THE EFFECTS OF HIGH TEMPERATURE UPON PERFORMANCE OF CERTAIN PHYSICAL TASKS BY HIGH SCHOOL STUDENTS

DISSERTATION

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ABSTRACT


This study has five chapters, organized in the following manner: (1) Chapter I contains the introduction, statement of the problem, purposes of the study, hypotheses, and significance of the study; (2) Chapter II is a review of the literature; (3) Chapter III is a description of subjects and tests and the procedures for treating the data; (4) Chapter IV contains the statistical technique of the analysis and the findings related to the hypotheses; and, (5) Chapter V consists of the summary, conclusions, and recommendations.

The purpose of this study was to determine performance levels in the areas of (1) agility, (2) endurance, (3) reaction time, and (4) strength at high (ninety degrees Fahrenheit) and ideal (sixty-eight degrees Fahrenheit) environmental temperatures.

The subjects were stratified according to grade classification and sex, then randomly placed in one of two groups for testing. The four components of motor fitness were tested using a shuttle run, a 440-yard run, a reaction
timer, and a grip dynamometer. Subjects took each test twice; once under ideal temperature and once under high temperature. The Fisher's $t$-test for significance of difference between the means of two related samples was the statistical technique used for this study. The hypotheses were accepted at the .05 level of significance. Twenty-five subjects completed all of the testing procedures.

The following hypotheses were tested:

1. It was hypothesized that agility, as measured by the Shuttle Run, would be significantly quicker at ideal temperature rather than at the high temperature of ninety degrees Fahrenheit.

2. It was hypothesized that endurance as measured by the time it takes to run the 440-yard dash, would be significantly improved at ideal temperature rather than at the high temperature of ninety degrees.

3. It was hypothesized that reaction time as measured by the American Automobile Association Reaction Timer, would be significantly less at ideal temperature rather than at the high temperature of ninety degrees.

4. It was hypothesized that strength as measured by a grip dynamometer, would be significantly greater at ideal temperature rather than at the high temperature of ninety degrees.

The results of the study supported three of the four hypotheses. Agility, endurance, and strength were improved
significantly at the ideal temperature. While there was a slight improvement in reaction time performance at the ideal temperature, the difference was not statistically significant.

On the basis of the findings it was concluded that (1) high temperature (ninety degrees Fahrenheit) causes human motor performance to deteriorate, and ideal temperature (sixty-eight degrees Fahrenheit) causes human motor performance to be improved; (2) the three components which showed a significant difference required more muscular action than did the component (reaction time) which showed no significant difference; (3) the majority of previous findings agree with the present research in respect to agility and reaction time; and (4) results were evenly divided as to the effects of heat on endurance and strength, with present research adding credence to improved performance in ideal temperature.

It was recommended that (1) all high school gymnasiums be air conditioned if the facilities are to be used during the summer months; and that (2) further studies should be conducted to determine the effect that age, sex, humidity, air circulation, and acclimatization have upon human motor performance.
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CHAPTER I

INTRODUCTION

As a result of the passage of Texas House Bill 1078, which was introduced in March, 1971, by Representatives Blanton, Graves, Boyle, Coats, Braun, Truan, Swanson, Golman, D. Jones, Poff, Kubiak, Grant, C. Parker, McKissack, and Johnson, the public schools of the state are going to be operating on the quarter system. The school districts may operate all or some of their schools for all four quarters with state funding for three quarters of attendance for any one student.\(^1\) Representative Dan Kubiak, Chairman of the House Education Committee, drew up legislation to delay the method's start until the 1975-76 term.\(^2\)

To accommodate students in comfort, public school buildings are being built with air-conditioning; some districts are air-conditioning their gymnasiums while others are not. Yet, the mean maximum temperature during the summer in all but two of Texas' two hundred fifty-four counties is above ninety degrees Fahrenheit.\(^3\)

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\(^2\)Austin McCallum Shield, November 1, 1973.

\(^3\)Texas Almanac, The Dallas Morning News (Dallas, 1974-'75), pp. 563-568.
Since more school facilities will be in use during the summer months, the failure to air-condition a gymnasium may be more acutely felt in the future than before.

On the basis of research now available, it is controversial whether the performance of individuals in physical education will be significantly different under ideal temperature or whether merely comfort is affected. If administrators can see that in their districts student performance in physical education classes and indoor competition can be improved, they may be more willing to air-condition their gymnasiums.

Statement of the Problem

The problem is a comparison of performance levels of participants at high and moderate temperatures on specific components of motor fitness. These components are agility, endurance, reaction time, and strength.

Purposes of the Study

One purpose of this study is to determine performance levels in the areas of (1) agility, (2) endurance, (3) reaction time, and (4) strength at high and moderate environmental temperatures. A second purpose is to make recommendations pertaining to the feasibility of air-conditioning high school gymnasiums on the basis of human motor performance.
Hypotheses

To carry out the purposes of this study, the following hypotheses were formulated:

1. Agility, as measured by the Shuttle Run, will be significantly quicker at ideal temperature rather than at the high temperature of ninety degrees.

2. Endurance, as measured by the time it takes to run the 440-yard dash, will be significantly improved at ideal temperature rather than at the high temperature of ninety degrees.

3. Reaction time, as measured by the American Automobile Association's Reaction Timer, will be significantly less at ideal temperature rather than at the high temperature of ninety degrees.

4. Strength, as measured by a grip dynamometer, will be significantly greater at the ideal temperature rather than at the high temperature of ninety degrees.

Background and Significance

Since 1923, when Yagloglou\(^4\) began his first in a series of investigations of man and the comfort zone, investigators have been probing the effects of the thermal environment on human performance.

Investigators have probed the subject-climate interaction. Belding and Hatch\(^5\) considered air temperature, temperature of the walls, temperature of the skin, vapor pressure at the skin, air speed, body heat production, body surface area and postural attitude, and clothing. They also found that other relevant factors were subject's age, degree of acclimatization to hot conditions, physical fitness, working task, exposure duration and feelings toward the situation.

Bell and Provins found that in investigations of . . . thermal effects on the ability to carry out physical work, the experimenter is able to calculate the energy cost of a given rate of work at a given task for a given length of time by a given subject . . . Adverse thermal effects may be noted in changes in the efficiency of the physical effort task and/or changes in body temperature and circulatory functions. The investigator thus has two sources of information about the effect of a particular thermal environment -- variations in work output at a known energy cost and changes in the thermal balance of the body.\(^6\)

Bell and Provins advocate that adverse thermal conditions for the present, have to be measured by performance scores.\(^7\)

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\(^7\)Ibid., p. 205.
Studies of discomfort have been done by Broadbent in which he found that exposure to high environmental temperatures may be similar to the effects on performance of uncomfortably noisy environments.8

Educational investigations seem to be confined mainly to temperature and student performance in the classroom. Chiles found no performance deterioration in a range of environmental temperatures from seventy-six degrees to ninety-one degrees Fahrenheit on complex mental tasks.9

Peccolo, before beginning his doctoral dissertation, found "... no specific scientific research which establishes a definite relationship between learning and thermal environment."10 Yet, he felt the preponderance of data and the supposition that human performance falls off rapidly above the comfort zone, made a scientific study feasible and necessary. His study with a control group and an experimental group of fourth graders showed definite benefits in learning performance.11


11Ibid., p. 137.
Hansen's investigation was also based on classroom tasks because he felt that "... the research in the area is too limited to base the relationship on scientific evidence." At the conclusion he found a definite relationship between thermal environment and learning.

The above studies involved the traditional classroom; as such, they are not applicable to physical education motor tasks without some additional investigation.

Several experiments have been designed to investigate the effects of high-temperature environments on reaction time. Pace and others found no consistent variation in performance as temperatures climbed. He measured simple auditory and visual choices.

In their review of reaction time studies, Bell and Provins found generally no significant variance in reaction time at temperatures below one hundred seventeen degrees Fahrenheit.

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14 Bell and Provins, op. cit., p. 207.
Sensory motor tasks have been tested by Weiner and Hutchinson, who found performance on a fine motor manipulation test deteriorated significantly at ninety-one degrees Fahrenheit;\(^{15}\) Blockley and Lyman, who found no significant lag in performance on a psychomotor task until subjects had been in the environment thirty minutes;\(^{16}\) and, by Pepler, who found "warmth reduces accuracy" on a visual vigilance task.\(^{17}\)

Bernauer concluded that the thermal environment had a limiting effect upon duration of muscular endurance tasks.\(^{18}\)

On the basis of the present study, Texas school administrators can determine the need for air-conditioned gymnasiums with attention to the fact that, effective in 1975, the Texas Education Agency has increased the required time in physical education classes from one and one-half semester units to five quarter units.\(^{19}\) This amounts to thirty-five more clock hours of physical education. According to the Texas Education


Agency, a longer period would have advantages for physical education instruction. This extended time period would give students "... ample opportunity for skill development during the class period..."\(^2\) Some students will choose physical education for the summer quarter if their school districts give them a choice of all four quarters.

Further significance of the study is that administrators of public schools in geographical areas with similar thermal conditions may also be able to make decisions with the aid of this study. Some conclusions may also be drawn in relation to the current energy crisis.

Definition of Terms

For the purposes of this study the following definitions are formulated:

**Agility** is the speed in changing body position or in changing direction.

**Endurance** is the result of physiological ability of the individual to sustain movement over a period of time.

**High temperature** is ninety degrees. (This temperature is based upon a preliminary study which was conducted during the summer of 1973. In this study it was found that the average mean temperature in four different Wichita Falls public school gymnasiums between the hours of 1 p.m. and 1:30 p.m. was 90.59 degrees Fahrenheit. These temperatures

were taken during the school days of June, July, and August of 1973.) (See Appendix A.)

Ideal temperature is sixty-eight degrees. (In gymnasiums, for school time use, space temperatures should be kept at sixty-eight degrees Fahrenheit to stimulate student activity and minimize sweating.)

Reaction time is the time that it takes to respond by movement to a certain stimulus.

Strength is the force a muscle or a group of muscles exerts against a given resistance.

Delimitations of Study

In each of the four tested areas, air movement, relative humidity, and radiation were kept constant, with only air temperature being a variable.

Procedures for Collecting Data

During June and July of 1974, twenty-five of the thirty-one volunteer high school students completed all the tests which were utilized in the study. Approximately one half of the subjects were male and one half were female. A general information sheet was kept on each subject. (See Appendix B.)

The collection of the data took sixteen days. In an attempt to make the study more valid, the thirty-one subjects

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were divided into two groups, Group A and Group B. The membership in the two groups was determined by the use of a stratified random sample technique. Subjects were stratified by grade classification and sex. Once stratification was accomplished, subjects were randomly placed in a group. Any subject not finishing all of the tests was eliminated from the study.

Procedures for Analysis of Data

Each of the hypotheses in this study was tested by using Fisher's $t$-test for two related samples. The null hypotheses were rejected at the .05 level of significance.
CHAPTER II

REVIEW OF THE LITERATURE

The effects of temperature on the performance of four motor skills, namely, (1) agility, (2) endurance, (3) reaction time, and (4) strength, was the concern of this study. A review of the literature shows a considerable amount of research, some of it conflicting.

Heat Stress and General Tasks

The effects of heat on man have been investigated at least since 1775 when Blagden placed men in a dry atmosphere of two hundred fifty degrees Fahrenheit for fifteen minutes without ill effects. The Industrial Revolution brought attention to the effects of heat on factory laborers in England, and government regulations were placed on factory conditions in the early Nineteenth Century. Bedford relates the awareness which researchers in his country of England portrayed in the Twentieth Century by citing a number of investigations. Early researchers made pioneer observations. Haldane (1905, 1907) directed studies

. . . in Cornish tin mines, and drew conclusions as to the maximum wet-bulb temperatures which

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could be tolerated. . . . At about this time Dr. Leonard Hill showed the striking effects of air movement in mitigating conditions in hot and humid places. In 1914 he introduced his kata thermometer which is still widely used.2

A scale of warmth used more commonly in the United States is effective temperature. Effective temperature is

. . . the temperature and humidity condition, or the heat and moisture condition, of the air which determines the transfer of heat between it and the human body, normally clothed. A more simple definition is: Effective temperature is an index of the degree of warmth which a person will experience for all combinations of temperature and humidity.3

The above concept is that of Houghten and Yagloglou after testing one hundred individuals of both sexes, wearing widely different types of clothing. The investigators searched for the comfort zone by using two rooms. In both, floors were covered with rugs; comfortable chairs were provided, as were small tables for light activities such as reading and card playing. Rooms were maintained for two hours at various atmospheric conditions. Consensus was that 64.5 degrees effective temperature was the one of maximum comfort.4

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4 Ibid., p. 526.
Bedford quotes Caplan's 1946 experimental study of laborers in the Kolar gold mines as declining in efficiency at temperatures above 83 degrees Fahrenheit. Bedford also notes Mackworth's findings of increased errors by telegraph operators at effective temperatures above 82 degrees Fahrenheit; and Vernon's observations that accidents were at a minimum when temperatures were between 65 degrees and 69 degrees Fahrenheit in munitions factories. The rate rose twenty-three per cent higher at temperatures over 75 degrees Fahrenheit. Heat is a stressful condition, and Fraser defines stress as being applied to

. . . anything which in relatively extreme form tends to disrupt normal functioning. In any experimental situation it is necessary to show that the 'stress' conditions are liable to produce deterioration of performance; such deterioration need not necessarily occur on any given occasion but there must be a significant probability of its occurrence.

Belding and Hatch evaluate heat stress in terms of the following factors:

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7Ibid., citing H. M. Vernon, "An Investigation of the Factors Concerned in the Causation of Industrial Accidents," Health of Munitions Workers Committee Memo No. 21, Code 9046.

(a) air temperature; (b) temperature of solid surroundings (walls); (c) temperature of the skin; (d) vapor pressure at the skin; (e) environmental vapor pressure; (f) air speed; (g) body heat production; (h) body surface area and postural attitude; and (i) clothing.9

Provins and Bell agree that the measurement of high atmospheric temperatures on human performance is complicated by variables in any given situation. They cite Mackworth's study and note that the more skilled telegraph operators were less affected by heat because the

. . . nearer the subjects were working to their maximum capacity under ordinary conditions, the greater the effect of the experimental variable on performance. Thus, the more highly skilled subjects showed little effect of heat or time on their performance, presumably because they could compensate for the increased stress by 'drawing on their reserves' as it were or putting an increased effort into maintaining their level of performance.10

These two authors call for further research on human performance under high temperatures, for they note,

. . . the point on the effective temperature scale at which the body (i.e. rectal) temperature begins to rise is approximately the same as the point at which performance has been found to deteriorate significantly, that is between 85 degrees and 90 degrees Fahrenheit.11

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11Ibid., pp. 364-365.
Acclimatization has bearing on experiments in heat. Hellon and others point to the fact that if subjects live or work in warm climates for long periods of time they not only become used to conditions and experience less discomfort than when first exposed to the heat, but their bodily responses modify in order to maintain a heat balance, and they experience a recovered ability to perform muscular work.12

Edholm, Adam, and Fox found their sixteen subjects acclimatized to heat in seven days. They used two groups of eight subjects lifting twenty-three kilogram load to a stool one hundred twenty centimeters in height and down again to the floor. This task was repeated regularly for thirty minutes in each hour; the cycle lasted four hours. After eight days performance, one group continued the task in cold surroundings; the second group did the same task in a hot environment. The pulse rate and body temperature increments during work showed the two groups' responses to be similar in the first phase of the experiment. The group performing in the heat had a steeper rise in body temperature and an increase in pulse rate increments during work. Both pulse rate and body temperature rise decreased with more exposure.13


Provins and others investigated further the belief that individuals vary widely in their ability to remain in hot and humid atmospheres by exposing a larger number of subjects than had McConnell, Houghten and Yagloglou to a selected range of climates. Experiments were conducted on eight young men who were tested in pairs over a period of two weeks. Subjects were performing a visual vigilance task. The purpose was to define climatic conditions limiting continuous work but also to describe times for which other climates may be tolerated for resting subjects.14

Kaufman tested mildly exercising men at temperatures in excess of 110 degrees Fahrenheit for the space program. He found individual variations in tolerance to thermal stress was great. However, his research supports previous investigations at lower thermal temperatures in that all subjects had begun a physiological decline. Kaufman suggests further experimentation to determine performance capabilities.15

Dill and Consolazio tested themselves in a longitudinal study of thirty years involving metabolic rate, environmental temperature and the heart rate. They kept the humidity constant and varied the temperature. Observations for Dill showed the heart rates about the same as thirty years ago both in easy work and in moderate work except at 122 degrees


15Kaufman, op. cit., pp. 889, 892, 896.
Fahrenheit where the rates were about twenty beats per minute greater. For Consolazio at all work levels the heart rates were the same from thirty-two degrees Fahrenheit to sixty-eight degrees Fahrenheit and about ten beats lower at eighty-six degrees Fahrenheit and 104 degrees Fahrenheit. At 122 degrees Fahrenheit his heart rates were ten beats higher in easy to moderate work and the same in hard work. Some of these changes were attributed to the lowered capacity for work.¹⁶

Lovingood, Blyth, Peacock, and Lindsay performed ninety-six experiments on twenty-four young male subjects to determine effects of d-amphetamine sulfate, caffeine, and a restricted environment of 125.6 degrees Fahrenheit with a relative humidity of twenty-five to forty per cent. Tested were effects on man's capacity to perform psychomotor, mental, and strength tasks. The subjects had an average age of twenty-one years and an average weight of 167 pounds, thirteen ounces. There were four separate days scheduled in random order for each of the twenty-four subjects. The Latin square technique of randomization was used to determine the order of performance tasks. Seven days were devoted to acclimatization with each subject exposed to treadmill walking in an ambient temperature of 125.6 Fahrenheit. Conclusions were that fifteen milligrams of d-amphetamine

sulfate significantly improved performance but caused a
significant increase in heart rate; that 500 milligrams of
citrated caffeine did not produce a significant change in
either the performance tasks or physiological measures; that
high ambient temperature of 125.6 Fahrenheit produced a
significant improvement in performance.  

Heat and Learning

Mincy found control of humidity and air movement was
important to learning and the classroom. He found the con-
trol of air temperature to be the critical issue in
maintaining an optimum thermal environment.

A Texas study was done by Nolan, who concluded that high
temperatures have an adverse effect on learning. The Nolan
study acccents the need for air-conditioned buildings to meet
the needs of the quarter system legislated to go into effect

17 Bill Lovingood, Carl S. Blyth, William H. Peacock, 
Robert B. Lindsay, "Effects of d-Amphetamine Sulfate, Caffeine, and High Temperature on Performance," Research 
Quarterly XXXVIII (March, 1967), 64, 65.


19 Ibid., p. 31, citing J. A. Nolan, "Influence of Classroom Temperature on Academic Learning," Automated Teaching 
In addition, more clock hours of physical education will be required under the quarter system since five quarters will be required and as many as twelve quarters will be possible.  

Peccolo used twenty-two matched pairs of fourth graders in two classrooms to determine the effects of thermal environment on learning. The air temperature at the home school which was not air-conditioned ranged from seventy degrees to ninety-two degrees Fahrenheit. Temperatures varied from seventy-two degrees to eighty-one degrees at the research school. Humidity at the home school was from thirty-three to seventy-five per cent. Relative humidity varied from thirty-five to sixty-seven per cent in the air-conditioned research school. The conclusions reached by the researcher were that the experimental group occupying the room with ideal thermal conditions improved more than the control group. 

For a contrary finding, Lovingood and others found an improved performance on a mental task of adding two digit numbers in an ambient temperature of 125.6 degrees Fahrenheit.

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22 Peccolo, op. cit., pp. 41, 64, 127, 134, 136.
23 Lovingood, op. cit., p. 67.
Heat and Agility

Weiner and Hutchinson cited previous findings that a prolonged stay in a hot, humid environment caused a "... tendency to forgetfulness, to some slowing of one's movements. ... a measurable impairment of manual dexterity or co-ordination occurs at high environmental temperature." Testing apparatus consisted of a gramophone disc rotated at constant speed by an electric motor. The gramophone top is

... mounted at an inclination of thirteen degrees to the horizontal and carries a bakelite plate provided with an inner and outer series of perforations. The task set for the subject is as follows: Using a pair of forceps, and in as short a time as he is able, the subject is required to pick up from the inner circle of holes each of eighty-four small steel ball bearings (3/8 inch) and deposit these in the outer series of holes while the gramophone disc is rotating. Any balls which are not accurately placed in the holes or which slip from the forceps, run down the sloping disc into a tray from which they must be picked up until all the balls have been successfully deposited. The subject then returns the balls from the outer circle of holes to the inner, retrieving any dropped balls from the trays as before. This transfer of balls from the inner to the outer ring and back to the inner constitutes a complete 'run'. Two minutes after the completion of the first run the second run is performed, and after a rest of fifteen seconds the third run is performed. The time taken to complete each run is noted by means of a stop watch and the total test time for the three runs is obtained. The number of balls retrieved from the tray for each run is also noted and hence the total number of balls actually handled during each run is known. Since the time for each run is recorded,

the average time taken to handle each ball can be calculated.25

Six subjects, ages twenty-five to thirty-five, were tested. They were well acclimatized to working in hot, humid environments. Effective temperature was ninety-one degrees Fahrenheit with dry bulb ninety-five degrees and wet bulb ninety degrees; air movement was thirty feet per minute. Total test time in the hot room was longer than that in ordinary room temperature. The difference in the mean test time in the heat from that in ordinary room temperature was fourteen per cent. The number of balls dropped in the hot room was higher. Subjects time per movement per ball was longer, indicating they had impaired accuracy in the hot room. Subject movements were slower in the hot room than in the ordinary room temperature by an average of six per cent. A conclusion of these investigators is that motor coordination is impaired in a hot, humid environment.26

Heat and Endurance

Bernauer tested seven subjects for endurance with two treadmill runs at seventy degrees corrected effective temperature followed by thermal exposure at fifty, sixty, eighty, and ninety degrees corrected effective temperature. Optimum run time was at sixty degrees, but the individual optima occurred at either sixty degrees or seventy degrees

25 Ibid.
26 Ibid., pp. 154, 155, 157.
corrected effective temperature. All subjects but one were highly trained distance runners.27

Variance in run times attributed to ambient temperature was statistically significant with an F-ratio of 14.6 and a corresponding (P) of < .001. The inter-individual variance in run time decreased with an increase in ambient temperature.28

Heat and Reaction Time

Kleitman, Titelbaum, and Feiveson investigated variability in performance of simple tasks and more complicated tasks under the influence of temperature fluctuations at different times of the day. The time required to react to visual and auditory stimuli was studied. The five subjects consisted of an instructor and male graduate students. Tests were made at various times of the day.29 A complete test...

... consisted of twenty trials each for (a) simple reaction: to white light; (b) simple reaction: to sound of a telegraph key; (c) choice reaction: response to green light but not to red; (d) choice reaction: response to sound of a bell, but not to the telegraph key.30


28Ibid., p. 68.


30Ibid., pp. 495, 496.
Reaction time was measured in thousandths of a second (sigmas) by a Hipp chronoscope. The results were stated as follows:

Since a small reaction signifies good performance, the ability to respond promptly appears to be best in the middle of the day when the temperature is highest, and poorest in the morning and late evening, when temperature is lowest.

The researchers found the effect of temperature significantly more marked with respect to reaction with choice than in simple reaction.

Fraser cites a range of temperatures of eighty-five degrees to ninety-two and five tenths degrees Fahrenheit as comprising a stress condition on a visual vigilance task for seventy-two subjects, and he says,

If we now examine the effect of adding hard physical work to the heat stress we find that there is a dramatic increase in the number of missed signals in the heat plus work condition as compared with the heat only condition. This difference is significant at the 2.5 per cent level.

Fraser hypothesizes that there are two kinds of vigilance, which are as follows:

(a) Vigilance I—which occurs when a subject is set to observe a very occasional signal during a long period of watch. In this case, we might expect the typical deterioration after half-an-hour and the greatly prolonged reaction times.

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31 Ibid., p. 496.
32 Ibid., p. 497.
33 Ibid., p. 500.
34 Fraser, op. cit., p. 251.
(b) Vigilance 2--where the subject is set for a short period of observation, and the stimuli are presented at high speed and in comparatively large numbers. Here, we might expect the small but finite and constant proportion of missed signals observed in the present investigation to occur with no significant change in the mean reaction time.\textsuperscript{35}

His investigation shows his hypothesis to have substance. He states,

\ldots in the case of the 100 degree Fahrenheit temperature there is a sharp rise in the number of missed signals from zero to about twelve and one-half per cent approximately twenty minutes after entry to the heat chamber. Considering the ninety-five degree Fahrenheit temperature we find that up to twenty-five minutes the percentage of missed signals is no higher than two per cent. Between twenty-six and thirty minutes after entry into the heat chamber there is a sudden rise to over eight per cent.

\ldots If we now consider the time taken to respond to the significant signals we have a rather unexpected paradox. In the original Mines Rescue Experiment there was a sharp decrease in the speed of reaction under the 100 degree Fahrenheit (heavy work) condition and some evidence of a decrease in speed of reaction in the other conditions as compared with the control. In the second set of experiments, however, there was no significant change in reaction time throughout all the heat stress conditions including the heat plus work conditions.\textsuperscript{36}

Lovingood and others used a multi-purpose psychomotor testing device for simple reaction time. The examiner's panel contained a built-in standard chronoscope which measured time directly on a dial. The front panel contained a power switch, clock reset, and clock motor. The subject's

\textsuperscript{35}Ibid., p. 252.

\textsuperscript{36}Ibid.
panel contained a microswitch and a stimulus light. Reaction time improved at the .01 level of significance in high ambient temperature of 125.6 degrees Fahrenheit with humidity forty to sixty per cent over performance at seventy-four degrees Fahrenheit with humidity less than sixty per cent.37

Pace and others studied the physiological, psychological, and clinical effects of living continuously in a hot, humid environment as compared with the effects of intermittent exposure, twelve out of twenty-four hours to a tropical environment. Subjects were twelve seamen, eighteen years old, divided into two groups of six each. All volunteered and were offered twenty days leave if they completed the test. The subjects were tested for three days in order to equate the groups in a maximum number of tasks. One group was designated the hot group, and the other was the cool group. The men wore shorts throughout the experiment. The thirteen tests were ataxiagraph, code test, computation test, critical flicker frequency, dark adaptation, hand dynamometer, pursuit rotor, reaction time (auditory), reaction time (complex visual), reaction time (two-choice visual), steadiness (hand), tapping (complex), visual field.38 Of these thirteen, four

37 Lovingood, op. cit., p. 67.

were relevant to the present study. These were hand dynamometer, reaction time (auditory), reaction time (complex visual), and reaction time (two-choice visual). Comparisons were made between the mean daily performance of the two groups, hot and cool, using Fisher's t-test for small independent samples. Results showed no significant difference on any day during the experiment for hand dynamometer and auditory reaction time. On two reaction time tests, the complex visual and the two choice visual, the mean score of the hot group was consistently superior to that of the cool group. In the complex visual reaction time the differences between means were significant beyond the five per cent level of confidence on the twentieth experimental day and thereafter.39

The two groups lived in approximately eighty-five degrees effective temperature for nine hours daily. One group, the hot or continuous exposure group, remained at this temperature for twelve hours at night. The other group spent twelve hours at approximately seventy-five degrees Fahrenheit. Both groups spent three hours at approximately ninety degrees performing treadmill work tests.40

To summarize, effects of high ambient temperatures on reaction time are shown by some to have a negative effect. Fraser's study shows this to be true, along with another

39 Ibid., pp. 11, 12.
40 Ibid., p. 1.
which he co-researched with Jackson. Other studies show that reaction time improves in high ambient temperatures. Teichner reviews studies on reaction time and concludes,

The general result of these studies is that ambient temperatures between a range of minus fifty degrees Fahrenheit and 117 degrees Fahrenheit have little or no effect on either reaction time or more complex reaction time. This conclusion was reached by Forlano, Barmack, and Coakley after a careful review of the effects of ambient and body temperatures on reaction time. Most of the studies available for evaluation, however, are distinguished by the degree with which several main variables are confounded in one experiment, and consequently are given to difficulty of interpretation. Such a conclusion, therefore, should not be accepted as firmly established.

Heat and Strength

Strength tests were performed better at 125.6 degrees Fahrenheit than at seventy-four degrees according to Lovingood and others. The instrument used to measure the grip strength of the right and left hand was a Smedley dynamometer with an adjustable grip.

Pace and others tested strength with a hand dynamometer, also with a Smedley. The subject was required to make a

---


44 Lovingood, op. cit., pp. 67, 70.
series of pulls at regular intervals at settings which mandated increased strength. He continued until he could no longer achieve the required level of performance. Grip was relaxed between pulls. The score was the mean of the highest levels pulled by the two hands, tested separately.\textsuperscript{45} There was no significant difference shown on the hand dynamometer test on any day during the experiment.\textsuperscript{46}

On the other hand, Russell's contradicting evidence is "... that at air temperatures above seventy-three degrees Fahrenheit effective temperature some impairment of maximum grip strength may be expected. ..."\textsuperscript{47}

A considerable amount of research dealing with effects of temperature on performance is available in the literature. Findings, however, are inconclusive and contradictory. Variables in the different tests lead to a variety of conclusions.

\textsuperscript{45}Pace and others, op. cit., p. 8.
\textsuperscript{46}Ibid., p. 12.
CHAPTER III

PROCEDURES OF THE STUDY

Selection and Description of Subjects

During the spring semester of 1974, principals and coaches in Wichita Falls and the Wichita Falls area were asked to help solicit volunteer high school students to participate in the study during the months of June and July. Initially, there were thirty-one volunteers; sixteen girls and fifteen boys. The subjects involved in the study included three seniors, five juniors, ten sophomores, and thirteen freshmen. Subjects who did not complete all tests were eliminated from the study. Six subjects were in this category, leaving a total of twenty-five who completed all testing. There were two seniors, four juniors, ten sophomores, and nine freshmen who completed all of the tests. Testing was completed by thirteen female and twelve male subjects.

Some of the subjects were familiar with the instruments used while many were not; therefore, it was necessary to have an orientation period. Subjects were granted the use of Midwestern University facilities for the Summer of 1974 as a result of their having participated in the study.
Grouping of Subjects

In an attempt to make the study more valid, the original thirty-one subjects were divided into two groups. These groups were assigned the labels of Group A and Group B. Subjects were stratified by grade classification and by sex. As much as possible each group had males and females for each of the following categories: seniors, juniors, sophomores, and freshmen. Once this stratification was accomplished, subjects were randomly placed in either Group A or Group B. The random selection was accomplished by the drawing of names from a box. The purpose of stratification was to guarantee that there would be boys and girls in each group and also that there would be freshmen, sophomores, juniors, and seniors in each group. Group A consisted of eight females and eight males while Group B consisted of eight females and seven males. Two seniors, two juniors, five sophomores, and seven freshmen were in Group A. One senior, three juniors, five sophomores, and six freshmen made up Group B.

Description of the Instruments

Four of the main components of motor fitness are (1) agility, (2) endurance, (3) reaction time, and (4) strength. These four components were tested respectively by using a shuttle run, a 440-yard run, a reaction timer, and a grip dynamometer.

The shuttle run was used to measure agility. Many test batteries designed to measure motor fitness use various forms
of the shuttle run to determine agility. Two parallel lines were marked on the floor thirty feet apart. The runner began behind one line, ran across the other line, returned to the starting position and repeated this procedure two times. With the exception of the starting line, subjects crossed each line with only one foot. The score was the total time required for the three round trips. The average score out of three trials was used. According to McCloy and Young, the validity coefficient for the thirty-foot shuttle run is .829. The reliability coefficient for the same test is .932.¹

A 440-yard run was used to test for endurance. To perform this test, subjects ran around the outside of a roped-off basketball court. They were required to use the upright starting position. Each subject ran counterclockwise until he completed the 440 yards of running. Time was kept to the nearest tenth of a second. Each subject ran five full laps, with each lap consisting of eighty-eight yards.

The following diagram illustrates how the track was set up on the gymnasium floor:

Each of the six turns on the course was marked with a standard five feet in height. The standards were made of two inch posts with a base sixteen inches square. The entire base was on the inside of the track with the post at each point of intersection.

The American Automobile Association's Automatic Reaction Timer (Model No. 3548) was used to measure simple reaction
time, as determined by movement of the foot. Green and red lights were mounted in the front of a cabinet. The green light was normally "on" to indicate that the test was working properly. When the green light went off and the red light came on, the subject was to step on the brake as quickly as possible. The timer was mounted inside the cabinet and was visible only to the examiner. When the subject responded, the timer automatically stopped and recorded reaction time to the nearest 1/100 of a second.² Each subject responded five times, and the average score was used.

There are many methods of measuring strength, but the instrument used in this study was a grip dynamometer. This instrument gives an accurate measurement of hand strength. The subject first chalked his hands. Each subject had access to chalk and cotton towels to remove perspiration from his hands so that the grip dynamometer would not slip. Then, the grip dynamometer with the indicator toward the palm was placed in the hand. The edge of the dynamometer with the ends curved upward was against the fingers and the rounded edge against the base of the hand. With the body in any desired position, the subject gripped the dynamometer as vigorously as possible. The hand and fingers did not rest against the body or against any object.³ The subject

³ McCloy and Young, op. cit., p. 148.
repeated the procedure using the opposite hand. This process was repeated with the subject making one more grip with each hand. The four scores were averaged and recorded as one score.

Collection of Data

One week prior to the beginning of the actual testing, all volunteers were asked to come to the Midwestern University gymnasium for a period of orientation. Thirty-one subjects came to this orientation. During this session, four procedures were carried out. First, each participant in the study filled out the General Information Sheet (See Appendix B). Second, the subjects were familiarized with the instruments to be used. Third, the volunteers were placed into either Group A or Group B. After this was accomplished, each subject was given a sheet indicating the days that his group would be tested. Finally, subjects drew numbers from a box to determine the order in which they would take each of the four tests.

All subjects were asked to be dressed in a like manner. This consisted of white cotton socks, tennis shoes, white cotton shorts, and a white cotton shirt. Also, they were asked to wear the same pair of tennis shoes throughout the testing period.

All tests were conducted in the Midwestern University gymnasium, with a constant humidity reading of forty per cent. Air movement was also kept constant for all tests.
Subjects were in the gymnasium for twenty minutes before each test was conducted. This represented the midpoint of a typical high school class. During this twenty-minute period all participants were engaged in organized games of "twenty-one." This basketball activity kept the subjects active but was not too strenuous.

Twenty-five of the original thirty-one subjects completed all of the testing procedures. Included in this total of twenty-five were thirteen girls and twelve boys. Completing the testing program were two seniors, four juniors, ten sophomores, and nine freshmen. The subjects who failed to finish all of the tests, for various reasons, included one senior girl, one junior girl, one freshman girl, and three freshmen boys.

Each of the four tests took four days to complete, since eight to ten hours were required to change the temperature from ninety degrees to sixty-eight degrees, and a counterbalancing technique was used, with one-half the subjects in each group. For example, on the agility test, Group A on the first day was tested at the ideal temperature. On the second day, they were tested at the high temperature. The reverse procedure was used for Group B. On the third day, Group B was tested at the high temperature. On the fourth day, Group B was tested at the ideal temperature. Each test
was administered between the hours of one and two in the afternoon. The tests were carried out in the following manner:

<table>
<thead>
<tr>
<th>TEST</th>
<th>GROUP</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Day Agility</td>
<td>A</td>
<td>Ideal</td>
</tr>
<tr>
<td>2nd Day Agility</td>
<td>A</td>
<td>High</td>
</tr>
<tr>
<td>3rd Day Agility</td>
<td>B</td>
<td>High</td>
</tr>
<tr>
<td>4th Day Agility</td>
<td>B</td>
<td>Ideal</td>
</tr>
<tr>
<td>5th Day Endurance</td>
<td>B</td>
<td>Ideal</td>
</tr>
<tr>
<td>6th Day Endurance</td>
<td>B</td>
<td>High</td>
</tr>
<tr>
<td>7th Day Endurance</td>
<td>A</td>
<td>High</td>
</tr>
<tr>
<td>8th Day Endurance</td>
<td>A</td>
<td>Ideal</td>
</tr>
<tr>
<td>9th Day Reaction Time</td>
<td>A</td>
<td>High</td>
</tr>
<tr>
<td>10th Day Reaction Time</td>
<td>A</td>
<td>Ideal</td>
</tr>
<tr>
<td>11th Day Reaction Time</td>
<td>B</td>
<td>Ideal</td>
</tr>
<tr>
<td>12th Day Reaction Time</td>
<td>B</td>
<td>High</td>
</tr>
<tr>
<td>13th Day Strength</td>
<td>B</td>
<td>High</td>
</tr>
<tr>
<td>14th Day Strength</td>
<td>B</td>
<td>Ideal</td>
</tr>
<tr>
<td>15th Day Strength</td>
<td>A</td>
<td>Ideal</td>
</tr>
<tr>
<td>16th Day Strength</td>
<td>A</td>
<td>High</td>
</tr>
</tbody>
</table>

Treatment of the Data

Each of the four hypotheses in this study was tested by using the Fisher's t-test for two correlated samples. The hypotheses were accepted at the .05 level of significance.
CHAPTER IV

RESULTS OF THE STUDY

It was the purpose of this study to determine the effects of high temperature upon performance of certain physical tasks by high school students. Data was collected from high school students using four components of motor fitness. The four components were the following: agility, endurance, reaction time, and strength. These four components were tested respectively by using a shuttle run, a 440-yard run, a reaction timer, and a grip dynamometer. Subjects took each test twice; once under ideal temperature and once under hot temperature. The data obtained from these tests served as the basis for the findings of this study.

Statistical Technique of the Analysis

The Fisher's $t$-test for significance of difference between the means of two related samples was the statistical technique used for this study. The $t$-test formula used to analyze the data was as stated by Roscoe.$^1$

For each of the research hypotheses the null hypothesis was tested and the .05 level of significance was used as the criterion for rejection. Using a one-tailed test of

significance, a $t$ ratio of 1.711 or greater was necessary to reject the null hypothesis.\textsuperscript{2}

Findings Related to Hypothesis I

Hypothesis I stated that agility, as measured by the Shuttle Run, will be significantly quicker at ideal temperature rather than at the high temperature of ninety degrees.

The raw scores for each subject on the agility run are presented in Table I. Each score is recorded to the nearest tenth of a second.

\textbf{TABLE I}

\textbf{RAW DATA COLLECTED FOR THE AGILITY RUN}

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To Nearest Tenth of A Second</th>
<th>Raw Scores In High Temperature To Nearest Tenth of A Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.6</td>
<td>14.0</td>
</tr>
<tr>
<td>2</td>
<td>15.9</td>
<td>16.7</td>
</tr>
<tr>
<td>3</td>
<td>16.8</td>
<td>16.9</td>
</tr>
<tr>
<td>4</td>
<td>14.3</td>
<td>14.5</td>
</tr>
<tr>
<td>5</td>
<td>15.2</td>
<td>15.6</td>
</tr>
<tr>
<td>6</td>
<td>15.2</td>
<td>15.1</td>
</tr>
<tr>
<td>7</td>
<td>15.3</td>
<td>15.4</td>
</tr>
<tr>
<td>8</td>
<td>16.5</td>
<td>16.3</td>
</tr>
<tr>
<td>9</td>
<td>14.6</td>
<td>15.4</td>
</tr>
</tbody>
</table>

\textsuperscript{2}\textit{Ibid.}, p. 293.
TABLE I -- Continued

RAW DATA COLLECTED FOR THE AGILITY RUN

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To Nearest Tenth of A Second</th>
<th>Raw Scores In High Temperature To Nearest Tenth of A Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>14.6</td>
<td>14.6</td>
</tr>
<tr>
<td>11</td>
<td>15.3</td>
<td>14.5</td>
</tr>
<tr>
<td>12</td>
<td>15.1</td>
<td>15.2</td>
</tr>
<tr>
<td>13</td>
<td>13.5</td>
<td>14.0</td>
</tr>
<tr>
<td>14</td>
<td>14.6</td>
<td>14.5</td>
</tr>
<tr>
<td>15</td>
<td>16.9</td>
<td>17.2</td>
</tr>
<tr>
<td>16</td>
<td>16.1</td>
<td>16.4</td>
</tr>
<tr>
<td>17</td>
<td>15.9</td>
<td>16.1</td>
</tr>
<tr>
<td>18</td>
<td>13.9</td>
<td>14.1</td>
</tr>
<tr>
<td>19</td>
<td>15.4</td>
<td>16.0</td>
</tr>
<tr>
<td>20</td>
<td>13.5</td>
<td>13.3</td>
</tr>
<tr>
<td>21</td>
<td>15.6</td>
<td>15.5</td>
</tr>
<tr>
<td>22</td>
<td>16.0</td>
<td>15.9</td>
</tr>
<tr>
<td>23</td>
<td>14.9</td>
<td>14.9</td>
</tr>
<tr>
<td>24</td>
<td>15.8</td>
<td>16.0</td>
</tr>
<tr>
<td>25</td>
<td>15.8</td>
<td>17.1</td>
</tr>
</tbody>
</table>

The standard deviation for the set of raw scores in the ideal temperature for the shuttle run was .9188. The standard
deviation for the set of raw scores in the high temperature was 1.0579.

The \( t \) ratio for the significance of difference between the means in the Shuttle Run at high temperature and ideal temperature is presented in Table II.

**TABLE II**

MEAN SCORE AND \( t \) RATIO FOR PERFORMANCE SCORES ON THE SHUTTLE RUN

\( N = 25 \)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Mean Score</th>
<th>( t ) Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>15.408</td>
<td>1.777</td>
</tr>
<tr>
<td>Ideal</td>
<td>15.252</td>
<td></td>
</tr>
</tbody>
</table>

The mean score for the Shuttle Run in the high temperature was 15.408 seconds, while the mean score in the ideal temperature was 15.252 seconds. Calculation of the \( t \) ratio for the data collected from the Shuttle Run yielded a ratio of 1.777, which was statistically significant at the .05 level. Hypothesis I was supported by the data and was accepted.
Findings Related to Hypothesis II

Hypothesis II stated that endurance, as measured by the time it takes to run the 440-yard dash, will be significantly improved at ideal temperature rather than at the high temperature of ninety degrees.

The raw scores for each subject on the 440-yard dash are presented in Table III. Each score is recorded to the nearest tenth of a second.

TABLE III
RAW DATA COLLECTED FOR THE 440-YARD DASH

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To Nearest Tenth of A Second</th>
<th>Raw Scores In High Temperature To Nearest Tenth of A Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81.1</td>
<td>82.4</td>
</tr>
<tr>
<td>2</td>
<td>88.7</td>
<td>88.6</td>
</tr>
<tr>
<td>3</td>
<td>97.1</td>
<td>98.0</td>
</tr>
<tr>
<td>4</td>
<td>88.5</td>
<td>88.1</td>
</tr>
<tr>
<td>5</td>
<td>94.6</td>
<td>102.3</td>
</tr>
<tr>
<td>6</td>
<td>91.3</td>
<td>90.7</td>
</tr>
<tr>
<td>7</td>
<td>91.9</td>
<td>93.2</td>
</tr>
<tr>
<td>8</td>
<td>105.7</td>
<td>97.3</td>
</tr>
<tr>
<td>9</td>
<td>76.5</td>
<td>78.8</td>
</tr>
<tr>
<td>10</td>
<td>87.4</td>
<td>93.5</td>
</tr>
<tr>
<td>11</td>
<td>90.8</td>
<td>93.5</td>
</tr>
<tr>
<td>12</td>
<td>89.8</td>
<td>84.8</td>
</tr>
</tbody>
</table>
TABLE III -- Continued

RAW DATA COLLECTED FOR THE 440-YARD DASH

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To Nearest Tenth of A Second</th>
<th>Raw Scores In High Temperature To Nearest Tenth of A Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>74.4</td>
<td>79.0</td>
</tr>
<tr>
<td>14</td>
<td>80.0</td>
<td>82.8</td>
</tr>
<tr>
<td>15</td>
<td>111.7</td>
<td>124.4</td>
</tr>
<tr>
<td>16</td>
<td>79.5</td>
<td>79.9</td>
</tr>
<tr>
<td>17</td>
<td>85.2</td>
<td>90.2</td>
</tr>
<tr>
<td>18</td>
<td>68.5</td>
<td>68.3</td>
</tr>
<tr>
<td>19</td>
<td>91.9</td>
<td>88.4</td>
</tr>
<tr>
<td>20</td>
<td>74.1</td>
<td>82.5</td>
</tr>
<tr>
<td>21</td>
<td>79.8</td>
<td>80.6</td>
</tr>
<tr>
<td>22</td>
<td>94.6</td>
<td>93.4</td>
</tr>
<tr>
<td>23</td>
<td>85.4</td>
<td>89.4</td>
</tr>
<tr>
<td>24</td>
<td>84.6</td>
<td>86.4</td>
</tr>
<tr>
<td>25</td>
<td>82.8</td>
<td>86.6</td>
</tr>
</tbody>
</table>

The standard deviation for the set of raw scores in the ideal temperature for the 440-yard dash was 9.7256. The standard deviation for the set of raw scores in the high temperature was 10.4151.

The $t$ ratio for the significance of difference between the means in the 440-yard dash at high temperature and ideal temperature is presented in Table IV.
TABLE IV
MEAN SCORE AND t RATIO FOR PERFORMANCE SCORES ON THE 440-YARD DASH
N = 25

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Mean Score</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>88.92</td>
<td>2.170</td>
</tr>
<tr>
<td>Ideal</td>
<td>87.04</td>
<td></td>
</tr>
</tbody>
</table>

The mean score for the 440-yard dash in the high temperature was 88.92 seconds, while the mean score in the ideal temperature was 87.04 seconds. Calculation of the t ratio for the data collected for the 440-yard dash yielded a ratio of 2.169 which was statistically significant at the .025 level. Hypothesis II was supported by the data and was accepted.

Findings Related to Hypothesis III
Hypothesis III stated that reaction time as measured by the American Automobile Association's Reaction Timer, will be significantly less at ideal temperature rather than at the high temperature of ninety degrees.
The raw scores for each subject on the reaction timer are presented in Table V. Each score is recorded to the nearest hundredth of a second.

### Table V

**Raw Data Collected for Reaction Time**

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To The Nearest Hundredth of a Second</th>
<th>Raw Scores In High Temperature To The Nearest Hundredth of a Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.34</td>
<td>.31</td>
</tr>
<tr>
<td>2</td>
<td>.39</td>
<td>.40</td>
</tr>
<tr>
<td>3</td>
<td>.37</td>
<td>.40</td>
</tr>
<tr>
<td>4</td>
<td>.34</td>
<td>.34</td>
</tr>
<tr>
<td>5</td>
<td>.40</td>
<td>.40</td>
</tr>
<tr>
<td>6</td>
<td>.37</td>
<td>.36</td>
</tr>
<tr>
<td>7</td>
<td>.37</td>
<td>.36</td>
</tr>
<tr>
<td>8</td>
<td>.35</td>
<td>.33</td>
</tr>
<tr>
<td>9</td>
<td>.37</td>
<td>.34</td>
</tr>
<tr>
<td>10</td>
<td>.38</td>
<td>.39</td>
</tr>
<tr>
<td>11</td>
<td>.34</td>
<td>.38</td>
</tr>
<tr>
<td>12</td>
<td>.35</td>
<td>.39</td>
</tr>
<tr>
<td>13</td>
<td>.38</td>
<td>.36</td>
</tr>
<tr>
<td>14</td>
<td>.38</td>
<td>.34</td>
</tr>
<tr>
<td>15</td>
<td>.37</td>
<td>.37</td>
</tr>
<tr>
<td>16</td>
<td>.39</td>
<td>.42</td>
</tr>
</tbody>
</table>
The standard deviation for the set of raw scores in the ideal temperature using the reaction timer was .0242. The standard deviation for the set of raw scores in the high temperature was .0320.

The $t$ ratio for the significance of difference between the means in the reaction time at high temperature and ideal temperature is presented in Table VI.

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To The Nearest Hundredth of a Second</th>
<th>Raw Scores In High Temperature To The Nearest Hundredth of a Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>.38</td>
<td>.39</td>
</tr>
<tr>
<td>18</td>
<td>.35</td>
<td>.36</td>
</tr>
<tr>
<td>19</td>
<td>.35</td>
<td>.38</td>
</tr>
<tr>
<td>20</td>
<td>.33</td>
<td>.32</td>
</tr>
<tr>
<td>21</td>
<td>.43</td>
<td>.44</td>
</tr>
<tr>
<td>22</td>
<td>.40</td>
<td>.36</td>
</tr>
<tr>
<td>23</td>
<td>.37</td>
<td>.40</td>
</tr>
<tr>
<td>24</td>
<td>.33</td>
<td>.35</td>
</tr>
<tr>
<td>25</td>
<td>.36</td>
<td>.40</td>
</tr>
</tbody>
</table>
TABLE VI

MEAN SCORE AND t RATIO FOR PERFORMANCE SCORES ON THE REACTION TIMER

N = 25

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Mean Score</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>.372</td>
<td>.800</td>
</tr>
<tr>
<td>Ideal</td>
<td>.368</td>
<td></td>
</tr>
</tbody>
</table>

The mean score on the Reaction Timer in the high temperature was .372 seconds, while the mean score in the ideal temperature was .368 seconds. Calculation of the t ratio for the data collected from the Reaction Timer yielded a ratio of .800 which was not statistically significant. Hypothesis III was not supported by the data and was not accepted.

Findings Related to Hypothesis IV

Hypothesis IV stated that strength, as measured by a grip dynamometer, will be significantly greater at the ideal temperature rather than at the high temperature of ninety degrees.

The raw scores for each subject using the grip dynamometer are presented in Table VII. Each score is recorded to the nearest pound of pressure.
<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Raw Scores In Ideal Temperature To The Nearest Pound Of Pressure</th>
<th>Raw Scores In High Temperature To The Nearest Pound Of Pressure</th>
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<tr>
<td>1</td>
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</table>
The standard deviation for the set of raw scores in the ideal temperature using the grip dynamometer was 24.0383. The standard deviation for the set of raw scores in the high temperature was 24.6982.

The $t$ ratio for the significance of difference between the means with the grip dynamometer at high temperature and ideal temperature is presented in Table VIII.
TABLE VIII
MEAN SCORE AND t RATIO FOR PERFORMANCE SCORES ON THE GRIP DYNAMOMETER
N = 25

<table>
<thead>
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<th>Temperature</th>
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<th>t Ratio</th>
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<tr>
<td>Ideal</td>
<td>79.44</td>
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The mean score with the grip dynamometer in the high temperature was 76.80 pounds, while the mean score in the ideal temperature was 79.44 pounds. Calculation of the t ratio for the data collected from the grip dynamometer yielded a ratio of 2.627 which was statistically significant at the .01 level. Hypothesis IV was supported by the data and was accepted.

The results of the study supported three of the four hypotheses. Agility, endurance, and strength were all improved significantly at the ideal temperature. While there was a slight improvement in reaction time performance at the ideal temperature, the difference was not statistically significant.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem under consideration in this study was the effect that high temperature (ninety degrees Fahrenheit) had upon performance levels of four specific components of motor fitness. The components were agility, endurance, reaction time, and strength. A comparison was made to determine if there was a significant difference in performance levels at a high temperature (ninety degrees Fahrenheit) and a moderate temperature (sixty-eight degrees Fahrenheit). The four components were tested by using a shuttle run, a 440-yard run, a reaction timer, and a grip dynamometer. It was hypothesized that performance would be improved in the ideal or moderate temperature.

During June and July of 1974, thirty-one high school subjects took part in the study. Twenty-five of the original thirty-one completed all of the testing. A total of seventeen days was used to carry out the study. The first day was for orientation, and the last sixteen days were for actual testing. The subjects were divided into two groups. Subjects were stratified according to grade classification and sex. Once this stratification was accomplished, subjects were randomly placed in either Group A or Group B.
Each of the tests required four days of testing. For example, on the agility test for the first day, Group A was tested at the ideal temperature. On the second day, they were tested at the high temperature. The reverse procedure was used for Group B. On the third day, Group B was tested at the high temperature. On the fourth day, Group B was tested at the ideal temperature.

The Fisher's t-test for significance of difference between the means of two related samples was the statistical technique used in the study. The hypotheses were accepted at the .05 level of confidence.

A summary of the findings with respect to the hypotheses is as follows:

I. It was hypothesized that agility, as measured by the Shuttle Run, would be significantly quicker at ideal temperature rather than at the high temperature of ninety degrees Fahrenheit.

Data collected from the Shuttle Run yielded a t ratio of 1.777, which was statistically significant at the .05 level of confidence. Therefore, the hypothesis was accepted.

II. It was hypothesized that endurance, as measured by the time it takes to run the 440-yard dash, would be significantly improved at ideal temperature rather than at the high temperature of ninety degrees.
Data collected from the 440-yard dash yielded a $t$ ratio of 2.170, which was statistically significant at the .025 level of confidence. Therefore, the hypothesis was accepted.

III. It was hypothesized that reaction time as measured by the American Automobile Association's Reaction Timer, would be significantly less at ideal temperature rather than at the high temperature of ninety degrees.

Data collected from the Reaction Timer yielded a $t$ ratio of .800, which was not statistically significant at the .05 level of confidence. Therefore, the hypothesis was not accepted.

IV. It was hypothesized that strength, as measured by a grip dynamometer, would be significantly greater at ideal temperature rather than at the high temperature of ninety degrees.

Data collected using the grip dynamometer yielded a $t$ ratio of 2.627, which was statistically significant at the .01 level of confidence. Therefore, the hypothesis was accepted.

Conclusions

Based on the findings of the study the following conclusions were drawn:

1. High temperature (ninety degrees Fahrenheit) causes human motor performance to deteriorate, and ideal temperature (sixty-eight degrees Fahrenheit) causes human motor performance to be improved.
2. The three components which showed a significant difference required more muscular action than did the component (reaction time) which showed no significant difference.

3. The majority of previous findings agree with the present research in respect to agility and reaction time.

4. Results were evenly divided as to the effects of heat on endurance and strength with present research adding credence to improved performance in ideal temperature.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are made:

1. New high school gymnasiums should be air-conditioned if the facility is to be used during the summer months.

2. Old high school gymnasiums should be air-conditioned if the facility is to be used during the summer months.

3. Further studies should be conducted to determine the relationship between thermal stress and ability in the performance of a physical task.

4. Additional research should be conducted to determine the optimal temperature for performance of physical tasks.

5. Further studies should be conducted to determine the effect that acclimatization has upon motor performance in high temperature.
6. Additional research should be conducted to determine the effect that age has upon motor performance in high temperature.

7. Further studies should be conducted to determine the effect that sex has upon motor performance in high temperature.

8. Further research should be conducted to determine the effect that varying air circulation has upon motor performance when humidity and temperature are kept constant.

9. Further research should be conducted to determine the effect that varying humidity has upon motor performance when air circulation and temperature are kept constant.
APPENDIX A

SUMMER TEMPERATURES (1973)

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* T-Temperature  H-Humidity (Indoor temperatures and humidities were recorded with a Sling Psychrometer)
**Outdoor - Official National Weather Service temperature between 1 p.m. and 2 p.m.
### APPENDIX A

**SUMMER TEMPERATURES (1973)**

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| TOTALS | 1878 | 1090 | 1920 | 778 | 2150 | 980 | 2027 | 1112 | 2058 | 920 |

| AVERAGE | 89.13 | 51.90 | 91.43 | 37.04 | 102.38 | 46.60 | 96.52 | 52.95 | 98.00 | 43.81 |

* T-Temperature  
H-Humidity (Indoor temperatures and humidities were recorded with a Sling Psychrometer)
## APPENDIX A

### SUMMER TEMPERATURES (1973)

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### Summer Totals

- Barwise: 4622 2870
- Reagan: 4691 2124
- Zundy: 5347 2547
- W.F.H.S.: 4907 2691
- Outdoor: 4994 2431

### Summer Average

- 85.59 53.15
- 86.87 39.33
- 99.02 47.17
- 90.87 49.83
- 92.48 45.02

Average for four Wichita Falls gymnasiums during school days of June, July, August between 1 p.m. and 2 p.m.

- **Temperature**: 90.59
- **Humidity**: 47.37

* T-Temperature  H-Humidity (Indoor temperatures and humidities were recorded with a Sling Psychrometer)
APPENDIX B

GENERAL INFORMATION SHEET

PLEASE PRINT.

Name ____________________________________________

Last First Middle

Address ____________________________________________

Phone Number ____________________________

Date of Birth ____________________________

Age ______

Sex ______

High School Attending ____________________________

Grade Level ______

Height ______

Weight ______

High School Varsity Experience

Sport ____________________________ Years ______

Sport ____________________________ Years ______

Sport ____________________________ Years ______

Sport ____________________________ Years ______

Sport ____________________________ Years ______

Sport ____________________________ Years ______
APPENDIX C

June 29, 1974

Representative Dan Kubiak
Texas House of Representatives
Austin, Texas

Dear Representative Kubiak:

I would like to ask your reasoning as you introduced the bill (H.B. 1078) which placed Texas public schools on the quarter system. Since I am working on my doctoral dissertation at North Texas State University, and the paper concerns temperature and performance in Texas public schools, any of the research done by your staff in preparation for passage of the bill could add to the background which I need.

Our mutual friend Jo Ann Lane, (Mrs. Jimmy) assures me that you serve educators all over Texas as well as in your own district. I appreciate your efforts for education in our state and would appreciate having salient points about the legislation which you can add.

Thank you.

Don Flatt

Don Flatt
Mr. Don Flatt  
Midwestern University  
3400 Taft  
Wichita Falls, Texas 76308  

Dear Professor Flatt:

I was pleased to receive your letter requesting information regarding the enacting legislation for the quarter school system and to learn of your interest in this area.

It has been a very thrilling experience for me to watch the quarter system evolve in Texas from an idea—being researched and developed into legislation—and to now be on the threshold of its fruition.

I have asked my secretary to prepare some materials for your use which you shall be receiving shortly under separate cover. We have also requested materials from the Texas Education Agency for you relating to implementation of the plan. If you require further information, please do not hesitate to let my office know, and best wishes on your dissertation.

Sincerely,

Dan Kubiak

DK/cc
Mr. Don Flatt, Associate Professor  
Midwestern University  
3400 Taft  
Wichita Falls, Texas  76308  

Dear Mr. Flatt:  

In response to a request from Representative Kubiak's office, I am enclosing materials relating to planning and implementing the quarter system in public schools.  

We are pleased to make this information available to you.  

Very truly yours,  

[Signature]  
M. L. Brockett  
Commissioner of Education  

enclosures
August 5, 1974

Representative Dan Kubiak
P. O. Box 272
Rockdale, Texas

Dear Representative Kubiak:

I have received the materials which you and your staff compiled on the quarter system, and I am in the process of incorporating them into my chapter on related research. I also received and am using the packet from the Texas Education Agency which you requested that they send me.

I appreciate very much your help in this matter, and I will continue to admire your work for Texas education.

Thank you.

Sincerely,

Don Flatt
Health, Physical Education
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Research Project of the Architectural Research Group, Texas Engineering Experiment Station Educational Facilities Laboratories, *Shelter for Physical Education*, A & M College of Texas, College Station, 1961.


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Unpublished Materials


Newspapers

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