The Effects of Interval Training in Ambient Temperature Variations as Measured by Cardiovascular Endurance

Bernard Alexander Moore

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THE EFFECTS OF INTERVAL TRAINING IN AMBIENT TEMPERATURE VARIATIONS AS MEASURED BY CARDIOVASCULAR ENDURANCE

BY

BERNARD ALEXANDER MOORE

A thesis submitted in partial fulfillment of the requirements for the degree Master of Science, Major in Health, Physical Education, and Recreation South Dakota State University 1970
THE EFFECTS OF INTERVAL TRAINING IN AMBIENT TEMPERATURE VARIATIONS AS MEASURED BY CARDIOVASCULAR ENDURANCE

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

Head, Health, Physical Education and Recreation Department
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CHAPTER I

INTRODUCTION

Significance of the Study

The dedication and desire to excel of today's track athletes have brought forth an intensity of training so demanding that track participants must use almost every available day of the year for training purposes. Intensive training demands that the track athlete subject himself, at various times of the year, to very harsh environmental conditions. The role environmental conditions (altitude, cold, heat, and humidity) play in training is of great interest to athlete and coach alike.

Wilt points out that it has become necessary, in the past few years, for the track athlete who wants to excel to train the year around.¹ This necessity poses some problems in the northern part of the United States and Canada, where the winter season is very cold. The general procedure for training during this cold season has been to train indoors. Training indoors is appropriate for the athletes who attend a high school or college which has an adequate facility that is designed to provide effective training the year around. However, most high school and college track and field athletes are not exposed to adequate indoor facilities. It is recognized that some track and field athletes can train in a restricted indoor area.

The middle distance and distance runners, however, require more running area for proper indoor training. The only alternative for middle distance and distance runners to maintain a high level of conditioning during the winter months is to train outdoors in a cold environment. This would require training in an ambient temperature range of -40 to 30 degrees F during the winter months.\(^2\)

Studies recently completed have examined the effects different environments have on the results of training and performance. However, the chief concern of these studies was the effect of training and performance in a high ambient temperature range, 60 to 100 degrees F, and the effects of different humidity levels within this temperature range.\(^3,4\)

This investigator was curious about what effect cold ambient temperature had on conditioning using a selected training method, compared to the effect warm ambient temperature had on conditioning using the same training method.

**Statement of the Problem**

The purpose of this study was to investigate the effect of interval training in a warm environment and the effect of interval

\(^2\)Ibid.


\(^4\)Dennis Loiselle, "The Effects of Various Thermal Environments on Selected Physiological Variables" (unpublished Master of Science thesis, University of Alberta (Edmonton), Department of H.P.E.R., August, 1966).
training in a cold environment on cardiovascular endurance, and to compare the effects of interval training in the two environments.

Hypothesis

There will be no significant difference in the improvement of cardiovascular endurance in comparing interval training in a warm temperature environment to interval training in a cold temperature environment.

Delimitations

1. Only male freshman college students were used as subjects in this study.

2. No attempt was made to control the subjects' living habits during this study.

3. This study was restricted to Brookings, South Dakota, and conducted during the months of February and March, 1970.

4. This study involved only 20 sessions of training which were completed in five successive weeks.

Limitations

1. This study was subjected to the weather conditions of Brookings, South Dakota, during the months of February and March, 1970.

Definitions of Terms

1. Ambient temperature. Ambient temperature refers to the surrounding atmospheric Fahrenheit temperature.

2. Cold environment. Cold environment refers to the conditions existing in a circular building enclosing a 138-yard banked indoor,
dirt track with no heating facilities. Temperature ranged from -3 to 42 degrees F.

3. **Warm environment.** Warm environment refers to the conditions existing within a circular building, which encloses classrooms and a circular corridor 152 yards in length. The corridor's surface consists of a flat, hard, tile floor. The range of the warm environment was 76 to 79 degrees F.

4. **Interval training.** Interval training refers to a system of repeated efforts in which a distance of measured length is run on a track at a timed pace alternately with measured recovery periods of low activity.

5. **Conditioning.** Conditioning refers to a state of physical fitness or readiness for strenuous activity.

6. **Cardiovascular endurance.** Cardiovascular endurance refers to the ability of the cardiorespiratory system to supply oxygen to the active tissues for a prolonged period of time and was measured by the 600-yard run.5

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CHAPTER II

REVIEW OF RELATED STUDIES

A survey of literature concerning interval training, physiological effects of training, and effects of ambient temperature variations on training is presented in this chapter.

Interval Training

Nocker states that the use of such training methods as interval training is rational and intelligent and that specialized medicine has given a better idea of the adaptive possibilities of the organism, especially the heart. The principal qualities of this adaptation of the organism through training that are known at present are these: a) an increase in muscular strength through enlargement of the trained muscle, b) a profound improvement in the circulatory system through cardiac, vascular, and capillary action, c) an improvement in the resistance to (carbon) poisoning, d) a more rapid and complete response of the organism when demanded, e) greater economy during both exertion and repose, and f) a faster recovery after exertion. Nocker further states that it is not the effort itself, but the beginning of the recuperation phase which is the principal element. The reaction of adaption of the organism is directly related to the intensity of stimulation (degree or effort). The rhythm of the adaption is directly dependent on the number of times that the organism has been called upon for exertion. The adaptation of the musculature requires an intensity of work greater than the adaptation of the circulatory system. Nocker's most important point is that the duration
of this adaptation depends on the time that is devoted to its acquisition; it lasts just as long as the period during which it was developed.  

Nett in his examination of the effects of interval training points out the two primary kinds of muscles being emphasized, the skeletal and heart muscles. In order to improve the functions of these muscles, the skeletal muscle must receive a strong "stress stimulus," whereas the heart must undergo a powerful "expansion stimulus." The "stress stimulus" of the skeletal muscles will occur in the all-out running phase of interval training; the "expansion stimulus" required by the heart to improve its function will occur upon completion of the run, that is, at the beginning of the rest period, where-upon a very strong "expansion stimulus" is exerted upon the walls of the heart.

Doherty commenting on interval training states the following:

The efficiency of runners in terms of fatigue decreases to the fourth power as pace increases. That is, if we double the speed of running, the oxygen requirements of muscles increase eight times. It is easily understood then that, when practice time is limited doing speed work in practice produces fatigue much more quickly than slower pace running. Further, it has been observed that in slower pace running, men are more conscious of the feeling of fatigue and tend to slow their pace before becoming really tired physically.

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6Dr. Nocker, "Physiological Problems in Training for Track," Track Technique (June, 1962), p. 244.


Roskamm et al. concluded that the advantage of interval training lies in the saving of time and in the bonus of speed, strength, and local stamina improvement derived from it.  

Gerschler in describing the components of interval training includes the following: a) the length of the distance, b) the chosen speed, c) the duration of the recovery interval, d) the number of repetitions. Gerschler points out the advantages of interval training: 1) it lasts for a shorter time; 2) it imposes more powerful stimulus on the musculature; 3) it enables to define in a more precise way the intensity of stimulus and the duration of the effort.

The Gerschler-Reindel Law governing interval training as stated by Sprecher points out the following three primary concepts:

1. Bring the heart to 120 beats per minute by a preliminary warm-up - not only by running on the track but also by exercise of all kinds in order to begin the workout effectively.
2. From this point, the runner does a given distance - 100, 150, or 200 meters in a given time which will bring the heart up to about 170 - 180 beats per minute.
3. Soon afterward, the heart ought to take a maximum of 1 minute, 30 seconds to return to about 120 beats per minute. This time could be shortened however, but what is important is the return of the heart to 120 - 125 beats per minute. When this occurs the runner should begin running again.

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9Dr. H. Roskamm, Professor Dr. H. Reindell, Dr. J. Keul (West Germany), "Physiological Fundamentals of Training Methods," Run, Run, Run, ed. Fred Wilt (California: Track and Field News, 1968), p. 196.

10Dr. Woldemar Gerschler, "Interval Training," Track Technique (September, 1963), p. 393.

Sprecher later states that Dr. Gerschler emphasized that it is the recovery phase that strengthens the heart, that is, during the time the pulse is returning from 180 to 120 beats a minute.  

Denevan's study shows that the method of known recovery, that is, three-minute rest period between bouts of hard running, and the method of unknown recovery, that is, when the subject jogs or walks until heart beat drops to range of 110 - 130 beats per minute in interval training both significantly improved cardio-respiratory efficiency of the subjects. But, the study shows that the unknown recovery period for improving cardio-respiratory efficiency, seemed superior to the known three-minute test period of recovery for the heart after exercise.  

Hamak's study shows that the fact that interval training significantly improved oxygen debt repaid indicates improvement in circulorespiratory efficiency.  

Almond in his summary of the physiological basis for interval training suggests that short work periods of not more than 30 seconds, during which the heart rate should be sustained above 140 beats per minute and followed by a recovery of not longer than 90 seconds, should

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12 Ibid.  
produce maximal training effects.  

Summary of Interval Training

The review of related literature indicates agreement that interval training is based on sound physiological principles and that it is a valid means of improving the condition of an athlete. However, the literature did point out that to get the best benefit from this type of training, which is mostly anaerobic, it should be preceded by early training of mostly an aerobic nature, long distance running. The literature also pointed out that interval training improves strength, speed, and endurance, but that the length of retention of this improvement is directly related to the amount of time it took to acquire this improvement. It further indicated that interval training is heart training— that is, it is the recovery phase which strengthens the heart, and this recovery phase is described as the "interval." With interval training, there is an association of intense effort, to bring the heart beats per minute to about 180, followed by a recovery period of about 1 minute, 30 seconds, which will lower the heart beats per minute to about 115. From the literature, interval training was shown to be advantageous because it saves time, imposes a powerful stimulus on the musculature, and improves strength, sprinting ability, and endurance.

Physiological Effects of Training

Doherty comments on the fundamentals of training for distance running in the following way:

Running, gradually increased over a period of months in distance, speed, and intensity, is invigorating, mentally wholesome, and organically sound activity that will continue to build up the healthy boy and in no sense tear him down.¹⁶

Lydiard and Gilmour feel that the limit of an athlete's performance depends upon his ability to breathe in, transport and utilize oxygen, and to withstand an oxygen debt. The higher the level of the oxygen "steady state," the greater the work that can be done aerobically. Therefore, according to these two authors, when training an athlete, one should do a great amount of work in an aerobic state in early season which will develop an efficient minute and stroke volume of the heart of the athlete, and he, in turn, will be able to handle more and faster speed training later.¹⁷

Lydiard and Gilmour further state that, when in training speed is increased above the "steady state," one should begin exercising in an anaerobic state. The oxygen debt doubles, squares, and cubes as speed is increased; lactic acid and other waste products are developed in the muscles; and this accumulation, in turn, upsets the neuro-muscular co-ordination. If this type of hard training is continued excessively, the athlete with a low "steady state" quickly develops and retains a low or acid blood pH. This change upsets the nutritive


system as vitamins and enzymes will not function properly in an acid state. The recovery rate is thus retarded, further limiting the athlete's ability to do hard, fast work-outs.\textsuperscript{18}

Gordon's statements regarding training the middle-distance runner reflect the attitude of most coaches in North America today. He comments that year-round training, with cross-country running in the fall, is a consistent pattern of training for the successful "440 and 880" runner. He goes on further to state that although the 440-yard dash is essentially a sprint race, speed should not be emphasized in training at the expense of endurance. And commenting on training for the 880-yard runner, he states that a combination of training designed to develop endurance, knowledge of pace, and sprinting ability should be used.\textsuperscript{19}

Cooper in describing the "training effect" explains the physiological responses to training by describing what happens to certain body systems. But he states first that the rock-bottom basis of conditioning is getting oxygen to the body tissues. Cooper states that the training effect makes a person's lungs more efficient organs to process more air and extract more of the essential oxygen. The training effect produces more blood, specifically more hemoglobin which carries the oxygen, more red-blood cells which carry the hemoglobin, more blood plasma which carries the red-blood cells, and consequently more total blood volume. The training effect does four things for

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\end{itemize}

\textsuperscript{18}Ibid.

\textsuperscript{19}James A. Gordon, \textit{Track and Field} (Boston, Massachusetts: Allan and Bacon Inc., 1966), pp. 51-58.
the blood vessels: enlarges them, makes them more pliable to pressure, increases their number for saturation coverage, and helps keep their linings clear of corrosive materials for speedier routes. Training affects the muscular system by improving the muscle tone of the whole body. Training conditions the heart to reduce its maximum rate and also to strengthen it so that it can hold near-maximum rates for longer periods before fatigue sets in. Conditioning relaxes the body, sleep comes easier, and one gets more benefit from it in a shorter time.20

Faulkner's study of appropriate physiological data on athletes and animals was used to evaluate current training practices and to suggest new perspectives for training the athlete. A review of the three theories of training which provide the fundamental basis of today's training follows: a) overload—in order for skeletal muscle cells to increase in size or function ability, they must be taxed to the limit of their present ability to respond; b) specificity—training is specific to the cells and to the specific structural and functional elements within a cell that are overloaded; hence transfer of training occurs only to the extent that the same muscle fibers are recruited and used in a similar manner; c) reversibility—the effects of training are transient; that is, exercise results in immediate changes in the relative amount of various constituents in different muscle compartments and in the activity of enzyme systems. This increase of the skeletal muscle cells immediately requires respiratory

and circulatory adjustments. Faulkner states, "An important theoretical concept is that training occurs at the cellular level." 21

As a result of his investigation, Faulkner showed that blood lactate concentration increases as exercises intensify or increase in duration, reaching a peak at the end of exercise, and that the concentration drops slowly during the recovery phase. The oxygen uptake during exercise is a measure of the aerobic metabolism; (during the first few minutes of adjustment to exercise, the oxygen uptake gradually increases to meet the increased metabolic demands of the contracting skeletal muscle fibers). Anaerobic metabolism may be estimated from the raised metabolism after exercise. The difference between the resting baseline and the raised metabolism after exercise is termed "oxygen debt." There is a slight rise again after exercise which can be explained by the fact that the body replenishment of energy stores to normal resting levels. 22

Faulkner's study further points out the three stimuli required for training of muscle fibers: strength training stimulus, speed training stimulus, and endurance training stimulus; and also the three stimuli required for training the transport system: respiratory training stimulus, cardiovascular training stimulus, and sweat training stimulus. Faulkner makes the following statement concerning a


22 Ibid., p. 119.
"diagnostic approach" to training:

A quantitative diagnostic approach to the training of athletes, in keeping with the hypotheses of overload, specificity, and reversibility and with an awareness of the mechanisms of training at the cellular level, could make athletics more rewarding for the participant and more intellectually challenging for the coach.23

Summary of the Physiological Effects of Training

The literature reviewed dealing with physiological aspects of training showed that the limit of an athlete's performance depends on his ability to breathe in, transport and utilize oxygen, and to withstand an oxygen debt. It was also shown that training improves the efficiency of the lungs, produces more total blood volume, enlarges the blood vessels, makes them more pliable to pressure, increases their number for saturation coverage, and keeps their linings free of corrosive materials. Also training improves the muscle tone of the whole body as well as conditioning the heart to reduce its maximum rate and to strengthen it to hold near-maximum rates for longer periods of time. That training occurs on the cellular level is of primary importance. Faulkner's summary of the physiological aspects of training brings out key concepts:

A quantitative diagnostic approach to the training of athletes, in keeping with the hypotheses of overload, specificity, and reversibility and with an awareness of the mechanisms of training at the cellular level, could make athletics more rewarding for the participant and more intellectually challenging for the coach.24

23 Ibid., p. 122.
24 Ibid.
Effects of Thermal Variations on Training

Lydiard, commenting on training in unfit weather, feels that the weather is no excuse for the runner to miss training; however, common sense would prevent a runner from training in all weathers, such as, a heat wave or snowstorm. Lydiard does feel that training in all weathers strengthens resistance to disease.\(^{25}\)

Bernauer concluded from his study that the thermal environment has a limited effect upon the duration of muscular endurance performance exhibiting an optimum between 60 and 70 degrees F, which corresponds with the zone of vasomotor control. Thermal regulation was least stressed within this zone, and a minimum amount of energy was expended by the organism to maintain body temperature.\(^{26}\)

Dawson et al. conducted a study to examine cardiac output in the cold-stressed swimming rat. The rats were forced to swim in various temperatures: 2, 16, 22, and 37 degrees C. It was observed that the rats could swim approximately 5, 11, 18, and the full 30 minutes, respectively. It was observed that the onset of exhaustion hastened with a drop in environmental temperature, when the core temperature of the body dropped below thermoneutrality. The study showed that cardiac output depended on the body temperature and that

\(^{25}\)Lydiard, op. cit., p. 50.

as the body temperature dropped, so did cardiac output.27

Bannister and Cotes in their study were concerned with the effect changes in ambient temperature in the range of 15 - 25 degrees C, had on performing a very strenuous exercise or participating in a major athletic contest. The investigators concluded that variations in ambient temperature within the normal range can affect athletic performance in subjects with a normal body temperature response to exercise.28

Wilson states that under the cold conditions of his investigation of a five-week period of increased physical activity, there was a significant increase of 20 percent in the Basal Metabolic Rates of his subjects.29

Costill points out that one of the most deceiving indications of heat stress from the environment is the air temperature. A temperature of 60 degrees F can be just as deadly as 90 degrees F if the humidity of the first condition is 95 - 100 percent.30

Wilber found high blood lactate concentrations in guinea pigs
forced to swim to exhaustion in water of 15 or 25 degrees C, as compared to those which swam in water 39 degrees C. Wilber found that swimming time to exhaustion was not increased by increasing the oxygen pressure. If the high lactate reported after swimming in cold water was involved in limiting performance, a circulatory rather than a respiratory insufficiency might be indicated.31

Yank and Lissak reported high blood lactate concentrations in rats which swam to exhaustion in water of 18 and 24 degrees C as compared to those which swam to exhaustion in water near thermoneutrality. They attributed this failure of the animals in cold water to disturbance in the oxidative processes, one of which may be oxygen transport via the circulatory system.32

Astrand et al. indicate that a large lactate concentration exceeding 100mg/100ml is a common finding after maximal muscular exercise involving large muscles.33

Nettinger and his associates conducted studies which show that trainability is affected by the month of the year. The lowest trainability was observed during December, January, and February--the winter months--with a slight increase as spring approached. The

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highest trainability occurred during the summer and autumn months, with a sharp drop in trainability evident, as winter set in. Large amounts of vitamin C and D did not significantly affect trainability. Hettinger commented that upon further search through literature, it was revealed that ultra violet light increases physical fitness. Hettinger explained trainability as "the speed in increase of strength during a training session."\textsuperscript{34}

Bolotnikov and Travin comment favorably on training in the winter time by citing the advantages of training on snow. They also point out that the work done under the winter conditions should be over-strenuous and exhaustive and that by observing basic rules of hygiene, such as warm clothing to keep warm yet retain freedom of movement, one can train outdoors effectively in cold and snow throughout the entire winter.\textsuperscript{35}

\textbf{Summary of the Effects of Thermal Variations on Training}

From the review of literature on the effects of thermal variations on training, there are indications that there is a difference that could be expected in training at different thermal conditions, as was found in training at different altitudes. The literature, however, points out only possible reasons, such as rise in basal metabolic rate because of cold, increase in blood lactate concentration, and lowering of cardiac output as core temperature

\textsuperscript{34}Theodore Hettinger, \textit{Physiology of Strength} (Springfield, Illinois: Charles C. Thomas, 1961), pp. 41-44.

drops. The literature is in partial agreement that athletes could train in cold environments without harmful effects, but it does not suggest that such training is advantageous over training in a warm environment. However, the literature reviewed did point out that certain physiological adjustments by the body upon exposure to cold were similar to physiological adjustments by the body upon severely strenuous physical activity. From the review of literature many questions seemed unanswered in the area of environmental research covering training in cold weather as compared to training in warm weather.

36 Yang and Lissak, loc. cit.
37 Astrand et al., loc. cit.
CHAPTER III

PROCEDURE FOR OBTAINING DATA

The purpose of this investigation was to investigate the effect of interval training in a warm environment to the effect of interval training in a cold environment on cardiovascular endurance.

The subjects, the training program, the tests, and instruments used for obtaining data, are described in this chapter.

Source of Data

Twenty-four volunteer subjects were selected from male students enrolled in the basic instruction program at South Dakota State University during spring semester, 1970. The subjects were pre-tested by the 600-yard run, a cardiovascular endurance test. All twenty-four subjects ran the 600-yard run in both a cold and a warm environment. A mean score of both runs was determined for each subject. All subjects' mean scores were placed in rank order, and the subjects were divided into three equated groups, with eight subjects in each group. The three groups--experimental group "C," experimental group "W," and control group "C₁,"--were assigned designation randomly by the track pill box method.

Organization of the Study

Subjects in the experimental group, who were to train in a

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cold environment were referred to as Group C (Figure 1). Those subjects in the experimental group who were to train in a warm environment were referred to as Group W (Figure 2). The third group of subjects acted as a control and did not participate in the training program, but continued in a regular physical education basic instruction course. The control group was referred to as Group C<sub>1</sub>.

The subjects were asked to refrain from any other running or strength-building program during the months involved in the study. The participation by the subjects in extra-curricular activities, such as intramurals, was not discouraged, but they were asked not to change their present living habits.

Subjects in Group C (cold) were instructed to wear track sweat suits, furnished by the Health, Physical Education, and Recreation Department, South Dakota State University, in addition to their basic instruction program uniform. Subjects in Group W (warm) were instructed to wear their basic instruction program uniform. Both experimental groups were instructed to wear sneakers, or training shoes, but no spikes.

Subjects were tested on four occasions by running the 600-yard run. Times were recorded to the nearest tenth of a second. Two pre-tests before the interval training program and two post-tests at the completion of the training program were administered identically. Each subject within all groups was pre-tested in both the cold and warm environments. For the post-test, all subjects were tested in the same order as in the pre-tests. The training program lasted five weeks, beginning on February 10, 1970, and ending March 17, 1970. An
Figure 1. Cold Environment Training

Figure 2. Warm Environment Training
informal warm-up was employed prior to both the pre-tests and the post-tests.

The following instructions were given to all subjects before both the pre-tests and the post-tests:

1. All subjects will jog 3 laps, followed immediately by stretching exercises of your own choice for approximately three minutes; then take one lap at a fast pace.

2. All subjects will take a two-lap walk-jog warm-down upon completion of their timed 600-yard run. Do your warm-down on the extreme outside edge of the running area.

3. All subjects will take the 600-yard test in their gym outfit. No sweat clothes are to be worn by any subject during the test. Sweat clothes or warm outer clothes should be worn for the warm-up and warm-down.

4. This is a maximum test. Try to cover the 600 yards in as short a time as possible. You will be told how many laps you have remaining as you are completing the 600-yard run. Run through the tape.

Training Program

Upon consideration of the facilities to be used in this study and after a review of literature concerning interval training, and consultation with the head track coach, South Dakota State University and the investigator's thesis adviser, and the investigator's past experience as a track athlete and track coach, the following progressive interval training program was devised and administered to both
experimental groups in an identical manner.

It should be noted that the progressive interval training program that follows was based on the Gerschler-Reindel Law governing interval training as reported by Sprecher.\(^{39}\) Also the four components of interval training as employed by Gerschler were adjusted throughout the training program in order to facilitate an improvement in the subject's level of conditioning.\(^{40}\) The subject's adjustment and subsequent progression through the interval training program were gauged by taking heart rate checks of each of the subjects throughout the twenty training sessions. Heart-rate checks were taken upon immediate completion of a work bout and within the last 20 seconds of the recovery period. Heart beats per minute were determined for each subject by having each subject count heart beats for 10 seconds, by placing the fingers of his right hand over the carotid artery, left side of his neck, and counting the number of beats. This figure was multiplied by 6 to give the subject's heart rate per minute.

The first level of the progressive interval training program for Group C and W consisted of four training sessions.

1. All subjects jogged 880 yards, followed by 3 to 5 minutes of stretching, which served as a routine warm-up which was repeated for all 20 training sessions. The subjects then ran 150 yards in 25 seconds, followed by a recovery


\(^{40}\) Dr. Woldemar Gerschler, "Interval Training," Track Technique (September, 1963), p. 393.
period of walking for 1 minute, 45 seconds. Subjects repeated the 150-yard run in 25 seconds 8 times followed by recovery periods of 1 minute and 45 seconds. Upon completion of the eight work bouts, the subjects jogged 880 yards for a warm-down, which served as a routine warm-down.

2. All subjects performed the routine warm-up. Subjects then ran 150 yards in 25 seconds followed by a recovery period of 1 minute, 45 seconds after the first five work bouts, and a recovery period of 2 minutes after the next five work bouts. Subjects repeated the 150-yard run in 25 seconds 10 times. The subjects then performed the routine warm-down.

3. All subjects performed the routine warm-up. Subjects then ran 150 yards in 25 seconds followed by a recovery period of walking for 1 minute, 45 seconds. This procedure was repeated 10 times. Subjects then performed the routine warm-down.

4. All subjects performed the routine warm-up. Subjects then ran 150 yards in 24 seconds followed by a recovery period of walking for 2 minutes. This procedure was repeated 10 times. The subjects then jogged 880 yards for the routine warm-down.

The second level of the progressive interval training program consisted of four training sessions.

1. All subjects performed the routine warm-up. Subjects then ran 300 yards in 55 seconds followed by a recovery period
of walking after the first and second 300-yard run of 2 minutes, 30 seconds, and a recovery period of 3 minutes after the third, fourth, and fifth 300-yard run. Subjects repeated the 300-yard run in 55 seconds 6 times. The subjects then performed the routine warm-down.

2. All subjects performed the routine warm-up. Subjects then ran 300 yards in 55 seconds followed by a recovery period of walking for 2 minutes, 30 seconds after the first five 300-yard runs and a recovery period of 3 minutes after the sixth and seventh 300-yard run. The subjects repeated the 300-yard run in 55 seconds 8 times. The subjects then performed the routine warm-down.

3. All subjects performed the routine warm-up. Subjects then ran 300 yards in 54 seconds followed by a recovery period of walking for 2 minutes, 30 seconds. This procedure was repeated 8 times. The subjects then performed the routine warm-down.

4. All subjects performed the routine warm-up. Subjects then ran 300 yards in 54 seconds followed by a recovery period of walking for 2 minutes, 30 seconds. This procedure was repeated 8 times. The subjects then performed the routine warm-down.

The third level of the progressive interval training program consisted of four training sessions.

1. All subjects performed the routine warm-up. Subjects then ran 150 yards in 22 seconds with a recovery period of
walking for 1 minute, 45 seconds after the first five 150-yard runs and a recovery period of 2 minutes after the sixth and seventh 150-yard runs. Subjects repeated the 150-yard runs in 22 seconds 8 times. The subjects then performed the routine warm-down.

2. All subjects performed the routine warm-up. Subjects then ran 150 yards in 23 seconds followed by a recovery period of walking for 2 minutes. This procedure was repeated 10 times. The subjects performed the routine warm-down.

3. All subjects performed the routine warm-up. Subjects then ran 150 yards in 23 seconds followed by a recovery period of walking for 2 minutes. Subjects repeated this 12 times. Subjects then performed the routine warm-down.

4. All subjects performed the routine warm-up. Subjects then ran 150 yards in 23 seconds followed by a recovery period of walking for 1 minute, 45 seconds. This procedure was repeated 10 times. Subjects then performed the routine warm-down.

The fourth level of the progressive interval training program consisted of four training sessions.

1. All subjects performed the routine warm-up. Subjects then ran 300 yards in 50 seconds followed by a recovery period of walking for 2 minutes after the first and second 300-yard run, and a recovery period of 3 minutes after the third, fourth, and fifth 300-yard run. Subjects repeated the 300-yard run in 50 seconds 6 times. The subjects then
performed the routine warm-down.

2. All subjects performed the routine warm-up. Subjects then ran 300 yards in 50 seconds with a recovery period of walking for 2 minutes after each 300-yard run. Subjects repeated the 300-yard run in 50 seconds 6 times. The subjects then performed the routine warm-down.

3. All subjects performed the routine warm-up. Subjects then ran 300 yards in 50 seconds followed by a recovery period of walking for 2 minutes. This procedure was repeated 6 times. The subjects then performed the routine warm-down.

4. All subjects performed the routine warm-up. The subjects then ran 300 yards in 50 seconds followed by a recovery period of walking for 2 minutes after the first four 300-yard runs, and a recovery period of 2 minutes, 30 seconds after the fifth, sixth, seventh, eighth, and ninth 300-yard run. The subjects repeated the 300-yard run in 50 seconds 10 times. The subjects then performed the routine warm-down.

The fifth and final level of the progressive interval training program consisted of four training sessions.

1. All subjects performed the routine warm-up. Subjects then ran 150 yards in 22 seconds followed by a recovery period of walking for 1 minute, 30 seconds after the first four 150-yard runs and a recovery period of 2 minutes after the next five 150-yard runs. Subjects repeated the 150-yard runs in 22 seconds 10 times. The subjects then performed
the routine warm-down.

2. All subjects performed the routine warm-up. The subjects then ran 300 yards in 48 seconds followed by a recovery period of walking for 1 minute, 45 seconds after the first and second 300-yard run, and a recovery period of 2 minutes after the third, fourth, and fifth 300-yard run. Subjects repeated the 300-yard run in 48 seconds 6 times. The subjects then performed the routine warm-down.

3. All subjects performed the routine warm-up. Subjects then ran 150 yards in 21 seconds followed by a recovery period of walking for 1 minute, 45 seconds after the first and second 150-yard run, and a recovery period of 2 minutes after the third, fourth, and fifth 150-yard run, and a recovery period of 2 minutes, 30 seconds after the sixth and seventh 150-yard run. The subjects repeated the 150-yard run in 21 seconds 8 times. The subjects then performed the routine warm-down.

4. In the last training session before the post-tests, all subjects (control group included), jogged 600 yards at a moderate pace. Then the subjects in Group C and W continued jogging for a total elapsed time of 10 minutes. This training session was identical to the pre-test procedures.
Collection of the Data

Cardiovascular Endurance Test. Cardiovascular endurance was measured by the 600-yard run. The 600-yard run had a reliability of +.80 for cardiovascular endurance as established by Fleishman in a study involving 20,000 subjects.\textsuperscript{41} The 600-yard run was timed initially and finally in both a cold and warm environment to determine the effect that the interval training program in ambient temperature variations had upon the improvement of cardiovascular endurance. The subjects ran one at a time to eliminate the advantage of competition for some subjects and were instructed to cover the distance in as short a time as possible. Subjects maintained their order of testing for both pre-tests and both post-tests. In the initial and final 600-yard tests, the time of each subject was recorded to the nearest one-tenth of a second by using two certified track and field stop watches. The investigator was assisted in the timing of all test runs by the head track coach of South Dakota State University.

Environmental Factor Measurements. The ambient temperature was recorded three times during each training session with the use of a laboratory Fahrenheit thermometer. The temperature readings were taken during the warm-up, half-way, and during the warm-down of each training session. The mean of the three readings for ambient temperature was determined and recorded as the temperature reading for that training session. This procedure was kept constant throughout the 20 training sessions for both the warm and cold environments.

\textsuperscript{41}Fleishman, loc. cit.
The relative humidity for the warm environment was also recorded during each training session by the use of a sling psychrometer. When the relative humidity measurements were taken, the sling psychrometer was spun in a circular motion for approximately 30 seconds. When the temperature of the wet bulb thermometer stopped dropping, the temperature was recorded. The difference in the wet and dry bulb temperature was recorded along with the dry bulb temperature. From the psychrometric tables, furnished by the State Climatologist for South Dakota, Brookings, South Dakota, the relative humidity was calculated for the warm environment. The investigator became proficient in this procedure under the guidance of Walter Spuhler, Weather Bureau State Climatologist, Brookings, South Dakota. Relative humidity data were obtained for the cold environment from the State Climatologist Office, Agriculture Engineering Department, South Dakota State University, Brookings, South Dakota.

The raw data for the initial and final cardiovascular endurance tests appear in Appendix A. All measurements of the environmental factors recorded appear in Appendix B.
CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Treatment

The data were organized in a manner that permitted an analysis of the changes that occurred between the means on the initial and final tests in the warm and cold environments for the 600-yard run of each of the three groups (warm, cold, and control). Each subject's time was recorded in seconds and tenths of a second for the initial and final tests in both environments. An analysis of variance was computed to complete an F test to determine whether there was a significant difference among the changes of the groups' means. When an F ratio was significant, the Duncan Multiple Range Test was used to locate the significant differences between the respective groups. The .05 level of confidence was accepted as the minimal level needed in order for a difference to be significant. Raw scores for all four 600-yard tests appear in Appendix A.

The data obtained from the measurements of the environmental factors were displayed to show the difference of the two environments in which the experimental groups trained. The raw data for the environmental factors appear in Appendix B.


**Analysis of the Data**

Analysis of variance was computed by using the change among each group's means as the criterion for the analysis. The limits which the F ratio must equal to achieve significance with two and twenty-one degrees of freedom were 3.47 and 5.78 at the .05 and .01 levels of confidence, respectively.44

Table I shows the analysis of variance for the three groups in a warm environment pre-to-post test. The F ratio of 3.68 obtained from this portion of the data indicated a significant difference among the groups at the .05 level of confidence.

**TABLE I**

**ANALYSIS OF VARIANCE FOR WARM ENVIRONMENT PRE-TO-POST TEST AMONG THE GROUPS**

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Degrees of freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>24</td>
<td>1379.98</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Reduction</td>
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<td>1171.89</td>
<td>390.63</td>
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<td>MU</td>
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<td>1098.90</td>
<td>1098.90</td>
<td>--</td>
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<tr>
<td>Treatment</td>
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<td>72.98</td>
<td>36.49</td>
<td>3.68</td>
</tr>
<tr>
<td>Error</td>
<td>21</td>
<td>208.08</td>
<td>9.90</td>
<td>--</td>
</tr>
</tbody>
</table>

*F* .05(2/21) = 3.47  
*F* .01(2/21) = 5.78

The results of the Duncan Multiple Range Test analyzing the group mean changes between the initial and final tests in a warm environment are shown in Table II. The mean improvement of 7.6 seconds shown by group W and the mean improvement of 8.3 seconds shown by group C was significantly better than the 4.3 second improvement shown by the control group C₁. The difference between the mean improvement of the warm and cold groups, 0.7 seconds, was not significant.

### TABLE II

RESULTS OF THE DUNCAN MULTIPLE RANGE TEST COMPARING THE CHANGE IN GROUP MEANS BETWEEN INITIAL AND FINAL TESTS IN A WARM ENVIRONMENT

<table>
<thead>
<tr>
<th>GROUP</th>
<th>C₁</th>
<th>W</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN CHANGE</td>
<td>4.3</td>
<td>7.6</td>
<td>8.3</td>
</tr>
<tr>
<td>C₁</td>
<td>-</td>
<td>3.3*</td>
<td>4.0*</td>
</tr>
<tr>
<td>W</td>
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<td>-</td>
<td>0.7</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Significant at .05 level of confidence.

R₂: .05 = 3.28  
R₃: .05 = 3.44

The results of the analysis of variance among the changes of each group's means between the initial and final tests in a cold environment are shown in Table III. The F ratio of 8.90 obtained from this portion of the data indicated a significant difference among the groups at the .01 level of confidence.
TABLE III
ANALYSIS OF VARIANCE FOR COLD ENVIRONMENT
PRE-TO-POST TEST AMONG THE GROUPS

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Degrees of freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
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</tr>
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<td>1699.22</td>
<td>566.40</td>
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<td>MU</td>
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<td>1516.85</td>
<td>1516.85</td>
<td>--</td>
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<td>Treatment</td>
<td>2</td>
<td>182.36</td>
<td>91.18</td>
<td>8.90</td>
</tr>
<tr>
<td>Error</td>
<td>21</td>
<td>214.97</td>
<td>10.23</td>
<td>--</td>
</tr>
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</table>

*F (2/21) = 3.47  
F.05(2/21) = 5.78

The results of the Duncan Multiple Range Test analyzing the group mean changes between the initial and final tests in a cold environment are shown in Table IV. The mean improvement of 8.0 seconds shown by group W and the mean improvement of 11.2 seconds shown by group C was significantly better than the 4.5 second improvement shown by the control group C1. The difference between the mean improvement of the warm and cold groups of 3.2 seconds approached significance at the .05 level of confidence.
TABLE IV
RESULTS OF THE DUNCAN MULTIPLE RANGE TEST COMPARING THE CHANGE IN GROUP MEANS BETWEEN INITIAL AND FINAL TESTS IN A COLD ENVIRONMENT

<table>
<thead>
<tr>
<th>GROUP</th>
<th>MEAN CHANGE</th>
<th>C1</th>
<th>W</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>4.5</td>
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<td>11.2</td>
</tr>
<tr>
<td>C1</td>
<td>4.3</td>
<td></td>
<td>3.5*</td>
<td>6.7**</td>
</tr>
<tr>
<td>W</td>
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<tr>
<td>C</td>
<td>11.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05 level of confidence.
**Significant at .01 level of confidence.

R2: .05 = 3.33
R2: .01 = 4.55
R3: .05 = 3.50
R3: .01 = 4.74

The comparison of the warm and cold environments the experimental subjects trained in, is displayed in Figures 3 and 4. All temperature readings were recorded in Fahrenheit degrees. All relative humidity readings were recorded in percent Fahrenheit temperature.

As shown in Figure 3, the ambient temperature of the warm environment ranged from 76 to 79 degrees, with a mean of 77.1 degrees and a standard deviation of ± .9. This result is contrasted to the cold environment with a range of -3.1 to 42 degrees and a standard deviation of ± 9.9 about the mean of 18.8 degrees.
As shown in Figure 4, the comparison of the relative humidity reveals that the cold environment had a range of 79 to 97 percent with a mean of 89 percent and a standard deviation of ± 5. The warm environment relative humidity ranged from 19 to 34 percent with a mean of 24 percent and a standard deviation of ± 4.
Summary and Discussion of Results

The results of the analysis of the change that occurred between each of the three group’s (warm, cold, and control) means on the initial and final tests in the warm and cold environments for the 600-yard run revealed that a significant difference between at least two groups had occurred.

For the warm environment initial to final test, a significant difference of .05 was obtained from the F test. The results of the Duncan Multiple Range Test indicated that both the cold group and the
warm group improved significantly at the .05 level over the control group. This improvement of both training groups over the control group was expected and supported from the review of literature. 45, 46, 47, 48, 49

For the cold environment initial to final test, a significant difference of .01 was obtained from the F test. The results of the Duncan Multiple Range Test indicated that the warm group had improved significantly over the control group at the .05 level of confidence. The Duncan's test revealed that the cold group had improved significantly over the control group at the .01 level of confidence. The cold group's improvement of 3.2 seconds over the warm group's improvement from initial to final test for the 600-yard run in a cold environment approached significance at the .05 level of confidence.

The significant statistical value obtained from analysis of variance and the results of the ensuing multiple range test among


group mean changes between initial and final tests for the 600-yard run in both a warm and cold environment permitted the investigator to accept the null hypothesis (see Tables II and IV). Such evidence implies that under the conditions of the investigation cardiovascular endurance, as measured by the 600-yard run, was significantly improved upon completion of an interval training program in either a warm or a cold environment. Such evidence further implies that there was no significant difference in the improvement of cardiovascular endurance as measured by the 600-yard run between the cold environment training group and the warm environment training group.

However, as indicated by the statistical analysis (see Table IV), group C's (cold) mean improvement exceeded group W's (warm) mean improvement in a cold environment by 3.2 seconds, which approached a significant difference at the .05 level. This mean improvement between the groups implies that under the conditions of this present investigation the cold environment appears to be a better environment for interval training to improve cardiovascular endurance as measured by the 600-yard run in a cold environment.

The implication that the cold environment is superior to the warm environment for the improvement of cardiovascular endurance, as measured by the performance time of the 600-yard run in a cold environment, is of interest to the investigator as a track coach. That group C (cold) had a mean improvement of .7 seconds over group W (warm) for the warm pre-to-post test, and a 3.2 second improvement (which approached significance) for the cold pre-to-post test has led the investigator to feel that track athletes, especially middle-distance
and distance runners who are concerned with the improvement and maintenance of cardiovascular endurance, should do the bulk of their training during the winter season, outdoors. That track athletes who are concerned with the maintenance and improvement of cardiovascular endurance can expect favorable results from outdoor, cold-weather training is supported in part by Lydiard, Wilson, Astrand et al., Bolotnikov and Travin, and Hettinger.


51 Ove Wilson, "Field Study of the Effect of Cold Exposure and Increased Muscular Activity upon Metabolic Rate and Thyroid Function in Man," Federal Proceedings, XXV, 1966, 135-137.


CHAPTER V

SUMMARY

Summary of Study

The purpose of this investigation was to compare the effect of interval training in a warm environment to the effect of interval training in a cold environment on the improvement of cardiovascular endurance.

The subjects were twenty-four volunteer subjects selected from male students enrolled in the basic instruction program at South Dakota State University during the spring semester, 1970. The twenty-four subjects were equated into three groups by using the scores of the pre-test for the 600-yard run in both a warm and a cold environment. The three groups were randomly assigned an experimental treatment and were designated as group C (cold), group W (warm), and group C (control) by the pill box method.

After consideration of the facilities to be used, a review of literature, consultation with the head track coach, South Dakota State University, and other experienced track coaches, the investigator selected the progressive interval training program, which appears in Chapter III of this present study, and administered it to both experimental groups in an identical manner.

The data collected were recorded and statistically analyzed to compare the effect of interval training in a warm environment to the effect of interval training in a cold environment on the improvement of cardiovascular endurance. An analysis of variance was computed to
complete an F test to determine whether there was a significant change among the means of the three groups. When an F ratio was significant, the Duncan Multiple Range Test was used to locate the significant differences between the respective groups. The .05 level of confidence was accepted as the minimal level needed in order for a difference to be significant.

The significant statistical value obtained from analysis of variance and the results of the ensuing multiple range test among group mean changes between initial and final tests for the 600-yard run in both a warm and cold environment permitted the investigator to accept the null hypothesis.

Conclusions

Under the conditions of this present study, and within the limitations described, the following conclusions were drawn:

1. Cardiovascular endurance as measured by the 600-yard run was significantly improved by interval training in either a warm or a cold environment.

2. There was no significant difference between interval training in a warm environment as compared to interval training in a cold environment according to the improvement of cardiovascular endurance as measured by the 600-yard run; however, cardiovascular endurance as measured by the 600-yard run was improved to a greater extent through interval training in a cold environment as compared to interval training in a warm environment.
Recommendations for Further Research

Based on the findings of this investigation, the investigator proposes the following recommendations for further study:

1. That a similar study be conducted to investigate the comparison of interval training in a warm environment to interval training in a cold environment on the improvement of cardiovascular endurance as measured by maximal oxygen uptake.

2. That a study be conducted to investigate the effects of training, using a bicycle ergometer, in a stable cold environment as compared to the effects of training in a stable warm environment as measured by blood lactate concentration and maximal oxygen uptake.

3. That a similar study be conducted over a longer period of time.
BIBLIOGRAPHY


Roskamm, Dr. H., Professor Dr. H. Reindell, Dr. J. Keul (West Germany). "Physiological Fundamentals of Training Methods," *Run, Run, Run,* ed. Fred Wilt. California: *Track and Field News,* 1968.


APPENDICES
## APPENDIX A

**RAW DATA: CARDIOVASCULAR ENDURANCE TEST 600-YARD RUN (SECONDS)**

### COLD ENVIRONMENT TRAINING GROUP

<table>
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<td>Initial</td>
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</tr>
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<tr>
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<td>92.6</td>
</tr>
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<tr>
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<tr>
<td>5</td>
<td>102.8</td>
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<td>6</td>
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<td>8</td>
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### WARM ENVIRONMENT TRAINING GROUP

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### CONTROL GROUP

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### APPENDIX B

**RAW DATA: ENVIRONMENTAL FACTORS MEASUREMENTS**

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<tr>
<th>Training Session Number</th>
<th>Warm Environment</th>
<th>Cold Environment</th>
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<td>20</td>
<td>78.0</td>
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600-YARD RUN

**PRE-TEST**

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<th>2nd. session</th>
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<tr>
<td>Temperature*</td>
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<td>76.2</td>
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<tr>
<td>Relative** Humidity</td>
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<tr>
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</tr>
<tr>
<td>Relative** Humidity</td>
<td>91</td>
<td>86</td>
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</table>

**POST-TEST**

<table>
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<th>2nd. session</th>
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</thead>
<tbody>
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<td>Temperature*</td>
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<td>78.0</td>
</tr>
<tr>
<td>Relative** Humidity</td>
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<td>21</td>
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<tr>
<td>Temperature*</td>
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<td>31.0</td>
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<tr>
<td>Relative** Humidity</td>
<td>87</td>
<td>95</td>
</tr>
</tbody>
</table>

*Temperature recorded in Fahrenheit degrees.

**Relative Humidity recorded in percent Fahrenheit degrees."