A STUDY OF THE EFFECTS OF HEAT AND COLD ON REACTION TIME, STEADINESS BALANCE, AND MOTOR PERFORMANCE

by

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CHAPTER I

INTRODUCTION

In the field of Physical Education there have been many research studies done on general motor ability, physical fitness, and motor performance. Skills tests have been devised for most of the sports activities included in a well-rounded Physical Education program. Attitude studies have been compiled as well as studies on programs and curriculum. Other research dealing with the physiological aspects of performance have been and are being compiled in the field of Physical Education as well as in related fields. In the field of Physiology, there has been significant research done in the area of stress. (45) One aspect of stress that has received a great deal of attention in the past few years deals with the effects of temperature or thermal stress on the human body.

It is known, from research done in Physiology, that there are many external stimuli that affect the physiological functionings of the body. As a result of the studies compiled by such men as Winslow and Herrington(17), Schneider and Karpovich(12), and others, it is evident that heat and cold have definite effects on the physiological functioning of the human body.

It would add to the current knowledge to know the effects, if any, that thermal stress has on the motor functioning of the body. Some research has been completed in this area but little has been connected directly with the field of Physical Education.

During the Second World War, the Division of Medical Sciences of the National Research Council formed a committee of competent and able researchers who were able to contribute important information to the Armed Services that would help to relieve many of the climatic problems with which service men were forced to cope.[10]

Today there are industrial attempts to adjust man's thermal environment by air conditioning or heating in factories, offices, and work areas. Presumably this effort to make man thermally comfortable is for the express purpose of protecting his health and to make his surroundings conducive to better and more productive work.

All of these aspects of research and the contributions that have been made in the area of thermal stress in the fields of Physiology and Physical Education have provided valuable information not only to the industrialist and the Armed Services, but also to the Physical Education teacher who is responsible for the conduct of the weekly activity classes.

With the information provided by the wealth of research completed in the fields of Physiology and Physical Education, the alert and inquiring Physical Education teacher has the opportunity to better understand the total functioning of the body. He can know more about how, and when, and why performance in motor skills may or may not be affected by thermal environment as well as by other external or internal stimuli.

For years questions have been asked by Physical Educators. What happens to motor performance in an individual or individuals who are not used to the extremes of heat or cold? What happens to an individual's performance who does not seem to be bothered by the thermal environment in which he is being active? Does the competitor at a swimming meet perform up to par when the competition is held on a particularly cold day? What of the tennis player who wants to perform at her peak and the temperature on the courts is in the high nineties or low one hundreds? Do the students in a field hockey class play better when it is warm or does their game improve when the weather is a little brisk?

Questions similar to these have been asked perhaps by every Physical Educator, athlete, coach, or professional sports person. With these questions in mind, the writer has attempted in this study to determine some of the effects of external heat and cold on steadiness, dynamic balance, reaction time, and motor performance.

CHAPTER II

STATEMENT OF THE PROBLEM

The purpose of the study was to determine the effects of selected external temperatures on arm-hand steadiness, dynamic balance, movement reaction time, and motor performance.

The selected experimental temperatures used in this study included exposures at a base temperature of 75° to 80°, and the five experimental temperatures of 110°, 94°, 58°, 37°, and 8°. All temperatures used throughout the paper are in Fahrenheit terms.

Steadiness was tested by the use of an arm-hand steadiness testing apparatus which was made up of an electrically activated metal plate and stylus. Movement reaction time was measured by the use of visual light stimuli and electrical response units. Balance was measured by use of the Bass Test for Dynamic Balance and motor performance was measured by the use of the French-Cooper Volley Ball Wall Volley Test.

The main purpose of the study was to compare the results of performance in all of the selected tests at the base temperature to performance at all of the selected experimental temperatures to determine the effects of these temperatures on motor performance. This study also included a comparison of all scores at the selected experimental temperature to each other.

CHAPTER III

REVIEW OF LITERATURE

In the past few years there has been much research done in the field of Physiology in regard to the effect of thermal stress on the human body. According to Hans Selye,

> ...stress is the consequence of wear and tear in a biological system. The system may be the organism as a whole (systemic) or one of its parts (topical stress). The visible manifestations of the former constitute the general adaptation syndrome, while those of the latter are known as the local adaptation syndrome (L.A.S.).(45:660)

There are innumerable stressors that affect the workings of the body, and the atmosphere and temperatures in which man lives are two of the more common and persistent effectors in his daily life.

To a large extent, thermal stress is dependent upon climate and the climate depends on many things, i.e., wind, humidity, and temperature. Different environmental temperatures can cause physiological changes in skin temperature, heart rate, sweat secretion, and total heat production, as well as the heat insulating value of peripheral tissue.(6) The humidity, atmospheric pressure and air movement all affect the control of body temperature. Cooling of the body can take place without altering the temperature, by decreasing the humidity and increasing the air move-move.(12)

Since the body operates most efficiently in a "comfort range" of temperature and humidity, research has long sought to establish this comfort range. As a result of research on the part of the American Society of Heating and Ventilation Engineers, temperature comfort zones have been established for the normally dressed person at rest in still air. The winter comfort zone is established at 63° to 71°, while the summer zone ranges from 66° to 75°. The optimal zone for all seasons is set at 66° to 71° with a relative humidity from thirty per cent to seventy per cent.[(17)] In man the minimum metabolic rate has been established at 68° to 122° and if external temperatures of the body go below 68° or above 122° there is a tendency for the metabolic rate to rise. The normal internal or deep body temperature is approximately 98.6°. Metabolism is one of the important heat regulatory mechanisms of the body. Basal metabolism is the ability of the body to produce enough heat energy to sustain life at a resting rate. It is basically the building up and tearing down process of living material in the body. Metabolic rate is, "The sum of the heat and external work produced by an organism in a given time. The fundamental measure is by calorimetry, but in practice it is measured by oxygen consumption."[(3:446)]

Basal metabolism can be reduced to a degree and restored to normal for adaptation to heat but it is doubtful that it can be raised above normal to aid in heat production in long exposures to cold. In hot conditions a loss of about thirteen per cent total heat production occurs through the feet. The loss is not as great in cool conditions. In high temperatures the loss of most of the body heat is by evaporation of actively secreted sweat, at moderate temperatures by convection, and in low temperatures again through evaporation as a result of lower convective loss.[1]

According to Hart[32], the two general modes of heat production are gross motor activity and shivering.

> Of the two, voluntary motor activity appears to be relatively unsuitable in the cold when the end product desired is heat because a) voluntary activity can not be chronically sustained, b) energy is converted to mechanical work, and c) voluntary activity reduces body insulation thereby sustaining a large metabolic cost to derive a gain in stored heat.[32:1046]

According to Wells:

> Under ordinary conditions, the temperature regulatory mechanism of the human body is adequate to meet the needs brought about by external temperature changes. This adjustment is brought about by the balance maintained between heat production and heat loss. In the normal resting individual the balance is so maintained that there is uniformity in blood pressure, pulse rate, frequency, depth of respiration, and body temperature.[47:108]

The transfer of heat and heat production are such that normally the body is able to maintain a constant internal temperature of approximately 98.6°. The regulation of thermal balance in the body is controlled somewhat by heat production but it is chiefly maintained by heat loss.

The loss of body heat occurs through expired air, evaporation of sweat, conduction, convection, and radiation. Radiation is "... the exchange of thermal energy between objects,..".[5:79] This process is affected by the temperature only and the nature of the radiating object. It is the exchange of heat from a hot (radiating) surface exposed to a cooler surface.

Conduction is "The flow of heat through a medium without the physical transfer of material...".(5:88)

"Convection is a term which refers to the exchange of heat between hot and cold objects by the physical transfer of the liquid or gas with which the objects are in contact. This type of heat transfer depends on the existence of a fluid medium between the warm and cold objects... ."(5:92)

Evaporation takes place at the skin surface and body heat is carried off by the sweat which vaporizes at body temperature, and is then passed off into the atmosphere to cool. It is estimated that "... about 25 per cent of the metabolic heat is carried away from the body by the water evaporated from the skin and lungs."(5:99) The loss of body heat can be reduced by roughening the skin, which sets up hairs limiting air movement over the skin. Heat losses can thus be increased by increasing the air movement through exercise, and under some conditions, the heat loss may be greater than that produced by the exercise.(1)

According to Schneider and Karpovich(12), research indicates that a cool and comfortable temperature of about 68° F with a relative humidity of fifty per cent is beneficial, and that high temperatures can cause severe disturbances to physiological processes. The principle cause of these disturbances is the inability of the body to cool itself properly as a result of the temperature and high moisture content of the surrounding air. With a rise in external temperature, the blood vessels dilate exposing a greater volume of blood to the outside air. There is an increase in loss of body heat and blood leaving the skin is highly oxygenated. Karpovich[7] states that this is an indication that the increased blood supply is determined by the temperature and not by tissue activity.

PHYSIOLOGICAL ADAPTATIONS TO HEAT

Under conditions of thermal stress of high temperatures, the body adapts to these conditions and the following are basic physiological adjustments compiled by Robinson[11] and others.

Circulation. During work in high temperatures, thermal equilibrium can be maintained by conducting body heat from the tissues where it is being produced to the skin and respiratory system. Circulation is mainly responsible for this. The blood supplies the skin with water and it in turn is then cooled. There is vaso-dilation of the cutaneous blood vessels which brings about an increased blood flow to the skin, and under ordinary conditions causes the skin temperature to rise. This allows for more heat loss from the skin by evaporation and convection.

Sweating. Sweating is the chief mechanism of the body that prevents over heating and it can be caused by muscular exercise, thermal atmosphere, and emotional and psychological stress. Sweating usually starts anywhere from five to forty minutes after exposure to the hot environment. Winslow and Herrington[17] found that sweating starts when the mean skin temperature reaches 95.1°. "During rapid elevation of the body temperature by acute exposure to extreme heat stress, the rising metabolism of man may increase by twenty-five to thirty-five per cent over the control values."[11:221] This rise in the metabolism causes discomfort and lowers the efficiency of the individual. There is evidence that the skin temperature increases with an increase in environmental temperature.

Respiration. In exposure to heat, frequency of breathing increases along with an increase in rectal temperatures. If the temperature rise be rapid then breathing tends to become faster as well as deeper, causing a marked loss of carbon dioxide which eventually results in a marked alkalosis of the blood. Along with the rise in metabolism, and the evidence of increased skin temperature, pulmonary ventilation also contributes to heat exchange by convection and evaporation depending on the depth of respiration, the temperature and relative humidity. Usually a rise in the core (deep body) temperature will cause an increase in respiration, adding to the heat loss from the body.[11]

If a subject was exposed to temperatures of 140° to 167° he would have difficulty in remaining in an upright position and would have little tendency to vigorous action. He would sweat profusely and, in time, if over exposed the body would become dehydrated and the subject would collapse. The common posture is one of complete relaxation to the point of being limp, with the arms and legs spread in order to expose as much body surface to facilitate heat loss.[17]

Herrington[6] showed that heat as well as cold fosters physiologic change in the human body. In extreme heat the warming of the body tissue and the rise in metabolic rate accentuate the heating of the body itself, and if this condition is prolonged it can induce heat stroke. In such a situation the body is unable to give off heat and the core temperature rises; and if the core temperature goes above 105° for a prolonged period of time, death can result.

> Heat exhaustion with fatal termination following periods of heat stress appears to involve a progressive alteration of temperature regulation which does not seem to be a conspicuous feature of cold exposure fatalities.[6:266]

In a study by Schneider and Karpovich[12], subjects were placed in a temperature chamber from four to seven hours in temperatures of 68° with fifty per cent relative humidity and this condition caused a fall in body temperature. However, if the temperature of 75° were maintained and fifty per cent relative humidity were held, the body temperatures remained almost constant. In contrast when the subjects were exposed for three hours in a temperature of 104° and ninety-five per cent relative humidity, the body temperature rose six Fahrenheit degrees. Although man's body or core temperature tends to remain constant when at rest, it is possible for it to vary one to two and a half degrees. The atmospheric surroundings will affect the amount of heat loss by convection and the humidity of the immediate surroundings will regulate heat loss by evaporation.(12)

Driver(22) did a study in which she attempted to trace the physiological differences between people who preferred a hot climate to those who preferred a cold climate. She noted that summer preferrers had higher blood pressures in all stress conditions. She concluded that it was possible that people with normally lower blood pressure prefer cool weather. The final results on metabolism showed that there was no significant change in the groups and no significant differences between the groups.

A study on racial differences by Baker(18) compared the heat stress resistance of American white males to American negro males. He wanted to determine if climate played a role "...in the selection of certain morphological characteristics."(18:287) Two separate experiments were conducted, one in moderate hot-wet conditions in Virginia and the other in hot-dry conditions in the Yuma desert. The purpose of this study was to determine the differences in the ability of White and Negro soldiers to withstand heat stress. Out of two hundred men, forty pairs were chosen and each pair was matched as closely as possible to another pair for per cent of body fat, fat free weight, and stature. The pairs were then exposed to equal heat stress and the strain responses were measured. "As measured by a paired "t" test, there was a significant difference at the 0.05 level or better between rectal temperatures of the Negroes and Whites both before the walk and afterwards. The difference was increased by the exercise."(18:291-2) Eighteen of the Whites came from the north, so Baker then compared them to eighteen white southern males and found that there were slight differences that indicated that the southerners were slightly lower in heat resistance than the northerners. The differences were not statistically significant and Baker felt that this comparison indicated that the locale of the subjects did not influence their heat tolerance. The total results of both studies showed that:

1. Under hot-wet conditions with both Negroes and Whites clothed and walking, the Negroes had a higher physiological tolerance.
2. Under hot-dry conditions with both groups clothed walking or sitting they had about equal tolerance.
3. Under hot-dry conditions with both groups nude and exposed to the sun, sun-tanned Whites had the higher tolerance. (18:303)

"The results further suggested that the differences found were not a function of transient environmental effects and may be mostly genetic in origin."(18:303)

PHYSIOLOGICAL ADAPTATIONS TO COLD

It is equally important to understand the effects of cold on the human body and to know how the body adapts physiologically.

Sellers(44) believed that,

> A greater understanding of fundamental physiological changes in cold may be anticipated. However, a knowledge of how to live in the cold and the ability to adapt sociologically is more important than any physiological changes

likely to occur.[44:117]

This may be true in theory but it is important to know more about the specific physiological effects of cold stress. It is necessary for safety purposes to ascertain more definite facts concerning the regulation of body temperature, physiological adjustments to cold, and the effects cold has on body heat production and heat loss.

Circulation. Spealman's[14] study on adjustments to cold showed that, in response to cold stress, there is constriction of the peripheral blood vessels. The flow of blood to the skin is reduced and the heat normally given off from the blood is retained in the body. The surface temperatures of the body tend to fall, and shivering occurs. The shivering mechanism or reaction increases heat production and brings the heat balance back into equilibrium.[14]

Respiration. According to Winslow and Herrington[17], in exposure to cold, respiration becomes labored and the pulse becomes slower. If the exposure is prolonged the body tends to become rigid because of muscular contraction. Eventually it becomes almost impossible for the muscles to be voluntarily relaxed. The respiratory muscles become affected and breathing becomes difficult. The tensing of the body is an involuntary reaction and it reduces the surface area of the body that is exposed to the air and prevents too much loss of heat. In its early stages this reflex action is usually a good stimulus for exercise.

Shivering. Exposure to cold causes a vaso-constriction of cutaneous vessels and tissue. Shivering often occurs which is a result of contractions of small motor units that act alternately with antagonistic muscles thus reducing gross motor movements. This is important during shivering since the heat that is produced from the muscular action of shivering is needed to maintain deep body temperature at a normal level. Although heat is produced from shivering, the amount of heat is usually not adequate to maintain the deep body temperature if the exposure to cold is prolonged.[1]

According to Herrington[6], the results of many studies have shown that the effects of cold can be harmful when body temperature is lowered to 93.2°. At this temperature, shivering usually occurs and at a lower temperature of 79.7° subjects being tested could give no verbal response and it was suggested that beyond this limit there would be no recovery from cold stress.

The studies of the effects of cold on man, have pointed out that there is a great variance in temperatures on different parts of the body, while the deep body temperature will remain constant under ordinary conditions.[44] The fundamental reactions of the body are the lowering of the skin temperature, due to constriction of the peripheral blood vessels, and if exposure is long the metabolic rate usually increases and this increase is often accompanied by shivering. If there be a sudden drop in body temperature to 79.8° or below, a rapid increase in heat loss is produced.[17]

Although general external and internal temperatures affect the normal functioning of man, it is possible for the individual to adjust or become acclimated to abnormal temperatures. Studies conducted by Goldsmith and Lewis[28] in the Arctic and Antarctic regions deal with the physiological and psychological adjustments to cold stress. The subjects for these studies were scientists who were members of polar expeditions. Buston's results, as cited by Goldsmith and Lewis[28], indicate that the men became acclimated to cold as evidenced by the fact that they became used to wearing the same type of clothing, which they selected for comfort, in spite of drops in temperature at seasonal changes. Later expeditions kept track of the clothing worn, the environmental conditions, and the type and amount of work accomplished. The records showed that in general, the men did not vary their clothing. In still later expeditions it was recorded that the men did change the type of clothing worn in the varying climatic conditions. However, the records indicated that for similar or comparable climatic stress, they wore fewer clothes at the end of the stress period than at the beginning. It was assumed that they were better able to withstand the cold.[28]

Scholander[42] stated that ". . . white man has a critical temperature of about 27C, 65.6F . . . ."(42:1054) He expressed the theory that man is considered adapted to his thermal environment when he can sleep and rest in it comfortably. Scholander used this criteria for judging the results of his studies which were conducted on camping trips in the Norwegian mountains. At night the subjects were exposed to temperatures that were cold enough to cause shivering and restlessness, but the temperatures were low enough so that the subjects were able to overcome the shivering and restlessness during sleep by becoming acclimated. The men slept naked in a one blanket sleeping bag at a temperature of 41° to 36°. The period of exposures lasted for two weeks and after a few uncomfortable nights, the chill sensation left but shivering remained although it was not enough to waken the subjects. The men were then taken back to the base camp where they slept out of doors with a control group that had not been acclimated. Both groups shivered during the night but the acclimated group did not waken, while the control group had very restless and fitful sleep. Both groups had shown evidence of higher metabolic rates but the controls showed additional dropping peripheral temperatures; the test group stayed warm all over. Scholander summed up by stating that "...the metabolic response in humans is directly produced by the stress, (thermal), and it disappears when this is over, leaving sometimes a very slightly elevated basal metabolic rate."(42:1055)

Scholander(42) did a similar study on Australian Aborigines who were able to lie naked on the ground between small fires and sleep in temperatures as low as 46.6° Their basal metabolic rate was normal, which seemed to support the fact that metabolism has very little to do with acclimation. He found that Whites could also sleep in these conditions provided there was no wind. The Aboriginies slept at a sub-basal rate cooling off more on the surface than the Whites did. The author compared this ability of the Australians, to sleep at a sub-basal rate, to the insulative power of animals.

One of the important factors in acclimation to cold is the development of local resistance to cold injury. Acclimation, however, is only one of degree and does not ignore the need for proper protection and caution in the extreme cold.

Sellers(44) reported that there is some evidence that humans, who have become acclimated, have greater tolerance for cold than those who are not acclimated and that they are less susceptible to cold injury and frost bite. He summarized his findings by stating that acclimation "... can, and does occur, but in extreme cold the relative importance of this to other factors is small."(44:117)

Kreider, Iampietro, Buskirk, and Bass(36) reported on the significant changes in skin and rectal temperatures that occur during nocturnal exposures. The subjects for the study were army men who were exposed to a constant temperature of 60° for fourteen days. Rectal and skin temperatures were taken regularly and the results showed that during the day, rectal temperatures showed a normal increase while skin temperatures were five to six Centigrade degrees lower than during the night or control period. At night, during the cold exposure, the rectal temperatures dropped to a lower value and at an earlier hour than they did during previous warmer exposures at 80°. Rectal temperatures also dropped to a lower level during the earlier cold exposures than in the later cold exposures at night. The experimentation also showed that during the later nocturnal exposures, the subjects' toes re-warmed faster and the temperature of the toes was twenty-seven degrees higher than during the earlier tests. The arch of the foot and the calf of the leg followed the same pattern of change as the toes but the change was not as marked. The final results of the study showed that the only modifications in body temperature occurred during the cold sleeping period when the subjects were covered. The researchers felt that this might be evidence enough to indicate that in order to find evidence of acclimation to cold, research might best be done during the re-warming period of the body during sleep and not during periods of severe continuous exposures. Kreider et. al., as a result of this study, raised the question of

> ...whether increased skin temperature of the extremities, in the face of a continuing constrictor stimulus, e.g. cold, can be interpreted to indicate physiological acclimation unless the possibility of reactive hypermia is definitely ruled out.(36:45)

THERMAL STRESS

Sex Differences. Hardy and DuBois(31) approached the problem of thermal stress from a different point of interest. They investigated the sex differences in relation to thermal environment. They studied physiological reactions of both sexes to thermal stress and found that the rectal temperatures were the same under comparable external temperatures. Nevertheless, they did find some major differences.

a. Throughout the test the women's skin conductance was less than the men's.
b. Because of the difference of skin conductance, the skin temperature of the women was 1.8° lower in the cold exposure and 1.26° higher than the men in the warmer temperatures.
c. Because of lower conductance and lower skin temperature, the heat loss for women was ten per cent lower than that of the men.
d. In the hotter temperature the metabolism of the women fell to an operative temperature of 78.8°. The difference was so marked that it was fourteen to twenty per cent below that of the men in the hot testing zone.
e. The women started to actively secrete sweat when the air temperature reached 89.6° to 91.4° while the men began to vaporize at 84.2°.
f. The final net results of the study showed that when a certain level of heat was reached the men had a range of two to three degrees in which no active secretion was evident. The women had a range of six degrees in which no active secretion took place.

Nutrition. In other studies done on the nutritional approach to thermal stress, Goldsmith and Lewis(28) reported their studies as showing that the fatty diet of Eskimos and their skinfold thickness was not due to their cold environment. Research was done on members of expeditions and it was determined that skinfold thickness did not vary as a result of the cold climate but was related to the changes in the types of activities in which the subjects engaged. Goldsmith and Lewis believed that "Even if the increase of subcutaneous fat were a response to cold, the amount required to increase insulation would be much larger than has been found."(28:120) It is true, however, that in extreme cold when the skin is cold and the blood vessels are constricted, fat will aid in preserving body heat.

Myology. It was found that heat has definite effects on posture as well as the more specific physiological functionings of the body. In extreme heat the posture is one of almost complete limpness as compared to the tensing of the body when exposed for a length of time to extreme cold.(17)

> Basically, however, we may say with assurance that the progressive decay of posture in warm environments, and its accentuation, breaking over into a desire for physical action in cool environments, are extreme examples of a marked reflex association between temperature and posture regulation mechanisms. At the extremes of exposure we are not able, by voluntary effort, to support a posture contrary to the pattern set by this association.(17:67-8)

With this tenet set before us, it seems logical to surmise that thermal stress does have definite effects on muscular exercise and tends to affect to a degree, the amounts and type of work that man can expect to accomplish under varying conditions. It also seems logical to say that physiological responses to heat and cold would be different during, before, and after physical exercise.

EFFECTS OF HEAT AND COLD ON MUSCULAR EXERCISE AND COORDINATION

Heat. The energy put out by an individual muscle is made up of two parts. When a certain tension is held in a muscle, the heat that is produced is referred to as "tension heat." When a muscle unit is moving continuously, the heat produced is called "friction heat."(26:67) According to Schneider and Karpovich(12), the contraction of muscle depends on temperature and in the human body, if the temperature of the muscle is decreased or goes below normal, the irritability and work capacity of the muscle is lowered. On the other hand, Watkins, as cited by Schneider and Karpovich(12), reported that if strenuous work is to be accomplished, the temperature of the muscle increases above normal. Long continuous exposure to moderate heat will gradually lower the physical tone of a worker.

Usually in heavy muscular exercise during heat exposure, there is a rise in rectal temperature. In connection with this, Benedict and Cathcart, as cited by Schneider and Karpovich(12), found that this rise in rectal temperature occurred during the first seven minutes of work. For the first seven minutes the rise was rapid, it then continued to rise gradually. The rectal temperatures then fell off slightly and stayed at a constant level. This observation agrees with findings reported by Schneider and Karpovich(12) that the body temperature does level off but when it continues to rise, exhaustion occurs. This was found to be true in both hot and cold conditions.

Campbell and Angus, are reported by Schneider and Karpovich(12) to have found that, during moderate exercise in still air at 50° to 77°, there is an increase in loss of water, and at 77° there was marked evaporation from the skin. When sweating occurs, large quantities of sodium chloride are lost from the body and if the loss is profuse, at high temperatures, cramps may develop in the leg and abdominal muscles.

Schneider and Karpovich(12) reported on the effects of heat and cold on pulse rate during muscular work. The subjects were comfortably clothed in a temperature of 54° for sixty minutes. One subject had to stop work after forty-nine minutes when exposed to a temperature of 93°. In the cold room his pulse rate rose steadily to 136 beats per minute in the first twelve minutes, while in the heated atmosphere it rose rapidly to 170 beats in about seventeen minutes. During this hot exposure the pulse rate continued to rise to 180 beats per minute. This study which was conducted by Dill and co-workers, and reported by Schneider and Karpovich(12), concluded that, "The heart has much more work to do under warm conditions, with a low cooling power of the air, than under cool conditions, with a higher cooling power of the air."(12:248)

In a study done by Pepler(40), subjects were exposed to a warm temperature of 116° for a period of thirty minutes. The subjects were to control a pointer and keep it aligned as accurately as possible with a moving target. "Movements of the pointer tended to decrease slightly, errors aligning the pointer and target increased progressively, while rectal temperature rose during exposure to heat."(40:384) There was a steady decrease in the ability to keep the pointer aligned and it appeared that the subjects were not able to adjust or compensate for the heat even when they were told of their inaccuracies. All of the subjects were tested a second time and there was no evidence that they had acquired heat tolerance. Two of the subjects after a little more than an hour had to be helped from the chamber. Some of the symptoms evident were, tendencies to slump over the instrument, labored and irregular breathing, stamping the feet and stretching the arms, and every so often backward and forward swaying of the body. The results of this study by Pepler showed a deterioration in performance and this deterioration became more pronounced in the last half of the exposure period. Pepler felt that the deterioration could have been due to loss of efficiency in sight.

Cold. During exposures to extreme cold it has been shown that the muscles of the body tend to become tense and this can interfere with breathing as well as other physiological functionings.

In another study similar to that of Pepler, tracking efficiency was tested by Payne.(39) The subjects had to make well adjusted coordinated movements on a simulated air craft instrument panel. The temperatures in which they worked ranged from 70° to 55° and then at 40°. Cold had some detrimental effects on proficiency and under acute conditions most of the subjects shivered. They became antagonistic and criticized the conditions in which they were being tested; some of the subjects even dropped out of the experiment. Nevertheless the test showed that 70° to 75° was the best temperature for performing and executing perceptual skills.

Dill and co-workers, as reported by Schneider and Karpovich(12), found that when they put five subjects into hot and cold situations, and had them do the same amount of work, four out of the five showed an increase in heart output per minute. Heart output increased per minute from one to four liters more in heat than in cold. The pulse was proportionately faster than the minute volume and from these results, Dill concluded that the blood put out by the heart per beat was less with an increase in external temperature.

Schneider and Karpovich(12) reported on research done by Benedict and Parmenter on the effects of muscular exercise on skin temperature. The experimentation with cold was done out of doors at temperatures ranging from 12° to 52° and the indoor studies were conducted at approximately 68°. The outdoor studies done under various work conditions showed that normal skin temperatures of about 68° were much lower after prolonged activity. When temperatures were reduced most on the extremities and face, the trunk temperatures also fell. The heat produced from very strenuous sports could not prevent the fall in skin temperature.

Yaglou, cited by Schneider and Karpovich(12), reported that in temperatures between 40° and 75° men could work almost continuously and that the capacity for work gradually diminished until 80° was reached. At this point the work output gradually fell off but this could be overcome by air movement which tends to cool the body.

Specific research has been done that deals with the more functional aspects of muscular work and stress from heat and cold. LeBlanc(38) explored the effects of cold on manual dexterity. He found that if the hands were exposed to cold the small movements of the joints are enhanced, but if larger movements are employed there was much impairment of movement. This evidence was interpreted as being due to the viscosity of synovial fluid. He found evidence that other factors must be involved since the same impairment was evident when the hands were kept warm and the arm was cooled. In this case the arm was immersed in agitated cold water and the hand was kept out. The surface temperature of the arm dropped. The Hunter tapping test was administered and the dexterity was impaired. During recovery, the dexterity gradually improved with the increase of the arm temperature.

In LeBlanc's(38) second test there was direct cooling of the hand and this had more effect on another type of dexterity test that required greater range of movement. The results of LeBlanc's studies contradicted the theory that if both hands are warm and the rest of the body is cold there is no impairment of dexterity in the fingers.

Another aspect of cold stress in connection with work and exercise is hypersensitivity to cold. Goldberg and Pittman[27] felt that cold hypersensitivity is important and should not be overlooked especially since it can prove to be extremely dangerous to those who may be so afflicted and do not realize it. With hypersensitivity there is rapid fall in blood pressure on exposure to the cold and "... peripheral vascular collapse."[27:508]

The United States Army Hospital Arctic Air Force Base reported the case of a boy whose hands were swollen. He had shown no sensitiveness to cold until two years previous when he had suffered a mild case of frost bite. The Army researchers gave him a complete set of tests to determine if the attacks were related to exercise, smoke, or drink. All stimuli proved to be negative. The Army did further tests by immersing one of the subject's hands in ice water. After forty-five seconds the subject reported a numb burning sensation in the hand, at the end of sixty seconds the fingers began to feel stiff, and finally after two and a half minutes he could not feel his fingers. Swelling of the hand was accompanied by a warm burning sensation in the wrist and forearm. A normal subject was also tested with the same results but his recovery time was as much as two minutes shorter than that of the hypersensitive subject.

Other research dealing specifically with swimmers was done in this same area by Horton and Gabreilson.[34] The symptoms displayed by the subjects when the hands were immersed in cold water were described as, pallor of the skin followed by redness and swelling, and an increase in skin temperature after the affected part was removed from the water. After a period of three to four minutes the characteristics of the systemic effects began to appear. There was a sharp decrease in blood pressure, the pulse rate increased, the face became flushed and there was a tendency toward unconsciousness. In the first test, the subject's hand was immersed in cold water for a fixed period of time. In the second test ice cubes were placed directly on the subject's arm for three minutes. If the subject was sensitive to cold, a wheel and flare effect appeared on the arm within two to five minutes.

Another study was done by Happ, Tuttle, and Wilson[30] in which they studied the effects of abdominal cold packs on the reduction of and recovery from fatigue. Their problem was to determine if the application of abdominal cold packs would reduce fatigue and or shorten the recovery period after the subjects had performed vigorous physiological work for a short period of time. The responses studied were body temperature, basal metabolic rate, oxygen consumption, pulse rate, venous, systolic, and diastolic blood pressure. The work load consisted of working on a bicycle ergometer for one minute which was followed by a ten minute rest period. The rest was then followed by another work period. On alternate days the cold packs were applied during the rest periods and after the final work period. The results showed less loss of work output when the packs were applied and in three cases the work output was actually increased. There was a drop in body temperature that was evident at the one per cent level of confidence. With the cold packs there was a consistent reduction in oxygen consumption which was statistically significant at the one per cent level and in all subjects there was a rise in diastolic blood pressure which again was statistically significant at the one per cent level of confidence. There was no significant rise or change in the systolic pressure. From these results it was concluded that fatigue and recovery from fatigue were significantly aided by the application of abdominal cold packs.

Most of the studies and research that have been done in the field of thermal stress have been concerned primarily with the basic physiological effects of heat and cold on the body. The wealth of information is staggering. However, there seems to be much less research done in connection with the effects of heat and cold on the practical motor functionings of the human body.

MOVEMENT AND REACTION TIME

Man's ability to move and work efficiently under conditions of thermal stress is as important to his total welfare as the bodies ability to adjust physiologically to the same kind of stress.

Movement may be classified as either reflex or voluntary. Reflex action stems from the stimulation of the sensory receptors, the stimulus then being conducted to the spinal cord. The reflex action is a sensory response that originates in the spinal cord and comes directly from the spinal cord to produce muscular action. The character of this type of response is determined by the receptor stimulated, i.e., sense of touch, smell, taste, heat, and cold. A particular reaction is produced according to the receptor stimulated and this reflex action is, in most instances, produced without the person being aware of it.[2,8,9,13]

Voluntary responses originate in the motor area of the cerebral cortex. This is the type of muscular action and nerve response that is necessary for learning motor skills.

The nature of the response is not only determined by the nature of the stimulus but it is also regulated by past motor experience. The response originates in the large pyramidal cells of the cerebral cortex where it is transmitted by the pyramidal track to the spinal cord. From the spinal cord the response is finally released as selected muscular contraction. It is believed that the pre-motor area of the cerebral cortex is the area for learned motor action and skilled movements and that the cerebellum is responsible for determining the strength of muscular contraction and the range of movement in the joints.[2,8,9,13]

Reaction Time. One aspect of movement in the human body is reaction time. Reaction time is effected by the nature of the stimulus and the functional integrity of the nervous system. Usually muscular reaction is quickest to sound and touch but if the stimuli are complicated or difficult to perceive the reaction to them tends to be slower. In general, men tend to react muscularly faster than women. The period in life when reactions are the most rapid is between the ages of twenty-one and thirty years of age.[12]

Biese and Peasley[20] in their research on reaction time, speed of movement, and agility of big muscle groups, and sports, experimented with the assumption that the response time of skilled and unskilled individuals differs. The subjects for test one were divided into three groups. Group I was selected on the basis of skill in tennis, golf, or archery and all subjects were considered to be outstanding performers in each sport. Group II subjects were selected on their demonstrated inability in Physical Education activities and on the basis of poor coordination. Group III was made up of students who ranked low in the first set of exercises in the Brace Motor Ability Test, and the girls who ranked high on the Brace test were also included in this group. All persons tested were subjected to the same test which measured reaction time, speed of movement, and agility. The test included running from the starting spot marked by an electrically controlled plate to a second plate about twenty-seven inches away. At plate number two the subject was instructed to depress that plate and then at another light signal she was to negotiate a circuitous path around three benches and then proceed back to the original starting point. Reaction time was recorded from the first light flash to the time that it took the subject to release pressure on plate one. Speed of movement was recorded from the time the subject left plate one to the time she depressed plate two. Agility was timed when the subject left plate two, ran through the circuitous path and depressed plate one again. This study showed that there was a significant difference in reaction time, speed, and agility between the skilled group and the unskilled group. The skilled group showed greater stability in reaction time but they also showed differences in all three measurements according to the type of activity.

The second study by Biese and Peasley[20] was done to determine the effects of training on reaction time, speed, and agility. Again tennis, golf, and archery were the sports activities used. One group of subjects were girls who had not had instruction in the activity to which they were assigned while the other group of people were skilled in the activity in which they were being tested. They were tested before they started a seven week instruction period of two hours a week and the test was adminstered at the end of the instructional period. The results of this second series of tests indicated that although the subjects met twice a week for seven weeks there was no significant improvement in either reaction time, speed, or agility.

In research completed by Elbel[23] finger reaction time and total body reaction time were tested. The subject stood behind a line that was no closer to the timing device than his own height. On perceiving the light stimulus the subject stepped forward and contacted a switch that timed the interval between the administering of the stimulus and the contact made by the subject. In correlating the practice trials for the total body reaction time, the testing procedure showed a reliability score of .9875. Before the actual response testing, the subjects were required to exercise for a definite length of time and then the tests were administered. The exercise that the subjects were made to do consisted of a stool stepping exercise and push ups. In relation to hand and body reaction time, Elbel[23] found that the push up and stool stepping exercise showed no evidence of affecting the subject's reaction time. After athletic competition, however, there was a significant shortening of the response time.

Youngen[49] compared the reaction time of women athletes and non-athletes. Reaction and movement times were compared for the two groups in relation to selected sports activities. The activities included were tennis, swimming, fencing, and field hockey. The recording device was made up of a response unit, a light stimulus, an electric beam and a card target that was placed two inches behind the electric beam. The recordings were made by two calibrated chronoscopes. One recorded the time interval between the start of the stimulus and the time it took the subject to react to it. The other recorded the time from the release of the response key by the subject to the time the subject broke the electric beam and touched the card. Thirty-five trials were given in succession, the mean individual scores were computed and significance of difference was calculated. A score of 4.85 showed a significant difference between the two groups. This difference was significant at the one per cent level in favor of the athletes. The results showed that field hockey, fencing, and tennis are closely related to speed of reaction time and movement. There was no relation between reaction time and movement time. Youngen(49) concludes from this study that:

a. Women athletes are faster in speed of arm movement and reaction time than non-athletes.
b. The reaction time did not differ for all in the activities chosen.
c. There is only a low correlation between reaction time and speed of movement.

Burley(21) in a similar study on men of different athletic ability, tested complex reaction time in which the subject was given no verbal signal before the stimulus was given and the time interval between signals varied but was kept within the four second limit. The subjects were also given a simple reaction time test during which the operator gave a verbal signal before the presentation of each stimulus and the time intervals between signals were varied but administered according to a set pattern. Burley's(21) results of both tests pointed out that in the complex reaction test all of the subjects reacted more slowly. The reactions varied more to the complex stimuli than to the simple stimuli, and the scores for the athletes were significantly higher than the non-athletes.

A study done by Pierson and Williams(41) contradicts Burley and Youngen. Pierson and Williams(41) measured the reaction and movement time of four hundred male subjects between the ages of eight and eighty. As a result of a final analysis of data, they found that movement and reaction time were significantly related. The testing apparatus was the same type used by Youngen but the scores were computed by using the last fifteen of thirty trials. Pierson and Williams felt that there is greater possibility for error in results of studies done on college students and objected to Burley's using the conclusions of their college men's scores to apply to all males. They also believed that reaction time and movement time may be a function of maturity or incidence of employment, since the correlation for subjects over twenty years old differed from that for subjects between eight and twenty-one.

Slatter-Hamel(46) studied the effects of blinking on reaction time. During blinking, it appears that there is a period of black out and that, in activities that include reaction and movement speed, this blink factor could be the reason for reaction time variability in individuals. He found that the blinking rate was about six times more pronounced between reaction time periods than during the actual reaction time situations. Blinks during reaction time did not occur in ninety-one per cent of the cases while fifty-five per cent exhibited blinking between periods. Only one per cent blinked when the stimulus was given and from all of the results, Slatter-Hamel suggested that blinking can not be used to account for the variability of reaction time for individuals.

Research in reaction time and rhythm has been done by Wilson(48) in which a series of rhythmic and non-rhythmic stimuli were given to determine if subjects would react faster to rhythmic presentations of football signals. A visual signal was flashed in a set pattern as a warning signal before the response stimulus. When the stimulus was given, the subject removed his finger from the response key then moved the arm up and over a barrier and hit a tennis ball suspended from a string which automatically stopped the timing device. The study showed that reaction times were faster with the rhythmic presentation of the response signals. The average reaction time was .198 seconds for the rhythmic presentations. The average movement time was .208 seconds. Wilson concluded from the study that reaction time is faster when the stimulus is presented rhythmically.

Balance. According to Scott and French:

> The ability to balance easily in a static position or in motion is a function of the mechanism in the semi-circular canals, the kinesthetic sensations in the joints and muscles, visual perception of motion, and the degree of coordination in response to these three sources of stimuli. ... From the skill standpoint and from the safety standpoint, good balance seems important.(13:319)

The stretch reflex which is best in the extensor muscles is important to posture and balance. This reflex is controlled by sensory receptors and the higher brain center, both of which are necessary in maintaining an upright position. The sensory sources that indicate reflex movements are visual stimuli, the proprioceptors of the inner ear (semi-circular canals), and stretch receptors of the neck. When the head is not in line with the center or pull of gravity, the body will be unbalanced and the stretch reflex is the mechanism that helps to maintain a balanced posture. The body righting reflex is affected mainly by visual and labyrinthin reflexes. The neck is righted first by the reflex contraction of the neck muscles which in turn cause another reflex stretch of the arm, leg, and trunk muscles which all work to bring the body back to its normal position.[7,8]

The semicircular canals of the inner ear are arranged in the three planes of space. Each is filled with liquid and nerve endings in the ear are stimulated by movement of this fluid. When the body moves, the fluid flows in the opposite direction, it builds up at a point where the sensory receptors of the canal are stimulated. The balance of the body in skilled movement is dependent on the proper functioning of the semi-circular fluids.

Balance may be measured as static or dynamic. Seashore[43] gives two definitions for balance. Static balance is described as that posture of the body in which the use of antagonistic muscles is employed to keep the body in a position where there is a minimum of body sway. This is more clearly described as a still or non-ambulatory balance.

Dynamic balance is a moving or ambulatory balance in which the actions of the muscles are continuously changing and which requires organized muscular activity to maintain and re-establish "posturalorientation."(43) Seashore devised a walking beam test to attempt to get an accurate measure of students ability to maintain balance. The beams varied in width from four inches to one quarter of an inch on the top surface, and were approximately four inches high. The test itself consisted of walking in a heel-toe manner from a designated starting point with the hands placed on the hips. If the subject stepped off the beam, dropped his hands, or stepped across the beam he was told to start again at that point, but if he made a second error,the test was ended. Seashore found that for adolescents (ages thirteen to eighteen) height and weight were not closely related to balance scores. In the lower age group (ages five to twelve) the balance scores did relate significantly to height and weight.

Bass(19) devised a test that would measure dynamic balance and one that could be easily administered. In the Bass Stepping Stone Test of Dynamic Balance, ten circles eight and a half inches in diameter are placed in a set pattern on the floor and at a signal to start the subject standing on his right foot in the starting circle, leaps to the alternate foot for the next circle and continues in this fashionto the end of the pattern. The subject must land on the ball of the foot not touching the boundary lines of the circle. The supporting foot must remain still and he must maintain a steady posture up to but not exceeding five seconds. Usually three practices are allowed. The final score is the total time plus fifty, minus three times the errors. The reliability of the test has been established at .952. The correlation of the Bass test with other balance tests shows significantly high scores, especially with the static tests that demand that the eyes be closed. Bass has also devised a Stick test for static balance which has shown a reliability of .8 and .9.

Espenchade, Dable, and Schoendube(24) attempted to relate dynamic balance to maturity. The subjects were young boys from ages eleven to sixteen years of age. They were divided into five maturity groups and the Seashore test was administered. Espenchade concluded that at puberty the rate of improvement in balance is lower than in post and pre-pubescent years. There was consistent improvement in dynamic balance for the boys between the ages of thirteen and fifteen years of age. The results of the test also showed that dynamic balance was found to be common to all of the stunts of the Brace Motor Ability Test.

Another test completed in the area of balance was done by Gross and Thompson.(29) As a result of the work done by Espenchade et. al., Gross and Thompson recognized the fact that balance is one of the basic motor skills and it is important to successful performance in sport skills. This study was concerned with dynamic balance and success in swimming. The subjects for this particular test were male students between the ages of seventeen and twenty-eight; all were classified as advanced swimmers. They were given a six week training and conditioning program and during this time they were taught nine swimming skills. At the end of this period they were graded on their ability to swim and in performing the strokes and skills that they were taught. The subjects were then given the Bass Dynamic Balance test and they were timed for three sprints in the thirty yard dash.

The evidence from the scores showed that there was a significant relation between dynamic balance and speed in swimming. A critical ratio of 15.12 between the mean scores of those who did well in the balance test and those who were low in balance may be significant to speed swimming. The results were significant at the one per cent level of confidence. "A relatively high and significant correlation coefficient of .75 .05 was obtained between the scores of the subjects on the Bass Test of Dynamic Balance and speed in swimming the 30 yard sprint."[29:345] The results showed that the dynamic balance measured in the test was not a chance factor and may be important in swimming ability and speed.

In a study by Estep[25] the relationship between static equilibrium and ability in motor activities was measured by use of the Miles ataximeter, which measures lateral sway. Static equilibrium was studied and the results of the study supported the theory that balance is an important factor in success in performing motor skills.

Thermal stress is one type of stress that man has to adapt to continuously throughout life. A review of the research that has been conducted in this area, shows that the human body is capable of adjusting physiologically to both aspects of thermal stress namely heat and cold. In exposure to cold, the heat regulatory mechanism preserves body heat under normally cold conditions and in exposures to heat, the body adjusts by the process of evaporation of body sweat and by a reduction of heat production through a lowering of the metabolic rate. It has been shown that, although man is capable of becoming acclimated to the heat and cold, this adjustment is only one of degree. Under extreme exposures in either hot or cold temperatures, man's physiological processes can be disturbed to the point of either simply reducing the muscular work capacity of the individual or, producing a complete collapse of body functions.

The literature available in regard to reaction time and balance shows that both of these are important factors in the successful performance of sports skills as well as being closely related to general motor ability. However, a review of the studies on reaction time and balance indicates that no specific research has been done that shows the effects of hot and cold temperatures on either reaction time, balance, or general motor performance. Since the body is affected in so many ways by temperature, it seems logical to surmise that man's motor performance as well as physiological functions could be affected by exposures to extreme hot and cold temperatures.

CHAPTER IV

PROCEDURE

The purpose of this study was to determine the effects of heat and cold on dynamic balance, movement reaction time, arm-hand steadiness, and motor performance.

SELECTION OF SUBJECTS

The subjects for this study were twelve women graduate students of The Woman's College of The University of North Carolina. The subjects were a volunteer group ranging in age from twenty-two to thirty-two years of age. Nine of the group were majors in Physical Education, two were majors in Music, and one majored in Home Economics. The motor ability of the group, according to their scores in the Brace Motor Ability Test, as compared to the norms for college women, ranged from poor to good with the majority of the subjects in the average category. The pertinent data on each subject may be found in the Appendix.

SELECTION OF TESTS

Brace Motor Ability Test. (16) The Brace Motor Ability test was chosen because it had been closely correlated with balance. (24) The majority of the stunts included in the test, included the ability to balance as one of their prime factors. The ease of administering the test, and the facility of scoring it, as well as the reliability of the test were factors that determined the selection of the Brace Motor Ability Test.

The subjects were arranged in two groups and were assigned partners. The investigator read the general directions to the entire group then administered the test giving the first ten of the twenty stunts to Group I. Group II observed and scored for their partners. Group II was then administered the test while Group I observed and scored. This procedure was followed until both groups had performed the twenty stunts included in the test. Before each test item the investigator carefully read instructions to the subjects. This was followed by a demonstration; the common errors were pointed out and then the subjects were directed to perform the stunt. The original directions for this test called for no equipment but, because of the difficulty of some of the stunts, the investigator felt it would be safer to use gymnastic mats for the protection of the subjects. Score cards were given to each of the subjects.

General Directions:

1. No practice trials are allowed and you are to start only on the command, "go".
2. Do each stunt carefully and slowly. The group sitting will watch their partners carefully and will score their performance.
3. Each stunt must be executed exactly as it is explained.
4. If the stunt is performed exactly as it is explained mark X, but if the subject fails to perform the stunt successfully mark O.
5. Only one trial is allowed. Listen carefully and do your best on each stunt.

The final score was the total of the stunts passed.(16:68)

The Tests.

1. Walk in a straight line, placing the heel of one foot in front of and against the toe of the other foot. Start with the left foot. Take ten steps in all, five with each foot. (Eyes open) It is a failure if you lose your balance and step out of line, if you do not walk in a straight line, if you do not place heel to toe.

2. Stand with the feet apart, jump into the air and clap both feet together once, and land with the feet apart (any distance). It is a failure if you land with the feet touching each other or if you fail to clap the feet in the air once.

3. Lie flat on the back on the floor. Fold the arms across the chest. Raise the trunk to a sitting position. Do not raise the feet above the floor, or unfold the arms. It is a failure to raise the feet above the floor (this does not include sliding the feet along the floor,which is permissible), to unfold the arms or not to sit up.

4. Stand with the arms folded behind the back. Kneel on both knees. Get up without losing the balance or moving the feet about. It is a failure to lose the balance either going down or getting up, to move the feet after standing up, to unfold the arms.

5. Take a front leaning rest position, i.e., place the hands on the floor, the arms straight, extend the feet back along the floor until the body is straight (in an inclined position to the floor). Bend the arms, touch the chest to the floor, and push up again to straighten arms. Do this three times in succession. Do not touch the floor with the legs or the waist. It is a failure if you do not push up three times, if you do not touch the chest to the floor each time, or if you rest the knees, thighs or waist on the floor at any time.

6. Squat on the heels with the feet together and the knees out, and hands between the knees with the finger tips touching the floor. Spring up on both heels, with legs straight and toes up, and swing both arms out at the

side level with the floor. The feet should then be about eighteen inches apart. Head up. Repeat this exercise three times (in all) rhythmically. It is a failure if the arms and legs are not in the correct position, if the stunt is not done three times in succession without stopping.

7. Stand with the feet together. Jump into the air and make a full turn to the left, landing on the same spot. Do not lose the balance or move the feet after they strike the floor. It is a failure if a full turn is not made or if the feet are moved after they strike the floor.

8. Jump into the air and clap the feet together twice and land with the feet apart (any distance). It is a failure if the feet are not clapped together twice or if the feet are together on landing.

9. Stand on the right foot. Grasp the left foot behind the right knee with the right hand. Bend and touch the left knee to the floor, and stand up without touching any other part of the body to the floor, or losing the balance. It is a failure to touch the floor with any part of the body except the left knee, to let go of the foot, or not to touch properly and stand with the leg straight and without losing the balance.

10. Hold the toes of either foot in the opposite hand, in front of the body. Jump up and jump the free foot over the foot that is held without letting go. It is a failure to let go of the foot that is held or not to jump through the loop made by holding the foot.

11. Jump into the air and slap both heels with the hands, behind the back. It is a failure if both heels are not touched.

12. Stand, kick the right foot up so that the toes come at level with the shoulders. Do not fall down on the floor. It is a failure not to kick as high as the shoulders or to fall down and touch the floor with any part of the body other than the feet.

13. Stand on the left foot. Bend forward and place both hands on the floor. Raise the right leg and stretch it back. Touch the head to the floor, and regain the standing position without losing the balance. It is a failure if the head is not touched to the floor, if the balance is lost, if the right foot is touched down, or to step about.

14. Stand with both feet tight together. Bend down, extend both arms down between the knees, around behind the ankles, and hold the fingers together in front of the ankles without losing the balance. Hold this position for five seconds (counted by scorer). It is a failure to fall over, if the fingers of the two hands are not touching and held together, or if the position is not held for five seconds.

15. Stand with both feet together. Swing the arms and jump up in the air, making a full turn to the right. Land on the same spot and do not lose the balance, that is, do not move the feet after they first strike the floor. It is a failure if a full turn is not made so that the facing is the same direction as the start or if the balance is lost with a stepping about to keep from falling.

16. Kneel on both knees. Extend the toes of both feet out flat behind. Swing the arms and come to the feet without rocking back on the toes, or losing the balance. It is a failure to have the toes curled back under, or to rock back on the toes, or not to execute the jump and stand still on both feet.

17. Fold the arms across the chest. Cross the feet and sit down crossed legged. Get up without unfolding the arms or having to move the feet about to regain balance. It is a failure to unfold the arms, to lose the balance, or not to get up.

18. Stand on the left foot. Hold the bottom of the right foot against the inside of the left knee. Place the hands on the hips. Shut both eyes and hold the balance for ten seconds (to be counted by the scorer), without shifting the left foot about on the floor. It is

a failure to lose the balance, to take the right foot down, to open the eyes, or to remove the hands.

19. Take a squat rest position. That is, place the hands on the floor between the knees and close to the feet. Bend the elbows slightly and place both knees well over the elbows. Rock forward on the hands, raising the feet from the floor. Support the body on the hands. Hold the position for five seconds (as counted by the scorer). It is a failure if the body is not kept off the floor for five seconds.

20. Stand on the left foot with the right foot extended forward off the floor. Sit down on the heel of the left foot, without touching the right foot or hands to the floor. Stand full up without losing the balance. It is a failure not to sit all the way down on the left foot, to touch the right hand or foot to the floor, not to stand up with the left leg straight before touching the right foot.

Arm-Hand Steadiness Test. The arm-hand steadiness test was given to determine the effects of heat and cold on fine controlled movement. The equipment used was a standard metal plate with holes of varying dimensions, manufactured by the C. H. Stoelting Company, 424 North Homan Avenue, Chicago 24, Illinois. This was wired to a Mercury non-resetable counter, manufactured by the Production Instrument Company, Chicago, Illinois. The make of the counter was M E A - N5 - 6D. This apparatus was activated by a twenty-two and a half or a forty-five volt dry cell battery. A metal stylus was also wired to the apparatus. The stylus was inserted into a predetermined hole on the metal plate, and when the stylus contacted the side of the opening each touch was recorded on the counter.

The subjects were instructed to sit a distance from the table that would not make it possible for the subject to lean or support herself on the table. The stylus was held in the preferred hand, the arm or hand was not allowed to rest on the table, and the shoulder of the preferred hand was placed in line with the opening on the metal plate. The subject was then instructed to place the stylus into the appropriate opening, after which the investigator timed the subject with a stop watch for thirty seconds. At the end of the allotted time the investigator gave the command "stop" and then recorded the number of touches made during that trial. Two such trials were administered at each of the testing periods. The test was scored by taking the sum of the touches for the two trials.

Movement Reaction Time. The equipment consisted of a stimulus unit and a response unit. It was timed by a Cralab Universal Timer, patent number 2562546, type 172., manufactured by Demco-Gray Company, Dayton, Ohio.

The stimulus unit consisted of two one-hundred watt standard electric bulbs that could be seen by the subject through openings in the front panel. The lights and timer were activated by micro switches and a re-set micro switch located on the back panel. The response unit consisted of two micro switches placed in front of but not attached to the front panel. When a subject hit either of these response switches when the light stimulus was given, the current was broken and the electric timer stopped. The electric timer was calibrated to measure time in terms of quarter seconds.

In order to measure movement reaction time, the subjects were instructed to stand behind a predetermined line marked on the floor in front of the testing apparatus. The distance for each subject was a designated line that corresponded to the distance that was closest to twice the subject's height. The distances used were: ten feet, ten and a half feet, eleven feet, and eleven and a half feet. The tester sat behind the apparatus facing the rear panel and the electric timer. The response switches were placed on the table in front of the front panel. The subjects were unable to see the examiner, the electric timer, and the switches for the stimulus lights. Each subject was directed to take her place behind the line designated for her, and she was told to move forward as quickly as possible and hit the appropriate switch when the stimulus light was flashed on. The electric timer recorded the number of seconds from the time the stimulus light was flashed on, to the time that the subject contacted the response switch and stopped the timer. There was no set time interval between each stimulus presentation and the order in which the stimuli were given was varied to avoid the possibility of learning the pattern of presentations. Five different series of stimuli presentations were set up and the testers used a different series for the different testing periods. The pattern used was consistent for all subjects within a testing period. Before each stimulus was given, the tester pressed the reset button which was audible to the subject, and this was an indication to the subject that the stimulus light would be flashed but the subjects were given no spoken warning preceding the presentation of each stimulus. Twenty trials were given at each testing period and the last fourteen trials for each test were used in calculating the final score for the test.

Bass Dynamic Balance Test. The Bass Dynamic Balance Test was chosen because primarily it is a test of moving balance and because of the high reliability of the test, .95.[36] The pattern for this test can be found in the Appendix. The pattern is a series of eleven circles eight and a half inches in diameter. The starting circle is marked X and the distance between circle X and the first circle is eighteen inches from the edge of one to the edge of the other. The distance between each of the remaining circles measured thirty-three inches. The angles between the circles were measured with a gonoimeter, starting from the center of one circle to the center of the next circle. The entire pattern was cut out on a large sheet of brown heavy paper to facilitate the use of the test and to insure that the series of circles was the same each time the test was given.

A subject was directed to stand on the right foot in the circle marked

X (the starting circle). She was then told to leap into the circle marked one, land on the ball of the left foot, and to continue on to the remaining circles until the entire pattern was completed. She was told to alternate feet from one circle to the next. The subject was instructed to remain stationary in each circle for no longer than five seconds or until she started to lose balance, and then continue on to the next circle. The test was demonstrated and explained to each subject and the errors were pointed out.

> The errors are as follows: (1) touching the heel to the floor, (2) moving the foot while standing in the circle, (3) hopping upon the supporting foot, (4) touching the floor out side of the circle, (5) touching the floor with the other foot, (6) touching the floor with any other part of the body (37:106)

The investigator scored the errors and an assistant timed the test and counted the seconds aloud for the subject. When the subject moved to the next circle, the assistant started a new count. Practice trials were allowed before the first testing period to familiarize the subjects with the test and to eliminate the gross errors, such as stepping outside of the circle with the free foot, touching the heel of the supporting foot, and others. Three trials were given at each of the testing periods and the average of the three trials was used as the final score for that test. After the first testing period no practice trials were allowed. It was felt that, by eliminating the practice trials, the learning factor would be minimized. The test was scored by adding the amount of seconds to negotiate the pattern to fifty, minus three times the errors. One penalty point was given for each error and if the subject remained in the circle for more than the allowed five seconds, the additional seconds were deducted from the total time.

French-Cooper Repeated Wall Volley Test. (13) This test was chosen as the measure of motor performance. The volley ball test was chosen because it was felt by the investigator that the subjects would all be familiar with this particular skill. It was also chosen for ease of administering the test, the facility in scoring, the minimum amount of equipment needed, and the wall and floor space necessary for conducting the test. A line was marked on the wall seven and a half feet from the floor and ten feet long. Another restraining line was marked on the floor three feet from the wall. The subject was instructed to stand behind the three foot line and on the signal "go" she was told to throw the ball underhand against the wall and volley it as many times as she could on or above the seven and a half foot line. Ten trials of fifteen seconds duration were administered at each testing period. The investigator scored the number of volleys hitting on or above the seven and a half foot line while an assistant timed and watched for foot faults. The subject was allowed to set up the ball as many times as was necessary and was told to retrieve the ball as soon as possible if it went out of control. Each new start was started with an underhand throw and the assistant said aloud, "line," if the subject was on or over the three foot line. The test was timed from the signal "go" until the command stop was given at the end of the fifteen second time limit. The test was scored by taking the sum of the five best trials out of the ten.

ADMINISTRATION OF TESTS

The investigator met with the subjects and explained briefly the purpose of the study and the time that would be involved in taking part in the experiment. The entire group met one afternoon between the hours of three and five and were given the Brace Motor Ability Test.(16) The remaining testing procedure consisted of three testing periods held in the gymnasium on three separate days between the hours of two and five p.m. These tests were used to establish base scores for each of the subjects and the approximate temperatures in which they were administered ranged from 75° to 80°. The temperatures in this testing area did change slightly from the beginning of each testing period to the end of each of these three testing periods. The subjects were dressed in light clothing that consisted of a cotton gym suit, a sweat shirt, socks, and sneakers. The subjects were scheduled at different times to facilitate the testing procedure, to economize on the subject's time and to insure that all of the subjects were exposed to the different temperatures for the same amount of time. The author was the principal tester and was aided by two assistants who received previous instruction practice in administering all of the tests. Because of the time element and the difficulty in scheduling times for the subjects it was not possible for the subject to have the same test administrator each time but the author was able to test the majority of the subjects in the heat exposures, and all of the subjects in the remaining exposures.

The exposure temperatures were as follows: two heat exposures for fifteen minute durations; one at 94° with a very high relative humidity, and the second at 110° with a high relative humidity. A third exposure was taken at a temperature of 58° and the two cold exposures were at 8° low relative humidity and 37° low relative humidity. The subjects were exposed to these temperatures for fifteen minutes during which they were allowed to walk about but were not allowed to do any vigorous activity. The heat exposures took place in the deck and balcony area of the college swimming pool, the moderate temperature exposure took place out of doors but in an area that was protected from the wind and in a room just off the testing area that was opened and cooled to the outside air temperature. The two cold tests were administered in two separately thermostatically controlled cold storage rooms. All of the tests were administered on separate days between the hours of ten in the morning and seven thirty in the evening. The clothing remained the same for all of the tests except for the cold tests, and for the protection of the subjects they were allowed to add slacks to the clothing in order to protect the skin from the cold. All of the testing was done directly in the exposure areas. The order in which the four tests were given was as follows: the Arm-hand Steadiness Test, the Movement Reaction Time Test, the Bass Dynamic Balance Test, and the French - Cooper Volley Ball Wall Volley Test.

One of the subjects was unable to complete the series of exposures. With this one exception, all of the subjects completed all of the exposure testing periods.

CHAPTER V

PRESENTATION OF DATA

The purpose of this study was to determine the effects of external temperatures on arm-hand steadiness, dynamic balance, movement reaction time, and motor performance as measured by the wall volley test. Three initial base testing exposures were administered at temperatures varying from 75° to 80°. The scores obtained from these tests were combined for each subject and a mean score was calculated with regard to each of the tests administered. This mean score was used as a base score, or the average homeostatic score for each person in normal room temperature. In the five remaining selected experimental temperatures, 110°, 94°, 58°, 37°, and 8°, the raw scores were calculated from direct rather than derived measurements for the four items tested. Since all of the thermal measurements used in the study have been converted to the Fahrenheit scale, all of the temperatures mentioned are in Fahrenheit degrees.

STATISTICAL ANALYSIS

To determine the directional change within the group under the differing conditions, and to compute the differences between means, Fisher's "t"(4:220), designed to compare correlated means, was used. In determining statistically significant differences, "t" values at the five per cent level of confidence or better were accepted.

Steadiness. The statistical data for steadiness are reported in Table I.

In comparing the base scores to scores obtained at 110°, 94°, 58°, 37°, and 8°, there was a statistically significant difference between the means at all of the temperatures, except at 8° where there was no significant difference between the means. There was an improvement in steadiness at the one per cent level of confidence at 110°, 94°, and 58°. There was also an improvement in steadiness at 37° over the base scores that was significant at the five per cent level of confidence. There was no significant change at 8° over the base scores.

There was no significant difference between mean score at 94° when compared to the mean scores obtained at 110°, 58°, 37°, and 8°.

The differences between mean score at 110° and the mean scores at 58° and 37° also showed no statistically significant difference between the means. However, the differences between the mean scores at 110° and 8° showed a decrease in steadiness that was significant at the two per cent level of confidence in the direction of decrease at the 8° temperature.

The mean score at 58° when compared to the mean scores at 37° and 8°, showed that at 37° there was no significant change, but at 8° there was a significant decrease in steadiness in favor of the 8° temperature, at the two per cent level of confidence.

TABLE I

SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF STEADINESS SCORES AT ALL TEMPERATURES

Conditions	Range of Diff. Scores	M. Diff.	"t"	Level of Confidence
Base - 110°	1.666 - 7.666	-3.430	3.304	.01
Base - 94°	1.666 - 7.666	-3.180	4.642	.01
Base - 58°	0.000 - 8.666	-3.346	3.837	.01
Base - 37°	1.000 - 6.666	-2.763	2.698	.05
Base - 8°	0.166 - 20.340	2.940	1.234	-
110° - 94°	0.000 - 5.000	-0.250	0.375	-
110° - 58°	0.000 - 4.000	0.083	0.415	-
110° - 37°	0.000 - 14.000	0.666	0.508	-
110° - 8°	0.000 - 28.000	6.272	2.773	.02
94° - 58°	0.000 - 6.000	-0.166	0.197	-
94° - 37°	0.000 - 14.000	0.416	0.304	-
94° - 8°	0.000 - 28.000	6.000	2.031	-
58° - 37°	0.000 - 14.000	0.583	0.440	-
58° - 8°	0.000 - 28.000	7.545	2.883	.02
37° - 8°	0.000 - 20.000	-5.545	2.803	.02

The difference between the mean score at 8° and the scores at 37°, showed that at 37° there was a statistically significant increase in steadiness over the 8° temperature. This difference was significant at the two per cent level of confidence. The over-all differences show that steadiness increased over the base temperature at all of the selected temperatures, except at 8°, and that at this temperature there was no statistical significant difference between the means. There was a statistically significant decrease in steadiness at the 8° temperature when the mean score for that temperature was compared to the mean score at 37°, 58°, and 110°. In comparing the scores of the other temperatures, excluding the base scores, there was no statistically significant difference between the mean scores.

Raw scores for steadiness can be found in the Appendix, Table V.

Reaction Time. The statistical data for reaction time are reported in Table II.

The differences between the mean base score and the scores at 110°, 94°, 58°, 37°, and 8°, indicated that at these five temperatures the reaction time was slower than at the base temperature. The differences between the means was statistically significant at the one per cent level of confidence in all these except for the 37° temperature, where the difference was significant at the five per cent level of confidence.

TABLE II

SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF REACTION TIME SCORES AT ALL TEMPERATURES

Condition	Range of Diff. Scores	M. Diff.	"t"	Level of Confidence
Base - 110°	0.310 - 4.834	1.321	11.587	.01
Base - 94°	0.099 - 2.584	1.150	7.500	.01
Base - 58°	0.166 - 4.267	2.754	4.605	.01
Base - 37°	0.310 - 2.834	1.025	2.762	.05
Base - 8°	0.060 - 7.334	2.842	3.419	.01
110° - 94°	0.250 - 3.000	0.170	0.362	-
110° - 58°	0.250 - 2.200	0.412	1.271	-
110° - 37°	0.000 - 2.750	-0.295	0.724	-
110° - 8°	0.000 - 3.500	0.950	2.069	-
94° - 58°	0.000 - 3.000	0.583	1.362	-
94° - 37°	0.000 - 2.000	-0.208	2.236	.05
94° - 8°	0.000 - 6.500	1.000	1.420	-
58° - 37°	0.000 - 3.000	-0.708	1.988	-
58° - 8°	0.250 - 3.750	0.545	1.066	-
37° - 8°	0.000 - 4.500	-1.090	1.936	-

There was no statistically significant difference between the mean score at 94° as compared to the mean scores at 110°, 58°, and 8°. The mean score at 94°, when compared to the mean score at 37°, showed an improvement in reaction time in the direction of the 37° temperature. This difference was significant at the five per cent level of confidence. There was no significant difference between the mean score at 110° compared to the mean scores at 58°, 37°, and 8°. Also, there was no significant change in reaction time between the mean score at 58° compared to the scores at 37° and 8°.

The significant differences in the reaction time mean scores showed that reaction time was slower at 110°, 94°, 58°, 37°, and 8° than it was at the base temperature of 75° to 80°. The only other significant difference between mean scores occurred when the mean score at 94° was compared to the mean score at 37°. This difference showed a significant increase in reaction time speed at the 37° temperature over the reaction time speed at 94°.

The raw scores for reaction time can be found in the Appendix, Table VI.

Dynamic Balance. The statistical data for dynamic balance are reported in Table III.

The difference between the mean base score and the scores at 110°, 94°, 58°, 37°, and 8°, showed a significant improvement in balance at

TABLE III

SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF BALANCE SCORES AT ALL TEMPERATURES

Condition	Range of Diff. Scores	M. Diff.	"t"	Level of Confidence
Base - 110°	0.500 - 93.000	37.133	2.850	.02
Base - 94°	9.833 - 103.067	34.175	2.896	.02
Base - 58°	1.500 - 76.900	41.193	5.549	.01
Base - 37°	1.000 - 79.000	30.075	3.534	.01
Base - 8°	0.667 - 66.967	20.245	2.511	.05
110° - 94°	0.700 - 35.400	2.141	0.372	-
110° - 58°	0.500 - 30.500	4.150	1.107	-
110° - 37°	0.000 - 36.000	-6.213	1.506	-
110° - 8°	2.100 - 26.500	-10.963	3.754	.01
94° - 58°	2.500 - 61.400	6.291	0.911	-
94° - 37°	2.500 - 67.800	-4.058	0.530	-
94° - 8°	0.000 - 53.000	-11.254	1.659	-
58° - 37°	0.500 - 38.800	-10.366	2.649	.05
58° - 8°	5.000 - 44.500	-16.863	4.618	.01
37° - 8°	4.500 - 33.500	5.363	1.285	-

the experimental temperatures over the base temperature. The "t" values at 110° and 94° were statistically significant at the two per cent level of confidence in favor of the higher temperatures. The "t" values at 58° and 37° were statistically significant at the one per cent level of confidence in the direction of the lower temperatures, while the "t" value at 8° was significant at the five per cent level of confidence in the direction of the 8° temperature.

In comparing the dynamic balance scores at 94° to the scores at 110°, 58°, 37°, and 8°, there was no statistically significant difference between the means.

The mean score at 110° compared to the mean scores at 58° and 37° showed no significant differences between the means. The mean score at 110° compared to the mean score at 8° showed a decrease in balance at the 8° temperature. This difference was significant at the one per cent level of confidence.

The difference between the mean score at 58° and the mean score at 8° showed a decrease in balance at the 8° temperature. This difference was statistically significant at the one per cent level of confidence. The difference between the scores at 58° and the scores at 37° showed a decrease in balance at the 37° temperature. This difference was statistically significant at the five per cent level of confidence.

There was no significant change in balance when the scores at 8°

were compared to the scores at 37°. The total results showed that when the mean base score was compared to the mean scores of the five selected temperatures, there was a statistically significant increase in balance at the experimental temperatures over the base temperatures. The only decrease in balance occurred when the scores at 110° were compared to the scores at 8°. In this instance the decrease in balance was at the 8° temperature over performance at 110°. Two other decreases in balance were significant when the mean score at 58° was compared to the mean scores at 37° and 8°. The decreases in balance ability in these two cases were at the 8° temperature and at the 37° temperature over performance at 58°.

The raw scores for dynamic balance can be found in the Appendix, Table VII.

Motor Performance. The statistical data for motor performance are presented in Table IV.

In motor performance there was no statistically significant difference between the mean base score and the scores at 110° and 94°. The differences between the mean base score and the scores at 58° and 37° showed an improvement in motor performance at the 58° and 37° temperatures over the performance at the base temperature. The differences were both significant at the one per cent level of confidence. There was also a statistically significant improvement in motor performance at the 8° temperature over the base temperature. This difference was significant at the five per cent level

TABLE IV

THE SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF MOTOR PERFORMANCE SCORES AT ALL TEMPERATURES

Conditions	Range of Diff. Scores	M. Diff.	"t"	Level of Confidence
Base - 110°	2.000 - 28.000	15.153	2.117	-
Base - 94°	2.667 - 24.000	6.819	1.937	-
Base - 58°	5.334 - 49.000	23.486	6.805	.01
Base - 37°	13.500 - 52.000	26.986	9.028	.01
Base - 8°	1.000 - 40.000	12.227	2.723	.05
110° - 94°	1.000 - 24.000	8.333	2.498	.05
110° - 58°	4.000 - 23.000	7.333	2.296	.05
110° - 37°	2.000 - 34.000	11.833	3.406	.01
110° - 8°	0.000 - 26.000	-4.000	1.018	-
94° - 58°	2.000 - 43.000	15.666	3.328	.01
94° - 37°	1.000 - 42.000	20.166	3.587	.01
94° - 8°	1.000 - 25.000	5.818	1.325	-
58° - 37°	2.000 - 28.000	4.500	1.085	-
58° - 8°	2.000 - 30.000	-12.727	3.365	.01
37° - 8°	2.000 - 41.000	15.727	4.900	.01

of confidence.

The differences between the mean score at 94^{o} compared to the mean score at 110^{o} showed an improvement in motor performance that was statistically significant at the five per cent level of confidence. This improvement was in favor of the 110^{o} temperature. The differences between the mean score at 94^{o} compared to the scores at 58^{o} and 37^{o} showed an improvement in motor performance over the 94^{o} temperature. These differences were both statistically significant at the one per cent level of confidence. The differences between the scores at 94^{o} and 8^{o} showed no significant difference between the mean scores.

The differences between the mean scores at 58^{o} and 8^{o} showed a significant decrease in motor performance at the 8^{o} temperature. This difference was statistically significant at the one per cent level of confidence. There was no statistically significant difference between the mean score at 58^{o} and the mean score at 37^{o}.

The difference between the mean score at 37^{o} and the mean score at 8^{o} showed a significant decrease in motor performance at the 8^{o} temperature. The difference was statistically significant at the one per cent level of confidence.

In general, the significant increases in motor performance occurred at the 58^{o}, 37^{o}, and 8^{o} temperatures, when compared to performance at the base temperature. There was also a significant increase in motor performance at 110°, 58°, and 37°, when compared to the performance at 94°. The only significant decrease in motor performance occurred at the 8° temperature when these scores were compared to the scores at 58° and 37°. There were no other significant differences between the mean scores of the remaining temperatures.

The raw scores for motor performance can be found in the Appendix, Table VIII.

CHAPTER VI

ANALYSIS OF DATA

The effects of various temperatures on balance, movement reaction time, steadiness, and motor performance were determined by comparing the mean scores obtained at the five selected variable temperatures to a base score which represented the average homeostatic score for the four items tested. In order to determine if a directional change between the mean scores of the four items at the six temperatures existed, Fisher's formula[4:220] for the significance of difference between correlated means was used.

Steadiness. The mean base score was compared to the mean scores at 110°, 94°, 58°, and 37°, and the results showed a statistically significant difference between the means. The significantly high "t" values showed that at these four temperatures there was an improvement in steadiness over the base temperature scores. The differences were all significant at the five per cent level of confidence or better. The scores obtained at the 8° temperature when compared to the scores at the base temperature, indicated that there was no statistical difference in steadiness. The over-all results would indicate that steadiness improved at the variable temperatures and that neither heat nor cold had a detrimental effect on steadiness, but instead, extremes in temperature tended to increase the steadiness of the individual.

The increase in steadiness level at the three colder temperatures, and the fact that in this study there was no significant directional change in steadiness at the 8° temperature, can be compared to similar results obtained by LeBlanc[38] in his study on the effects of cold on manual dexterity. LeBlanc found that if the hands were exposed to the cold, small movements of the joints were enhanced, while the larger movements were impaired. Since the steadiness test used in this study involved control of small movements, this factor could possibly be related to the improvement in steadiness at 58°, and 37° over the base temperature performance. It could also explain why there was no statistically significant change in steadiness at the 8° temperature over the base temperature.

When the score at 8° was compared to the scores obtained at 110°, 58°, and 37°, there was a decrease in steadiness that was significant at the two per cent level of confidence. This particular decrease occurred in the direction of the 8° temperature.

The total results, supported by the significantly high "t" values indicate that, with the exception of the 8° temperature, there was an improvement in steadiness at all of the other selected temperatures over the base temperature performance. Steadiness was affected most by the extreme cold temperature when compared to the other variant temperatures, but it was not significantly different from steadiness at the normal or base temperature. There was also no significant difference between the steadiness scores at 94° as compared to the scores at the 8° temperature. The final results also show that heat did not adversely affect steadiness at any of the selected temperatures, and that steadiness improved over the base performance.

Reaction Time. The results of the reaction test show that reaction time decreased at all of the selected temperatures when compared to performance at the base temperature. The differences were statistically significant at the one per cent level of confidence, with the exception of the 37° temperature, and the significant difference in this case was at the five per cent level of confidence. The only increase in reaction time occurred at the 37° temperature when the scores for that temperature were compared to the scores at 94°. The difference between the mean scores was significant at the five per cent level of confidence.

There is some possibility that the reaction time scores might have been faster at the 58° temperature. The running surface used at this exposure was a smooth hard-top finish, and the subjects complained of not being able to keep their footing on their starts when the stimulus lights were flashed. They also had difficulty in stopping on the approach to the reaction time apparatus.

There was no significant difference between the mean scores when the mean scores of the remaining temperatures were compared to both the hot and cold temperatures. In studying the "t" values for these tests, found in Table II, page 61, it would appear that although the differences were not significant they tended to be faster in the hotter temperatures than at the cold temperatures. The one exception was at the 37° temperature. At this particular temperature, reaction time had a tendency to be faster than at the other selected temperatures.

Therefore, it would seem that mild cold enhances reaction time up to a point; that heat retards reaction time and that extreme cold also retards reaction time. In other words, so far as reaction time is concerned, it would appear that cold and heat both adversely affected reaction time and that of the two temperatures, cold had less effect than the heat.

Dynamic Balance. The significant "t" values indicate that when the mean base score was compared to the mean scores at 110°, 94°, 58°, 37°, and 8°, there was a significant improvement in balance at all of the experimental temperatures. These differences were all statistically significant at the five per cent level of confidence or better. There was no significant change in balance when the scores at 94° were compared to the scores at 110°, 58°, 37°, and 8°. The "t" values showed a significant decrease in balance at 37° when the scores obtained at 37° were compared to the scores at 58°. This difference was statistically significant at the five per cent level of confidence. The balance scores at 8° were also significantly lower at that temperature than they were at 110° and 58°. The differences between the means in both cases were statistically significant at the one per cent level of confidence. The significant "t" values showed that the only decreases in balance occurred at 37° and 8° when the scores were compared to the scores at the moderately cold temperature, and to the extremely hot temperature scores. This would indicate, that in so far as dynamic balance is concerned, it would appear that although balance at the extreme temperatures was better than at the base temperature, balance was still better in the hotter temperatures than it was at the cold temperatures. This also indicates that extreme cold appears to have more adverse effects on balance than do the extremely hot temperatures.

According to the "t" values for the remaining temperatures, when the mean scores were compared to each other, there were no statistically significant differences between the means but the differences that did exist seem to indicate a trend. In referring to the statistical data in Table III, page 63, it can be seen that, although the differences were not significant between the scores at 37° compared to the scores at 110° and 94°, there was a decrease in balance at the 37° temperature. There was also a decrease in balance at the 8° temperature in comparison to the scores at 94°. There was another decrease in balance at 58° when these scores were compared to the scores at 110°. It appears from the results of the testing that, although balance did not improve over the base temperature at all of the selected experimental temperatures, heat seemed to enhance balance and the cold temperatures seemed to have had more adverse effects on dynamic balance.

The 8° temperature seemed to have the most adverse effects on balance when compared to the scores at the base temperature, as well as compared to performance at 58° and 110°. In view of all of the results, the cold therefore appeared to affect balance to a greater extent than the hotter temperatures.

Motor Performance. In the results of the wall volley test, when the mean base score was compared to the scores at 110° and 94°, the "t" values indicated no statistically significant differences between the means. There was definite improvement in motor performance when the mean base score was compared to the scores at 58° and 37°. This improvement was in the direction of the lower temperatures. The difference between the means was statistically significant at the one per cent level of confidence. The mean base score compared to the mean score at 8° also showed an improvement in motor performance over the base score at the five per cent level of confidence. The results indicated that the subjects performed the wall volley test better in the colder temperature than at the base temperature. Since there was no significant change between the base temperature motor performance scores, and the scores at 110° and 94°, there seems to be reason to assume that performance was better in the colder temperatures than it was in the warmer temperatures. In spite of the fact that the subjects complained that they could not control their hands in the cold exposure, they did perform better at those temperatures.

In interpreting the "t" scores that are available in Table IV, page 66, it appears that the cold temperatures, for the period of time in which the subjects were exposed, did stimulate motor performance. Any possible adverse effects that the cold might have had on the subjects could have been offset, because the wall volley was the last of the items tested. Previous to taking the wall volley test, the subjects had already been involved in the reaction time test which included some running, and also the balance test which for many of the subjects included a considerable amount of gross motor movement. This exercise could have warmed the subjects enough to overcome some of the effects of the cold.

When the base score was compared to the scores obtained at 110° and 94°, there were no significant differences between the mean scores.

Performances at 110°, 58°, and 37°, again showed a significant improvement over the performance at 94°. These differences were significant at the five per cent level of confidence or better. There was also a significant improvement in motor performance, at the five per cent level of confidence, when the mean score at 110° was compared to the mean score at 58°; the improvement being in the direction of the 58° temperature. At 37°, performance was also better, at the one per cent level of confidence, than it was at the 110° temperature. There was no significant difference between the scores at 110° compared to the scores at 8°.

The only two decreases in motor performance occurred when the 8° temperature scores were compared to the scores at 58° and 37°.

With the significant increases in motor performance, the "t" values indicate that motor performances increased in the cooler temperatures when compared to the base temperature. Heat did not significantly affect motor performance. The only decreases occurred when the cooler temperatures were compared to each other, and when they were compared to the extreme hot temperatures. In these cases the improvement in motor performance could have been partially due to learning. Although the tests were not administered enough times to be significantly affected by learning, it is possible that some learning did take place. It is doubtful, however, that a learning factor, considering the minimum number of times that the test was administered, could have produced such significant results in motor performance.

The temperature that affected motor performance the most was the 8° temperature. Compared to the base temperature, motor performance was better at 8°, but comparing 8° to the remaining temperatures the results indicated that performance was better at the other temperatures than at 8°. The scores at 8°, disregarding the base comparison, showed either no change at 8° or significant decreases in motor performance.

Temperature Analysis. In comparing steadiness at the experimental temperatures to performance at the base temperature, the results showed that steadiness could be expected to improve in the very warm temperatures, and also in the moderately cold temperatures. However, when the cold temperatures approach freezing, steadiness did not change. In the temperatures used for this study the results showed that the only instance in which steadiness did not improve over base performance was at the 8° temperature, and, at the 37° temperature. At the colder temperatures steadiness did not improve as much as it did at the warmer temperatures although it was better at either extreme than at the base temperature.

The hot and cold experimental temperatures also tended to improve balance when compared to base performance. When re-examining the scores the results showed that balance was best in the cooler temperatures, but it was not as good in the extreme cold, even though at that temperature it was better than at the base temperature. In general, the balance was best in the moderately cold temperatures and although performance was better in the warmer temperatures than at the base temperature, it did not exceed performance in the colder temperatures. The results would then indicate that although balance does improve in all of the variant temperatures, it is still best at a cool temperature that does not go too far below the freezing point.

In contrast to the effects of the variant temperatures on balance, the same temperatures produced the opposite results when reaction time was tested. The results in this case showed that reaction time was slower in the hot temperatures, and also in the colder temperatures, than it was at the base temperature. It appears then that for maximum movement reaction time performance, the base temperature would produce the best results. The other temperature at which reaction time might approach normal performance would probably be in a cooler temperature since the results showed that this was the experimental temperature at which reaction time was the fastest although it was not as fast as at the base temperature.

When motor performance was tested, the results showed that the cold temperatures tended to improve performance and that the hotter temperatures had little or no effect on motor performance. When the 8° temperature was involved, performance was not as good as at the more moderately cold temperatures and although performance did improve over the base, it was not a significant improvement.

Speaking more specifically then, it can be said that according to the results of this study, at 110°, 94°, 58°, and 37°, steadiness and balance could be expected to improve over performance at the base temperature.

At 58°, and 37°, steadiness, balance, and motor performance could be expected to improve over performance at a 75° to 80° temperature.

In steadiness and balance, there could be an expected improvement at 110° and at 94°, but in motor performance there would probably be no significant change in performance.

At all of the five selected temperatures, reaction time could be expected to be slower than performance at a temperature between 75° and 80°, but at a colder temperature, approaching 37°, it would more nearly approximate the average or base performance.

Finally, at the 8° temperature, the results indicate that in balance and motor performance there would be an improvement in performance, while steadiness would most likely show no change from performance at the base temperature.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effects of variant selected temperatures on performance in movement reaction time which involved total body movement, dynamic balance, which is an ambulatory balance, arm-hand steadiness, and motor performance as measured by performance in a volley ball wall volley test.

The subjects for the study were twelve women graduate students ranging in age from twenty-two years to thirty-two years. Their motor abilities ranged from poor to good as measured by the Brace Motor Ability Test.(16)

The four items tested in this study were performed at three different times in a temperature ranging from 75° to 80°. The scores from these three initial testing periods were combined, and a mean score was established for each of the subjects in each of the four items tested. This mean base score was then statistically compared to performances at the five selected experimental temperatures: 110°, 94°, 58°, 37°, and 8°. During each of the five experimental testing periods, the subjects were exposed to the selected temperature for a period of fifteen minutes. During the exposures, the subjects were allowed to walk about but were not allowed to exercise further. Following the fifteen minute exposure, the subjects were administered the four tests in the exposure area. The results of the five testing periods were then compared statistically to the mean base score, and they were then compared to each of the other selected temperatures.

FINDINGS

Steadiness

1. The comparison between the base scores and the scores obtained at 110°, 94°, 58°, and 37°, showed that steadiness improved at these four selected temperatures over the base results.

2. Steadiness did not improve over the base temperature performance at the 8° temperature.

3. The only significant decrease in steadiness occurred at the 8° temperature when these scores were compared to performance at 110°, 58°, and 37°.

4. Although steadiness did improve over base performance at four of the five experimental temperatures, the colder temperatures in general appeared to have more of an adverse affect on steadiness.

5. The results showed that heat did not have any adverse effects on steadiness and that steadiness tended to improve at the higher temperatures.

Reaction Time

1. Reaction time was significantly slower at all of the selected

experimental temperatures than it was at the base temperature.

2. The one temperature that seemed to have the least effect on reaction time was the 37° temperature.

3. There was no significant change in reaction time, with the exception of performance at the 37° temperature when the experimental temperatures were compared to each other.

4. Reaction time was affected by both the heat and the cold, becoming slower in each temperature extreme.

Dynamic Balance

1. Balance improved at all of the five selected temperatures.

2. There was no significant directional change in balance when performance at 94° was compared to performance at 110°, 58°, 37°, and 8°.

3. There was a significant decrease in balance when performance at 37° was compared to performance at 58°.

4. A significant decrease in balance occurred at the 8° temperature when compared to balance at 110° and 58°.

5. Although the results were not significant, the scores showed that balance decreased when performance at 37° was compared to performance at 110° and 94°.

6. Balance tended to decrease at 8° when performance at 8° was compared to performance at 94°. The results, however, were not statistically significant.

7. The total results showed that the temperature variants used in

this study improved balance, and that heat enhanced balancing ability more than the colder temperatures.

Motor Performance

1. There was no significant directional change in motor performance at 110° and 94° when these scores were compared to performance at the base temperature.

2. Motor performance improved at 58°, 37°, and 8°, over performance at the base temperature.

3. Motor performance in the wall volley test was better at the 110°, 58°, and 37° temperatures than it was at the 94° temperature.

4. There were no significant changes in performance at 8° over performance at 94°.

5. Motor performance was better at 58° and 37° when compared to performance at 110°.

6. There was no significant change in performance at 110° when compared to the scores at 8°.

7. Motor performance decreased at the 8° temperature when compared to performance at 58°.

8. There was no statistically significant difference between the scores in motor performance at 58° and the scores at 37°.

9. Motor performance was better at 37° than it was at 8°.

10. Performance was significantly better at all of the colder temperatures,

which indicated that cold enhanced motor performance in this study.

11. Heat did not adversely affect motor performance.

TEMPERATURE ANALYSES

1. At the 110° temperature the results indicated that;
   a. Steadiness and balance improved at this temperature over base performance.

   b. There was no significant difference in motor performance at this temperature as compared to the base temperature.

   c. Reaction time was slower at this temperature than it was at the base temperature.

2. At the 94° temperature the results indicated that;
   a. Steadiness and balance improved over the base temperature.

   b. There was no significant change in motor performance at this temperature over the base performance.

   c. Reaction time was significantly slower at this temperature than it was at the base temperature.

3. At the 58° temperature the results indicated that;
   a. Steadiness, balance, and motor performance were all significantly better at this temperature than at the base temperature.

   b. Reaction time was significantly slower at this temperature than it was at the base temperature.

4. At the 37° temperature the results indicated that;
   a. Steadiness, balance, and motor performance were all significantly better at this temperature than at the base temperature.

   b. Reaction time was slower at this temperature than it was at the base temperature.

5. At the 8° temperature the results indicated that;

a. Balance and motor performance were significantly better at this temperature than at the base temperature.

b. There was no significant change in steadiness at this temperature compared to performance at the base temperature.

c. Reaction time was significantly slower at this temperature than it was at the base temperature.

CONCLUSIONS

Of the four items tested, reaction time was the only item that was adversely affected by all of the selected experimental temperatures. In view of these results, it is possible to surmise that gross motor activities involving total body movement and split second reactions, would be better performed at temperatures approximating 75° to 80°, rather than at temperatures that are extremely hot or close to or below freezing. However, sports skills that involve smaller movements could probably be performed more successfully in cool or moderately cold temperatures. Activities involving a high degree of balance, according to the results of this study, would appear to be more effectively performed in either the very hot or slightly below average temperatures, but the results also indicate that performance would tend to deteriorate in temperatures below freezing. Activities and motor coordinations that would be similar to the eye-hand coordination involved in the steadiness test, apparently, would be more successful in the warmer temperatures as opposed to the extremely cold temperatures.

In general, it appeared,that when gross motor activity involving the use of the entire body was concerned, all of the selected temperatures had significant effects on performance. Activity that included smaller movements, such as the eye-hand coordination in steadiness and the wall volley, were not affected as much by the variant temperatures.

The writer would like to suggest that more studies be undertaken in this area. A study that would involve the testing and comparing of the performance of a group of subjects with high scores in general motor ability, to a group with low motor ability scores might offer additional knowledge when related to temperature variation. It is also suggested that the exposure periods might be lengthened. In conjunction with this, it would be interesting to administer a predetermined physiological work load along with the testing to be carried on in the study.

As Physical Educators add to their knowledge concerning performance at variable temperatures, the probability of optimum performance level will become more meaningful.

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APPENDIX

TABLE V

MEAN BASE SCORES AND RAW SCORES FOR STEADINESS AT ALL TEMPERATURES

Subject	Base	110°	94°	58°	37°	8°
1	6.000	0.000	0.000	4.000	0.000	20.000
2	2.000	5.000	0.000	1.000	0.000	10.000
3	1.666	0.000	0.000	0.000	0.000	0.000
4	8.666	1.000	6.000	0.000	2.000	6.000
5	1.666	0.000	0.000	0.000	0.000	0.000
6	1.833	0.000	0.000	0.000	0.000	4.000
7	1.000	3.000	6.000	1.000	0.000	2.000
8	6.166	0.000	0.000	0.000	0.000	6.000
9	2.333	0.000	0.000	0.000	0.000	0.000
10	6.666	0.000	0.000	0.000	1.000	2.000
11	7.666	0.000	0.000	0.000	14.000	28.000
12	4.500	0.000	0.000	4.000	0.000	*****

TABLE VI

MEAN BASE SCORES AND RAW SCORES FOR REACTION TIME AT ALL TEMPERATURES

Subject	Base	110°	94°	58°	37°	8°
1	21.875	21.000	22.750	21.250	22.250	21.500
2	21.416	21.000	22.750	22.750	22.750	24.500
3	26.666	27.250	28.250	26.500	27.000	28.500
4	21.940	22.250	21.250	21.750	22.250	22.000
5	20.916	22.250	22.000	21.500	21.500	21.000
6	21.416	21.800	23.250	24.000	23.000	23.250
7	19.733	22.750	21.000	24.000	21.000	23.250
8	21.166	25.000	22.000	24.750	24.000	28.500
9	21.416	21.000	22.250	22.000	21.750	21.000
10	18.583	21.250	20.750	22.750	21.250	21.250
11	22.666	27.500	25.250	26.250	24.750	28.750
12	24.401	25.000	24.500	25.500	23.000	****

TABLE VII

MEAN BASE SCORES AND RAW SCORES FOR DYNAMIC BALANCE AT ALL TEMPERATURES

Subject	Base	110°	94°	58°	37°	8°
1	288.500	288.000	267.000	287.000	287.500	282.000
2	252.333	282.000	288.000	292.000	285.000	277.500
3	219.533	294.000	287.300	293.000	294.000	286.500
4	193.933	265.100	297.000	267.800	229.200	244.000
5	271.166	298.900	286.000	298.400	279.500	286.000
6	251.333	271.300	272.000	269.500	256.500	252.000
7	219.366	255.000	270.000	251.800	241.000	246.500
8	209.333	271.500	289.500	267.000	278.500	245.000
9	250.833	285.400	283.600	294.000	280.500	287.500
10	290.333	269.500	280.500	300.000	288.000	272.500
11	213.133	221.500	186.100	247.500	222.000	203.000
12	178.000	271.000	241.000	254.900	257.000	****

TABLE VIII

MEAN BASE SCORES AND RAW SCORES FOR MOTOR PERFORMANCE AT ALL TEMPERATURES

Subject	Base	110°	94°	58°	37°	8°
1	55.500	78.000	64.000	62.000	69.000	52.000
2	111.666	133.000	100.000	143.000	137.000	125.000
3	53.000	81.000	77.000	102.000	105.000	93.000
4	82.000	100.000	91.000	110.000	105.000	103.000
5	103.000	119.000	120.000	129.000	133.000	131.000
6	98.666	117.000	116.000	124.000	115.000	94.000
7	106.000	118.000	111.000	132.000	125.000	107.000
8	114.000	129.000	122.000	124.000	152.000	133.000
9	97.333	112.000	88.000	118.000	120.000	112.000
10	115.333	124.000	118.000	136.000	141.000	120.000
11	55.000	53.000	45.000	76.000	87.000	46.000
12	92.666	102.000	114.000	98.000	119.000	****

TABLE IX

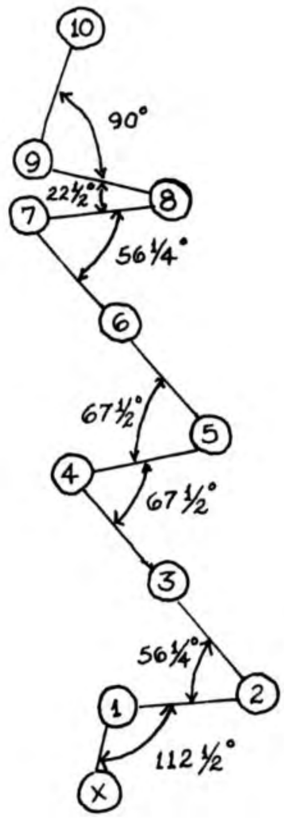
RAW SCORES FOR BRACE MOTOR ABILITY TEST

Subject	Tests Passed	T- Scores*	Rating
F. B.	12	52	Average
G. B.	15	63	Good
M. C.	10	45	Average
J. E.	11	48	Average
L. K.	10	45	Average
P. K.	10	45	Average
E. M.	11	48	Average
S. N.	8	37	Poor
J. O.	13	56	Average
N. P.	15	63	Good
M. S.	8	37	Poor
M.A.V.	10	45	Average

*Reference 16:72 gives source for T scores.

FIGURE I

FLOOR PATTERN FOR BASS DYNAMIC BALANCE TEST



Measurements

Circles - 8 1/2 inches in diameter

Distances Between Circles
18 inches from circle X to circle 1.
33 inches between circles 1. through 10.

Typed by Marie Teague