath as compared to the control group employing a rest period in this investigation.

IV. CONCLUSIONS

From the findings of this investigation, the following conclusions were drawn:

That a cold water application of 34° - 40°F. decrease surface temperature significantly during a short recovery period.

That body temperature and heart rate measures are lower with the use of the cold water application than that of a rest period, but not significantly.

V. RECOMMENDATIONS FOR FURTHER STUDY

Based on the information obtained in this study, the investigator would make the following recommendations for further study:

1. That a similar study be conducted over the entire basketball season, including all practice sessions.
2. That a similar study be conducted by immersing the feet in a cold water bath of 34° - 40°F. for a longer period of time ranging from two to three minutes.
3. That a similar study be conducted whereby the subjects alternate the use of the cold water application one day and the rest period on the following day.

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APPENDIXES

APPENDIX A

Raw Data: Mean Heart Rate for Pilot Study

Subjects	Pre-test	Immediately after practice	Five minutes after practice	Ten minute practices
1	39.5	60.0	55.0	53.0
2	44.0	63.5	56.5	55.0
3	37.0	57.0	51.2	47.0
4	35.0	52.5	45.1	43.5
5	40.0	55.5	50.5	48.5
6	36.5	53.5	49.0	46.5
7	36.5	54.5	51.5	48.5
8	35.5	53.0	50.0	49.5
9	35.0	56.0	48.5	44.5
10	32.0	53.5	48.5	45.5
11	41.0	61.0	52.5	47.5
12	39.0	53.5	50.0	46.5

Recording Card

NAME _____ DATE _____ NO. OF TIMES TESTED _____

SURFACE TEMPERATURE

	Ball	Arch	Heel	Body Temp.	30 Seconds heart rate
Pre-test	___	___	___	_____	_____
Immediately after	___	___	___	_____	_____
Five minutes	___	___	___	_____	_____
Ten minutes	___	___	___	_____	_____

APPENDIX B

Raw Data for Pair 1

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
84.0	83.5	82.0	97.0	42	84.0	84.5	79.5	96.1	41
94.0	95.5	94.2	98.4	57	95.0	96.7	93.7	96.6	67
77.5	73.5	74.0	98.5	52	88.5	94.5	87.3	97.2	60
91.2	93.2	93.5	99.2	50	94.4	93.0	91.6	98.4	53
				Test 2					
81.6	86.0	82.5	96.4	38	82.8	84.5	79.6	96.0	39
92.5	95.2	95.0	96.0	59	97.2	96.8	92.7	96.0	68
89.2	87.5	90.0	97.8	50	94.3	95.5	93.3	96.6	58
91.8	94.2	93.9	99.0	49	93.7	95.3	93.3	98.6	55
				Test 3					
82.0	80.6	70.0	98.0	44	83.5	84.7	75.0	96.0	42
89.8	92.8	90.0	97.2	70	95.2	95.0	92.0	96.4	78
82.0	77.9	78.9	98.1	56	91.0	92.8	90.0	97.6	60
92.0	92.0	90.3	98.6	52	91.8	91.5	90.5	98.6	56

APPENDIX B

Raw Data for Pair 1 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
87.0	86.6	88.3	97.4	40	82.2	83.6	74.8	96.0	44
93.6	95.3	94.7	96.4	72	94.0	95.0	90.1	96.0	80
89.3	90.1	90.0	97.8	53	93.7	94.0	92.0	97.0	64
94.0	95.2	94.2	98.5	50	94.0	94.0	92.5	98.2	60
				Test 5					
87.2	83.8	76.0	97.7	38	83.2	84.5	75.5	97.1	36
92.5	95.5	90.5	96.0	56	91.5	93.4	90.0	96.0	64
86.2	85.6	88.1	98.2	51	91.2	93.0	91.0	97.6	53
91.0	93.2	93.8	99.2	50	93.1	93.5	92.2	98.8	52
				Test 6					
91.2	90.5	90.0	97.8	40	87.0	88.3	83.5	98.3	36
95.8	95.0	95.5	96.2	72	96.5	97.0	93.3	96.6	76
89.5	90.8	89.5	98.6	55	94.2	95.0	93.3	98.1	60
93.0	95.2	95.5	99.7	51	94.5	94.1	94.1	99.3	57

APPENDIX C

Raw Data for Pair 2

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
77.5	81.0	77.5	96.0	37	80.0	84.5	79.5	96.1	41
93.2	94.5	93.6	96.0	57	95.0	96.2	93.7	96.6	67
88.0	85.5	82.4	98.3	51	94.7	91.5	87.3	97.2	60
91.6	91.3	89.5	98.2	49	94.4	93.0	91.6	98.4	53
				Test 2					
80.2	84.2	80.0	96.0	35	81.8	83.2	82.2	97.1	36
92.2	94.2	92.1	96.0	57	93.5	95.0	92.4	96.0	62
87.3	80.2	82.1	97.4	45	93.4	95.5	93.1	98.6	56
93.0	94.0	92.0	98.2	43	94.0	95.1	94.5	99.2	48
				Test 3					
82.3	82.6	77.2	97.0	39	80.5	82.0	80.5	96.4	39
93.5	95.6	94.2	96.0	56	96.2	97.0	95.5	96.4	68
92.0	86.7	82.3	97.8	52	96.8	97.5	97.0	98.8	49
94.8	95.3	93.2	98.3	49	95.8	96.2	95.5	99.7	48

APPENDIX C

Raw Data for Pair 2 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
80.2	87.4	83.6	97.4	39	85.8	86.4	82.5	98.2	39
92.8	96.3	93.6	96.4	56	95.0	96.3	94.8	96.0	65
93.0	94.5	94.2	98.6	48	87.5	84.8	82.5	96.4	53
93.3	94.4	94.9	99.3	46	92.5	91.6	90.5	97.8	50
				Test 5					
85.5	86.2	79.5	97.6	35	84.3	86.6	86.0	96.0	37
94.2	95.5	94.2	96.4	58	93.8	96.0	94.5	96.0	66
93.5	95.0	94.5	98.5	51	86.0	82.5	75.2	96.1	50
93.0	94.5	93.7	99.4	50	93.5	90.2	85.5	97.4	48
				Test 6					
84.4	86.4	80.0	97.0	40	86.0	86.4	83.5	97.9	38
93.8	95.1	93.4	96.0	59	94.8	94.5	93.5	96.4	60
86.0	81.8	79.0	97.7	51	94.5	93.5	93.0	98.6	52
93.0	92.1	91.5	98.3	45	94.0	95.5	94.2	99.5	48

APPENDIX D

Raw Data for Pair 3

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
82.5	83.0	77.0	96.0	37	85.6	87.3	82.7	96.1	35
96.0	96.5	93.8	96.0	66	95.0	95.4	94.0	96.0	63
79.5	76.8	77.5	96.0	53	94.0	94.6	92.3	96.8	56
90.8	78.8	85.5	97.3	52	95.0	94.0	93.0	98.2	53
				Test 2					
84.6	85.5	80.2	97.4	39	84.8	85.9	80.9	96.0	34
96.2	97.6	96.0	96.0	69	95.4	96.1	94.8	96.0	69
82.8	80.7	77.6	96.0	52	94.4	96.0	94.5	96.8	53
90.2	90.8	85.0	97.9	50	95.8	96.0	93.7	97.6	49
				Test 3					
83.2	85.0	79.8	98.0	43	77.3	81.6	74.0	96.0	33
94.8	95.1	93.5	96.0	69	92.0	95.5	91.0	96.0	69
78.5	80.2	72.8	97.4	61	93.4	94.1	92.0	97.4	55
88.0	87.6	77.9	98.0	53	92.1	94.0	91.5	98.4	50

APPENDIX D

Raw Data for Pair 3 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
85.8	86.4	82.5	98.2	39	84.5	84.3	78.5	96.6	33
95.0	96.3	94.8	96.0	65	95.5	95.8	95.5	96.0	71
87.5	84.8	82.5	96.4	53	94.3	95.0	92.7	97.4	57
92.5	91.6	90.5	97.8	50	93.9	94.3	92.5	98.1	47
				Test 5					
84.3	86.6	86.0	96.0	37	83.2	85.2	78.2	96.6	38
93.8	96.0	94.5	96.0	66	95.7	96.5	94.0	96.0	65
86.0	82.5	75.2	96.1	50	93.8	94.5	92.0	97.1	53
93.5	90.2	85.5	97.4	48	94.0	94.2	90.0	98.0	50
				Test 6					
85.8	85.0	81.3	98.6	41	87.0	87.5	80.6	96.8	37
94.5	96.5	93.8	96.0	65	94.0	96.5	95.2	96.0	63
85.7	84.0	75.1	96.1	55	95.5	95.0	93.6	97.3	55
90.3	87.5	82.8	97.8	51	95.1	94.0	92.0	97.7	52

APPENDIX E

Raw Data for Pair 4

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
82.3	84.0	78.7	99.0	36	85.0	87.0	84.3	97.6	34
93.8	96.3	92.5	96.0	51	95.5	97.5	92.6	98.4	61
90.2	83.0	79.3	96.0	49	93.0	94.8	91.3	98.6	53
92.5	89.0	86.2	97.4	47	95.5	95.3	93.1	99.5	50
				Test 2					
80.0	80.5	73.8	99.0	36	80.6	84.2	82.0	96.9	32
95.2	96.4	93.5	96.0	51	96.9	96.6	94.7	97.7	57
90.9	82.0	79.3	96.0	47	93.4	95.2	90.1	98.4	51
93.0	92.8	86.2	97.4	46	93.4	95.0	93.2	99.5	50
				Test 3					
84.5	86.0	82.3	98.0	35	85.6	85.7	78.5	98.2	32
93.5	94.0	90.0	96.0	50	93.5	95.0	90.6	97.4	55
87.2	84.0	77.0	97.4	48	92.5	93.4	90.0	98.5	51
91.2	88.0	83.1	98.0	46	92.9	93.3	92.5	99.2	49

APPENDIX E

Raw Data for Pair 4 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
82.5	84.7	80.1	97.9	32	87.4	88.6	83.8	97.2	38
96.0	95.2	93.9	96.0	69	94.8	95.6	92.2	96.0	63
86.5	81.5	77.4	97.6	50	92.3	93.6	91.5	98.4	51
92.3	88.2	84.1	98.1	47	94.0	93.5	90.5	98.8	49
				Test 5					
87.0	88.2	84.5	98.6	35	89.0	89.6	85.6	96.9	34
95.5	95.5	93.8	96.0	61	97.5	98.0	94.0	97.2	69
89.5	81.2	79.6	96.6	47	95.8	96.6	92.0	98.3	53
95.5	92.5	90.8	98.4	45	96.2	96.5	91.0	99.2	49
				Test 6					
87.2	88.3	86.5	98.5	35	88.3	90.0	84.0	97.7	32
93.5	94.5	92.3	96.0	60	96.2	93.0	91.2	96.8	54
84.5	80.0	78.0	96.0	50	94.5	93.0	88.3	97.4	47
92.0	87.2	85.0	98.2	46	94.2	92.8	88.2	98.5	46

APPENDIX F

Raw Data for Pair 5

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
83.2	83.8	82.5	97.5	35	77.8	80.1	73.2	96.2	29
91.0	94.3	93.2	96.0	55	92.8	93.6	92.5	96.0	66
85.0	85.2	86.3	97.6	43	92.6	93.0	92.6	96.6	49
89.6	92.3	92.2	98.8	40	92.8	93.1	92.3	98.2	40
				Test 2					
77.6	82.8	77.3	97.2	33	86.5	87.0	80.1	97.2	27
95.2	97.4	96.0	96.0	63	94.5	96.2	95.2	96.0	60
89.5	84.4	86.3	97.5	50	93.7	95.1	95.3	97.2	52
91.6	92.6	93.6	98.6	47	96.1	96.4	95.5	98.7	46
				Test 3					
73.8	79.0	73.0	96.8	37	83.3	85.0	77.5	97.4	27
93.5	95.0	93.3	96.0	63	92.6	93.5	89.0	96.0	66
88.5	81.1	84.1	97.2	54	92.0	92.5	89.1	96.0	54
91.5	91.5	92.0	98.2	50	91.5	92.3	87.4	97.2	43

APPENDIX F

Raw Data for Pair 5 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
80.5	83.7	82.5	96.8	36	82.6	84.5	78.4	96.0	27
92.5	95.3	95.3	96.0	60	92.5	93.5	92.2	96.0	59
88.1	84.8	86.5	97.0	49	92.0	91.5	91.7	96.0	51
89.7	91.5	90.8	98.2	47	92.5	92.0	91.0	96.8	49
				Test 5					
78.8	82.0	75.5	96.4	36	84.5	87.5	80.0	96.5	27
96.0	96.3	94.5	96.0	63	93.4	95.0	92.0	96.0	65
89.5	83.2	85.7	96.5	52	92.5	92.8	89.0	97.0	49
92.5	93.0	91.5	97.8	48	93.5	92.9	89.5	97.8	43
				Test 6					
82.1	84.8	80.0	96.8	36	86.8	87.1	83.0	96.0	26
95.5	96.0	94.0	96.0	59	93.5	95.3	92.8	96.0	66
87.5	81.5	80.7	97.4	47	91.5	93.0	89.0	96.8	54
93.5	92.0	92.5	98.4	45	92.1	92.0	88.3	97.4	45

APPENDIX G

Raw Data for Pair 6

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 1					
85.5	87.1	83.4	96.0	42	84.8	85.0	81.6	96.8	35
94.2	95.0	92.0	96.0	60	94.0	94.7	92.8	96.0	61
81.2	80.6	80.7	96.2	50	93.5	94.2	93.5	97.6	48
89.9	85.8	83.6	96.8	48	93.6	93.6	92.0	99.0	43
				Test 2					
84.1	85.2	77.6	96.0	39	86.9	87.2	83.2	97.7	37
95.6	96.3	92.8	96.0	70	92.6	94.0	91.4	96.0	55
84.4	81.7	76.8	96.1	55	91.5	93.8	93.6	97.3	49
93.3	89.1	80.9	97.2	49	93.2	94.0	93.6	98.4	47
				Test 3					
87.8	87.9	81.7	96.0	39	89.1	87.9	85.8	97.6	37
94.1	94.9	91.2	96.0	63	92.3	93.8	92.2	96.0	57
83.3	81.4	71.1	96.0	50	91.6	92.2	91.1	97.8	48
92.5	83.4	75.8	96.6	47	93.4	93.5	91.9	98.2	45

APPENDIX G

Raw Data for Pair 6 (continued)

EXPERIMENTAL					CONTROL				
Surface temperature			Body	Heart	Surface temperature			Body	Heart
Ball	Arch	Heel	temperature	rate	Ball	Arch	Heel	temperature	rate
				Test 4					
85.5	86.8	80.5	96.0	40	85.4	85.5	82.0	97.8	41
95.0	94.2	93.0	96.0	64	91.4	92.3	92.0	96.0	54
87.0	82.0	78.2	96.0	53	92.2	94.2	93.0	98.6	53
91.5	88.8	87.5	98.2	48	92.5	93.6	91.2	99.6	46
				Test 5					
87.7	87.0	82.5	96.0	40	89.4	88.5	86.6	98.6	44
95.0	94.8	93.2	96.0	60	93.0	93.5	92.8	96.0	57
89.5	83.3	80.2	97.1	50	93.5	94.0	94.3	98.6	55
94.0	92.5	91.8	97.4	47	95.8	95.5	95.7	99.6	50
				Test 6					
87.0	87.0	82.5	96.5	37	88.5	89.3	87.5	97.5	36
95.0	95.6	93.0	96.0	63	95.2	96.5	94.5	96.0	59
85.0	80.6	74.5	96.2	53	92.8	94.2	92.9	98.0	54
92.5	87.5	80.2	98.0	44	92.5	92.6	93.2	99.2	47