THE EFFECT OF WIND ON HEART RATE AT SUBMAXIMAL PERFORMANCE OF CONDITIONED TREADMILL RUNNERS

by

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CHAPTER I

INTRODUCTION

This country is presently experiencing an increase in both interest and participation of all aspects of fitness. Results of the Kraus-Weber (21) test on European and American students sharply brought the need for personal fitness into focus for the American people. As a result of this and other studies (5, 19, 26) President Eisenhower established the President's Council on Physical Fitness. This interest in physical fitness was spurred on by the example of the Kennedy's. As a result the nation has taken to the streets to begin their own jogging and/or fitness program. Research has established that swimming, cycling, and jogging are excellent ways of maintaining or increasing cardiovascular fitness. However, environmental factors can both positively and negatively affect the fitness enthusiast. Depending on the given set of conditions, each factor making up the environment in which the subject works can be either an advantage or disadvantage to the fitness enthusiast. For example, on an extremely hot day, the presence of wind may have a physiological, as well as a psychological effect in improving performance. Conversely a high velocity of wind may add to the mechanical workload of the jogger.

Environment factors that affect exercise are classified into two areas; they are the macro and micro environments. Macro environment is the large environment that affects exercise such as sun, wind, heat, cold, humidity, altitude, and precipitation. The micro environment is the small environment immediately surrounding the body and is affected by the amount and type of clothing a person wears. People can usually regulate their micro environment to meet their needs, whereas the macro environment is not so easily controlled.

Wind, air movement, as a factor during exercise, has not been explored as much as some of the more obvious areas of environmental stress. From the research conducted to date it appears that wind has a similar effect on exercise as cold within limits. That is, wind has the effect of cooling and would tend to have a similar effect at reduced temperatures.

When wind has a chilling effect on body physiology, including heart rate, it evokes similar responses as does cold stress. Some authorities (18, 27) theorize that strong wind offers mechanical resistance to runners. There still needs to be much work done in this area before we can say when or to what extent or degree wind ceases to have a cooling effect and begins to offer mechanical resistance.

Wind below the temperature of the body and less than saturated produces a cooling effect through evaporation and convection heat loss (3, 14). Evaporation rate is usually increased with wind (15); since it helps reduce the partical pressure at the skin surface which is a major factor in evaporation rate. This increased cooling through evaporation should tend to reduce heart rate and cool the body. However, a very dry wind over 103°F can add more to heat stress while at the same time aiding in the evaporation. It may be possible to identify wind speeds, temperature, and humidity levels that would indicate cessation of work at various levels. A scale of this nature would operate on somewhat the same principle as the wind-chill-index. Presently we have the temperature-humidity-index (THI) (25) that uses temperature and relative humidity as indicators of conditions when exercising is contraindicated. By including wind as a factor in the index it may allow exercise when without the wind exercise would otherwise be discouraged. Just as temperature alone does not indicate the severity of the cold when wind is not taken into consideration, so also wind may be helpful on the other end of the continuum.

Joggers, under normal circumstances, experience the effect of air movement over their body. If heat dissapation is a factor to consider in human performance at high intensity levels, either from the standpoint of too little or too much, then careful consideration should be given to the method of this heat loss. Wells (37, 38) has indicated that as much as 73% of the total body heat loss can be attributed to conduction, convection, and radiation from the skin. In the running situation most heat loss would be from evaporation, convection and some radiation with conduction loss almost negligible.

When runners are tested in the laboratory situation often the effect of air movement across the body during treadmill run or work on a bicycle ergometer is not considered. Since much of all heat loss is by convection and evaporation, the body mechanisms for temperature regulation are severely reduced in the laboratory setting. A reduction of 60-65% of the normal process of heat loss could cause heat stress to result and would no doubt affect the data related to almost all physiological parameters studied.

Investigations by Dasler (13) have indicated that in an environment where external heat stress is generated that effective cooling will result with air movement over the body at the rate of 250/ft. per min. and that wind velocities up to and including 1400/ft. per min. do not yield an appreciable gain in effective cooling.

Since Dasler's work was concerned mainly with hot environments resulting from externally generated heat, it is important to investigate what takes place when the heat is internally generated and air temperature remains normal with various wind speeds. Heart rate is the single most utilized variable as a determinant of stress in the laboratory setting. Comparisons should be made regarding internally generated heat stress, heart rate, and wind velocity with results of externally generated heat stress. The most apparent and the most easily noticeable stress would be to the cardiovascular system. This could be very critical for the middle aged jogger as well as the laboratory investigator interested in accurate results.

Research findings (11, 17, 20, 29, 43) have indicated that through the use of personal fitness programs emphasizing cardiovascular endurance, the incidence and severity of coronary heart disease can be reduced.

PROBLEM STATEMENT

The purpose of this study was two-fold: first to investigate the effect of wind on internally generated heat stress in normal temperatures. The second purpose was to study the effect of wind on heart rate as it related to testing procedure. This was to determine how long a subject could work in a WIND condition without biasing the heart rate data.

NEED FOR THE STUDY

With the increase in coronary heart disease and a subsequent increase in physical fitness throughout this country, many individuals have selected jogging as their mode of improving cardiovascular fitness. Little data is available to investigate the effects of wind on the various physiological parameters with some reference as to its consequence to the average adult male jogger.

Since heart rate is a critical factor in human performance, it is necessary to isolate this single factor to determine the relationship between it and wind.

DEFINITIONS OF TERMS

In order to provide optimal understanding of the study it is important to understand the specific meaning of the terminology used.

Electrocardiogram (ECG)

This is a graphic tracing of the electrical current produced by the contraction of the heart muscle.

Thirty beat count

The method of determining heart rate by timing thirty consecutive R spikes with a stopwatch. The stopwatch is started on the first spike that is counted as 0, the next is 1 and so on. The time is read to the nearest 0.1 second. The resultant time is then converted to beats per minute. (See table in Appendix).

Bipolar leads

These are leads that are secured by pairing one electrode on the body with another electrode on the body for ECG reading.

F/S (feet per second)

The velocity of wind displacement measured at the front of the treadmill just as it hit the subject. This was constant for all subjects throughout the study and was converted to approximate MPH for easier understanding of the reader.

Internal heat

That heat generated inside the body as a result of metabolic processes taking place at the cellular level resulting from high level work, in this study running on a treadmill.

External heat

Heat produced outside the body and passed to the body in such forms as conduction, convection, radiation, and skin friction.

Effective temperature

The corresponding dry bulb temperature where loci for constant body wettedness caused by regulatory sweating intersects the 50% relative humidity curve of the standard psychometric chart (44).

LIMITATIONS

There were certain inherent limitations in this study that included:

1. ~~Testing~~ was done at the subject's convenience, therefore the time of day ~~testing~~ took place varied from subject to subject; however, the time of day for T_1 and T_2 remained constant for each subject.

2. Individual psychological factors that affect performance varied from ~~individual~~ SUBJECT to ~~individual~~ SUBJECT.

DELIMITATIONS

The delimitations of the study are:

1. This study was limited to adult males between 25 and 52 years of age. All subjects were experienced joggers capable of sustaining a pace of at least six miles per hour for 30 minutes.

2. Only one wind speed was compared with the no wind condition.

CHAPTER II

REVIEW OF LITERATURE

This chapter presents a review of literature related to environmental factors, specifically convection and evaporation effect, pertinent to this study. Three areas of review were specifically identified. They were the effect of wind on (1) work performance, (2) athletics and athletic performance, and (3) heart rate.

Metabolic demands of high level physical activity in a hot environment presents critical problems relative to man's heat balance and temperature regulation. Belding and Hatch (8) have identified factors determining heat stress. They include: (1) air temperature, (2) temperature of solid surroundings, (3) temperature of skin, (4) vapor pressure at the skin, (5) environment vapor pressure, (6) air speed, (7) body heat production, (8) body surface area and postural attitude, and (9) clothing. According to Belding and Hatch heat stress exists "whenever, despite vasomotor adjustment, metabolic heat production exceeds the combined losses by radiation and convection." (8:130) Heat stress may be a result of internally or externally generated heat or a combination of the two. In a neutral environment radiation effect can't be appreciably increased by wind, but it might assist in convection and evaporation.

Resulting strains from heat stress are divided into three groups, (1) capacity for circulating blood to the skin, (2) maintaining a wetted skin by sweating and (3) tolerance to elevated body temperature.

Several studies deal directly with sweating as a result of heat stress (2, 6, 8, 15, 28, 37). Wyndham and associates (41) and Belding and Hatch (8) reported that sweat rate is a primary result of heat strain and that sweating correlates highly with presumed stress as measured by Effective Temperature.

Several theories (2, 6, 7, 9, 30, 33, 36) have been advanced regarding causative factors of the initial onset of sweating. It appears that skin temperature is a major factor important in the regulation of sweating as a mechanism for body cooling.

Investigation concerning the initial onset of sweating has been done by Adolph (2), Bazett (6), Robinson and others (36), Belding and Hertig (7), Benzinger (9), Randall and associates (30), and Robinson (33).

Work by Randall (30), Belding and Hertig (7), and Robinson (33) indicates that when central body temperature reamins constant, sweating increases in proportion to increases of skin temperature up to 37°C.

Benzinger (9) feels that the onset of sweating is controlled by a centrally located sense organ (tympanic membrane). He found that at skin temperature below 33°C the sweat rate is suppressed and that skin temperatures above 33°C do not cause an increased sweat rate, but rather the centrally located sense organ is responsible for the increase.

Bazett (6) reported that onset of sweating does not begin until skin temperature reaches roughly 34.5°C. There appears to be some agreement between Bazett and Benzinger on the skin temperature at the onset of sweating, however, Bazett makes no attempt to identify the cause.

Adolph (2) in his study dealt with the initiation of sweating with regard to time. He found that after exposure to hot air, sweating is delayed from 5 to 15 minutes. Adolph suggests that this is a result of accumulation of heat by the whole body. That is to say that the body can accumulate or take on heat to a given level before it becomes necessary to control heat intake or reduce the effects of intake. Adolph suggests that the stimulus required for the onset of full sweating is an appreciable increase in the heat content of the body as a whole. As a result, promptness of onset of sweating is no indication of tolerance or acclimatization to heat.

Another factor indirectly related to sweating and heat stress is fluid loss. Fox (15) in research on marathon runners indicates that sweat loss strains the cardiovascular system by reducing blood volume. A reduction in blood volume would decrease cardiac output resulting in less than optimal performance. In order to maintain the same amount of blood flow following fluid loss the heart rate would have to increase to circulate the remaining blood faster. Along with increased heart rate, stroke volume or the amount of blood pumped each time the chambers emptied would also have to increase. If, however, stroke volume was close to maximum because of work intensity, then heart rate increase would be the only way of maintaining the same level of performance.

Reduced blood volume would also greatly reduce the major temperature regulatory system of the body. In order to provide optimum performance and maximum heat regulation the body is in the tenuous position of supplying blood to major working muscles and to subcutaneous capillary beds for cooling. A loss of blood fluid from sweating reduces effectiveness of both systems and if body temperature becomes too high, may ultimately cause stoppage of work until a more satisfactory body temperature level has been reached.

Pugh and associates (28) investigating over 60 marathon runners, found that fluid loss among the four runners who collapsed at the conclusion of the race was mainly extravascular or that blood volume had returned to normal within one hour after the race. If, as Pugh has indicated, fluid loss from sweating comes not from the blood, but rather from extravascular tissue, the amount of stress put on the heart and thermoregulatory system of the body has not been increased as a result of fluid loss. This does not eliminate the problem of appropriating sufficient blood supplies for metabolic work and thermoregulation of body temperature.

Fox (15) computed that in order to maintain a tolerable body temperature marathon runners would have to produce from $1\frac{1}{2}$ to 2 liters of sweat per hour or between 4 and 5 liters. According to McArdle (23), fit acclimatized young men normally produce 1 to $1\frac{1}{2}$ liters per hour for up to 4 hours. Adam (1) has recorded loss of 2 liters per hour for 4 hours. Pugh found that the sweat loss of the winner of the marathon was 5.1 liters or 6.7% of his total body weight.

This large amount of sweat loss raises two serious issues regarding performance and safety of runners. With such large amounts of sweat loss the ultimately limiting factor in performance under ideal atmospheric conditions may not be a result of internally generated heat or extended circulatory demands, but rather disruption of adequate conditions to carry on metabolism at the cellular level. If the runner is capable of controlling thermoregulation of the body through sufficient sweat loss, this large loss may disturb the homeostatic conditions of cellular metabolism to the extent that it cannot function properly. This may not be a valid consideration where atmospheric conditions are less than ideal. An elevated relative humidity would limit effective temperature regulation through the sweating mechanism. In this instance fluid loss from sweating may not be nearly as great. Regarding safety of runners, it appears that there is a possibility of circulatory failure (15) to the completely wetted runner at the end of the race when he reduces air speed over his body and consequently reduces the evaporative capacity. It may be necessary under such conditions to provide an immediate means of reducing body temperature or regulation of its adjustment as it moves back to a more normal range.

Rectal temperature has been studied as to determine its relationship to heat stress and related parameters. Belding and Hatch (8) concluded that rectal temperature along with other variables shows a significant correlation with environmental stress. Givoni and Sohar (16) determined limitations of work in environmental stress conditions based on rectal temperature changes. Their findings indicated that a rectal temperature rise of 1.0°C or less during the initial 30 minutes of activity would not be a limitation on long duration work. They did report that a rise of 1.5°C or more during the initial 30 minutes would be considered dangerous for all but very short work bouts.

Givoni and Sohar (16) used a rectal temperature value of 39.3°C as the termination point in their study. The critical value for rectal temperature was determined by Robinson (34) to be 41.1°C.

Causes for the rise in rectal temperature as compared to skin temperature were studied by Bazette (6). He concluded that rise in skin temperature was more closely related with environmental temperature, whereas rectal temperature increases were in direct proportion to intensity of work. Robinson (34) concurs with Bazett (6) that internal or rectal temperature of a man rise during work, the elevation of temperature being directly proportional to the intensity of the work and therefore to the metabolic rate of the man.

Bazett (6) also observed that rate of sweating shows a precise and linear relation to surface temperatures, but no obvious relation at all exists to rectal temperature. However, control of rectal temperature is achieved by sweating.

Wyndham (41) in his study of mine workers found that as wet-globe temperatures increased productivity was reduced. He used three different wind speeds (100, 400, and 800 ft/min) to ascertain their effect on production. 100% productivity was that amount of production reached at 27.7°C wet-bulb. At wind speeds of 100, 400, and 800 ft/min productivity was 21%, 44%, and 59% respectively. The effect of increasing wind velocity from 100 to 400 ft/min was significant above 32.8°; from 100 to 800 ft/min was significant above 31.1°.

Dasler (13) in his study of thermal stress aboard ships has refuted the once held theory that air velocities at supply ducts of 2,000 fpm or more supply optimal spot cooling. Rather, he suggests, that the key element in spot cooling is optimal effective velocity over the subject. Daslet found that nearly 80% effective cooling is obtained when the air flow over the subject is approximately 250 feet per minute. Increasing the velocity beyond this rate accounts for comparatively small gains in effective cooling. He also noted that air velocities over 1,500 ft/min in hot-humid environments leads to increased air friction at the skin level.

Several studies have been undertaken to specifically determine the effect of wind on athletic performance of track runners. Data indicates that a similarity does exist between track and treadmill running when comparison of speed of adjustment to various physiological responses were made. In the study of O_2 uptake in track and treadmill running the effect of overcoming air resistance accounted for 8% of the total energy cost while other studies showed that it accounted for only 3-5% of the energy cost.

The main reaction of circulatory parameters to heat is elevated heart rate at all levels of work up to near maximum. There appears to be conflicting views on fluid loss as to whether it comes from blood fluid or extravascular fluid.

Researchers are divided among at least two different theories of the factor initiating sweat response. Two critical rectal temperatures have been identified and an increase scale developed to provide criteria for stoppage of work. Contributing to the cooling process, wind has been identified as to its benefits on work load and cooling. Research is beginning to accumulate in the areas of wind effect in athletic performance, work load, heart rate, and regulation of body temperature.

CHAPTER III

PROCEDURE

The methods and procedures used in this study included selection of subjects, treatment WIND, treatment NO WIND, and the statistical treatment of the data.

SUBJECTS

The subjects were 17 male adult volunteers from the adult fitness program at Kansas State University. All subjects were experienced joggers and capable of completing a thirty minute continuous run on a treadmill.

The mean age of the subjects was 35.3 years with a mean height of 70.6 inches. Mean weight for the subjects was in the NO WIND treatment 172.49 pounds and for the WIND treatment 172.74 pounds. The mean air temperature was 21.48°C.

Before testing, all subjects returned an Informed Consent form signed by the subject and his wife, where applicable. Each subject had previously had a physical examination by an M.D. These records are on file in the Department of Health, Physical Education and Recreation at Kansas State University.

PREPARATION OF SUBJECTS

Subjects were instructed not to eat at least two hours before testing. Before they entered the lab each subject emptied his bladder and bowels. Subjects were weighed nude on a balance beam scale to the nearest $\frac{1}{4}$ ounce. This was done to ascertain the initial weight of each subject for later distinction of sweat rate. Height was measured on a medical scale. A rectal probe (Yellowsprings Model #401) was inserted 7 cm past the anal sphincter and held in place by contraction of the sphincter muscle on a modified bulb on the probe.

In preparation for electrode placement surface hair was shaved off in those areas where electrodes would be placed. Skin was washed with isopropal alcohol and the horny layer of epidermis was removed by dermal abrasion with a spatula. Electrode paste was applied to the specific area of electrode contact in a circle one-half inch in diameter. A liquid adhesive ("New Skin" by Johnson and Johnson) was then applied $\frac{1}{4}$ inch around the area where electrode contact would be made and contact paste had previously been applied. A double stick surfaced tape was attached to the electrode with paste used to fill the centers of the three electrodes. The electrodes were applied so that the paste filled centers were matched with the $\frac{1}{2}$ inch paste circles on the skin and so the adhesive tape backing matched with the liquid adhesive applied around the paste circles.

Electrodes were placed on the seventh intercostal space beneath and slightly lateral of the nipple line. The left side was the positive (+) lead and the right side was the ground electrode. The negative (-) lead was placed on the top of the sternum.

Those subjects unfamiliar with the treadmill were given instruction on running procedures and how it differed from normal running prior to testing. They were also given instructions on the use of the emergency shut-off switch that was available to them during the run.

Resting heart rate was recorded by a times 30 beat count of ECG R spikes as observed on the Hewitt-Packard Osciloscope. Short strips of ECG tape were recorded for further research. Subjects were clad in shoes, socks, and gym trunks. The treadmill speed was selected so that individual runners would participate at a level that could be sustained for 30 minutes. Subjects were tested at the same time of day with no more than a one day interval between tests.

Surface area was calculated using the formula of Dubois. A 60 minute lab clock with a one minute sweep hand was used to time the entire run. Both treadmill and fan were started simultaneously for the run with wind. During the first two to three minutes of the test the subject was closely observed by the investigator to determine if the subject was experiencing any difficulties. The investigator or an assistant was stationed at the back of the treadmill for spotting purposes.

Air temperature was obtained from a thermistor suspended from the treadmill frame above and slightly in front of the subject. The thermistor was approximately seven feet above the belt of the treadmill in the path of air flow during the WIND treatment.

Heart rate and rectal temperatures were recorded prior to starting and for minutes 4-5, 9-10, 14-15, 19-20, 24-25, 29-30 of the run.

Recovery data was recorded for the period beginning immediately after conclusion of the run. This data was recorded for minutes 0-1, 1-2, 2-4, 4-6, 6-8, 8-10.

Upon completion of the run and recovery period, each subject was again weighed to determine amount of sweat loss.

Each subject was tested twice; once with wind and once without wind. The order of WIND and NO WIND tests was randomized by listing subjects and then assigning them a number from a random number table. Odd numbers received WIND for the first run and even received NO WIND on their first run. All other factors were held constant (speed, temperature, PH_2O, testing, etc.).

STATISTICAL TREATMENT

The data was analyzed using a three-way analysis of variance (ANOVA) for repeated measures to compare heart rates in the WIND and NO WIND treatments for all test periods. Also, the air temperature, rectal temperature, and sweat rate for WIND were compared to the resting rate of NO WIND. Sheffe's Method was used to compare heart rate and rectal temperature values for each time interval of the WIND condition with the corresponding interval of the NO WIND condition. Comparisons were made for minute 4-5 of the WIND with minute 4-5 of the NO WIND for both heart rate and rectal temperature. The same was done for minutes 9-10, 14-15, 19-20, 24-25, and 29-30 of the run and for recovery 0-1, 1-2, 2-4, 4-6, 6-8, and 8-10.

CHAPTER IV

RESULTS AND DISCUSSION

This study investigated the effect of wind on internally generated heat stress, heart rate, and rectal temperature of adult male joggers. This chapter presents the results obtained from this study and a discussion of these results. The results will include: (1) statistical treatment of the general data, (2) ANOVA of climatic variables; (3) repeated measures analysis of heart rate, air temperature, and rectal temperature, and (4) Sheffe's procedure for testing all possible comparisons between means for heart rates under both conditions.

A summary of mean, standard deviation, and range of general data is presented in Table 1. The results indicate that the subjects were typically characteristic of adult males with mean age of 35.5 years, a mean height of 70.6 inches (5 feet 6 inches) and mean surface area of 1.95 m^2. The average treadmill speed was 6.62 mph with most subjects running at 6 mph indicated by the low standard deviation (0.65). A treadmill speed of 6.62 mph would allow the subject to cover just over three miles in 30 minutes.

Table 2 shows mean weights for pre, (weight in), and posttest, (weight out), for the WIND and NO WIND condition. This table also shows standard deviations and ranges for the pre and posttest weights for both conditions. From these values, mean values for weight loss and sweat loss were computed and are shown in Table 3. The WIND condition resulted in a slightly greater weight loss in pounds. The second

TABLE 1

MEANS, RANGE AND STANDARD DEVIATIONS FOR HEIGHT, AGE, SURFACE AREA, AND TREADMILL SPEED

Variable	N	$\bar{X}$	S.D.	Range Min.	Max.
Height (inches)	17	70.6	3.16	16	75
Age (years)	17	35.3	6.76	25	52
Surface Area	17	1.95	0.18	1.470	2.24
Treadmill Speed (MPH)	17	6.62	0.65	6	8

TABLE 2

MEANS, RANGE AND STANDARD DEVIATION FOR WEIGHT IN AND OUT UNDER WIND AND NO WIND

Variable	N	$\bar{X}$	S.D.	Range Min.	Max.
Weight In (W)	17	172.5	25.06	112.13	219.91
Weight Out (W)	17	171.08	24.70	111.56	217.65
Weight In (NW)	17	172.74	25.47	110.45	220.08
Weight Out (NW)	17	171.42	25.24	109.89	218.47

TABLE 3

MEANS, RANGE, AND STANDARD DEVIATIONS FOR
WEIGHT LOSS AND SWEAT LOSS

Variable	N	$\bar{X}$	S.D.	Range Min.	Range Max.
Weight loss (W) (lbs)	17	1.41	0.42	0.57	2.25
Weight loss (W) (lbs)	17	1.32	0.39	0.56	2.19
Sweat loss (W) gr/m/hr	17	659.58	145.15	352.10	912.1
Sweat loss (NW)	17	594.81	149.06	345.90	951.4

part of the table shows mean values of sweat loss converted to gr/m/hr, standard deviation and range. A t-test of significance indicated that a significant difference at the .01 level existed between sweat rates of the two conditions.

Table 4 indicates the levels of significance of the heart rate with respect to subject, treatment, time, and treatment as it relates to time. The data indicates a significant difference at the .01 level between the subjects. The effect of treatment on heart rate was significant at the .01 level. When considering the time intervals of rest, work, and recovery, the heart rate differences were significant at .01 level. A significant difference (Pl.01) was found in analyzing heart rates with respect to treatment and time. Figure 1 indicates a graphic representation of the heart rates during the intervals of rest, work, and recovery. The graph also indicates exact points during the work and recovery period where the differences in heart rate were significant at the .05 and .01 levels.

Table 5 shows mean heart rate values for the specific intervals of the test and for the two conditions. The table also shows standard deviations and T-probabilities for levels of significance using Scheffe's method. Heart rates were significantly different at .01 level from the 14th minute of the run through the second minute of the recovery. From the second minute through the eighth minute of recovery heart rates were significant at .05 level. For minutes eight to ten they were again significant at .01 level.

Table 6 shows repeated measures analysis of variance for air temperature between subjects, treatment, time, and treatment as related

TABLE 4

REPEATED MEASURES ANALYSIS OF VARIANCE FOR HEART RATE

Source	df	ss	ms.	f
Subject	15	11260.80	750.72	4.06**
Treatment	1	5772.02	5772.02	31.24**
Error A	15	2771.76	184.78	
Time	12	277612.23	23134.35	341.41**
Treatment x Time	12	2247.89	187.32	2.77**
Error B	354	23987.25	67.76	
Total	409			

* .05 significant level
** .01 significant level

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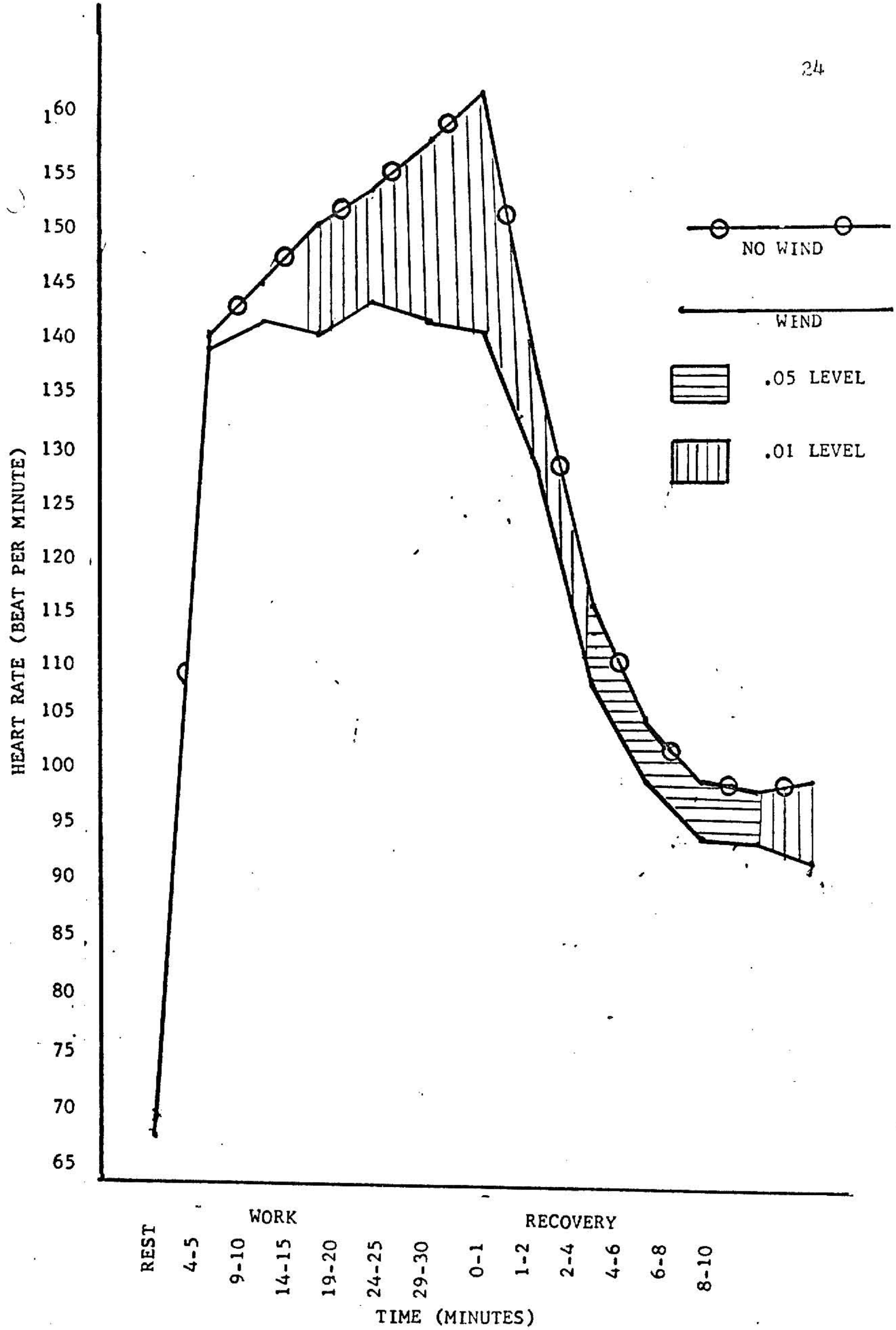

FIGURE 1. Mean Heart Rates with Statistically Significant Differences Indicated Using Scheffe's Method

TABLE 5

MEAN HEART RATES, STANDARD DEVIATION, AND LEVEL OF SIGNIFICANCE FOR WIND AND NO WIND CONDITIONS

Time	Heart Rate Wind Condition	Subjects	Heart Rate No Wind Condition	Subjects	Standard Deviation	T Probability
REST	68.396	17	69.283	17	-0.320	NS
WORK						
4- 5	138.278	17	140.047	17	-0.639	NS
9-10	142.454	17	145.812	17	-1.213	NS
14-15	141.369	17	150.405	16	-3.205	.01
19-20	143.572	17	153.968	16	-3.699	.01
24-25	142.925	17	155.718	16	-4.552	.01
29-30	141.219	17	158.593	16	-6.182	.01
RECOVERY						
0- 1	126.808	17	137.468	16	-3.793	.01
1- 2	108.158	16	116.047	17	-2.807	.01
2- 4	100.315	16	106.871	17	-2.333	.05
4- 6	95.808	17	101.165	17	-1.936	.05
6- 8	94.984	17	99.165	17	-1.511	.05
8-10	93.337	17	100.495	17	-2.586	.01

TABLE 6

REPEATED MEASURES ANALYSIS OF VARIANCE FOR AIR TEMPERATURE

Source	df	ss	ms	f
Subject	15	162.43	10.83	4.916**
Treatment	1	4.51	4.51	2.05
Error A	15	33.04	2.20	
Time	12	9.63	0.80	4.31**
Treatment x Time	12	1.96	0.16	0.877
Error B	355	66.14	0.19	
Total	410			

* .05 significant level
** .01 significant level

to time. There was a significant difference in air temperature at .01 level between subjects and during the different time intervals of the experiment. Air temperatures were not significantly different between the WIND and NO WIND treatment or between the treatment as it related to time.

In Table 7 rectal temperatures are compared for subjects, treatment, time, and treatment as related to time. Results indicate a significant difference at .01 level in rectal temperature between the subjects and between the time intervals. There was, however, no significant difference between treatment and treatment as related to time.

Table 8 summarizes the results of ANOVA for the three varaibles when compared with subject, time, treatment, and treatment as related to time. In all cases heart rates were significantly different at the .01 level. Although air temperature and rectal temperature were significantly different (Pl.01) for subject and time, they were not significantly different for treatment or treatment as related to time.

These data would seem to indicate that wind (air movement) over a jogger helps to reduce heart rate in prolonged runs over 13 min. This reduction in heart rate is more pronounced the longer he runs and also affects recovery heart rate even when air movement has stopped.

TABLE 7

REPEATED MEASURES ANALYSIS OF VARIANCE FOR BODY CORE TEMPERATURE

Source	df	ss	ms	f
Subject	15	34.97	2.33	3.85**
Treatment	1	0.11	0.11	0.18
Error A	15	9.07	0.60	
Time	12	61.17	5.10	207.60**
Treatment x Time	12	0.14	0.01	0.48
Error B	357	8.77	0.02	
Total	412			

* .05 significant level
** .01 significant level

TABLE 8

SUMMARY OF ANOVA FOR HEART RATE, AIR TEMPERATURE, AND RECTAL TEMPERATURE

Variable	Subject	Time	Treatment	Treatment as Related to Time
Heart rate	.01	.01	.01	.01
Air temperature	.01	.01	NS	NS
Rectal temperature	.01	.01	NS	NS

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The heart rate, sweat rate, and rectal temperature responses of the subjects were recorded for the 30 minute run. The following conclusions can be drawn from the results of the data collected.

1. There was no significant difference in the resting heart rates and body core temperatures for the WIND and NO WIND treatments. This is to be expected since up to this time the activity of the subjects has been minimal and only involved the preparation phase. Since the preparation phases were identical for the WIND and NO WIND treatment it would be highly unlikely that a significant difference would result in resting values.

2. Heart rate response during the first 10 minutes of the run were not significantly different in WIND and NO WIND. There was a significant difference in heart rate response for minutes 14 to 30 of the run and for 0-10 of the recovery. The wind significantly reduced the heart rates from the 14th minute of the run until the completion of the 30 minutes. There was also a significant reduction in recovery heart rate for the ten minutes of the recovery period.

3. Sweat rates for WIND and NO WIND were significantly different. A significantly greater amount of sweat was lost during the WIND than the NO WIND treatment.

4. Rectal temperatures were not significantly different in the WIND and NO WIND treatment.

RECOMMENDATIONS FOR FURTHER STUDY

Based on this data, further research is suggested in the following areas:

1. Tests should be conducted where normal ambient temperatures are maintained with a wide range of wind speeds at high metabolic work levels.

2. Further research should include a change in ambient temperature with wind velocity constant at 968 ft/min.

3. Investigations are recommended looking at wind effect with extreme humidity variation to see if the data is consistent and if reduced evaporation has an effect at high humidity.

4. Research is advised utilizing a range of ambient temperatures at different wind velocities with a high metabolic rate.

RECOMMENDATIONS FOR APPLICATION

When testing in the laboratory situation the following recommendations are made based on the results of this study:

1. Use air cooling for high level in normal temperatures if heart rate is a factor when testing will be longer than 13 minutes duration.

2. For shorter tests (less than 13 minutes) at lower intensity the additional trouble and expense of including air movement would be of no significant benefit.

These recommendations are made with reference to the age, sex, and fitness levels of the subjects in the study and should not be expanded for other age groups, sexes, fitness levels, or working conditions where heat that is generated is not solely a function of metabolism.

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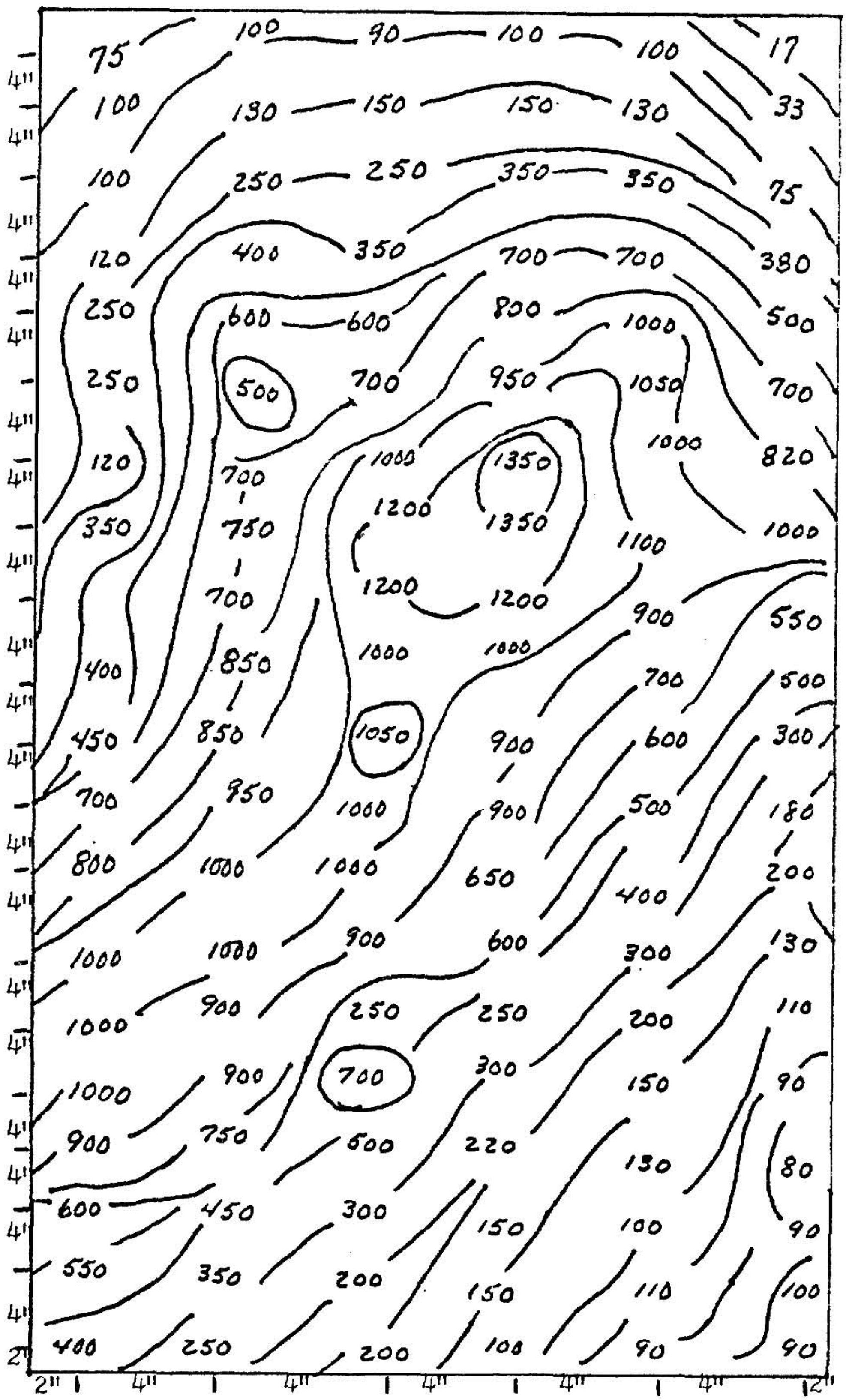
APPENDIX A

THIRTY SECOND CONVERSION CHART

22.0 sek.	82/min.	17.3 sek.	104/min.	12.6 sek.	143/min.
21.9	82	17.2	105	12.5	144
21.8	83	17.1	105	12.4	145
21.7	83	17.0	106	12.3	146
21.6	83	16.9	107	12.2	148
21.5	84	16.8	107	12.1	149
21.4	84	16.7	108	12.0	150
21.3	85	16.6	108	11.9	151
21.2	85	16.5	109	11.8	153
21.1	85	16.4	110	11.7	154
21.0	86	16.3	110	11.6	155
20.9	86	16.2	111	11.5	157
20.8	87	16.1	112	11.4	158
20.7	87	16.0	113	11.3	159
20.6	87	15.9	113	11.2	161
20.5	88	15.8	114	11.1	162
20.4	88	15.7	115	11.0	164
20.3	89	15.6	115	10.9	165
20.2	89	15.5	116	10.8	167
20.1	90	15.4	117	10.7	168
20.0	90	15.3	118	10.6	170
19.9	90	15.2	118	10.5	171
19.8	91	15.1	119	10.4	173
19.7	91	15.0	120	10.3	175
19.6	92	14.9	121	10.2	176
19.5	92	14.8	122	10.1	178
19.4	93	14.7	122	10.0	180
19.3	93	14.6	123	9.9	182
19.2	94	14.5	124	9.8	184
19.1	94	14.4	125	9.7	186
19.0	95	14.3	126	9.6	188
18.9	95	14.2	127	9.5	189
18.8	96	14.1	128	9.4	191
18.7	96	14.0	129	9.3	194
18.6	97	13.9	129	9.2	196
18.5	97	13.8	130	9.1	198
18.4	98	13.7	131	9.0	200
18.3	98	13.6	132	8.9	202
18.2	99	13.5	133	8.8	205
18.1	99	13.4	134	8.7	207
18.0	100	13.3	135	8.6	209
17.9	101	13.2	136	8.5	212
17.8	101	13.1	137	8.4	214
17.7	102	13.0	138	8.3	217
17.6	102	12.9	140	8.2	220
17.5	103	12.8	141	8.1	222
17.4	103	12.7	142	8.0	225

FLOW CHART OF AIR MOVEMENT (ft/sec)



THE EFFECT OF WIND ON HEART RATE AT SUBMAXIMAL PERFORMANCE OF CONDITIONED TREADMILL RUNNERS

by

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B. S., Briar Cliff College, 1973

AN ABSTRACT OF A MASTER'S THESIS

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The purpose of this study was to investigate the effect of wind on metabolic heat stress in normal temperatures (21.48°C) and to investigate the effect of wind on heart rate as it relates to testing procedure. The subjects were 17 adult male volunteers from the adult fitness program at Kansas State University. The mean age of the subjects was 35.29 years with a mean height of 70.59 inches. Mean weight for the NO WIND treatment group was 172.49 pounds and for the WIND treatment group was 172.74 pounds. Subjects participated in a 30 minute continuous run on a treadmill under two conditions, WIND (11 mph) and NO WIND. Heart rate and rectal temperature responses were recorded for the following time periods during the 30 minute continuous run and the 10 minute recovery period: rest, 4-5, 9-10, 14-15, 19-20, 24-25, 29-30, 0-1, 1-2, 2-4, 4-6, 6-8, and 8-10. Heart rates were obtained by direct wire ECG and monitored on an osciloscope while rectal temperatures were measured from a rectal temperature probe inserted 7 cm past the anal sphincter. Sweat loss was determined by pre and posttest nude weight on a balance beam scale with measurements made to the nearest one fourth ounce. Data were analyzed using a two-way analysis of variance (ANOVA) for repeated measures comparing heart rate at each interval in the WIND treatment with the corresponding interval in the NO WIND treatment and between time intervals. Treadmill speed was determined by estimating the work load at 50% of the subject's max VO_2. A t-test indicated that a significant difference (P .01) in sweat loss existed between the two conditions. Heart rate response during the first 10 minutes of the run showed no significant difference. There was a significant difference at the .01 level for minutes 14-30 of the run and during the recovery for minutes 0-2 and 8-10. For minutes 2-8 of the recovery the heart rates were significant at the .05 level. There was no significant difference in core temperature between the treatments. It was therefore concluded that heart rate during high level metabolic work of longer than 13 minutes duration could be reduced by movement of air across the body. It can also be concluded that at this level of work and under normal temperature and humidity conditions, wind of 11 mph has no effect on body core temperature.