COOLING EFFICIENCY OF DIFFERENT AIR VELOCITIES

IN HOT ENVIRONMENTS

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ABSTRACT

Four heat acclimated college student volunteers were exposed for 90 minutes
to each of the following combinations of work-heat conditions: 1) metabolic
level (M) of 200 kcal·hr^{-1}, and Wet Bulb Globe Temperatures (WBGT) of 28.9°C,
31.1°C, 32.8°C and 34.4°C; 2) M of 300 kcal·hr^{-1}, and WBGT of 27.2°C, 28.9°C,
31.1°C and 32.8°C. Two additional acclimated college student volunteers were
exposed to 120 minutes of the second combination of work-heat conditions.
Therefore, each of the four subjects were exposed in 32 exposures to the com-
binations of the above two M levels, four WBGT conditions and the following
four wind velocities: 0.5 m·s^{-1} (100 ft.min^{-1}), 1 m·s^{-1} (200 ft.min^{-1}), 2 m·s^{-1}
(400 ft.min^{-1}) and 4 m·s^{-1} (800 ft.min^{-1}). The additional two volunteers were
exposed for 120 minutes to 16 of the above combinations at M of 300 kcal·hr^{-1}
only.

The purpose of the study was to identify the effectiveness of increased wind
velocity in reducing strain at each of the above ambient conditions. The
criteria for strain were the following physiological responses: rectal tem-
perature (T_{re}), mean skin temperature ($\overline{T}_{sk}$), heart rate (H.R.), evaporation
(Ev) and sweating rates (Sw). The physiological responses were measured at
intervals throughout each exposure.

While there were differences in the physiological responses for the different
WBGT conditions, there were no significant differences due to the increase in
the wind velocities under these relatively hot dry conditions.

INTRODUCTION

The OSHA Standards Advisory Committee on Heat Stress (OSACHS) recommended a standard for work in hot environments (1976) which would require employers to follow certain work practices if employees are exposed to levels of heat which exceed specified temperatures. These temperatures were given as six Threshold Wet Bulb Globe Temperatures (WBGT) for combinations of three levels of work load and two levels of air velocity as follows:

THRESHOLD WBGT VALUES, °C (°F)

Work Load	Air Velocity Up to 300 fpm	Air Velocity 300 fpm or Above
Light (<200 kcal.hr^{-1})	30.0 (86)	32.2 (90)
Moderate (200 to 300 kcal.hr^{-1})	27.9 (82)	30.6 (87)
Heavy (>300 kcal.hr^{-1})	26.1 (79)	28.9 (84)

The Threshold WBGT values for the low air velocity conditions are based on, and are consistent with, the permissible exposure limits (PEL) recommended by Dukes-Dobos and Henschel (1973) and adopted as a Threshold Limit Value (TLV) by the American Conference of Governmental Industrial Hygienists in 1973. These threshold values were based on Lind's data (1963), which were expressed in terms of the effective temperature (ET). Comparison of the ET and the WBGT, in the range of WBGT 23.9 to 32.2°C shows that WBGT is 2-3°C higher than ET for air movement (v) above 300 fpm (according to Dukes-Dobos, ref. 3). It was then suggested that the threshold WBGT values for high air velocity conditions be 2.0 - 2.5°C (4-5°F) higher than those recommended by Dukes-Dobos and Henschel. Practical experience in industry seems to indicate reduced physiological strain when fans are placed in hot work areas. Therefore, it is assumed that workers benefit from increased air flow at velocities above those producing little or no further decrease in the WBGT Index. The permissible exposure limits (PEL) were based primarily on Lind's (1963, 1970) experiment with seminude non heat-acclimatized subjects. The adaptation of the WBGT and PEL for industrial situations, where employees are expected to be heat acclimatized, was derived from the observations made by Belding and Kamon (1973) that the effect of clothing reduces heat tolerance by about the same amount as acclimatization increases it. Since such indirect application of the effect of clothing is not satisfactory for occupational health problems where workers are fully clothed, it is necessary to study the cooling efficiency of air velocity on human subjects wearing the type of clothing typically worn by American workers in hot industries.

PURPOSE

The purpose of the present study was to investigate whether the increase in wind velocity could reduce the physiological strain accrued by the stresses of work in hot ambient conditions.

Specific questions with regard to this investigation were:

1) Are the suggested increased threshold WBGT levels for high air velocity justified or, if not, is there a need for other corrections?

2) Will the physiological strain decrease as a result of the increase of the wind velocity from 0.5 $m \cdot s^{-1}$ (100 $ft.min^{-1}$) to 1 $m \cdot s^{-1}$ (200 $ft.min^{-1}$); 2 $m \cdot s^{-1}$ (400 $ft.min^{-1}$) and 4 $m \cdot s^{-1}$ (800 $ft.min^{-1}$)?

3) Is the effect of the increased wind velocities different for clothed men working at metabolic level of 200 $kcal \cdot hr^{-1}$ than at 300 $kcal \cdot hr^{-1}$?

METHODS

Environmental Conditions

Preference was given to conditions that yield a relatively constant vapor pressure no matter how the dry bulb temperature (T_{db}), wet bulb temperature (T_{wb}), or air velocity (v) might be varied. The selected conditions are shown in Table 1, and are plotted on a psychrometric chart in Figure 1. As indicated in these illustrations, vapor pressure was maintained at approximately 20 mmHg and the dew point temperature (T_{dp}) at 22°C.

An illustration of the stability of the environmental conditions is presented in Figure 2. Following each thermal transient associated with changing environmental conditions, both T_{db} and T_{wb} were maintained within 0.5°C.

Wind Tunnel

Two contrarotating squirrel cage blowers, mounted one above the other were used to create the needed air movement. They were turned at 600 rpm by independent drive motors. The subjects walked on a treadmill in front of the blowers. A diffusing section was constructed between the blowers and the treadmill, designed to provide static pressure regain with discharge area of 1.8 m^2 (19.5 sq.ft.) covering the full height of a walking person. Laminar air flow toward the back of the subject was produced by straightening vanes at the diffuser discharge. Inlet baffles were designed for each air velocity required. The four settings of inlet baffles were painted identifying colors to ensure repetitive air velocity at each test.

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Wind Velocities

Air velocities were measured using an Alnor 6000P Velometer and a 6060P low flow pitot tube. Calibration for each air velocity and initial adjustment of the inlet baffles was carried out at different heights above the treadmill at the subject's walking location. The four wind velocities were 100, 200, 400 and 800 feet per minute, corresponding to about 0.5, 1, 2 and 4 meters per second. The results of the calibration of the wind velocities using the four sets of inlet baffles are shown in Fig. 3, for 10 heights across the subjects profile.

Natural Wet Bulb Temperature

Since WBGT calls for measurements of natural wet bulb temperature (T_{nwb}), comparison was made between the psychrometric (aspirated) wet bulb (T_{pwb}) and the T_{nwb} for the low wind velocities. The assumption was that differences ($T_{nwp}-T_{pwb}$) would occur with the air velocities of 0.5 $m \cdot s^{-1}$ (100 $ft.min^{-1}$) and 1 $m \cdot s^{-1}$ (200 $ft.min^{-1}$). Thus, the effect of these two rates of air movements were measured for the five WBGT values used in this study.

The differences ($T_{nwb}-T_{pwb}$) at each dry bulb temperature are shown in Figure 4. It can be seen that there is no significant increase in the difference as a function of air velocity. There was, however, a slight increase in the difference as T_{db} rose. Since air velocity was not a factor, the values of the $T_{nwb}-T_{pwb}$ differences obtained for the two wind velocities were averaged for each WBGT. The averaged values of the differences are given in Table 3. The rise in the T_{nwb}, T_{pwb} differences with T_{db} could also be expressed in the linear regression shown in Figure 4.

Since the difference in the wet bulb temperature was at the most 0.45°C (Fig. 4 and Table 3) it was felt that such a difference was not large enough to effect the calculation of the WBGT whether aspirated wet bulb or natural wet bulb was used.

Work Loads

The work loads for the four WBGT values between 28.9°C and 34.4°C were adjusted to yield a metabolic rate (M) of 200 $kcal \cdot hr^{-1}$. The work loads for the four WBGT values between 27.2°C and 32.8°C were adjusted to yield a M of 300 $kcal \cdot hr^{-1}$ (see Table 1). Work was performed by walking on a treadmill. In order to get an average M of 200 $kcal \cdot hr^{-1}$, it was found most convenient to schedule cycles of 15 minutes of work and 15 minutes of rest (sitting). The designed work load was obtained by adjusting the treadmill's speed and inclination for each subject. This required employing speeds of 2.5–3.5 mph and 2–3% inclination depending on the subject's height and weight. The external work (W) due to the treadmill's inclination was subtracted from the total energy expenditure to yield metabolic heat load. M of 300 $kcal \cdot hr^{-1}$ was obtained by continuous work (walking).

Subjects

These were six male university students. Their physical characteristics and aerobic capacity are shown in Table 2. Four subjects participated in the wind velocities WBGT combinations for the two M levels. Two subjects participated in the wind WBGT combination for the M of 300 $kcal \cdot hr^{-1}$ only. Thus for M = 300 $kcal \cdot hr^{-1}$ there were six participants and for the M = 200 $kcal \cdot hr^{-1}$ there were only four participants.

Clothing

Although the clothing workers wear when working in hot environments varies considerably, our choice was between an all cotton uniform (U.S. Army surplus) or commercial rental uniforms available in a blend of 65% polyester and 35% combed cotton fibers. With this uniform the long sleeved shirt is made from a $4\frac{1}{2}$ oz. leno weave fabric with the trousers from a $7\frac{1}{2}$ oz. twill weave fabric. Because the commercially available uniforms are "blends" and all cotton uniforms will be progressively more difficult to secure in the future, the blend uniform was chosen. Other items of clothing included: cotton jockey shorts, cotton or fiber blend short socks and comfortable low-cut walking shoes.

Measurements

Rectal temperature (T_{re}) was measured using a YSI thermistor inserted 8-10 cm. Mean skin temperature ($\overline{T}_{sk}$) was obtained using thermocouples on six sites: right and left thigh, forehead, forearm, back and chest, and averaging all the recorded values. A multipoint recorder (Esterline Angus) was used to continuously record the temperatures.

Sweat production and evaporated sweat were measured using change in body weight with adjustment for drinking and urine excreted. Weight was recorded every 30 minutes to indicate evaporation rate. Since the subjects were fully clothed, no allowance was made for sweat dripping off the subject in the calculation of evaporation rate. Total sweat production was determined by the nude body weight measured before and after the session in the heat.

Heart rates were recorded every 5 minutes (Hewlett Packard Cardiograph). Oxygen uptake was determined during one rest period and during two work periods for each session. The Douglas bag method was used. Volume was measured using a dry gas meter (Parkinson-Cowan). Gas concentrations were measured using a Beckman E-2 O_2 Analyzer and a MSA CO_2 Analyzer.

PROCEDURES

The overall purpose and procedure was explained to subjects during a visit to the laboratory. Each subject was qualified by a physician only after passing a physical examination, a satisfactory resting electrocardiogram and a graded exercise test up to a self-determined maximum. A signed consent form was required. Each subject was heat acclimatized before starting the experiment.

Acclimatization was achieved by ten daily 120 min. exposures to dry heat

conditions of T_{db}/T_{wb} 50°C/25°C followed by two sessions under wet heat conditions of T_{db}/T_{wb} 42°C/32°C. <u>Reacclimatization</u> to wet heat (42°C/32°C) was carried out every Monday.

Experimental Procedures

The experiments were conducted daily Tuesday through Friday. The combination of WBGTs and wind speeds were randomized. Each subject was tested at the same time each day. Upon arrival the subject prepared for the tests by placing the rectal probe, and attaching skin thermocouple and cardiogram electrodes. He then rested for 15-20 minutes prior to the onset of the test. Each exposure lasted 90 minutes for the four subjects who participated in the complete study. In the additional tests with two subjects at M of 300 $kcal \cdot hr^{-1}$ only, the exposures were extended to 120 minutes. Thus, four subjects were exposed to 32 conditions consisting of the combination of four wind velocities, four temperatures (WBGT) and two work loads. The two additional subjects were exposed to 16 conditions.

STATISTICS

A two way analysis of variance (ANOVA) with repeated measures was conducted for each of the five physiological variables measured; rectal temperature (T_{re}); skin temperature (T_{sk}); heart rate (HR); evaporation rate (Ev) and sweating rate (Sw). The change over time under each exposure condition for each physiological parameter was used for the ANOVA. Changes were derived from the values at the onset of the walking (zero time) and the final value at the end of walking. Since the walking periods differed for the two work levels employed, the final values used were also different. At 200 $kcal \cdot hr^{-1}$ the work-rest schedule involved 15 minutes of walking and 15 minutes of resting. Therefore, the values of the 75th minute, which were at the end of the last walking period were used to derive the changes in the physiological responses. At 300 $kcal \cdot hr^{-1}$, walking was continuous and the end values at the 90th minute were used.

The significance of the ANOVA was determined by the F-ratios for main effects with regard to each of the five physiological variables. When significant differences among the means of the variables were detected, a Tukey"s Wholly Significant Different Test was used to determine at which levels of either wind velocity or WBGT, the physiological responses did differ. The ANOVA and the location of significant differences were summarized in form of tables. The mean values were also used for graphical presentation of the results.

The additional 16 exposures (M=300 $kcal \cdot hr^{-1}$) on two subjects were compared by using the mean values of the physiological variables at the 120th minute.

RESULTS

Physiological Responses

The physiological responses in terms of the change from the base values at the onset of walking, are summarized separately for each variable. Each table provides the value at zero time (onset of walking) and the changes over

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15 minute intervals for each individual and as the mean ($\bar{x}$) for all the subjects. The additional information include standard deviation (s) and standard error of estimate ($S_{\bar{x}}$). Each table is a summary of all wind velocities under one WBGT. The results are summarized separately for the data during work at M of 200 kcal·hr^{-1} and the data during work at M of 300 kcal·hr^{-1}.

Work at 200 kcal·hr^{-1}

Rectal temperature (T_{re}) changes over 15 minute intervals are shown in Tables 4-7. Table 8 is the analysis of variance for the data shown in Tables 4-7. Since significant difference (F ratio for the main effects) were detected across WBGT (Treatment A) and across the wind velocities (Treatment B) further analysis was carried out to show the location of the difference. The locations of the difference are shown in Tables 9 and 10.

Significant T_{re} differences were found between WBGT 28.9°C and 31.1°C, and between 34.4°C and each of the other three WBGT values. A significant difference in T_{re} was noted between wind velocities of 0.5 m·s^{-1} and 2.03 m·s^{-1}.

The time courses of the change in T_{re} are shown in Figs. 5-8 for each of the WBGT conditions tested. Values are means for the four subjects. The figures illustrate the findings summarized in the Tables, that there was no consistent difference due to the wind velocities. This also is shown in Figure 9. Therefore, for practical purposes, no real effect was shown due to wind velocity.

Figure 9 shows the changes in T_{re} (ΔT_{re}) for the 90 min. exposures under each WBGT for each wind velocity. Although T_{re} increased with the rise in WBGT, there were no differences in the changes due to the wind velocity. Although exposure to the lowest v resulted in T_{re} value of about 0.2°C higher than the other v exposures, the difference was not significant.

Heart rates (HR) changes over 15 min. intervals are shown in Tables 11-14. Table 15 is a summary of the ANOVA for the data shown in Tables 11-14. Since HR revealed differences across WBGT only, the location of the differences were shown in Table 16 for WBGT only. Differences were found between WBGT 28.9°C and the two highest WBGT, 32.8°C and 34.4°C. No differences were located across wind velocities.

The time courses for the HR separately for the resting and the working periods are shown in Figures 10-13 for each of the WBGT conditions tested.

Figure 14 shows the changes in HR (ΔHR) over the 90 min. exposure under each WBGT. Similar to the results with ΔT_{re}, ΔHR clearly shows no significant differences due to the increase in wind velocity.

Skin temperature ($\bar{T}_{sk}$) changes over 15 min. intervals are summarized in Tables 17-20. Table 21 is the summary of the ANOVA for the data shown in tables 17-20. Again $\bar{T}_{sk}$ differences were noticed in the main effects of WBGT. Table 22 shows that the mean differences were between WBGT 28.9°C and the two highest WBGT values of 32.8 C and 34.4 C. No differences were detected among the different wind velocities.

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The time courses for T_{sk} are given in Figures 15-18 for each WBGT condition. It can be seen graphically that no differences were observed due to wind velocities.

Evaporation rates (Ev) in $g \cdot m^{-2} \cdot hr^{-1}$ were summarized in Table 23 for each wind velocity under each WBGT. The total weight loss over the 90 minutes of walking was used to derive the individual hourly evaporation rate. Mean values for the four subjects are also shown in Table 23.

ANOVA among mean values of evaporation revealed differences across WBGT (Table 24). Further analysis revealed differences due to WBGT as shown in Table 25. No difference due to wind velocities were found for evaporation rates.

Sweating rates (Sw) in $g/m^2/hr$ were summarized under each WBGT for each wind velocity (Table 26). Similar to the evaporation, sweating revealed differences across WBGT but not across wind velocities (Tables 27 and 28).

Work at 300 $kcal \cdot hr^{-1}$

This section of the investigation involved six subjects. The first four were the same subjects who participated in the section involving work at 200 $kcal \cdot hr^{-1}$. They walked continuously on the treadmill for 90 min. each session similar to the period of work in the section of work at 200 $kcal \cdot hr^{-1}$.

The additional two subjects walked on the treadmill for 120 minutes. The change in the physiological responses over 90 minutes were used in the analysis of variance among the means for the six subjects. The change over 120 minutes could be analyzed for the two additional subjects only. This was done by comparing the mean values at each of the physiological variables for the two subjects.

Rectal temperature (T_{re}) changes over 15 minute intervals, separately for the six individuals, and the average for all six subjects are summarized in Tables 29-32. Each table summarizes the T_{re} changes under one of the four WBGT conditions for the four wind velocities.

Similar to the results for the work at 200 $kcal \cdot hr^{-1}$, T_{re} increased with the increase in the WBGT conditions. Tables 33 and 34 respectively summarize the ANOVA and show that T_{re} was significantly higher under WBGT of 32.8°C as compared to each of the other three WBGT values; 27.2°C, 28.9°C and 31.1°C.

The F ratio for the main effects due to wind velocities (Treatment B) indicates no significant difference in T_{re} (Table 33).

The ineffectiveness of the wind can be seen in the time course of T_{re} for each WBGT condition shown in Figs. 19-22. The mean T_{re} for the six subjects follow similar patterns for all four wind velocities under each WBGT condition. The differences in T_{re} over the 90 minutes of exposure due to WBGT are shown graphically in Fig. 23 and the changes due to wind velocities in Fig. 24. The figures illustrate the findings shown in the tables, that WBGT was effective in changing the T_{re} responses but the wind was ineffective and T_{re} did not change due to the increase in velocity.

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Heart rate (HR) changes over 15 minute intervals are shown in Tables 35-38, each table for one WBGT condition. The ANOVA is summarized in Table 39, and the locations of differences are shown in Table 40 for the different WBGT conditions. Significant differences in HR were found between WBGT 31.1°C and the two lowest WBGT (27.2°C and 28.9°C), and between the highest WBGT (32.8°C) and all other WBGT values. No differences in HR were detected due to wind velocities.

The time courses of change in HR are illustrated in Figs. 25-28 separately for each WBGT condition. Values are means for the six subjects at each wind velocity. The figures provide graphical presentation to show that there was no difference in the change in HR due to wind. Although exposure to some v resulted in a higher change in HR, as compared to the other v exposures (2m/s, Fig. 26; 0.5m/s. Fig. 28) the difference was not significant.

Mean skin temperature ($\overline{T}_{sk}$) changes over 15 minute intervals are shown in Tables 41-44, each table for one WBGT condition. The ANOVA for the differences in $\overline{T}_{sk}$ is summarized in Table 45. It can be seen that F-ratio for main effect shows significant differences for WBGT (Treatment A) and for wind velocities (Treatment B). A post hoc Tukey's test for mean differences among measures shows that the differences due to WBGT is between 27.2°C and all other WBGT conditions (Table 46) and the differences due to wind velocities is between the 2 $m \cdot s^{-1}$ and 4 $m \cdot s^{-1}$ only (Table 47).

The time courses of the change in $\overline{T}_{sk}$ are illustrated in Figs. 29-32. The difference in $\overline{T}_{sk}$ due to WBGT conditions is because of the larger drop in T_{sk} at the low WBGT as compared to the other WBGT conditions. The difference due to wind velocities 2 and 4 $m \cdot s^{-1}$ most likely occurred at WBGT values of 27.2°C and 31.1°C.

Evaporation (Ev) rates for each individual and the mean for all six subjects are summarized in Table 48 for each wind velocity under each WBGT. Expectedly Ev increased with the increase in the WBGT conditions. The ANOVA for Ev summarized in Table 49, reveals significant differences due to WBGT (Treatment A) and due to wind velocity (Treatment B). The post hoc test for mean differences among the measures indicates that Ev differed significantly for all WBGT conditions (Table 50). The post hoc test reveals significant differences between the two lowest velocities (0.5 $m \cdot s^{-1}$ and 1 $m \cdot s^{-1}$) and the two highest velocities (2 $m \cdot s^{-1}$ and 4 $m \cdot s^{-1}$), see Table 51.

Sweating (Sw) rates for each individual and the mean for all six subjects are summarized in Table 52, for each wind velocity under each WBGT condition. Again, expectedly, sweating rates increase with the increase in WBGT. The increase was found to be significant (see F ratio for main effect, Table 53). The location of the differences in Sw due to WBGT were found between the two lowest WBGT (27.2°C and 28.9°C) and the two highest WBGT (31.1°C and 32.8°C). But no significant differences were indicated due to wind velocities.

Two Hours Exposure

An additional two subjects were exposed to work at 300 $kcal \cdot hr^{-1}$ under the four WBGT of 27.2°C, 28.9°C, 31.1°C and 32.8°C and the four wind velocities, but for 120 rather than 90 minutes. Although their physiological responses

after 90 minutes of exposure were pooled together with the results of the other subjects, additional summaries were conducted for the 120 minute exposures.

The changes in the rectal temperature, mean skin temperature and heart rate, over the 120 minutes of exposure were averaged for the two subjects. These changes are summarized in Tables 54 to 56 respectively for T_{re}, HR and $\overline{T}_{sk}$.

T_{re} reveals a trend of increase across the WBGT conditions. However, there is no trend of change across the wind velocities for any of the WBGT conditions (Table 54).

The HR responses are similar to the T_{re} responses in that a trend can be seen across WBGT; increments in HR as WBGT is increased, but no trends across the wind velocities (Table 55).

$\overline{T}_{sk}$ changes over the 120 minutes revealed no trends either across WBGT or across the wind velocities (Table 56).

Evaporation rates did indeed increase with the increase in WBGT, for each wind velocity, but the evaporation rates across wind velocity showed no trend for all but one WBGT. It seems that at the highest WBGT (32.8°C) Ev increases as the wind velocity was increased from 0.5 to 4 $m \cdot s^{-1}$. This is shown in Table 57.

Sweating rates are summarized in Table 58. There seems to be a trend of increase in Sw across WBGT conditions up to 31.1°C, then no real difference in Sw can be seen between the WBGT of 31.1°C and 32.8°C. No trend of change in Sw can be seen across wind velocities.

DISCUSSION

The most accepted indicators of physiological strain due to work-heat stress are the core body temperature and the heart rate. In this study T_{re} represents the core body temperature and HR reflects the circulatory load. In addition to T_{re} and HR, evaporation rate, sweating rate and the evaporative cooling as it is reflected in mean skin temperature, can also serve as indicators for strain under stresses of heat.

The results obtained from this study show that in general the work loads and the ambient conditions selected were not too demanding physiologically. It should be noted that the subjects were heat acclimatized and thus could sustain equilibrium in their physiological responses even under severe heat/work exposures. Although T_{re} and HR revealed a tendency to climb to higher values at high WBGT conditions as compared to the low WBGT conditions, the end values and rate of increase were quite moderate.

For all practical purposes, T_{re} and HR levelled off during the last 30 minutes of exposure. Very slight rise in these parameters was seen for exposure to low v and high WBGT. Although some individuals showed T_{re} above 38°C during the work at 300 $kcal \cdot hr^{-1}$ (12 out of 48 exposures), the average T_{re} did not exceed 38°C.

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Strain differences were expected to be seen in the rate of change in the physiological parameters. Thus, T_{re} and HR did show larger increases for the exposure to higher WBGT as compared to the exposure to lower WBGT. However, using the criteria of the increase in the T_{re} and HR it was clear that the strain did not decrease by the increase in the wind velocity from 0.5 $m \cdot s^{-1}$ (100 ft. min^{-1}) to 4 $m \cdot s^{-1}$ (800 ft. min^{-1}).

Thus, within the limits of the experimental conditions in this study, i.e., work loads demanding 200 $kcal \cdot hr^{-1}$ and 300 $kcal \cdot hr^{-1}$, no radiant heat, one moderate level of ambient vapor pressure (20mmHg) and air temperatures between 32.7 C and 48 C, increasing the wind velocity up to 4 $m \cdot s^{-1}$ was not effective in reducing the rate of rise in T_{re} and HR.

The other two indicators, $\overline{T}_{sk}$ and Ev (evaporation rate) did show some differences due to wind velocity, but only for the higher work load (M=300 $kcal \cdot hr^{-1}$). The changes in these two responses over the 90 minute exposure showed significant main effects (at 0.05 and 0.01 levels respectively for $\overline{T}_{sk}$ and Ev) across wind velocities (Tables 45 and 47). The $\overline{T}_{sk}$ revealed the lowest change (0.16°C) during work under the highest wind velocity (4 $m \cdot s^{-1}$). But unexpectedly the greatest $\overline{T}_{sk}$ change (0.64°C) occurred under the next highest velocity of 2 $m \cdot s^{-1}$. Therefore this mean difference between the $\overline{T}_{sk}$ for the two highest wind velocities was the only detectable significant difference. Since much practical value could not be given to this one case of $\overline{T}_{sk}$ difference due to wind velocity, it was concluded that increasing v did not effect $\overline{T}_{sk}$. Because difference in Ev due to v was found, a difference in $\overline{T}_{sk}$ was expected to follow. Actually, the findings on $\overline{T}_{sk}$ agreed with those on Ev for work at 200 $kcal \cdot hr^{-1}$ in that wind was ineffective for both. Evaporation was not significantly different for the four wind velocities, neither was $\overline{T}_{sk}$. However, there was a discrepancy in the findings of $\overline{T}_{sk}$ and Ev for the work at 300 $kcal \cdot hr^{-1}$. While the only significant difference in $\overline{T}_{sk}$ was between the two highest wind velocities (Table 47), there was no significant difference in Ev between those two highest wind velocities (Table 50). But, there were several significant differences between Ev at velocities of: 0.5 $m \cdot s^{-1}$ and the two highest velocities (2 $m \cdot s^{-1}$ and 4 $m \cdot s^{-1}$); and between 1 $m \cdot s^{-1}$ and 4 $m \cdot s^{-1}$. The largest difference of 28 $g \cdot m^{-2} hr^{-1}$, which was significant at the 0.01 level, occurred between the wind velocities of 0.5 $m \cdot s^{-1}$ and the 4 $m \cdot s^{-1}$. Although all comparisons of mean Ev were not significantly different from each other, they did show a trend of increase in magnitude with the increase in wind velocity (Tables 23 and 48). Such a trend was not noticable for $\overline{T}_{sk}$. This could result from evaporation at the surface of the clothing rather than at the skin surface, thus the cooling effect of the sweat on the body was lost to the environment.

The main factor in evaporative cooling is the level of wetness of skin and clothing. With a fully wet skin and clothing and ambient conditions which allow evaporation, cooling due to increase in v should be readily observed in both increased Ev and lowering of $\overline{T}_{sk}$. However at moderate ambient conditions even if Ev is unrestricted, increased v might have been ineffective due to low level of wetness. This has been observed during exposures to very high dry temperatures which allowed rapid evaporation rates (Kerslake, 1972). If the sweating rate is insufficient to wet large skin areas (or the clothing) the cooling efficiency of increased air movement may remain undetectable. This could be inferred from the ratio of evaporation to sweating.

The ratio between evaporation and sweating (Ev/Sw) for the work at 200 kcal·hr^{-1} was summarized in Table 60. A trend towards higher ratios was seen across the WBGT conditions. This indeed was found to be significant to the .03 level (Table 61), which is indicative for somewhat better cooling at the high WBGT. This was also reflected in the difference in T_{re} and T_{sk} across the WBGT conditions (Tables 9 and 22). However, no significant effect was found due to the air movements (v). The Ev/Sw ratio for work at 300 kcal·hr^{-1} was summarized in Table 62. Here there was no trend across WBGT (Table 63), but significant difference was found between the two extreme air movements only; 0.5 m/s vis. 4 m/s (Table 64). These calculations provide further support to the observation that the wetness of the skin, as indicated by the Ev/Sw ratio, was not high enough for the wind to reveal effectiveness in cooling.

The clothing used in this study, commercially available rental work uniforms were made of a blend of 65% polyester and 35% combed cotton fibers. Such fabric may have been responsible for interferring with some of the evaporative cooling due to increased wind velocity. While cotton could promote cooling by picking up sweat and allowing evaporative cooling, the polyester content may have decreased the capillary characteristics and made the uniform an obstacle to sweat evaporation. This factor could also impair the effectiveness of the increase in the wind velocity, by preventing the sweat to evaporate from the skin or the cotton underwear. This assumption was supported by the observation of the low ratio of evaporation to sweating. Although as Sw increased the ratio Ev/Sw also increased, indicating increased Ev as more sweat could reach the surface of the clothing, this extension of wetness to the surface of the clothing was not sufficient for cooling due to increased v.

The addition of tests on two subjects at work levels requiring 300 kcal·hr^{-1} was undertaken in order to allow longer exposures, which could result in increased wetness of the outer layer of the clothing. It was assumed that if the wetness will increase with time, better evaporative cooling could be detected. Therefore the two subjects were exposed to these four WBGT and four wind velocities for 120 minutes as compared to the 90 minutes of exposure for the other four subjects. However, the results after 120 minutes of exposure did not indicate any reduction in the rise in T_{re}, the increments in HR, or the increase in T_{sk}, due to the increased wind velocities.

In conclusion it can be stated that increasing the air movement during exposure to light or moderate work loads under heat stress levels which do not cause full wetness of skin and possibly clothing, in the absence of radiation, is ineffective in cooling clothed workers. Most occupational heat exposures fall under this category.

One way to increase the heat stress in a manner that simulates industrial situations, is the addition of radiant heat source. In this study wall temperature was almost equal to air temperature. Additional stress due to radiant heat would be detected physiologically, and cooling by increasing the wind velocity might be more effective. However, even then, the humidity level should be increased to above the levels used in this study. The ambient conditions should be in a range where the skin and clothing reach close to full wetness. At these ambient conditions the evaporative capacity of the air should still allow limited evaporation rate. Such conditions may occur in

industrial situations where work is accomplished in durations followed by longer rest periods. It might be argued that the direction of the wind played a role in the effectiveness of the cooling. In this experiment the air stream was aimed at the back of the subjects. It is possible that the same air velocity coming from the front could be more effective in reducing the physiological responses, thus indicating less strain. This could be a result of cooling the face more efficiently. However, since in industrial settings, the workers, most often, place the cooling fans behind them while they face the machine or work in front of a furnace, the conditions of these experiments better simulated industrial situations.

REFERENCES

American Conference of Governmental Industrial Hygienists. 1973. Threshold
     Limit Values for Chemical Substances and Physical Agents in the Workroom
     Environment with Intended Changes for 1973. pg. 69.
Belding, H. S. and E. Kamon. 1973. Evaporative Coefficients for Prediction
     of Safe Limits in Prolonged Exposures to Work Under Hot Conditions. Fed.
     Proc. 32:1598-1601.
Dukes-Dobos, F. and A. Henschel. 1973. Development of Permissible Heat
     Exposure Limits for Occupational Work. ASHRAE J. Vol. 15. (9) pp. 58-68.
Kerslake, D. McK. 1972. The Stress of Hot Environments. Cambridge University
     Press.
Lind, A. R. 1963. A Physiological Criterian for Setting Thermal Environ-
     mental Limits for Everyday Work. J. Appl. Physiol. Vol. 18, pp. 51-56.
Lind, A. R. 1970. Influence of Age and Daily Duration of Exposure on
     Response of Men to Work in Heat. J. Appl. Physiol. 29:50-54.
Ramsey, J. D. 1975. Threshold Limits for Workers in Hot Environments. Pro-
     ceedings. International Mine Ventilation Congress, South Africa,
     September 1975.
Standards Advisory Committee on Heat Stress-Recommended Standards for Work
     in Hot Environments. 1976. IN: Standards for Occupational Exposures
     to Hot Environments - Proceedings of Symposium. HEW Publication No.
     (NIOSH) 76-100, pp. 191-204.

TABLE 1. The Dry Bulb (T_{db}) and Wet Bulb (T_{wb}) Temperatures Utilized to Achieve the Respective Wet Bulb Globe Temperatures (WBGT) Values for Two Metabolic Rates (M). The Respective Dew Point Temperatures (T_{dp}) and Water Vapor Pressures (P_{wa}) are Also Provided.

M kcal·hr^{-1}	WBGT °C	(°F)	T_{db} °C	T_{wb} °C	T_{dp} °C	P_{wa} mmHg
300 / 200	27.2	(81)	32.7	24.9	22.0	19.8
	28.9	(84)	36.0	25.8	22.0	19.8
	31.1	(88)	41.0	26.9	22.0	19.8
	32.8	(91)	44.5	27.9	22.0	19.8
	34.4	(94)	48.0	28.6	22.0	19.8

T_{wb} — aspirated wet bulb temperature.

Table 2. Age, Physical Characteristics and Maximal Aerobic Capacity ($\dot{V}O_2max$) for Subjects

Subject	Age yr	Ht cm	Wt kg	S.A. m^2	HR$_{max}$ bpm	$\dot{V}O_2$ max ml/kg·min^{-1}
1	23	188.6	85.91	2.13	204	64.3
2	21	179.7	59.09	1.75	198	53.5
3	27	185.5	76.36	2.00	188	54.9
4	23	174.4	68.41	1.83	188	45.0
5*	24	173.0	69.09	1.82	197	57.5
6*	21	181.6	66.60	1.86	204	58.9

*) Participated in wind velocities, WBGT combinations for M = 300 kcal·h.r.$^{-1}$

Table 3. The average difference between natural and psychrometric wet bulb temperature for the five WBGT tested at wind velocities of 0.5 and 1.o M sec.[-1]

WBGT (°C)	27.2	28.9	31.1	32.8	34.4
T_{db} (°C)	32.7	36.0	41.0	44.5	48.0
*ΔT_{wb} (°C)	0.005	0.095	0.23	0.33	0.42

*ΔT_{wb} = Tnwb - Tpwb Calculated from Regression equation: Y = -0.89 + 0.027X, see Fig. 4.

Table 4 . Rectal Temperature for WBGT 28.9°C (M = 200 kcal/hr).

Wind Vel. (m/sec.)	Subject		Initial T_{re} °C	Change in T_{re} over 90 Minutes
				15	30	45	60	75	90
.5	1		36.90	.13	.17	.26	.17	.21	.20
	2		37.09	.14	.19	.27	.23	.36	.32
	3		37.40	.12	.15	.24	.12	.27	.25
	4		36.94	.10	.23	.55	.55	.65	.64
		$\bar{X}$	37.08	.12	.18	.33	.27	.37	.35
		s	.23	.02	.03	.15	.19	.20	.20
		$s_{\bar{x}}$	.11	.01	.02	.07	.10	.10	.10
1.01	1		37.18	.18	.22	.33	.17	.34	.56
	2		37.31	.03	-.13	.07	.01	.08	.22
	3		37.26	.07	.01	.19	.03	.14	.48
	4		36.88	.28	.35	.66	.70	.67	.79
		$\bar{X}$	37.16	.14	.11	.31	.23	.31	.51
		s	.19	.11	.21	.25	.32	.27	.24
		$s_{\bar{x}}$	.10	.06	.11	.13	.16	.13	.12
2.03	1		37.35	.06	.08	.12	.16	.12	.33
	2		37.32	.07	.04	.20	.08	.18	.56
	3		37.60	.01	-.08	.07	-.05	.06	.50
	4		36.70	.20	.36	.62	.63	.67	.91
		$\bar{X}$	37.24	.08	.10	.25	.20	.26	.58
		s	.38	.08	.19	.25	.30	.28	.24
		$s_{\bar{x}}$	.19	.04	.09	.13	.15	.14	.12
4.06	1		37.17	.11	.13	.28	.31	.24	.76
	2		37.15	.01	-.03	.16	.07	.17	.60
	3		37.60	.02	-.05	-.02	-.15	.02	.52
	4		36.56	.44	.61	.70	.56	.65	1.24
		$\bar{X}$	37.12	.14	.16	.28	.20	.27	.78
		s	.43	.20	.31	.31	.31	.27	.32
		$s_{\bar{x}}$	.21	.10	.15	.15	.15	.13	.16

Table 5 . Rectal Temperature for WBGT 31.1°C (M = 200 kcal/hr.)

Wind Vel. (m/sec.)	Subject		Initial T_{re}°C	Change in T_{re} over 90 Minutes					
				15	30	45	60	75	90
.5	1		36.69	.15	.27	.44	.50	.57	.56
	2		37.30	.10	.12	.21	.12	.28	.22
	3		37.10	.26	.30	.42	.42	.53	.48
	4		36.75	.13	.35	.66	.65	.77	.79
		$\bar{X}$	36.96	.16	.26	.43	.42	.54	.51
		s	.29	.07	.10	.18	.22	.20	.23
		$s_{\bar{x}}$	.14	.03	.05	.09	.11	.10	.12
1.01	1		37.24	.08	.07	.11	.15	.14	.13
	2		37.50	.05	-.03	.10	.08	.25	.32
	3		37.38	.11	.11	.26	.22	.28	.18
	4		36.71	.17	.35	.72	.75	.90	.87
		$\bar{X}$	37.21	.10	.12	.30	.30	.39	.38
		s	.35	.05	.16	.29	.30	.34	.34
		$s_{\bar{x}}$	.17	.02	.08	.15	.15	.17	.17
2.03	1		37.13	.05	.12	.31	.23	.39	.36
	2		37.24	.04	-.04	.08	.06	.20	.11
	3		37.49	.10	-.01	.16	.15	.33	.18
	4		37.03	.13	.24	.50	.52	.61	.57
		$\bar{X}$	37.22	.08	.08	.26	.24	.38	.30
		s	.20	.04	.13	.18	.20	.17	.21
		$s_{\bar{x}}$	.10	.02	.06	.09	.10	.09	.10
4.06	1		37.15	.06	.07	.25	.28	.29	.25
	2		36.89	.02	.06	.25	.21	.42	.40
	3		37.07	.20	.20	.42	.32	.43	.35
	4		36.64	.70	.84	.98	.82	.94	.69
		$\bar{X}$	36.94	.24	.29	.48	.41	.52	.42
		s	.23	.31	.37	.35	.28	.29	.19
		$s_{\bar{x}}$	.11	.16	.19	.17	.14	.14	.09

Table 6. Rectal Temperature for WBGT 32.8°C (M = 200 kcal/hr).

Wind Vel. (m/sec.)	Subject		Initial $T_{re}{}^oC$	Change in T_{re} over 90 Minutes					
				15	30	45	60	75	90
.5	1		37.34	−.03	−.01	.12	.18	.18	.33
	2		36.94	.24	.17	.35	.36	.55	.56
	3		37.45	.12	.23	.41	.44	.54	.50
	4		36.60	.59	.83	1.02	.87	1.05	.91
		$\bar{X}$	37.08	.23	.30	.48	.46	.58	.58
		s	.39	.26	.36	.38	.29	.36	.24
		$s_{\bar{x}}$	.19	.13	.18	.19	.15	.18	.12
1.01	1		37.05	0.00	−.04	.05	.08	.21	.23
	2		37.16	0.00	−.08	.06	.05	.08	.03
	3		37.38	.05	.05	.24	.16	.30	.17
	4		36.96	.17	.36	.76	.81	.93	.94
		$\bar{X}$	37.14	.06	.07	.28	.28	.38	.34
		s	.18	.08	.20	.33	.36	.38	.41
		$s_{\bar{x}}$	.09	.04	.10	.17	.18	.19	.20
2.03	1		37.18	.05	.01	.22	.23	.40	.41
	2		37.00	.12	.13	.28	.25	.44	.37
	3		37.43	.04	−.08	.12	−.03	.19	−.04
	4		36.97	.17	.35	.63	.60	.75	.78
		$\bar{X}$	37.14	.10	.10	.31	.26	.44	.38
		s	.21	.06	.19	.22	.26	.23	.34
		$s_{\bar{x}}$	.11	.03	.09	.11	.13	.12	.17
4.06	1		37.05	−.03	.04	.08	.08	.22	.33
	2		37.15	.05	.03	.14	.10	.30	.15
	3		37.42	.09	.08	.20	.12	.28	.16
	4		36.77	.22	.41	.68	.76	.81	.82
		$\bar{X}$	37.10	.08	.14	.28	.26	.40	.36
		s	.27	.10	.18	.27	.33	.27	.31
		$s_{\bar{x}}$	.13	.05	.09	.14	.16	.14	.16

Table 7 . Rectal Temperature for WBGT 34.4°C (M = 200 kcal/hr).

Wind Vel. (m/sec.)	Subject		Initial T_{re} °C	Change in T_{re} over 90 Minutes					
				15	30	45	60	75	90
.5	1		36.80	.02	.09	.35	.57	.71	.76
	2		36.89	.01	.07	.28	.36	.59	.60
	3		37.34	.14	.16	.41	.41	.56	.52
	4		36.82	.26	.44	.82	1.00	1.24	1.24
		$\bar{X}$	36.96	.11	.19	.46	.58	.78	.78
		s	.25	.12	.17	.24	.29	.32	.32
		$s_{\bar{x}}$	.13	.06	.09	.12	.14	.16	.16
1.01	1		37.00	.07	.11	.37	.40	.55	.55
	2		37.34	.01	-.05	.09	.12	.23	.23
	3		37.49	.06	.15	.29	.36	.48	.43
	4		36.96	.20	.47	.82	.94	1.06	1.08
		$\bar{X}$	37.20	.08	.17	.39	.46	.58	.57
		s	.26	.08	.22	.31	.35	.35	.36
		$s_{\bar{x}}$	.13	.04	.11	.15	.17	.17	.18
2.03	1		36.91	.03	.13	.33	.35	.56	.59
	2		37.30	.05	.00	.18	.16	.30	.22
	3		37.46	.07	.13	.22	.24	.25	.33
	4		36.94	.23	.46	.72	.80	.84	.85
		$\bar{X}$	37.15	.10	.18	.36	.39	.49	.50
		s	.27	.09	.20	.25	.29	.27	.28
		$s_{\bar{x}}$	.14	.05	.10	.12	.14	.14	.14
4.06	1		37.13	.11	.20	.32	.43	.43	.42
	2		37.20	.19	.23	.32	.35	.42	.40
	3		37.45	.13	.27	.44	.46	.45	.46
	4		36.76	.27	.48	.94	.89	1.17	.90
		$\bar{X}$	37.14	.18	.30	.50	.53	.62	.54
		s	.28	.07	.13	.30	.24	.37	.24
		$s_{\bar{x}}$	.14	.04	.06	.15	.12	.18	.12

Table 8. Analysis of Variance Among Mean Values of Changes in Rectal Temperature for Metabolic Rate of 200 kcal/hr.

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects(S)	3.4321	3	1.1440	
Within Subjects				
A Trts. (WBGTs)	.7849	3	.2616	14.17[b]
A x S	.1662	9	.0185	
B Trts. (Wind Vel)	.2848	3	.0949	4.80[a]
B x S	.1780	9	.0120	
A x B	.0965	9	.0107	.96
A x B x S	.3024	27	.0112	
Total	5.2449	63		

[a]Critical $F_{.05}$ (3,9) = 3.86

[b]Critical $F_{.01}$ (3,9) = 6.99

Table 9. Mean Differences Among Changes in Rectal
Temperature at different WBGTs (M = 200 kcal/hr.)

WBGT $^{\circ}$C	28.9 ($\bar{X} = .302$)	31.1 ($\bar{X} = .458$)	32.8 ($\bar{X} = .452$)	34.4 ($\bar{X} = .615$)
28.9 ($\bar{X} = .30$)	----			
31.1 ($\bar{X} = .458$)	.156[a]	----		
32.8 ($\bar{X} = .452$)	.150	.006	----	
34.4 ($\bar{X} = .615$)	.313[b]	.157[a]	.163[a]	----

[a] $p < .05$

[b] $p < .01$

Table 10. Mean Differences Among Changes in Rectal
Temperature at Different Wind Velocities (M = 200 kcal/hr.)

Wind Vel. (m/sec.)	0.5 ($\bar{X} = .566$)	1.01 ($\bar{X} = .415$)	2.03 ($\bar{X} = .393$)	4.06 ($\bar{X} = .452$)
0.5 ($\bar{X} = .566$)	----			
1.01 ($\bar{X} = .415$)	.151	----		
2.03 ($\bar{X} = .393$)	.173[a]	.022	----	
4.06 ($\bar{X} = .452$)	.114	.037	.059	----

[a] $p < .05$

Table 11. Heart Rate for WBGT 28.9°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial H.R. bpm	Change in H.R. over 90 Minutes					
				15	30	45	60	75	90
.5	1		64	22	1	21	-9	21	-14
	2		91	7	-9	-5	-17	0	-16
	3		83	11	-14	10	-8	2	-6
	4		96	5	-21	18	-20	12	-20
		$\bar{X}$	83.50	11.25	-10.75	11.00	-13.50	8.75	-14.00
		s	14.06	7.59	9.25	11.63	5.92	9.71	5.89
		$s_{\bar{x}}$	7.03	3.79	4.63	5.82	2.96	4.85	2.94
1.01	1		80	18	-12	25	-18	15	-8
	2		92	6	-8	2	-8	0	-22
	3		76	32	-7	9	-13	16	-2
	4		101	-2	-15	10	-18	4	-28
		$\bar{X}$	87.25	13.50	-10.50	11.50	-14.25	8.75	-15.00
		s	11.41	14.82	3.70	9.68	4.79	7.97	12.06
		$s_{\bar{x}}$	5.71	7.41	1.85	4.84	2.39	3.99	6.03
2.03	1		70	20	-7	17	-19	16	-6
	2		84	8	5	8	8	8	7
	3		82	8	-10	8	-22	1	-3
	4		92	8	0	12	-24	8	-14
		$\bar{X}$	82.00	11.00	-3.00	11.25	-14.25	8.25	-4.00
		s	9.09	6.00	6.78	4.27	14.98	6.13	8.68
		$s_{\bar{x}}$	4.55	3.00	3.39	2.14	7.49	3.06	4.34
4.06	1		70	28	-2	25	-11	26	-5
	2		99	-9	-16	-7	-24	-11	-19
	3		84	6	-9	10	-4	11	-10
	4		114	-10	-18	-8	-28	-12	-40
		$\bar{X}$	91.75	3.75	-11.25	5.00	-16.75	3.50	-18.50
		s	18.98	17.75	7.27	15.68	11.18	18.38	15.46
		$s_{\bar{x}}$	9.49	8.87	3.64	7.84	5.59	9.19	7.73

Table 12. Heart Rate for WBGT 31.1°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial H.R. bpm	Change in H.R. over 90 Minutes					
				15	30	45	60	75	90
.5	1		68	27	2	24	-5	26	4
	2		88	2	-13	7	-2	12	-6
	3		83	13	9	18	-1	16	2
	4		94	7	-18	12	-10	14	-8
		$\bar{X}$	83.25	12.25	-5.00	15.25	-4.50	17.00	-2.00
		s	11.12	10.81	12.62	7.36	4.04	6.22	5.89
		$s_{\bar{x}}$	5.56	5.41	6.31	3.68	2.02	3.11	2.94
1.01	1		85	10	-12	13	-25	8	-20
	2		84	8	0	10	6	16	-11
	3		80	8	0	1	-4	24	-16
	4		94	14	-10	12	-4	12	-18
		$\bar{X}$	85.75	10.00	-5.50	9.00	-6.75	15.00	-16.25
		s	5.91	2.83	6.40	5.48	13.05	6.83	3.86
		$s_{\bar{x}}$	2.96	1.41	3.20	2.74	6.52	3.42	1.93
2.03	1		70	11	-5	25	-10	24	-5
	2		82	4	-7	6	-5	8	0
	3		87	11	-8	12	-17	16	-16
	4		80	33	35	29	0	29	3
		$\bar{X}$	79.75	14.75	3.75	18.00	-8.00	19.25	-4.50
		s	7.14	12.61	20.87	10.80	7.26	9.22	8.35
		$s_{\bar{x}}$	3.57	6.30	10.44	5.40	3.63	4.61	4.17
4.06	1		68	24	-3	32	-8	21	2
	2		88	9	-5	12	-10	3	-19
	3		70	19	-4	28	8	20	5
	4		96	12	-12	15	-10	12	-16
		$\bar{X}$	80.50	16.00	-6.00	21.75	-5.00	14.00	-7.00
		s	13.70	6.78	4.08	9.74	8.72	8.37	12.25
		$s_{\bar{x}}$	6.85	3.39	2.04	4.87	4.36	4.18	6.12

Table 13. Heart Rate for WBGT 32.8°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject	Initial H.R. bpm	Change in H.R. over 90 Minutes					
			15	30	45	60	75	90
.5	1	78	20	-13	22	-12	2	-8
	2	91	10	-13	9	0	15	11
	3	70	24	12	31	4	22	-4
	4	108	12	-23	24	-12	21	-7
	$\bar{X}$	86.75	16.50	-9.25	21.50	-5.00	15.00	-2.00
	s	16.60	6.61	14.93	9.18	8.25	9.20	8.83
	$s_{\bar{x}}$	8.30	3.30	7.47	4.59	4.12	4.60	4.42
1.01	1	79	15	-23	21	10	24	-9
	2	100	-2	-20	11	5	5	-12
	3	77	14	-2	26	-1	19	2
	4	84	32	10	46	16	48	0
	$\bar{X}$	85.00	14.75	-8.75	26.00	7.50	24.00	-4.75
	s	10.42	13.89	15.56	14.72	7.23	17.91	6.80
	$s_{\bar{x}}$	5.21	6.94	7.78	7.36	3.62	8.95	3.40
2.03	1	70	24	-4	26	-7	30	40
	2	91	4	-11	0	-13	2	9
	3	77	21	-3	27	-5	25	9
	4	83	27	0	37	6	30	-1
	$\bar{X}$	80.25	19.00	-4.50	22.50	-4.75	21.75	14.25
	s	8.92	10.30	4.66	15.80	7.93	13.38	17.80
	$s_{\bar{x}}$	4.46	5.15	2.33	7.90	3.97	6.69	8.90
4.06	1	81	10	-17	15	-18	17	-16
	2	74	22	6	26	6	20	22
	3	78	20	-3	19	-12	25	-3
	4	90	24	-6	26	-6	26	-2
	$\bar{X}$	80.75	19.00	-5.00	21.50	-7.50	22.00	0.25
	s	6.80	6.22	9.49	5.45	10.25	4.24	15.84
	$s_{\bar{x}}$	3.40	3.11	4.74	2.72	5.12	2.12	7.92

Table 14. Heart Rate for WBGT 34.4°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial H.R. bpm	Change in H.R. over 90 Minutes					
				15	30	45	60	75	90
.5	1		96	-3	-30	6	-28	7	-16
	2		90	4	-4	12	-12	39	0
	3		86	15	-8	22	14	26	-2
	4		88	26	-4	32	6	34	-2
		$\bar{X}$	90.00	10.50	-11.50	18.00	-5.00	26.50	-5.00
		s	4.32	12.72	12.48	11.43	18.80	14.06	7.39
		$s_{\bar{x}}$	2.16	6.36	6.24	5.72	9.40	7.03	3.70
1.01	1		64	30	1	38	4	40	6
	2		83	19	14	19	-1	23	-2
	3		80	22	-9	29	5	29	3
	4		98	18	-7	22	10	32	0
		$\bar{X}$	81.25	22.25	-0.25	27.00	4.50	31.00	1.75
		s	13.94	5.44	10.44	8.45	4.51	7.07	3.50
		$s_{\bar{x}}$	6.97	2.72	5.22	4.22	2.26	3.54	1.75
2.03	1		73	28	-11	20	-6	36	1
	2		88	3	-6	4	0	14	11
	3		78	20	2	28	4	24	-1
	4		86	24	6	26	-4	34	2
		$\bar{X}$	81.25	18.75	-2.25	19.50	-1.50	27.00	3.25
		s	6.99	11.00	7.68	10.88	4.44	10.13	5.32
		$s_{\bar{x}}$	3.50	5.50	3.84	5.44	2.22	5.07	2.66
4.06	1		84	25	-4	26	-12	32	10
	2		85	-5	13	13	7	23	-1
	3		76	26	0	24	0	26	6
	4		99	23	-3	33	21	29	-11
		$\bar{X}$	86.00	17.25	1.50	24.00	4.00	27.50	1.00
		s	9.56	14.89	7.85	8.29	13.78	3.87	9.20
		$s_{\bar{x}}$	4.78	7.44	3.93	4.14	6.89	1.94	4.60

Table 15. Analysis of Variance Among Mean Values of Changes
in Heart Rate for Metabolic Rate of 200 kcal/hr.

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	1111.55	3	370.52	
Within Subjects				
A Trts. (WBGTs)	3588.30	3	1196.10	9.81[a]
A x S	1097.52	9	121.95	
B Trts. (Wind Vel.)	110.80	3	36.93	.40
B x S	831.52	9	92.39	
A x B	266.77	9	29.64	.37
A x B x S	2182.17	27	80.82	
Total	9188.63	63		

[a]Critical $F_{.01}$ (3,9) = 6.99

Table 16. Mean Differences Among Measures of Changes
in Heart Rate (M = 200 kcal/hr.)

WBGT °C	28.9 ($\bar{X}$ = 7.31)	31.1 ($\bar{X}$ = 16.31)	32.8 ($\bar{X}$ = 20.69)	34.4 ($\bar{X}$ = 28.00)
28.9 ($\bar{X}$ = 7.31)	----			
31.1 ($\bar{X}$ = 16.31)	9.00	----		
32.8 ($\bar{X}$ = 20.69)	13.38[a]	4.38	----	
34.4 ($\bar{X}$ = 28.00)	20.69[b]	11.69	7.31	----

[a] $p < .05$

[b] $p < .01$

Table 17. Skin Temperature for WBGT 28.9°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}$°C	Change in $\bar{T}_{sk}$ over 90 minutes					
				15	30	45	60	75	90
.5	1		33.60	-.21	.39	.11	.44	.33	.54
	2		33.83	.67	1.17	.75	1.34	1.34	1.07
	3		34.93	.98	1.43	1.00	1.14	.95	1.37
	4		35.13	.45	.82	.47	.43	.04	.50
		$\bar{X}$	34.37	.47	.95	.58	.84	.67	.87
		s	.77	.50	.45	.38	.47	.59	.42
		$s_{\bar{x}}$	.38	.25	.23	.19	.24	.29	.21
1.01	1		33.60	-.21	.61	.58	.97	.42	.90
	2		34.38	-.05	.79	.20	.79	.62	.79
	3		35.00	.52	.75	.52	.47	.51	.84
	4		35.43	.17	.59	.11	.49	-.43	.09
		$\bar{X}$	34.60	.11	.68	.35	.68	.28	.66
		s	.80	.32	.10	.23	.24	.48	.38
		$s_{\bar{x}}$	.40	.16	.05	.12	.12	.24	.19
2.03	1		33.94	-.31	.54	-.69	-.07	-.58	.20
	2		33.67	1.33	2.08	2.13	2.43	2.04	2.50
	3		35.46	.55	.73	.49	.80	.30	.68
	4		35.66	.67	.50	.33	.51	-.01	.18
		$\bar{X}$	34.68	.56	.96	.57	.92	.44	.89
		s	1.02	.67	.75	1.17	1.07	1.13	1.10
		$s_{\bar{x}}$	.51	.34	.38	.58	.54	.56	.55
4.06	1		32.35	.07	1.24	.19	1.32	1.22	1.33
	2		33.83	1.17	.92	.92	.88	.84	1.27
	3		35.33	.52	.56	.04	.00	.00	.62
	4		35.70	.13	.26	-.27	.04	-.64	.19
		$\bar{X}$	34.30	.47	.75	.22	.56	.36	.85
		s	1.53	.51	.43	.50	.65	.84	.55
		$s_{\bar{x}}$	.77	.25	.21	.25	.32	.42	.27

Table 18. Skin Temperature for WBGT 31.1°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}$°C	Change in $\bar{T}_{sk}$ for 90 minutes					
				15	30	45	60	75	90
.5	1		33.98	.53	1.80	.84	1.74	1.13	1.62
	2		34.08	.82	1.62	1.42	1.62	2.05	1.80
	3		35.53	.38	.89	.38	.58	.52	.42
	4		35.27	.54	.78	.87	.37	.73	1.13
		$\bar{X}$	34.72	.57	1.27	.88	1.08	1.11	1.24
		s	.80	.18	.51	.42	.70	.68	.62
		$s_{\bar{x}}$	.40	.09	.26	.21	.35	.34	.31
1.01	1		33.36	.56	1.39	.99	1.95	1.35	1.92
	2		34.80	.43	.32	.88	.53	.53	.62
	3		35.55	.56	.84	.66	.35	.57	.70
	4		35.05	.92	.85	1.27	.68	1.10	.87
		$\bar{X}$	34.77	.62	.85	.95	.88	.89	1.03
		s	.80	.21	.44	.25	.73	.40	.60
		$s_{\bar{x}}$	.40	.11	.22	.13	.36	.20	.30
2.03	1		33.90	.50	1.15	.39	1.09	.56	2.05
	2		34.18	.42	.74	.82	1.10	1.05	.72
	3		34.90	.92	1.35	.85	1.04	.94	1.25
	4		35.57	.66	.68	.83	.61	.68	.61
		$\bar{X}$	34.64	.63	.98	.72	.96	.81	1.16
		s	.75	.22	.32	.22	.23	.23	.66
		$s_{\bar{x}}$	.38	.11	.16	.11	.12	.11	.33
4.06	1		33.75	-.08	.82	-.31	1.24	.19	1.65
	2		33.42	.25	.91	.66	1.16	1.25	1.50
	3		35.79	.34	.56	.22	.73	.14	.80
	4		35.99	.34	.74	.03	-.07	-.10	.54
		$\bar{X}$	34.74	.21	.76	.15	.77	.37	1.12
		s	1.34	.20	.15	.40	.60	.60	.54
		$s_{\bar{x}}$	.67	.10	.07	.20	.30	.30	.27

Table 19. Skin Temperature for WBGT 32.8°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}°C$	Change in $\bar{T}_{sk}$ over 90 minutes					
				15	30	45	60	75	90
.5	1		34.39	1.10	1.88	1.07	1.74	1.17	1.85
	2		34.60	.88	.95	.87	1.08	1.46	1.52
	3		35.44	1.13	.81	.98	.76	.97	.00
	4		35.92	1.02	1.18	1.15	.71	.78	1.08
		$\bar{X}$	35.09	1.03	1.20	1.02	1.07	1.10	1.11
		s	.72	.11	.48	.12	.47	.29	.81
		$s_{\bar{x}}$	.36	.06	.24	.06	.24	.15	.40
1.01	1		34.42	.40	.89	.60	1.22	1.15	1.20
	2		32.82	2.21	2.56	2.46	2.74	2.68	3.35
	3		35.93	.49	.47	.48	.85	.36	.55
	4		36.43	-.05	.02	-.53	-.06	-.16	.22
		$\bar{X}$	34.90	.76	.99	.75	1.19	1.01	1.33
		s	1.63	.99	1.11	1.25	1.17	1.24	1.41
		$s_{\bar{x}}$	.81	.50	.55	.62	.58	.62	.70
2.03	1		33.75	.96	.25	1.52	2.12	1.27	1.81
	2		34.29	1.42	1.16	1.26	1.21	1.56	1.61
	3		35.51	1.05	1.15	.86	.65	.84	1.25
	4		35.35	.36	1.35	1.55	.99	1.23	2.46
		$\bar{X}$	34.73	.95	.98	1.30	1.24	1.23	1.78
		s	.85	.44	.49	.32	.63	.30	.51
		$s_{\bar{x}}$	.43	.22	.25	.16	.31	.15	.25
4.06	1		33.70	.52	1.13	1.65	.63	1.95	1.89
	2		34.70	1.05	.86	1.30	1.15	1.50	1.80
	3		35.77	.83	.43	.46	.52	.82	.75
	4		35.57	.40	.45	1.01	1.06	.46	.81
		$\bar{X}$	34.94	.70	.72	1.11	.84	1.18	1.31
		s	.94	.30	.34	.50	.31	.67	.62
		$s_{\bar{x}}$	.47	.15	.17	.25	.16	.33	.31

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Table 20. Skin Temperature for WBGT 34.4°C (M = 200 kcal/hr)

Wind Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}°C$	Change in $\bar{T}_{sk}$ over 90 minutes					
				15	30	45	60	75	90
.5	1		34.41	1.66	1.87	1.47	2.41	1.77	2.32
	2		34.17	.93	1.43	1.58	1.91	1.83	2.23
	3		35.34	.86	1.21	1.36	1.36	1.29	1.58
	4		35.98	1.03	1.21	.36	1.02	.86	.99
		$\bar{X}$	34.98	1.12	1.43	1.19	1.68	1.44	1.78
		s	.84	.37	.31	.56	.61	.45	.62
		$s_{\bar{x}}$	.42	.18	.16	.28	.31	.23	.31
1.01	1		34.79	.68	1.29	.80	1.66	1.05	1.73
	2		34.57	1.45	1.31	1.37	1.59	1.91	2.07
	3		35.83	.95	1.13	.87	.91	.88	1.27
	4		35.50	.75	1.12	.95	.95	1.03	1.58
		$\bar{X}$	35.17	.96	1.21	1.00	1.28	1.22	1.66
		s	.59	.35	.10	.26	.40	.47	.33
		$s_{\bar{x}}$	.30	.17	.05	.13	.20	.23	.17
2.03	1		34.00	1.28	1.32	1.60	2.77	1.60	2.67
	2		34.70	.66	1.08	1.17	1.30	1.72	2.10
	3		35.96	1.00	.85	1.03	.66	.96	.64
	4		36.02	.98	.13	1.33	.81	1.16	.96
		$\bar{X}$	35.17	.98	.84	1.28	1.38	1.36	1.59
		s	.99	.25	.51	.24	.96	.36	.95
		$s_{\bar{x}}$	.49	.13	.26	.12	.48	.18	.48
4.06	1		34.58	.37	.81	.36	1.39	.71	1.96
	2		35.25	.60	.75	.75	1.00	.55	1.30
	3		36.29	.82	.72	.68	.33	1.02	.96
	4		35.93	.29	1.20	1.10	1.25	1.56	1.35
		$\bar{X}$	35.51	.52	.87	.72	.99	.96	1.39
		s	.76	.24	.22	.30	.47	.45	.42
		$s_{\bar{x}}$	.38	.12	.11	.15	.24	.22	.21

Table 21 Analysis of Variance Among Mean Values of Changes in Mean Skin Temperature for Metabolic Rate of 200 kcal/hr.

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects	7.62	3	2.54	
Within Subjects				
A Trts. (WBGTs)	6.37	3	2.12	8.48[a]
A x S	2.21	9	.25	
B Trts. (Wind Vel.)	1.13	3	.38	2.92
B x S	1.13	9	.13	
A x B	.99	9	.11	.33
A x B x S	8.51	27	.32	
Total	27.96	63		

[a]Critical $F_{.01}$ (3,9) = 6.99

Table 22 Mean Differences Among Measures of Changes in Mean Skin Temperature (M = 200 kcal/hr.)

WBGT °C	28.9 ($\bar{X}$ = .43)	31.1 ($\bar{X}$ = .79)	32.8 ($\bar{X}$ = 1.13)	34.4 ($\bar{X}$ = 1.24)
28.9 ($\bar{X}$ = .43)	----			
31.1 ($\bar{X}$ = .79)	.36	----		
32.8 ($\bar{X}$ = 1.13)	.70[a]	.34	----	
34.4 ($\bar{X}$ = 1.24)	.81[b]	.45	.11	----

[a] $p < .05$

[b] $p < .01$

Table 23. Rate of Evaporation (g/m^2/hr) for Metabolic
Rate of 200 kcal/hr.

Experimental Condition	Subject	Wind Velocity (meters/sec.)			
		0.5	1.01	2.03	4.06
WBGT					
28.9°C	1	205	198	198	216
	2	175	182	203	174
	3	164	177	174	125
	4	198	173	141	175
	$\overline{X}$	186	182	179	172
	s	19	11	28	37
	$s_{\overline{x}}$	10	5	14	19
31.1°C	1	231	223	256	319
	2	216	250	228	266
	3	223	236	230	230
	4	167	206	208	210
	$\overline{X}$	209	229	231	256
	s	29	19	20	48
	$s_{\overline{x}}$	14	10	10	24
32.8°C	1	308	350	333	370
	2	303	268	269	330
	3	312	138	384	292
	4	267	299	246	274
	$\overline{X}$	297	267	308	316
	s	21	94	63	42
	$s_{\overline{x}}$	10	47	31	21
34.4°C	1	154	366	388	341
	2	349	350	385	347
	3	289	243	309	342
	4	331	270	320	354
	$\overline{X}$	281	308	350	346
	s	88	60	42	6
	$s_{\overline{x}}$	44	30	21	3

Table 24. Analysis of Variance Among Mean Values of Evaporation Rates (g/m²/hr.) for Metabolic Rate of 200 kcal/hr.

Source of Variation	Sums of Squares	df	Mean Squares	F
Between Subjects				
Subjects (S)	18398.83	3	6132.94	
Within Subjects				
A Trts (WBGTs)	197492.60	3	65830.87	42.17[a]
A x S	14051.44	9	1561.27	
B Trts. (Wind Vel)	10388.39	3	3462.80	1.49
B x S	20952.17	9	2328.02	
A x B	13270.70	9	1474.52	.78
A x B x S	51263.22	27	1898.64	
Total	325817.40	63		

[a]Critical $F_{.01}$ (3,9) = 6.99

Table 25. Mean Differences Among Measures of Evaporation Rates at Different WBGTs (M = 200 kcal/hr.)

WBGT °C	28.9 ($\bar{X}$ = 179.93)	31.1 ($\bar{X}$ = 231.26)	32.8 ($\bar{X}$ = 297.21)	34.4 ($\bar{X}$ = 321.22)
28.9 ($\bar{X}$ = 179.93)	----			
31.1 ($\bar{X}$ = 231.26)	51.33[a]	----		
32.8 ($\bar{X}$ = 297.21)	117.28[b]	65.95[b]	----	
34.4 ($\bar{X}$ = 321.22)	141.29[b]	89.96[b]	24.01	----

[a]$p < .05$

[b]$p < .01$

Table 26.   Rate of Sweating (g/m^2/hr) for Metabolic Rate of 200 kcal/hr.

Experimental Condition	Subject	Wind Velocity (meters/sec.)			
		0.5	1.01	2.03	4.06
WBGT					
28.9°C	1	306	250	262	382
	2	238	281	254	257
	3	240	228	206	186
	4	338	244	319	342
	$\overline{X}$	280	251	260	292
	s	50	22	46	88
	$s_{\overline{x}}$	25	11	23	44
31.1°C	1	289	258	314	382
	2	323	346	269	392
	3	285	328	288	231
	4	240	307	329	296
	$\overline{X}$	284	310	300	326
	s	34	38	27	76
	$s_{\overline{x}}$	17	19	13	38
32.8°C	1	439	413	368	471
	2	376	364	417	427
	3	355	205	397	330
	4	315	425	399	344
	$\overline{X}$	371	332	395	364
	s	52	93	20	72
	$s_{\overline{x}}$	26	46	10	36
34.4°C	1	300	470	392	387
	2	536	450	475	607
	3	391	344	441	463
	$\overline{X}$	439	426	448	454
	s	115	56	41	111
	$s_{\overline{x}}$	58	28	21	56

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Table 27. Analysis of Variance Among Mean Values of
Sweating ($g/m^2/hr$) for Metabolic Rate of 200 kcal/hr.

Source of Variation	Sums of Squares	df	Mean Squares	F
Between Subjects				
Subjects (S)	34216.01	3	11405.34	
Within Subjects				
A Trts (WBGTs)	270749.40	3	90249.80	17.23[a]
A x S	47137.72	9	5237.52	
B Trts (Wind Vel.)	7266.92	3	2422.31	.91
B x S	23947.44	9	2660.83	
A x B	10252.37	9	1139.15	.30
A x B x S	102378.50	27	3791.80	
Total	495948.36	63		

[a]Critical $F_{.01}$ (3,9) = 6.99

Table 28. Mean Differences Among Measures of Sweating Rates
at Different WBGTs (M = 200 kcal/hr.)

WBGTs °C	28.9 ($\bar{X}$ = 270.90)	31.1 ($\bar{X}$ = 304.83)	32.8 ($\bar{X}$ = 365.83)	34.4 ($\bar{X}$ = 441.88)
28.9 ($\bar{X}$ = 270.90)	----			
31.1 ($\bar{X}$ = 304.83)	33.94	----		
32.8 ($\bar{X}$ = 365.83)	94.93[a]	61.00	----	
34.4 ($\bar{X}$ = 441.88)	170.98[b]	137.05[b]	76.05	----

[a]$p < .05$

[b]$p < .01$

Table 29. Rectal Temperature for WBGT 27.2°C (M = 300 kcal/hr).

Wind Vel. (m/sec.)	Subject	Initial T_{re} °C	Change in T_{re} over 90 minutes					
			15	30	45	60	75	90
.5	1	37.42	.16	.33	.47	.46	.39	.46
	2	37.13	.09	.15	.26	.29	.29	.29
	3	37.12	.18	.41	.54	.71	.67	.61
	4	36.85	.25	.63	.81	.90	.95	.95
	5	36.60	.00	.31	.45	.57	.60	.59
	6	37.42	-.09	.01	.15	.21	.18	.20
	$\bar{X}$	37.09	.10	.31	.45	.52	.51	.52
	s	.32	.13	.21	.23	.26	.28	.27
	$s_{\bar{x}}$	.13	.05	.09	.09	.11	.12	.11
1.01	1	37.37	.10	.35	.49	.58	.58	.60
	2	36.82	.12	.33	.52	.60	.55	.56
	3	37.09	.23	.47	.57	.59	.55	.57
	4	36.95	.30	.60	.75	.80	.78	.82
	5	37.10	.00	.35	.45	.60	.50	.50
	6	37.60	-.16	-.10	.10	.09	.08	.06
	$\bar{X}$	37.16	.10	.33	.48	.54	.51	.52
	s	.28	.16	.24	.21	.24	.23	.25
	$s_{\bar{x}}$	.12	.07	.10	.09	.10	.09	.10
2.03	1	37.46	.04	.11	.16	.22	.21	.12
	2	37.00	.19	.32	.40	.44	.44	.49
	3	37.33	.08	.23	.38	.44	.46	.50
	4	36.68	.28	.74	.99	1.12	1.16	1.16
	5	36.80	.10	.35	.46	.60	.45	.50
	6	37.60	-.24	-.18	-.11	-.09	-.09	-.13
	$\bar{X}$	37.15	.08	.26	.38	.46	.44	.44
	s	.37	.18	.30	.37	.40	.41	.44
	$s_{\bar{x}}$	.15	.07	.12	.15	.16	.17	.18
4.06	1	37.50	.10	.16	.18	.14	.18	.12
	2	37.23	.05	.12	.17	.20	.24	.26
	3	37.18	.19	.32	.42	.43	.45	.44
	4	36.70	.45	.79	.95	1.00	.95	.95
	5	37.00	.00	.40	.50	.55	.60	.55
	6	37.52	-.18	-.03	.03	.06	.02	.02
	$\bar{X}$	37.19	.10	.29	.38	.40	.41	.39
	s	.31	.21	.29	.33	.35	.34	.34
	$s_{\bar{x}}$	.13	.09	.12	.14	.14	.14	.14

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Table 30. Rectal Temperature for WBGT 28.9°C (M = 300 kcal/hr).

Wind Vel. (m/sec.)	Subject	Initial T_{re} °C	Change in T_{re} over 90 minutes					
			15	30	45	60	75	90
.5	1	37.37	.19	.33	.41	.42	.36	.37
	2	37.13	.08	.28	.50	.51	.48	.46
	3	37.12	.27	.46	.60	.66	.69	.64
	4	36.77	.32	.77	1.02	1.14	1.18	1.18
	5	36.55	.15	.40	.55	.50	.50	.50
	6	37.39	-.15	-.13	-.05	-.03	.01	.01
	$\bar{X}$	37.06	.14	.35	.51	.53	.54	.53
	s	.33	.17	.29	.34	.38	.39	.38
	$s_{\bar{x}}$	.14	.07	.12	.14	.15	.16	.16
1.01	1	37.49	.06	.13	.13	.13	.19	.19
	2	36.82	.10	.19	.25	.35	.46	.57
	3	37.14	.20	.38	.46	.54	.54	.54
	4	37.05	.13	.44	.55	.64	.66	.64
	5	36.90	.35	.55	.65	.70	.70	.65
	6	37.50	-.11	.00	.10	.13	.15	.14
	$\bar{X}$	37.15	.12	.28	.36	.42	.45	.46
	s	.29	.15	.21	.23	.25	.23	.23
	$s_{\bar{x}}$	.12	.06	.09	.09	.10	.09	.09
2.03	1	37.36	.07	.26	.34	.33	.34	.29
	2	37.00	.09	.23	.34	.42	.44	.62
	3	37.06	.15	.36	.50	.50	.56	.59
	4	36.70	.43	.82	.98	1.01	.99	1.03
	5	36.80	.20	.40	.50	.60	.60	.65
	6	37.79	-.47	-.36	-.29	-.26	-.22	-.22
	$\bar{X}$	37.12	.08	.29	.40	.43	.45	.49
	s	.40	.30	.38	.41	.41	.40	.42
	$s_{\bar{x}}$	.16	.12	.16	.17	.17	.16	.17
4.06	1	37.32	.31	.48	.56	.56	.54	.56
	2	37.23	.40	.45	.51	.61	.69	.79
	3	37.26	.21	.52	.65	.65	.63	.59
	4	36.87	.28	.72	.91	.95	.98	.95
	5	36.70	.25	.60	.80	.90	.80	.80
	6	37.60	-.26	-.10	-.04	.01	.05	.08
	$\bar{X}$	37.16	.20	.45	.57	.61	.62	.63
	s	.33	.23	.28	.33	.34	.32	.31
	$s_{\bar{x}}$	.13	.10	.12	.14	.14	.13	.12

Table 31. Rectal Temperature for WBGT 31.1°C   (M = 300 kcal/hr).

Wind Vel. (m/sec.)	Subject	Initial T_{re} $^\circ$C	Change in T_{re} over 90 minutes					
			15	30	45	60	75	90
.5	1	37.76	.09	.26	.35	.34	.29	.31
	2	37.27	.11	.21	.28	.36	.47	.56
	3	37.51	.14	.28	.35	.35	.31	.32
	4	36.78	.05	.36	.64	.91	1.02	1.12
	5	36.50	.15	.51	.75	.95	1.03	1.11
	6	37.58	−.21	−.13	−.06	.01	.05	.11
	$\bar{X}$	37.23	.06	.25	.39	.49	.53	.59
	s	.49	.13	.21	.29	.37	.41	.43
	$s_{\bar{x}}$	.20	.05	.09	.12	.15	.17	.18
1.01	1	37.05	.25	.43	.49	.55	.51	.54
	2	37.40	.03	.07	.10	.18	.25	.30
	3	37.20	.23	.36	.44	.26	.26	.28
	4	36.95	.55	.77	1.01	1.14	1.20	1.28
	5	36.50	.10	.45	.55	.70	.80	.95
	6	37.71	.08	.19	.34	.41	.54	.65
	$\bar{X}$	37.14	.21	.38	.49	.54	.59	.67
	s	.41	.19	.24	.30	.35	.36	.39
	$s_{\bar{x}}$	.17	.08	.10	.12	.14	.15	.16
2.03	1	37.26	.06	.24	.38	.52	.58	.63
	2	37.21	.04	.13	.23	.38	.45	.40
	3	37.40	.15	.28	.37	.35	.35	.37
	4				NO DATA			
	5	36.65	.15	.36	.57	.70	.70	.75
	6	37.33	−.12	.05	.19	.20	.34	.39
	$\bar{X}$	37.17	.06	.21	.35	.43	.48	.51
	s	.30	.11	.12	.15	.19	.15	.17
	$s_{\bar{x}}$	.12	.05	.05	.07	.08	.07	.08
4.06	1	37.21	.16	.29	.37	.38	.43	.49
	2	36.94	.06	.16	.26	.36	.47	.59
	3	36.94	.28	.49	.62	.68	.72	.73
	4	36.89	.26	.71	.99	1.11	1.16	1.16
	5	37.10	.20	.35	.45	.50	.65	.65
	6	37.53	−.17	.02	.19	.29	.32	.34
	$\bar{X}$	37.10	.13	.34	.48	.55	.63	.66
	s	.24	.17	.24	.29	.31	.30	.28
	$s_{\bar{x}}$	.10	.07	.10	.12	.12	.12	.11

Table 32. Rectal Temperature for WBGT 32.8°C (M = 300 kcal/hr).

Wind Vel. (m/sec.)	Subject		Initial T_{re}°C	Change in T_{re} over 90 minutes					
				15	30	45	60	75	90
.5	1		37.58	-.02	.20	.39	.50	.59	.60
	2		36.70	.13	.31	.45	.64	.80	.89
	3		37.50	.08	.23	.28	.32	.35	.35
	4		36.80	.43	.95	1.36	1.55	1.68	1.80
	5		36.70	.10	.50	.70	.90	1.00	1.20
	6		37.46	-.12	.04	.22	.33	.41	.51
		$\bar{X}$	37.12	.10	.37	.57	.71	.81	.89
		s	.43	.19	.32	.42	.47	.49	.54
		$s_{\bar{x}}$	.18	.08	.13	.17	.19	.20	.22
1.01	1		37.26	.23	.39	.50	.60	.63	.64
	2		37.08	.02	.12	.30	.43	.59	.67
	3		37.06	.23	.44	.55	.62	.68	.75
	4		36.80	.30	.75	1.06	1.29	1.43	1.54
	5		37.05	.35	.50	.75	.85	.95	1.00
	6		37.33	-.06	.02	.20	.36	.44	.44
		$\bar{X}$	37.10	.18	.37	.56	.64	.79	.84
		s	.19	.16	.27	.31	.38	.36	.39
		$s_{\bar{x}}$	.08	.07	.11	.13	.15	.15	.16
2.03	1		37.10	.15	.40	.64	.80	.89	.98
	2		36.90	.11	.22	.34	.51	.67	.81
	3		37.33	.10	.23	.35	.44	.50	.55
	4		36.80	.30	.59	.87	1.03	1.11	1.15
	5		36.80	.33	.50	.60	.60	.70	.70
	6		37.68	-.23	-.05	.05	.10	.18	.25
		$\bar{X}$	37.10	.13	.32	.48	.58	.68	.74
		s	.35	.20	.23	.29	.32	.32	.32
		$s_{\bar{x}}$	.14	.08	.09	.12	.13	.13	.13
4.06	1		37.18	.13	.38	.65	.78	.85	.80
	2		37.04	.02	.06	.18	.35	.40	.56
	3		37.14	.21	.43	.54	.62	.67	.69
	4		36.84	.33	.84	1.09	1.25	1.30	1.34
	5		36.80	.20	.60	.85	1.00	1.10	1.20
	6		37.52	-.08	.10	.29	.42	.53	.54
		$\bar{X}$	37.09	.14	.40	.60	.74	.81	.85
		s	.26	.15	.30	.34	.35	.34	.34
		$s_{\bar{x}}$	.11	.06	.12	.14	.14	.14	.14

Table 33. Analysis of Variance Among Mean Values of Rectal Temperature
Changes for Metabolic Rate of M = 300 kcal/hr.   (N = 6)

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	7.71	5	1.54	
Within Subjects				
A Trts (WBGTs)	1.85	3	.62	11.73[a]
A x S (Error)	.79	15	.05	
B Trts (Wind Vel.)	.07	3	.02	1.15
B x S (Error)	.30	15	.02	
A x B	.21	9	.02	.71
A x B x S	1.46	45	.03	
Total	12.39	95		

a
   Significant at .01 level

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Table 34. Mean Differences Among Measures of Changes in Rectal
Temperature at Different WBGTs (M = 300 kcal/hr.)

WBGT	27.2°C ($\bar{X}$ = .47)	28.9°C ($\bar{X}$ = .53)	31.1°C ($\bar{X}$ = .63)	32.8°C ($\bar{X}$ = .83)
27.2°C ($\bar{X}$ = .47)	----			
28.9°C ($\bar{X}$ = .53)	.06	----		
31.1°C ($\bar{X}$ = .63)	.16	.10	----	
32.8°C ($\bar{X}$ = .83)	.36[b]	.30[b]	.20[a]	----

[a]
Significant at .05 level

[b]
Significant at .01 level

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Table 35. Heart Rate for WBGT 27.2°C (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject	Initial H.R. bpm	Change in H.R. over 90 minutes					
			15	30	45	60	75	90
.5	1	80	22	23	24	23	20	20
	2	76	4	9	5	-2	14	4
	3	80	12	5	1	0	4	4
	4	88	23	24	24	29	24	30
	5	58	39	37	35	40	45	46
	6	69	0	35	37	35	36	36
	$\bar{X}$	75.17	16.67	22.17	21.00	20.83	23.83	23.33
	s	10.44	14.33	13.09	15.01	17.86	14.84	17.19
	$s_{\bar{X}}$	4.26	5.85	5.34	6.13	1.29	6.06	7.02
1.01	1	77	13	15	18	12	9	13
	2	82	3	13	5	6	3	1
	3	65	18	24	29	15	17	19
	4	84	24	26	26	22	25	24
	5	51	44	42	41	39	42	43
	6	63	35	33	33	35	32	32
	$\bar{X}$	70.33	22.83	25.50	25.33	21.50	21.33	22.0
	s	12.83	14.91	10.93	12.53	13.13	14.57	14.67
	$s_{\bar{X}}$	5.24	6.08	4.46	5.12	5.36	5.95	5.99
2.03	1	80	12	8	8	8	16	8
	2	89	3	3	5	-3	9	-3
	3	70	19	23	24	16	14	14
	4	84	26	28	28	30	30	26
	5	75	23	20	17	22	25	22
	6	68	32	34	31	32	34	26
	$\bar{X}$	77.67	19.17	19.33	18.83	17.50	21.33	15.50
	s	8.16	10.38	11.83	10.68	13.41	9.83	11.52
	$s_{\bar{X}}$	3.33	4.24	4.83	4.36	5.47	4.01	4.70
4.06	1	62	30	28	26	24	24	23
	2	89	-4	5	-8	-2	-5	-2
	3	76	12	11	10	8	8	9
	4	89	20	22	21	22	21	20
	5	62	39	36	39	34	41	40
	6	59	35	39	36	38	34	39
	$\bar{X}$	72.83	22.00	23.50	20.67	20.67	20.50	21.50
	s	13.85	16.14	13.55	17.52	15.27	16.86	16.50
	$s_{\bar{X}}$	5.65	6.59	5.53	7.15	6.23	6.88	6.74

Table 36. Heart Rate for WBGT 28.9°C   (M = 300 kcal/hr)

Wind Vel. (m/sec.)	Subject	Initial H.R. bpm	Change in H.R. over 90 minutes					
			15	30	45	60	75	90
.5	1	93	9	9	-2	7	5	5
	2	82	13	10	4	3	5	7
	3	83	7	3	12	7	8	9
	4	96	19	25	28	28	26	32
	5	52	33	37	37	–	–	30
	6	64	36	39	40	35	32	34
	$\bar{X}$	78.33	19.50	20.50	19.83	16.00	15.20	19.50
	s	17.10	12.36	15.39	17.65	14.46	12.83	13.81
	$s_{\bar{x}}$	6.98	5.04	6.28	7.20	6.46	5.73	5.64
1.01	1	68	37	33	28	27	28	30
	2	82	13	9	8	-4	3	3
	3	68	13	21	15	14	22	16
	4	94	7	17	11	12	10	11
	5	84	26	24	24	25	24	29
	6	77	27	29	–	23	–	26
	$\bar{X}$	78.83	20.50	22.17	17.20	16.17	17.40	19.17
	s	10.05	11.31	8.59	8.53	11.58	10.48	10.94
	$s_{\bar{x}}$	4.10	4.62	3.51	3.81	4.73	4.68	4.47
2.03	1	65	36	23	25	23	28	24
	2	82	6	5	7	3	9	12
	3	77	12	9	11	9	17	17
	4	79	27	31	33	33	30	29
	5	60	44	39	36	38	43	41
	6	77	28	33	32	30	27	25
	$\bar{X}$	73.33	25.50	23.33	24.00	22.67	25.67	24.67
	s	8.73	14.31	13.71	12.23	13.92	11.66	10.05
	$s_{\bar{x}}$	3.56	5.84	5.59	4.99	5.68	4.76	4.10
4.06	1	75	25	33	25	22	21	18
	2	82	12	1	14	18	7	10
	3	82	6	13	10	5	9	13
	4	90	26	26	29	22	31	29
	5	78	18	18	22	16	12	18
	6	73	26	29	32	27	25	31
	$\bar{X}$	80.00	18.83	20.00	22.00	18.33	17.50	19.83
	s	6.10	8.40	11.83	8.56	7.55	9.63	8.47
	$s_{\bar{x}}$	2.49	3.43	4.83	3.49	3.08	3.93	3.46

Table 37. Heart Rate for WBGT 31.1°C   (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject	Initial H.R. bpm	Change in H.R. over 90 minutes 15	30	45	60	75	90
.5	1	84	22	27	32	34	28	30
	2	77	11	13	14	14	10	14
	3	71	19	10	22	29	22	22
	4	94	−5	4	12	22	17	17
	5	61	37	44	48	49	48	48
	6	57	47	53	53	50	48	52
	$\bar{X}$	74.00	21.83	25.17	30.17	33.00	28.83	30.50
	s	13.97	18.49	19.79	17.33	14.45	15.98	16.10
	$s_{\bar{x}}$	5.70	7.55	8.08	7.07	5.90	6.52	6.57
1.01	1	61	36	41	36	49	37	42
	2	84	18	4	8	8	6	6
	3	66	20	28	28	18	20	23
	4	90	26	40	28	40	50	52
	5	51	45	49	47	53	50	50
	6	85	16	23	29	34	−	32
	$\bar{X}$	72.83	26.83	30.83	29.33	33.67	32.60	34.17
	s	15.69	11.46	16.17	12.77	17.63	19.31	17.62
	$s_{\bar{x}}$	6.40	4.68	6.60	5.21	7.19	8.62	7.19
2.01	1	81	22	21	27	25	29	33
	2	86	12	6	4	4	2	2
	3	76	19	18	23	16	21	20
	4		NO DATA					
	5	59	41	45	44	45	41	45
	6	75	28	35	39	36	41	39
	$\bar{X}$	75.40	24.40	25.00	27.40	25.20	26.80	27.80
	s	10.16	10.92	15.22	15.63	16.15	16.25	17.14
	$s_{\bar{x}}$	4.54	4.88	6.79	6.98	7.21	7.26	7.65
4.06	1	76	14	16	16	12	16	14
	2	86	7	1	4	16	9	5
	3	72	15	16	14	19	18	13
	4	96	14	24	26	26	32	30
	5	84	24	28	14	28	20	26
	6	82	31	29	33	33	28	34
	$\bar{X}$	82.67	17.50	19.00	17.83	22.33	20.50	20.33
	s	8.36	8.55	10.47	10.21	7.97	8.34	11.33
	$s_{\bar{x}}$	3.41	3.49	4.27	4.17	3.25	3.40	4.62

Table 38. Heart Rate for WBGT 32.8°C (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject	Initial H.R. bpm	Change in H.R. over 90 minutes					
			15	30	45	60	75	90
.5	1	84	26	28	35	49	44	44
	2	67	16	23	28	31	43	41
	3	76	14	15	16	25	18	14
	4	84	38	52	59	66	66	71
	5	57	38	43	46	53	52	63
	6	65	49	53	65	65	65	65
	$\bar{X}$	72.17	30.17	35.67	41.50	48.17	48.00	49.67
	s	10.98	13.83	15.92	18.73	17.07	17.72	21.20
	$s_{\bar{X}}$	4.48	5.65	6.50	7.64	6.97	7.23	8.65
1.01	1	70	32	39	41	45	42	40
	2	68	7	14	20	19	19	26
	3	70	21	31	31	45	32	41
	4	98	12	21	28	34	42	40
	5	67	39	37	38	39	37	35
	6	76	34	34	–	–	–	34
	$\bar{X}$	74.83	24.17	29.33	31.60	36.40	34.40	36.40
	s	11.77	12.89	9.81	8.32	10.76	9.56	6.27
	$s_{\bar{X}}$	4.80	5.26	4.00	3.72	4.80	4.27	2.80
2.03	1	80	21	23	27	32	32	28
	2	84	5	4	8	6	10	26
	3	72	20	18	21	19	31	33
	4	74	32	36	45	46	45	46
	5	58	48	50	51	53	54	52
	6	90	21	31	31	30	35	35
	$\bar{X}$	76.33	24.50	27.00	30.50	31.00	34.50	36.67
	s	11.13	14.38	15.82	15.74	17.20	14.90	10.27
	$s_{\bar{X}}$	4.54	5.87	6.46	6.43	7.02	6.08	4.19
4.06	1	98	9	14	27	34	23	20
	2	73	19	27	25	30	19	19
	3	76	19	16	15	22	22	25
	4	110	11	19	25	25	26	30
	5	66	38	46	46	52	46	56
	6	80	30	38	32	38	42	41
	$\bar{X}$	83.83	21.00	26.67	28.33	33.50	29.67	31.83
	s	16.71	11.15	12.93	10.27	10.77	11.40	14.30
	$s_{\bar{X}}$	6.82	4.55	5.28	4.19	4.39	4.65	5.84

Table 39. Analysis of Variance Among Mean Values of Changes in Heart Rate for Metabolic Rate of 300 kcal/hr. (N = 6)

Source of Variation	Sums of squares	df	Mean Square	F
Between Subjects				
Subjects (S)	10284.33	5	2056.87	
Within Subjects				
A Trts. (WBGTs)	5163.21	3	1721.07	31.50[a]
A x S (Error)	819.42	15	54.63	
B Trts. (Wind Vel.)	675.54	3	225.18	2.46
B x S (Error)	1370.58	15	91.37	
A x B	1354.21	9	150.47	2.12
A x B x S	3187.67	45	70.84	
Total	22854.96	95		

[a] Significant at .01 level

Table 40. Mean Differences Among Measures of Changes in Heart Rate at Different WBGTs   (M = 300 kcal/hr.)

WBGT	27.2°C ($\bar{X}$ = 20.58)	28.9°C ($\bar{X}$ = 20.79)	31.1°C ($\bar{X}$ = 28.50)	32.8°C ($\bar{X}$ = 38.54)
27.2°C ($\bar{X}$ = 20.58)	----			
28.9°C ($\bar{X}$ = 20.79)	.21	----		
31.1°C ($\bar{X}$ = 28.50)	7.92[a]	7.71[a]	----	
32.8°C ($\bar{X}$ = 38.54)	17.96[b]	17.75[b]	10.04[b]	----

[a] Significant at .05 level

[b] Significant at .01 level

Table 41.   Skin Temperature for WBGT 27.2°C (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject	Initial $\bar{T}_{sk}$ °C	Change in $\bar{T}_{sk}$ over 90 minutes					
			15	30	45	60	75	90
.5	1	34.13	-.21	-.02	-.14	.40	.10	-.24
	2	32.92	0	-.04	.20	.08	.06	.56
	3	34.37	.58	.43	.66	.36	.39	.31
	4	34.85	.49	.79	.70	.75	.72	.81
	5	34.17	.03	-.24	-.27	.03	.18	.36
	6	34.08	-.14	-.10	-.41	-.30	-.40	.20
	$\bar{X}$	34.09	.13	.14	.12	.22	.18	.27
	s	.64	.33	.39	.48	.36	.37	.42
	$s_{\bar{x}}$	.26	.14	.16	.19	.15	.15	.17
1.01	1	33.96	-1.00	-.58	-.91	-.25	-.52	-.42
	2	33.85	0	-.33	-.32	-.27	-.27	-.25
	3	34.90	.40	.35	.01	-.10	-.26	-.39
	4	34.99	-.07	-.27	-.41	-.54	-.53	-.47
	5	34.76	-.46	-.51	-.74	-.70	-.56	-.44
	6	34.38	-.71	-.88	-1.23	-.95	-1.00	-.80
	$\bar{X}$	34.47	-.31	-.37	-.60	-.47	-.52	-.46
	s	.49	.51	.41	.45	.32	.27	.18
	$s_{\bar{x}}$	.20	.21	.17	.18	.13	.11	.07
2.03	1	33.84	-.73	-.69	-.97	-1.01	-1.06	-1.16
	2	33.89	-.23	.11	-.16	-.42	-.55	-.51
	3	34.61	.59	.47	-.08	.11	-.16	-.11
	4	34.32	.61	.34	.08	-.02	0	.04
	5	33.90	.10	-.33	-.33	-.10	-.27	-.27
	6	34.29	-1.36	-.81	-1.31	-1.17	-.82	-.54
	$\bar{X}$	34.14	-.17	-.15	-.46	-.44	-.48	-.43
	s	.31	.77	.54	.55	.54	.41	.42
	$s_{\bar{x}}$	.13	.32	.22	.23	.22	.17	.17
4.06	1	33.61	-.54	-.61	-.67	-.56	-.27	-.39
	2	32.63	-.01	-.25	-.40	-.51	-.74	-.62
	3	34.86	.09	-.14	-.37	-.32	-.70	-.76
	4	34.47	.69	.53	.32	.15	-.04	.04
	5	34.42	-.02	.04	-.22	-.20	-.32	-.27
	6	34.53	-.94	-1.26	-1.20	-1.04	-1.13	-1.09
	$\bar{X}$	34.09	-.12	-.28	-.42	-.41	-.53	-.52
	s	.82	.56	.61	.50	.40	.40	.40
	$s_{\bar{x}}$	.34	.23	.25	.21	.16	.16	.16

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Table 42. Skin Temperature for WBGT 28.9°C (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject	Initial $\bar{T}_{sk}$ °C	Change in $\bar{T}_{sk}$ over 90 minutes					
			15	30	45	60	75	90
.5	1	34.57	.26	.30	.34	.26	.26	.26
	2	33.43	.47	.73	.92	.97	1.01	1.25
	3	35.38	.26	.20	0	-.16	0	-.20
	4	34.78	.64	.98	.77	.91	.81	.67
	5	35.30	-.17	-.55	-.76	-.90	-.80	-.42
	6	33.94	.34	.61	.61	.96	.73	.83
	$\bar{X}$	34.57	.30	.38	.31	.34	.34	.40
	s	.77	.27	.54	.62	.76	.67	.64
	$s_{\bar{x}}$	.31	.11	.22	.25	.31	.27	.26
1.01	1	34.73	-.05	.04	.21	-.22	-.10	.23
	2	33.28	.12	.51	.67	.69	.77	1.16
	3	33.46	2.00	1.84	1.81	1.68	1.60	1.86
	4	34.90	.26	.29	.30	-.02	-.08	-.32
	5	34.89	-.24	.01	-.01	-.03	.11	.29
	6	35.02	-.44	-.76	-.68	-.80	-.80	-.53
	$\bar{X}$	34.38	-.03	.32	.38	-.01	.25	.45
	s	.79	.27	.86	.83	.89	.83	.91
	$s_{\bar{x}}$	.32	.11	.35	.34	.36	.34	.37
2.03	1	34.28	-.03	-.05	.51	.57	.45	.56
	2	33.24	.34	.51	.56	.59	.61	.66
	3	32.47	2.60	2.89	2.68	2.75	2.60	2.58
	4	34.75	.08	.20	.15	.31	.10	.15
	5	35.45	-.54	-.87	-.71	-.72	-.71	-.23
	6	34.10	-.32	-.35	.12	.92	.44	.92
	$\bar{X}$	34.05	.36	.39	.55	.74	.58	.77
	s	1.06	1.14	1.31	1.14	1.13	1.10	.97
	$s_{\bar{x}}$	.43	.47	.54	.46	.46	.45	.40
4.06	1	34.53	-.14	-.20	-.37	-.48	-.53	-.41
	2	34.27	.21	.33	.33	.31	.11	.14
	3	35.65	.05	.66	.45	.35	.40	.24
	4	34.85	.08	.12	.06	.21	-.19	.08
	5	35.42	-.64	-.74	-.84	-.84	-.80	-.75
	6	34.75	-1.07	-1.08	-1.40	-1.55	-1.38	-.84
	$\bar{X}$	34.91	.25	-.15	-.30	-.33	-.40	-.26
	s	.53	.50	.66	.72	.77	.65	.47
	$s_{\bar{x}}$	.22	.20	.27	.29	.31	.26	.19

Table 43. Skin Temperature for WBGT 31.1°C (M = 300 kcal/hr.)

Wind. Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}$ °C	Change in $\bar{T}_{sk}$ over 90 minutes					
.5	1		34.80	.08	.41	.37	.55	.63	.67
	2		33.96	.67	.88	1.05	1.14	1.04	1.22
	3		35.74	.50	.50	.48	.46	.46	.52
	4		34.84	.35	.48	.66	.64	.66	.77
	5		35.17	.01	.16	.13	.21	.25	.41
	6		35.05	.17	.23	.17	.25	.35	.22
		$\bar{X}$	34.93	.30	.44	.48	.54	.57	.64
		s	.58	.26	.25	.34	.34	.28	.35
		$s_{\bar{X}}$	.24	.10	.10	.14	.14	.11	.14
1.01	1		33.94	.76	.91	1.04	1.25	1.17	1.09
	2		34.21	.38	.65	.69	.82	.83	.79
	3		35.48	.62	.51	.40	.19	.24	.32
	4		35.68	.17	.23	.27	.45	.64	.55
	5		35.78	−.48	−.23	−.04	.00	.09	.09
	6		34.76	−.10	.23	.50	.75	.60	.82
		$\bar{X}$	34.98	.23	.38	.48	.58	.60	.61
		s	.79	.46	.40	.37	.46	.39	.36
		$s_{\bar{X}}$	.32	.19	.16	.15	.19	.16	.15
2.03	1		34.16	−.09	.41	.41	.36	.52	.84
	2		33.40	.57	1.18	.92	1.17	1.32	1.48
	3		35.20	.77	.53	.27	.64	.26	.84
	4		NO DATA						
	5		35.16	.33	.26	.21	.25	.22	.39
	6		35.19	−.29	−.13	−.29	−.01	.03	.40
		$\bar{X}$	34.62	.26	.45	.30	.48	.47	.79
		s	.81	.44	.48	.43	.45	.51	.45
		$s_{\bar{X}}$	.36	.20	.21	.19	.20	.23	.20
4.06	1		34.36	.29	.20	.12	.16	.28	.43
	2		33.62	.12	.15	.36	.64	.76	.79
	3		35.75	.50	.47	.37	.43	.43	.37
	4		35.22	.18	.37	.50	.69	.56	.66
	5		35.88	−.68	−.68	−.76	−.43	−.73	−.58
	6		35.28	−.33	−.05	−.25	−.05	−.23	−.32
		$\bar{X}$	35.02	.01	.08	.06	.24	.18	.33
		s	.87	.44	.41	.48	.43	.56	.48
		$s_{\bar{X}}$	.35	.18	.17	.20	.18	.23	.20

Table 44. Skin Temperature for WBGT 32.8 C (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	Subject		Initial $\bar{T}_{sk}{}^{\circ}C$	Change in $\bar{T}_{sk}$ over 90 minutes					
				15	30	45	60	75	90
.5	1		34.38	.98	1.25	1.40	1.50	1.56	1.53
	2		34.33	.75	.91	1.15	1.25	1.37	1.37
	3		35.97	.53	.41	.44	.44	.48	.39
	4		35.51	.61	1.02	1.15	1.15	1.11	.99
	5		35.12	.12	.23	.43	.86	.90	1.09
	6		35.05	.55	.94	.95	1.05	1.07	1.33
		$\bar{X}$	35.06	.59	.79	.92	1.04	1.08	1.12
		s	.64	.28	.39	.40	.36	.38	.41
		$s_{\bar{X}}$	.26	.12	.16	.16	.15	.15	.17
1.01	1		35.14	.61	.50	.64	.68	.78	.63
	2		33.80	.93	1.15	1.28	1.09	1.48	1.38
	3		35.59	.80	.45	.57	.57	.76	.54
	4		35.38	.98	.85	.91	1.19	.91	1.00
	5		35.90	-.23	-.22	-.06	.01	.14	.22
	6		35.12	.00	.01	.22	.38	.50	.50
		$\bar{X}$	35.16	.52	.46	.59	.65	.76	.71
		s	.73	.51	.51	.48	.44	.45	.41
		$s_{\bar{X}}$	.30	.21	.21	.19	.18	.18	.17
2.03	1		34.95	.13	.38	.67	.87	.79	1.04
	2		33.48	.99	1.40	1.60	1.79	1.92	2.27
	3		35.34	.81	.74	.74	.87	.86	.80
	4		34.78	.79	.97	1.19	1.34	1.30	1.32
	5		36.32	-.90	-.88	-.76	-.73	-.56	-.25
	6		35.60	-.33	-.24	-.21	-.11	-.35	-.45
		$\bar{X}$	35.08	.25	.40	.54	.67	.66	.94
		s	.95	.75	.84	.88	.93	.96	.85
		$s_{\bar{X}}$	.39	.31	.34	.36	.38	.39	.35
4.06	1		34.64	.08	.31	.43	.87	.73	.75
	2		33.34	.38	.63	.73	1.16	1.35	1.51
	3		35.93	.46	.30	-.11	-.31	-.35	-.35
	4		35.05	.64	.90	1.00	1.23	1.13	1.08
	5		35.35	-.07	.18	.27	.36	.37	.62
	6		34.95	-.24	.24	-.39	.53	.73	.87
		$\bar{X}$	34.88	.21	.43	.32	.64	.66	.75
		s	.87	.34	.28	.52	.58	.60	.62
		$s_{\bar{X}}$	.36	.14	.11	.21	.24	.25	.25

Table 45. Analysis of Variance Among Mean Values of Changes in Mean Skin Temperature for Metabolic Rate of 300 kcal/hr. (N = 6)

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	6.77	5	1.35	
Within Subjects				
A Trts. (WBGTs)	13.40	3	4.47	7.98[b]
A x S (Error)	8.39	15	.56	
B Trts. (Wind Vel.)	3.51	3	1.17	4.84[a]
B x S (Error)	3.63	15	.24	
A x B	1.96	9	.22	.80
A x B x S	12.32	45	.27	
Total	49.98	95		

[a] Significant at .05 level

[b] Significant at .01 level

Table 46. Mean Differences Among Measures of Changes in Mean Skin Temperature at Different WBGTs (M = 300 kcal/hr.)

WBGT	27.2°C ($\bar{X}$ = -.23)	28.9°C ($\bar{X}$ = .40)	31.1°C ($\bar{X}$ = .66)	32.8°C ($\bar{X}$ = .70)
27.2°C ($\bar{X}$ = -.23)	----			
28.9°C ($\bar{X}$ = .40)	.63[a]	----		
31.1°C ($\bar{X}$ = .66)	.89[b]	.26	----	
32.8°C ($\bar{X}$ = .70)	.93[b]	.30	.04	----

a
  Significant at .05 level
b
  Significant at .01 level

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Table 47. Mean Differences Among Measures of Changes in Mean Skin
Temperature at Different Wind Velocities (M = 300 kcal/hr.)

Wind Vel. m/sec	.5 m/sec. ($\bar{X}$ = .49)	1.01 m/sec. ($\bar{X}$ = .25)	2.03 m/sec. ($\bar{X}$ = .64)	4.06 m/sec. ($\bar{X}$ = .16)
.5 ($\bar{X}$ = .49)	----			
1.01 ($\bar{X}$ = .25)	.24	----		
2.03 ($\bar{X}$ = .64)	.15	.39	----	
4.06 ($\bar{X}$ = .16)	.33	.09	.48[a]	----

a
  Significant at .05 level

Table 48. Rate of Evaporation (g/m^2/hr) for Metabolic Rate of 300 kcal/hr.

Experimental Condition	Subject	Wind Velocity (meters/sec.)			
		0.5	1.01	2.03	4.06
WBGT					
27.2°C	1	146	231	245	251
	2	216	185	227	207
	3	174	177	138	197
	4	280	206	244	211
	5	235	234	234	249
	6	296	220	303	252
	$\overline{X}$	225	209	232	228
	s	58	24	53	26
	$s_{\overline{x}}$	24	10	22	10
28.9°C	1	293	308	300	295
	2	291	291	282	260
	3	213	227	154	245
	4	316	312	297	328
	5	236	336	307	260
	6	329	324	339	340
	$\overline{X}$	280	300	280	288
	s	46	39	64	39
	$s_{\overline{x}}$	19	16	26	16
31.1°C	1	396	352	381	399
	2	332	338	366	357
	3	154	172	315	279
	4	286	366	----	363
	5	407	386	379	432
	6	416	392	450	440
	$\overline{X}$	332	334	378	378
	s	100	82	48	60
	$s_{\overline{x}}$	41	33	22	24
32.8°C	1	458	425	458	504
	2	366	398	376	449
	3	371	263	364	358
	4	410	385	480	455
	5	429	461	498	567
	6	513	511	503	522
	$\overline{X}$	424	407	446	476
	s	56	84	61	72
	$s_{\overline{x}}$	23	34	25	30

Table 49. Analysis of Variance Among Mean Values of Evaporation Rates $(g/m^2/hr.)$ for Metabolic Rate of 300 kcal/hr. (N = 6)

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	174002.80	5	34800.57	
Within Subjects				
A Trts. (WBGTs)	583800.80	3	194600.30	130.08[a]
A x S (Error)	22440.27	15	1496.02	
B Trts. (Wind)	13090.18	3	4363.39	8.41[a]
B x S (Error)	7785.14	15	519.01	
A x B	13899.96	9	1544.44	1.18
A x B x S	58725.26	45	1305.01	
Total	873744.41	95		

[a] Significant at .01 level

Table 50. Mean Differences Among Measures of Evaporation Rates at Different WBGTs (M = 300 kcal/hr.)

WBGT	27.2°C ($\bar{X}$ = 224.54)	28.9°C ($\bar{X}$ = 287.59)	31.1°C ($\bar{X}$ = 357.24)	32.8°C ($\bar{X}$ = 433.61)
27.2°C ($\bar{X}$ = 224.54)	----			
28.9°C ($\bar{X}$ = 287.59)	63.05[a]	----		
31.1°C ($\bar{X}$ = 357.24)	132.70[a]	69.65[a]	----	
32.8°C ($\bar{X}$ = 433.61)	209.07[a]	146.02[a]	76.37[a]	----

[a] Significant at .01 level

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Table 51. Mean Differences Among Measures of Evaporation Rates at Different Wind Velocities (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	.5 (X = 312.18)	1.01 (X = 316.70)	2.03 (X = 333.58)	4.06 (X = 340.52)
.5 ($\bar{X}$ = 312.18)	----			
1.01 ($\bar{X}$ = 316.70)	4.52	----		
2.03 ($\bar{X}$ = 333.58)	21.40[a]	16.88	----	
4.06 ($\bar{X}$ = 340.52)	28.34[b]	23.82[a]	6.94	----

[a] Significant at .05 level

[b] Significant at .01 level

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Table 52. Rate of Sweating (g/m^2/hr.) for Metabolic Rate of 300 kcal/hr.)

Experimental Condition	Subject	Wind Velocity (meters/sec.)			
		0.5	1.01	2.03	4.06
WBGT					
27.2°C	1	284	339	390	288
	2	320	548	380	385
	3	222	238	222	213
	4	406	286	324	295
	5	250	327	289	368
	6	427	274	384	284
	$\overline{X}$	318	335	331	306
	s	83	110	67	62
	$s_{\overline{x}}$	34	45	27	26
28.9°C	1	513	403	366	339
	2	482	451	316	372
	3	320	279	312	409
	4	469	354	366	389
	5	336	392	354	369
	6	493	402	349	357
	$\overline{X}$	435	380	344	372
	s	84	58	24	24
	$s_{\overline{x}}$	34	24	10	10
31.1°C	1	586	586	586	494
	2	529	477	407	448
	3	250	296	419	315
	4	461	533	----	504
	5	566	648	44	483
	6	546	454	504	551
	$\overline{X}$	489	449	472	466
	s	125	110	74	81
	$s_{\overline{x}}$	51	45	33	33
32.8°C	1	659	668	718	668
	2	579	710	454	681
	3	542	361	443	427
	4	463	476	644	585
	5	561	592	552	699
	6	640	624	556	530
	$\overline{X}$	574	572	561	598
	s	71	130	107	106
	$s_{\overline{x}}$	29	53	44	43

Table 53. Analysis of Variance Among Mean Values of Sweating Rates $(g/m^2/hr.)$ for Metabolic Rate of 300 kcal/hr. (N = 6)

Source of Variation	Sums of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	238692.20	5	47738.44	
Within Subjects				
A Trts. (WBGTs)	711209.10	3	237069.70	22.56[a]
A x S (Error)	157660.10	15	10510.68	
B Trts (Wind Vel.)	6393.72	3	2131.24	.47
B x S (Error)	68197.18	15	4546.48	
A x B	35629.88	9	3958.88	.93
A x B x S	191107.10	45	4246.82	
Total	1408889.28	95		

a
Significant at .01 level

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Table 54. Mean Increase in Rectal Temperature over 120 Minutes Exposure for Two Subjects

WBGT °C	Wind Velocity $m \cdot s^{-1}$			
	0.5	1.01	2.03	4.06
27.2	0.46	0.28	0.22	·0.30
28.9	0.35	0.40	0.28	0.40
31.1	0.69	0.83	0.70	0.41
32.8	1.00	0.80	0.52	0.88

Table 55. Mean Increase in Heart Rates over 120 Minutes Exposure for Two Subjects

WBGT °C	Wind Velocity $m \cdot s^{-1}$			
	0.5	1.01	2.03	4.06
27.2	38.5	36.0	25.5	41.5
28.9	38.0	24.0	43.0	27.0
31.1	58.0	48.5	45.5	29.5
32.8	65.0	46.4	53.0	52.0

Table 56. Increase in Mean Skin Temperature over 120 Minutes Averaged for Two Subjects

WBGT °C	Wind Velocity $m \cdot s^{-1}$			
	0.5	1.01	2.03	4.06
27.2	0.14	0.60	0.30	0.52
28.9	0.57	−0.08	0.90	−0.56
31.1	0.30	1.02	0.80	−0.08
32.8	1.31	0.40	0.38	0.74

Table 57. Evaporation Rates (g/m^2/hr^1)   During 120 Minutes Averaged for Two Subjects

WBGT °C	Wind Velocity m·s^{-1}			
	0.5	1.01	2.03	4.06
27.2	266	229	270	253
28.9	282	330	323	299
31.1	413	389	414	437
32.8	471	488	501	546

Table 58. Sweating Rates (g/m^2/hr^1)   During 120 Minutes Averaged for Two Subjects

WBGT °C	Wind Velocity m·s^{-1}			
	0.5	1.01	2.03	4.06
27.2	340	300	338	326
28.9	416	397	351	362
31.1	557	551	474	519
32.8	600	608	555	614

Table 59. Mean Differences Among Measures of Sweating Rates
at Different WBGTs (M = 300 kcal/hr.)

WBGT	27.2°C ($\bar{X}$ = 308.98)	28.9°C ($\bar{X}$ = 380.16)	31.1°C ($\bar{X}$ = 476.57)	32.8°C ($\bar{X}$ = 532.25)
27.2°C ($\bar{X}$ = 308.98)	----			
28.9°C ($\bar{X}$ = 380.16)	71.18	----		
31.1°C ($\bar{X}$ = 476.57)	167.59[b]	96.41[a]	----	
32.8°C ($\bar{X}$ = 532.25)	223.27[b]	152.09[b]	55.68	----

[a] Significant at .05 level

[b] Significant at .01 level

Table 60.   Ratio of Evaporation ($g/m^2/hr$) to Sweating Rate ($g/m^2/hr$) at a Metabolic Rate of 200 kcal/hr.

Experimental Condition	Subject		Wind Velocity (m/sec.)			
			0.5	1.01	2.03	4.06
WBGT						
28.9	1		.67	.79	.75	.56
	2		.74	.64	.80	.68
	3		.68	.78	.84	.67
	4		.59	.71	.44	.51
		$\overline{X}$	.67	.73	.71	.61
		SD	.06	.07	.18	.08
		$S_{\overline{x}}$	.03	.03	.09	.04
31.1	1		.80	.86	.82	.83
	2		.67	.72	.85	.68
	3		.78	.72	.80	.99
	4		.70	.67	.63	.71
		$\overline{X}$	.74	.74	.78	.8
		S	.06	.08	.1	.14
		$S_{\overline{x}}$	.03	.04	.05	.07
32.8	1		.70	.84	.90	.78
	2		.80	.74	.64	.77
	3		.88	.67	.97	.88
	4		.85	.70	.62	.80
		$\overline{X}$	.81	.74	.78	.81
		S	.08	.07	.18	.05
		$S_{\overline{x}}$	.04	.04	.09	.02
34.4	1		.51	.78	.99	.88
	2		.65	.78	.81	.57
	3		.74	.71	.70	.74
	4		.62	.61	.66	.99
		$\overline{X}$	.63	.72	.79	.8
		S	.09	.08	.15	.18
		$S_{\overline{x}}$	.05	.04	.07	.09

Table 61. Analysis of Variance Among Mean Values of the Ratio of Evaporation Rate to Sweating Rate for a Metabolic Rate of 200 kcal/hr. (N = 4)

Source of Variation	Sum of Squares	df	Mean Square	F
Between Subjects				
Subject (S)	.12746	3		
Within Subjects				
A Trts. (WBGTs)	.10201	3	.03400	4.653[a]
A x S (Error)	.06578	9	.00731	
B Trts. (Wind)	.02565	3	.00855	0.469
B x S (Error)	.16424	9	.01825	
A x B	.10584	9	.01176	1.229
A x B x S	.25842	27	.00957	
Total	0.84940			

[a] Significant at .03 level

Table 62. Ratio of Evaporation (g/m^2/hr) to Sweating Rate (g/m^2/hr) at a Metabolic Rate of 300 kcal/hr.

Experimental Condition	Subject		Wind Velocity (meters/sec.)			
			0.5	1.01	2.03	4.06
WBGT						
27.2	1		.52	.68	.62	.87
	2		.33	.55	.60	.54
	3		.78	.74	.62	.92
	4		.69	.72	.75	.72
	5		.94	.72	.81	.68
	6		.69	.80	.79	.89
		$\overline{X}$	.715	.702	.707	.77
		s	.139	.084	.089	.149
		$s_{\overline{x}}$	.057	.034	.036	.061
28.9	1		.57	.76	.82	.87
	2		.60	.64	.89	.70
	3		.67	.81	.50	.60
	4		.67	.88	.81	.84
	5		.70	.86	.86	.70
	6		.67	.80	.96	.95
		$\overline{X}$	.647	.792	.807	.777
		s	.05	.086	.16	.131
		$s_{\overline{x}}$	.02	.035	.065	.053
31.1	1		.68	.60	.65	.81
	2		.63	.71	.88	.80
	3		.62	.58	.75	.88
	4		.62	.68	---	.72
	5		.72	.60	.85	.89
	6		.76	.86	.89	.80
		$\overline{X}$	.678	.72	.83	.835
		s	.054	.12	.102	.093
		$s_{\overline{x}}$	.022	.049	.045	.038
32.8	1		.69	.64	.64	.75
	2		.63	.56	.83	.66
	3		.68	.73	.82	.84
	4		.88	.81	.71	.78
	5		.76	.77	.90	.81
	6		.80	.81	.90	.98
		$\overline{X}$	.74	.72	.8	.803
		s	.091	.101	.105	.106
		$s_{\overline{x}}$	.037	.041	.043	.043

Table 63. Analysis of Variance Among Mean Values of the Ratio of Evaporation Rate to Sweating Rate for a Metabolic Rate of 300 kcal/hr. (N = 6)

Source of Variation	Sum of Squares	df	Mean Square	F
Between Subjects				
Subjects (S)	0.30334	5	.06067	
Within Subjects				
A Trts. (WBGTs)	0.04057	3	.01352	1.004
A x S (Error)	0.20203	15	.01347	
B Trts. (Wind)	0.18592	3	.06197	4.803[a]
B x S (Error)	0.19352	15	.01290	
A x B	0.09490	9	.01054	1.542
A x B x S	0.30780	45	.00684	
Total	1.32808			

[a] Significant at .015 level

Table 64. Mean Differences Among Measures of the Ratio of Evaporation to Sweating Rate at Different Wind Velocities (M = 300 kcal/hr.)

Wind Vel. (m/sec.)	.5 ($\overline{X}$ = 0.695)	1.01 ($\overline{X}$ = .733)	2.03 ($\overline{X}$ = .786)	4.06 ($\overline{X}$ = .796)
.5 ($\overline{X}$ = 0.695)				
1.01 ($\overline{X}$ = .733)	0.042			
2.03 ($\overline{X}$ = .786)	0.093	0.051		
4.06 ($\overline{X}$ = .796)	0.112[a]	0.070	0.020	

[a] Significant at .05 level

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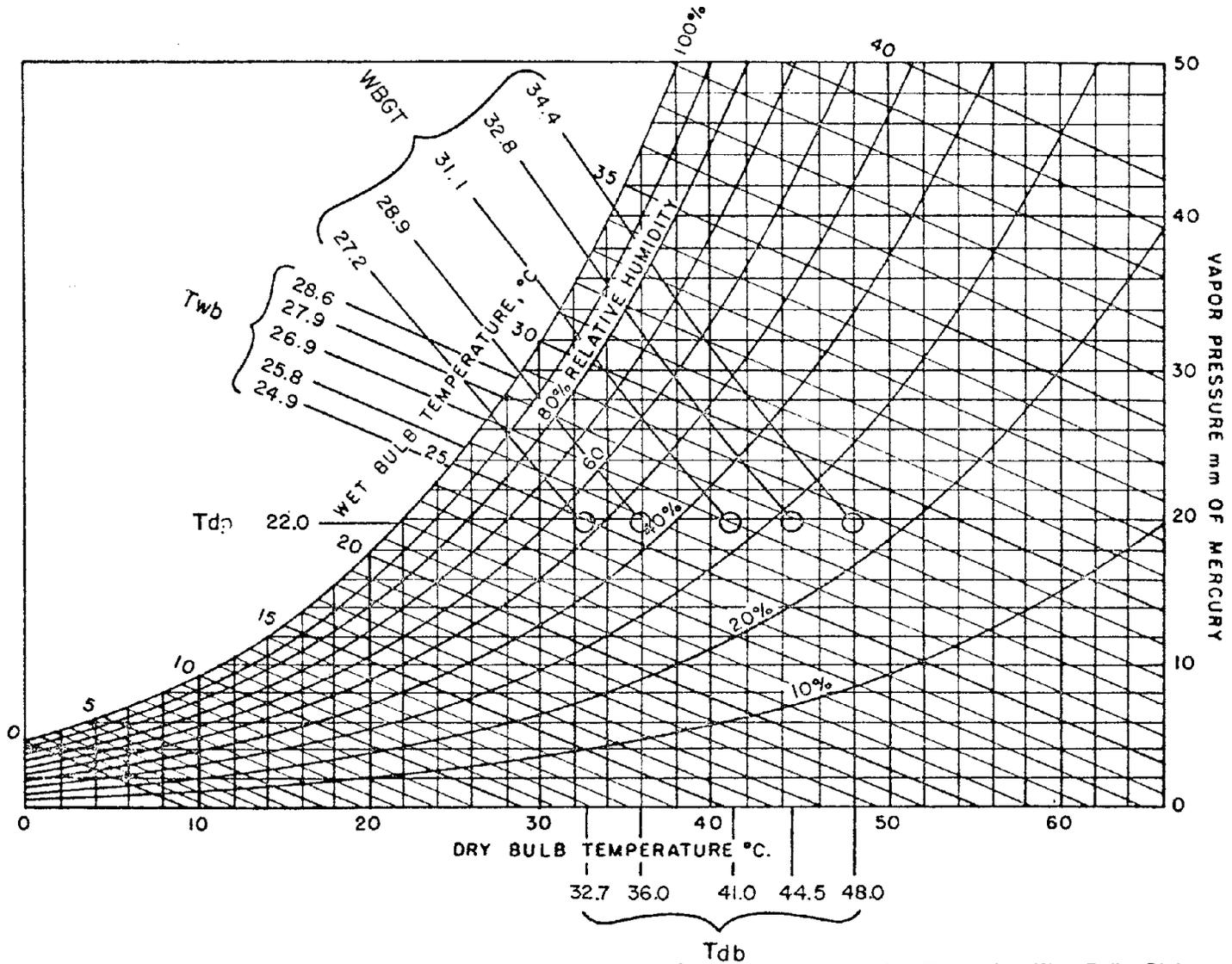
Figure 1. The Dry Bulb (T_{db}) and Wet Bulb (T_{wb}) Temperatures Utilized to Achieve the Respective Wet Bulb Globe Temperature (WBGT) Values. Vapor Pressure and Dew Point Temperature were Maintained Relatively Constant.
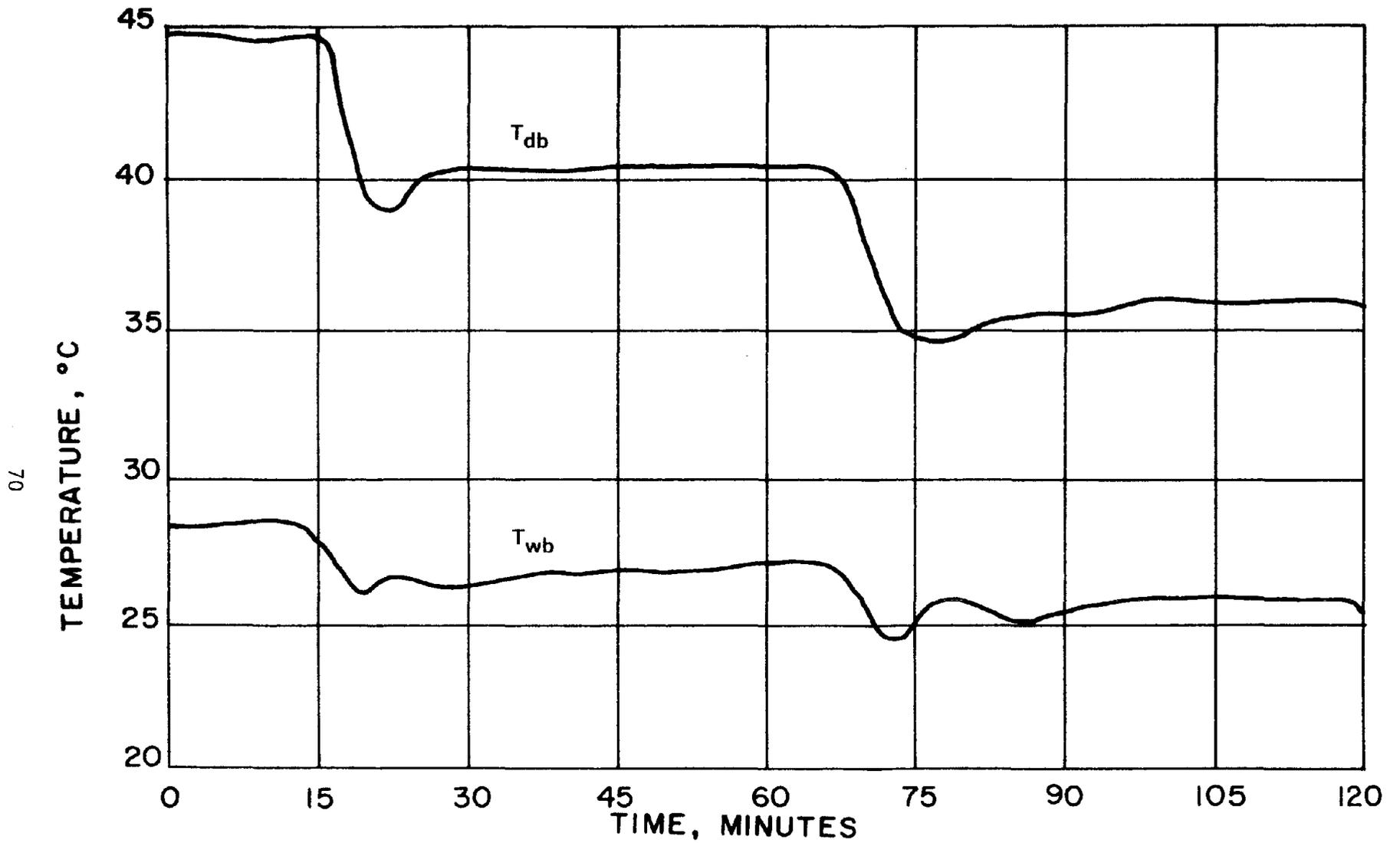
Figure 2. Dry Bulb (T_{db}) and Wet Bulb (T_{wb}) Temperatures Recording
Showing Response to Step Change and Long—Term Stability

WIND TUNNEL CALIBRATION

AIR VELOCITY vs. HEIGHT ABOVE TREADMILL
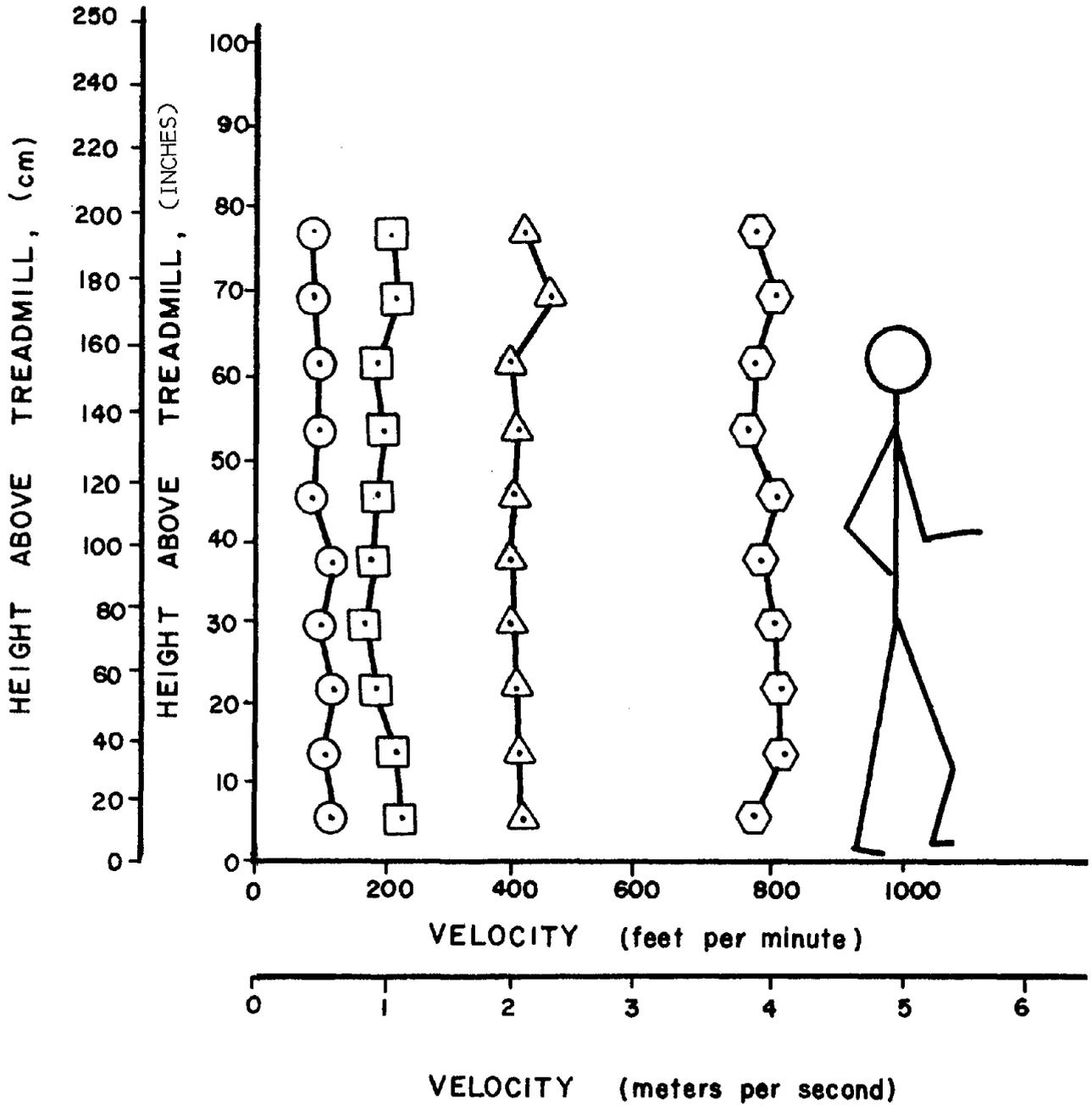
Figure 3. Air Velocity at Different Heights Above Treadmill.
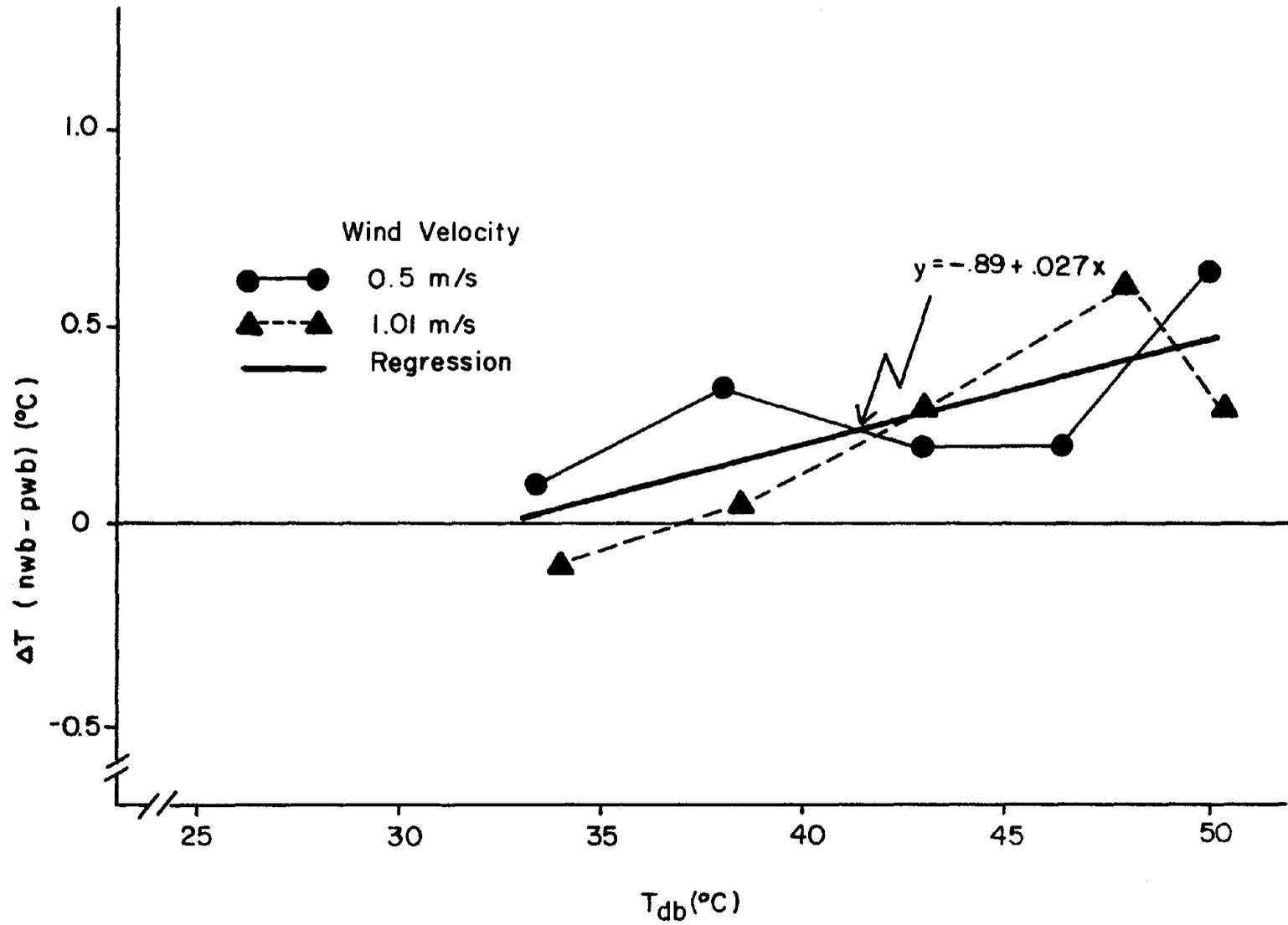
Figure 4 . The relationship between dry bulb temperature (T_{db}) and the difference between natural wet bulb and aspirated wet bulb temperatures. (ΔT).

Change in Rectal Temperature (Degrees Centigrade)

Wind Velocity (m/sec)

1 = 0.5
2 = 1.01
3 = 2.03
4 = 4.06

— — — — Rest period

——————— Work period

Time (Minutes)
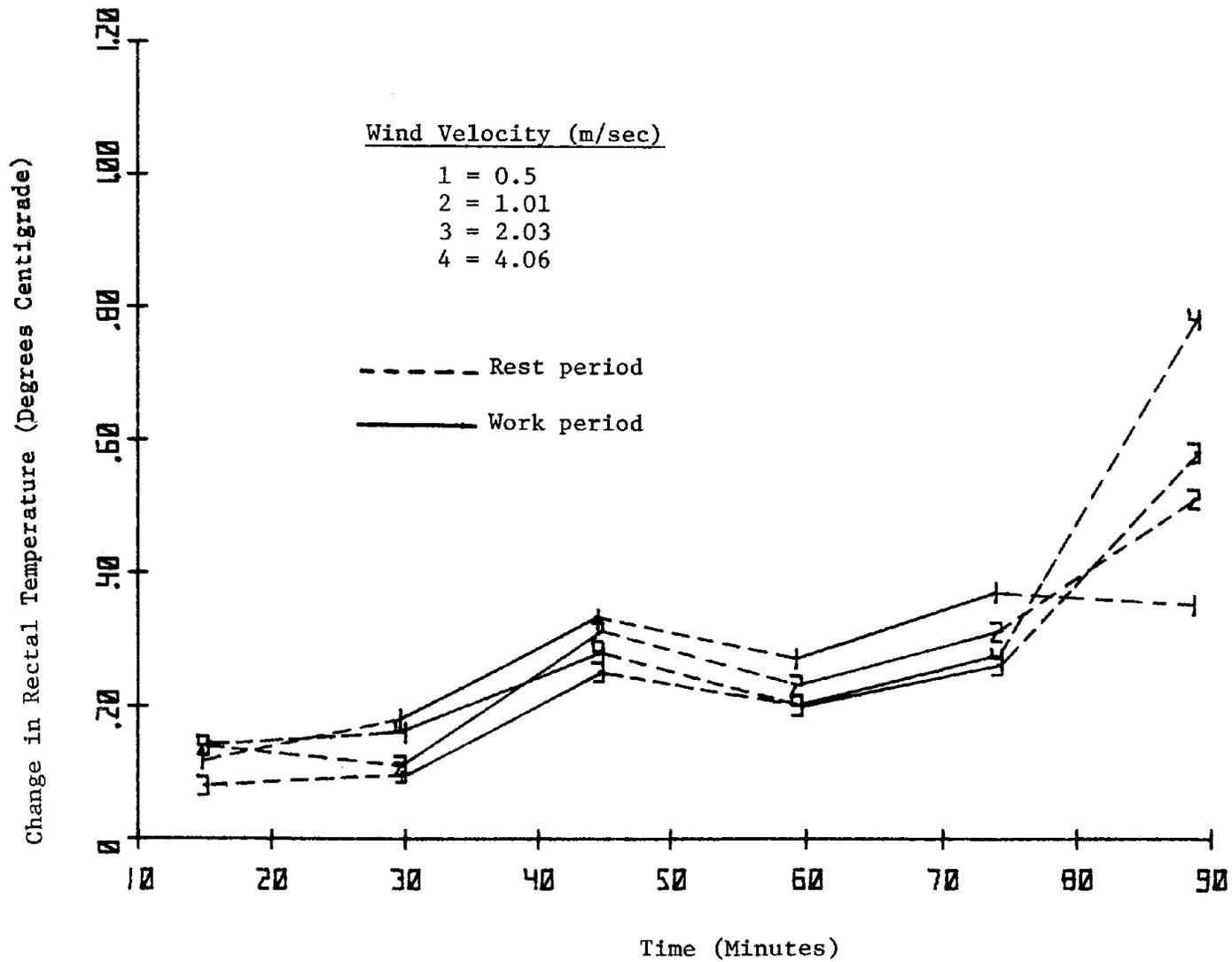
Figure 5 . Time course of rectal temperature changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 200 kcal/hr. (N = 4)
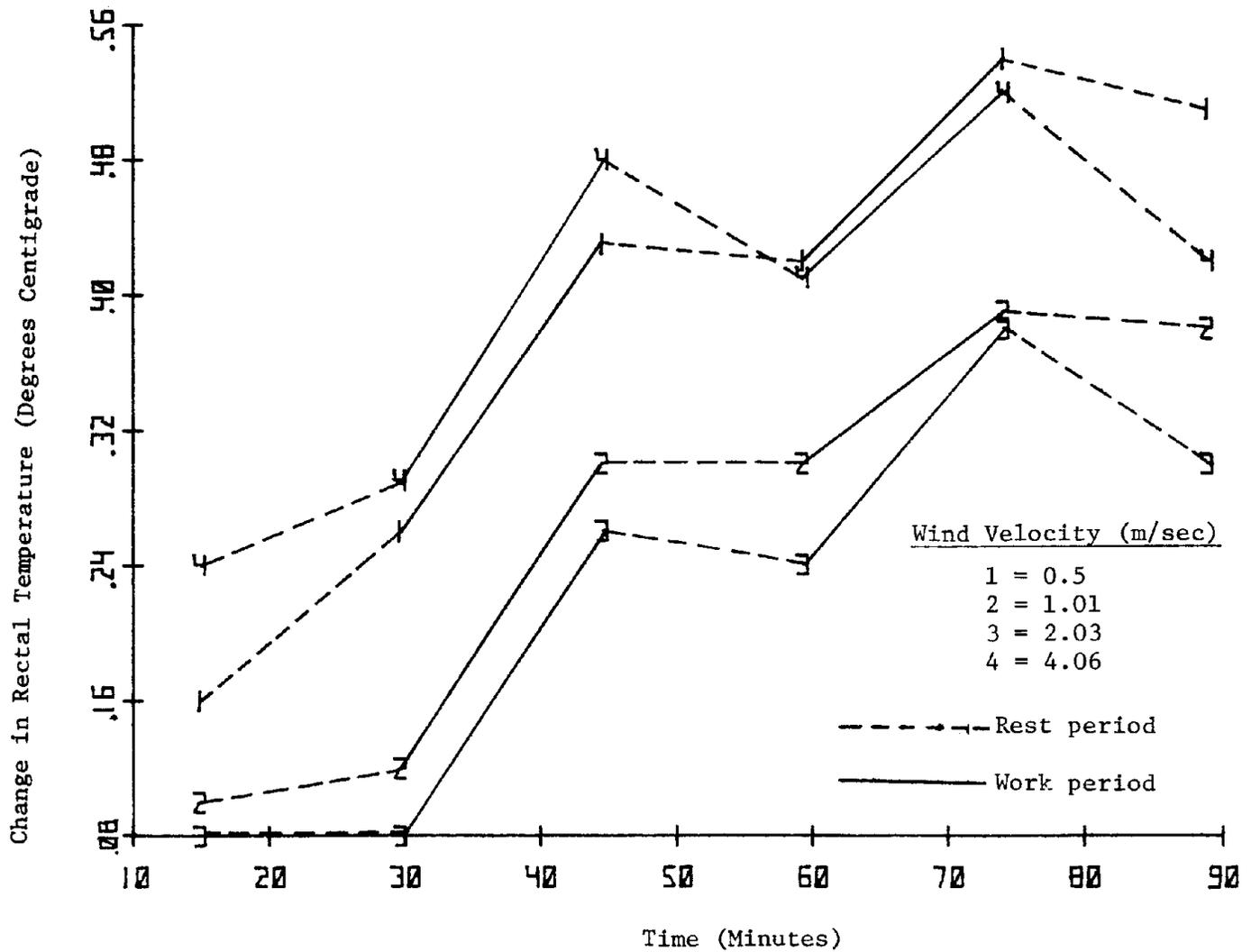
Figure 6 . Time course of rectal temperature changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 200 kcal/hr. (N = 4)

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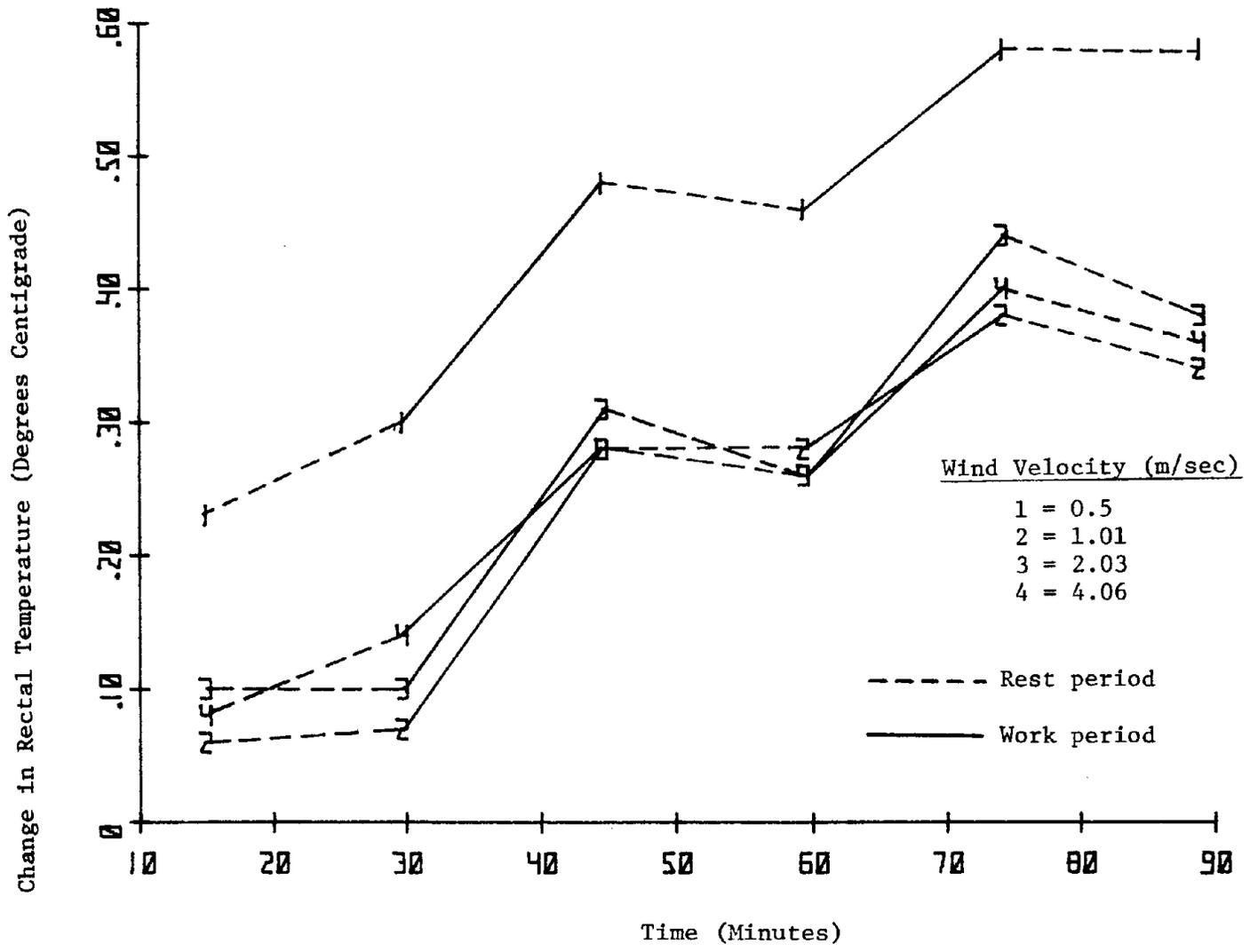
Figure 7 . Time course of rectal temperature changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 200 kcal/hr. (N = 4)
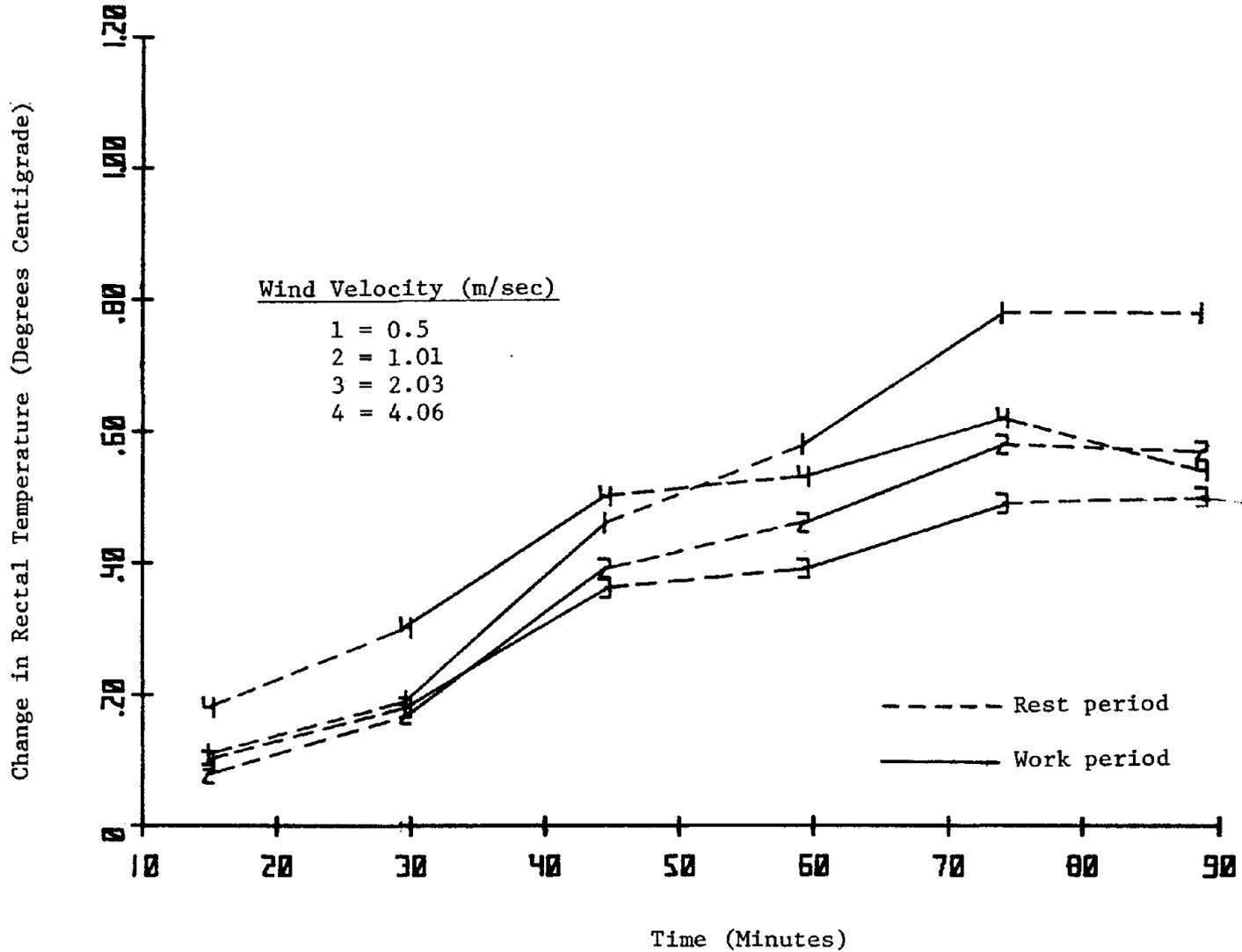
Figure 8 . Time course of rectal temperature changes as a function of wind velocity for WBGT 34.4°C and metabolic rate of 200 kcal/hr. (N = 4)
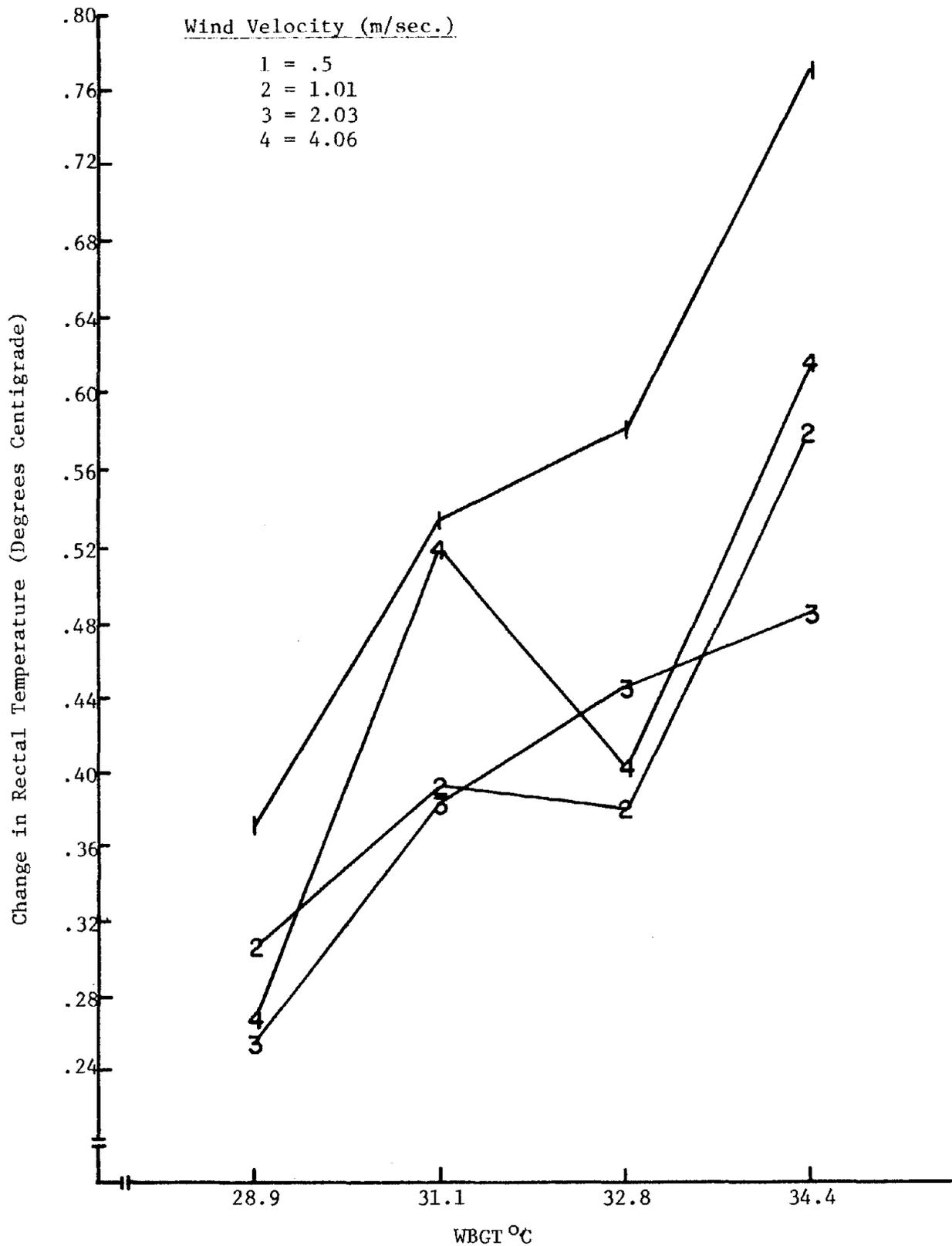
Figure 9 . Change in rectal temperature as a function of WBGT for different wind velocities (M = 200 kcal/hr). Mean values for 4 subjects.
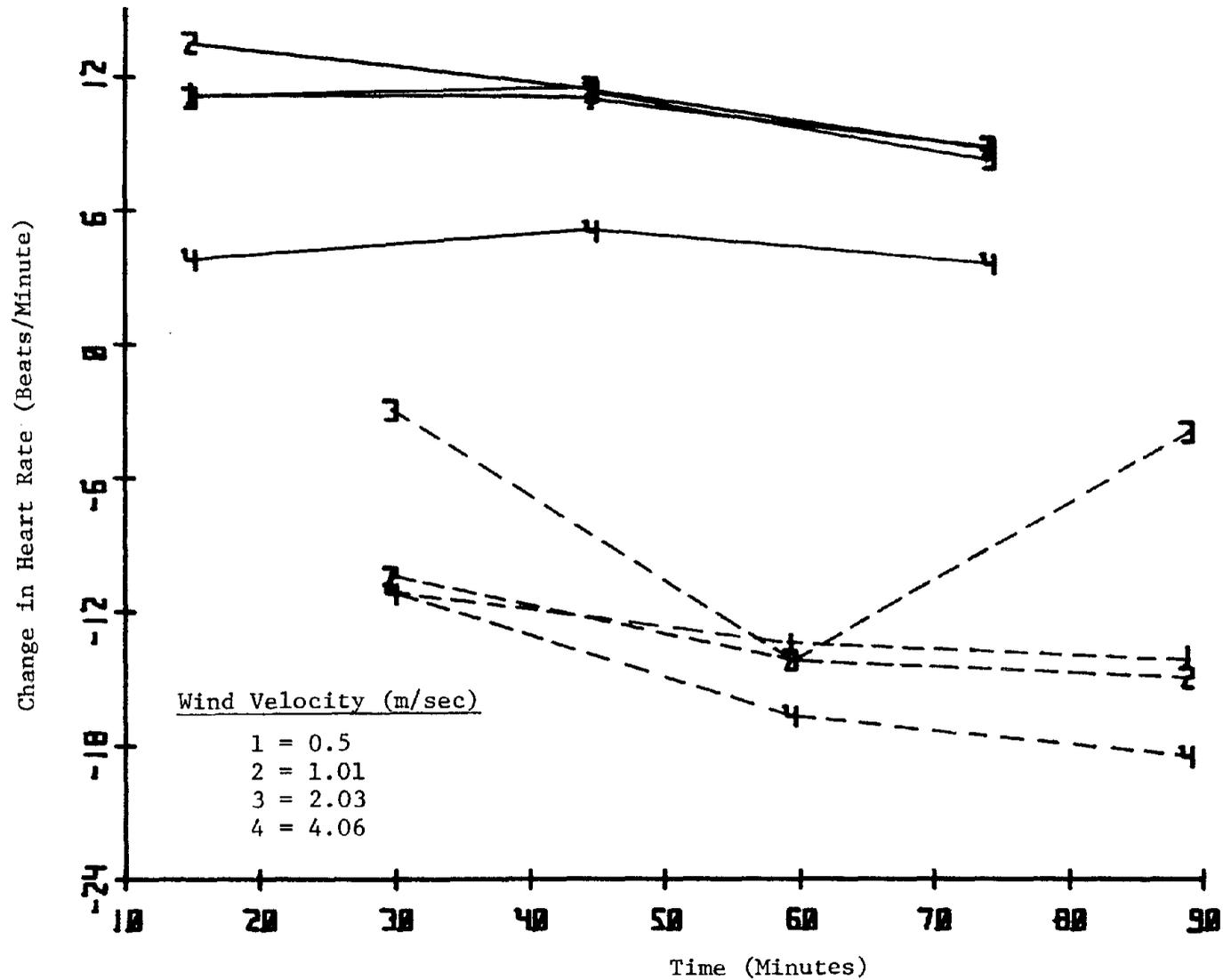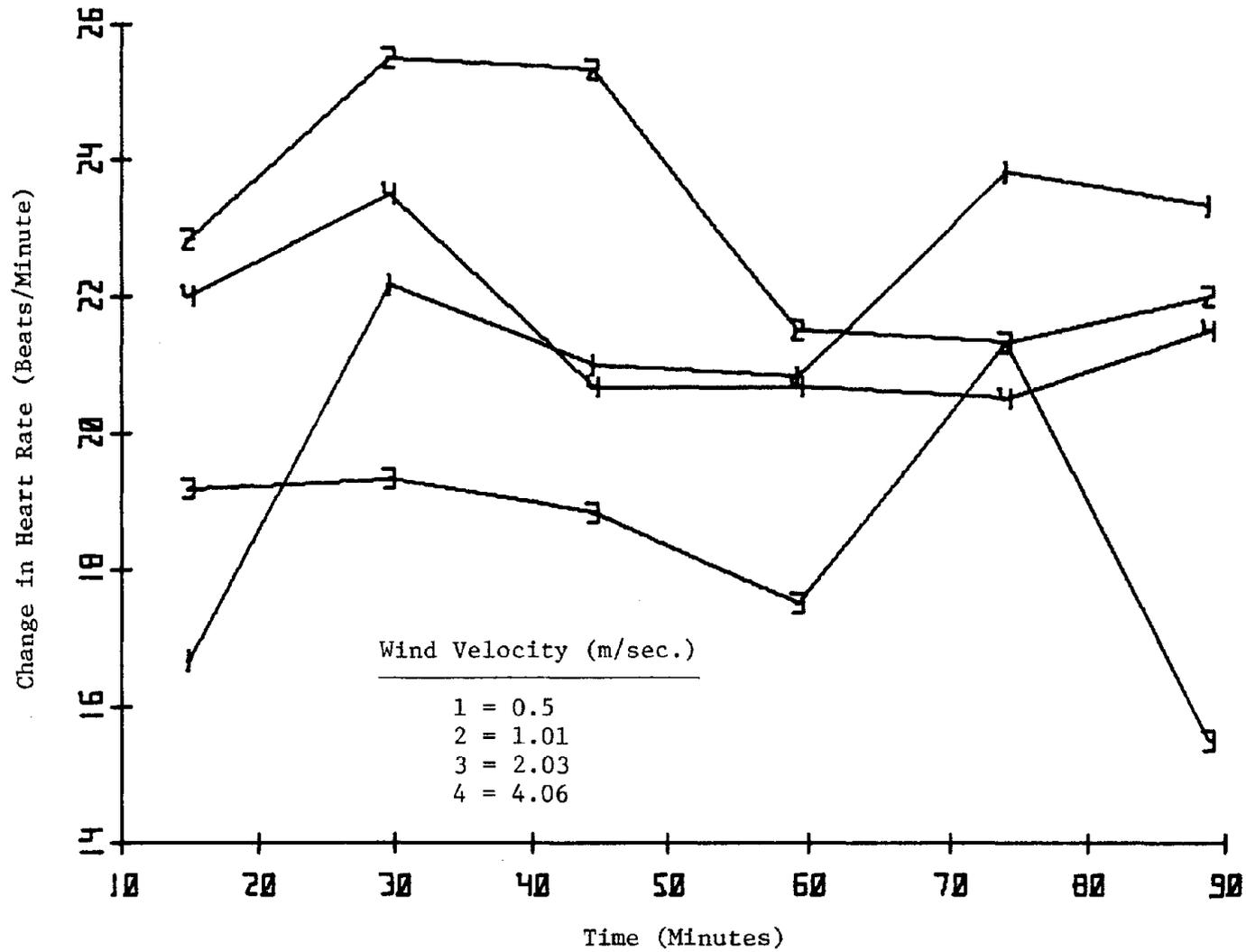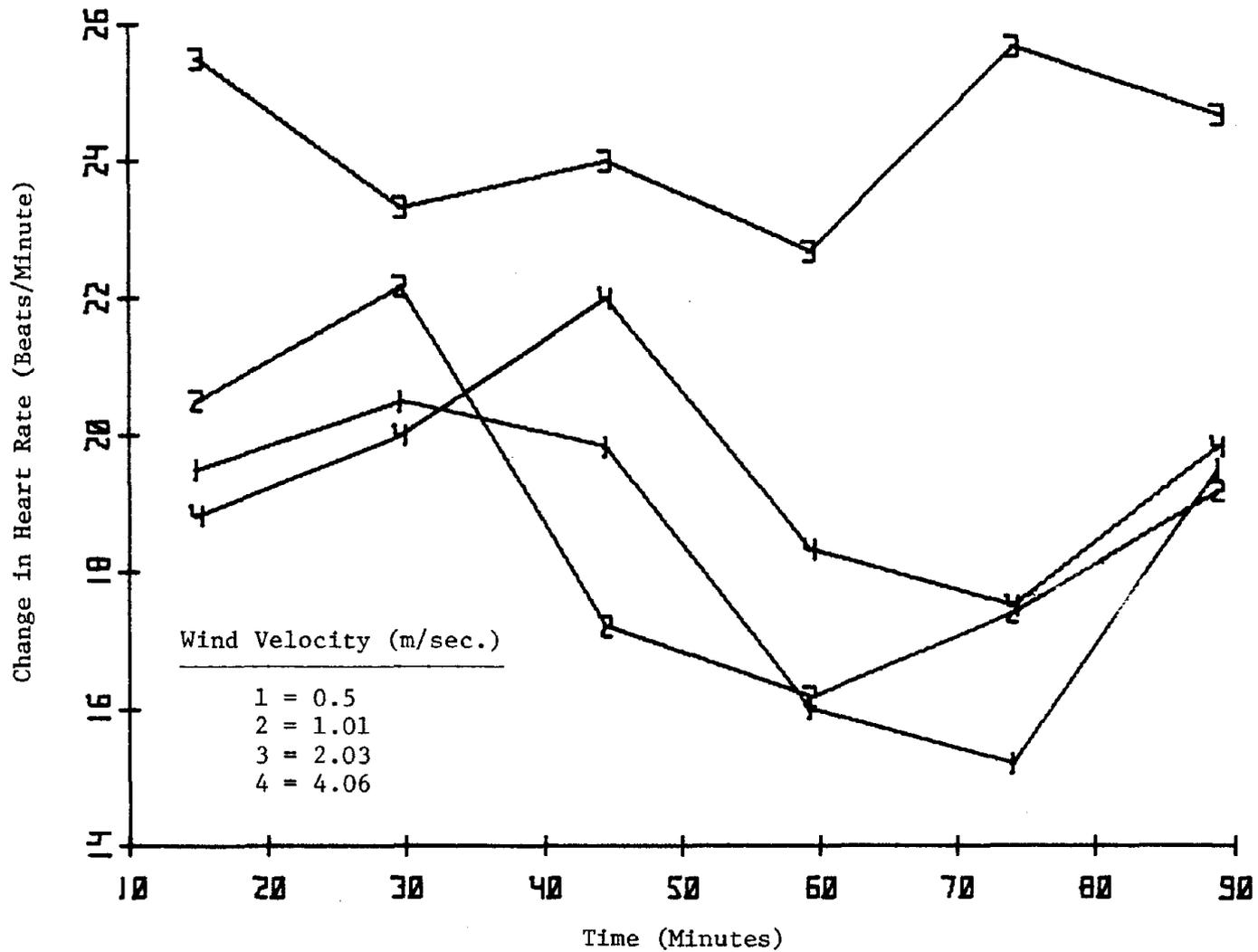
Figure 10. Time course of heart rate changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 200 kcal/hr. (N = 4)
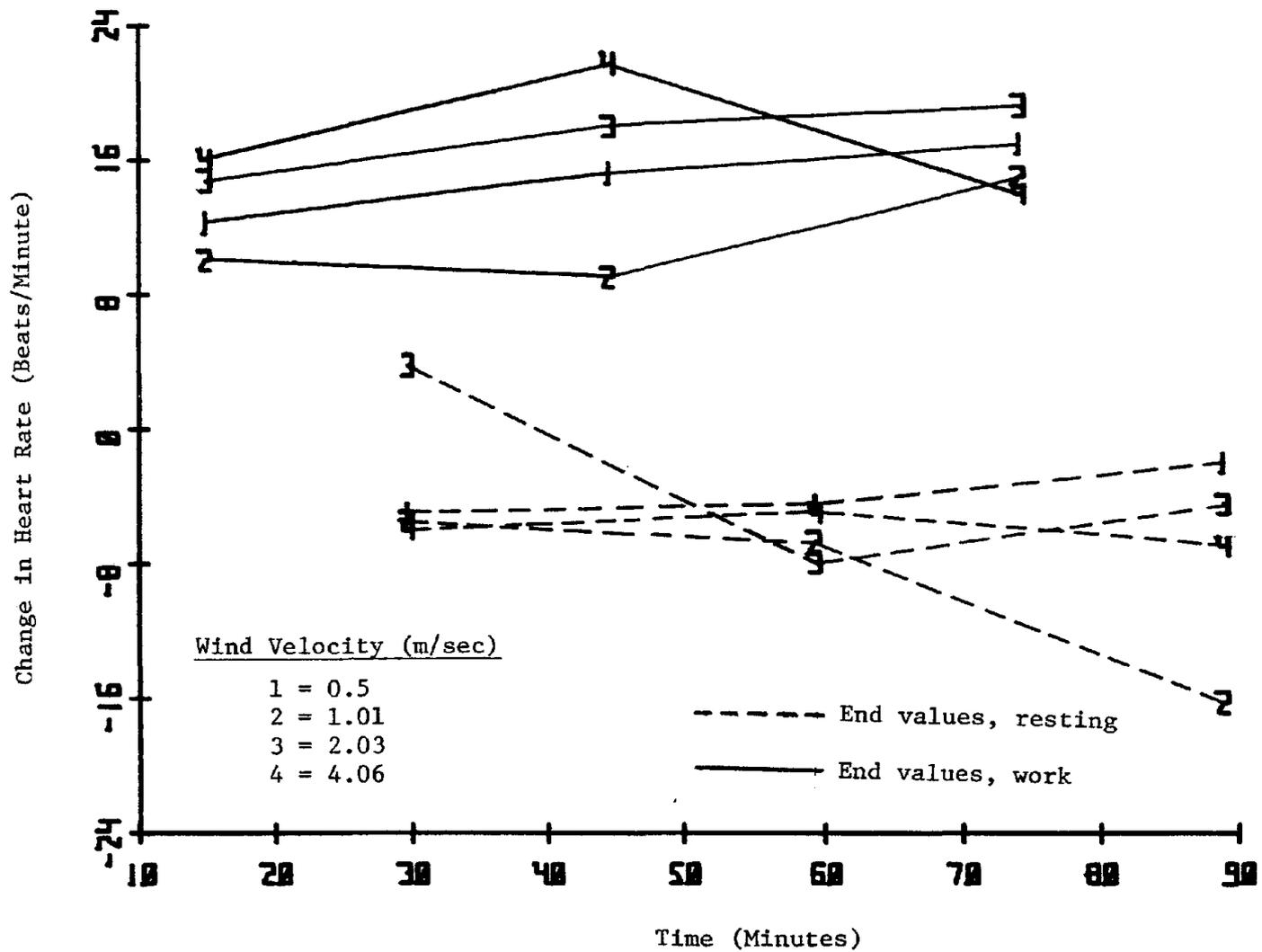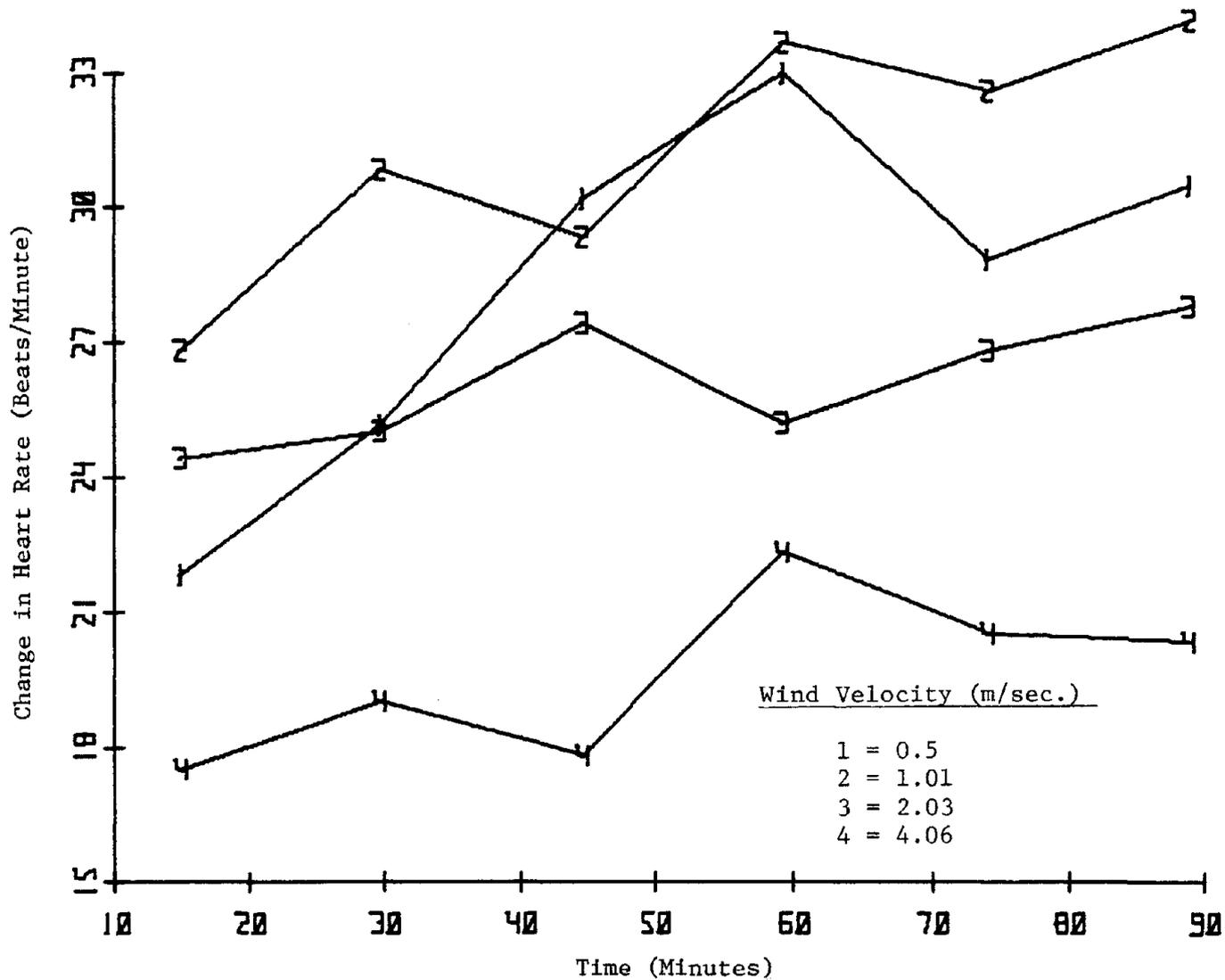
Figure 11. Time course of heart rate changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 200 kcal/hr. (N = 4)
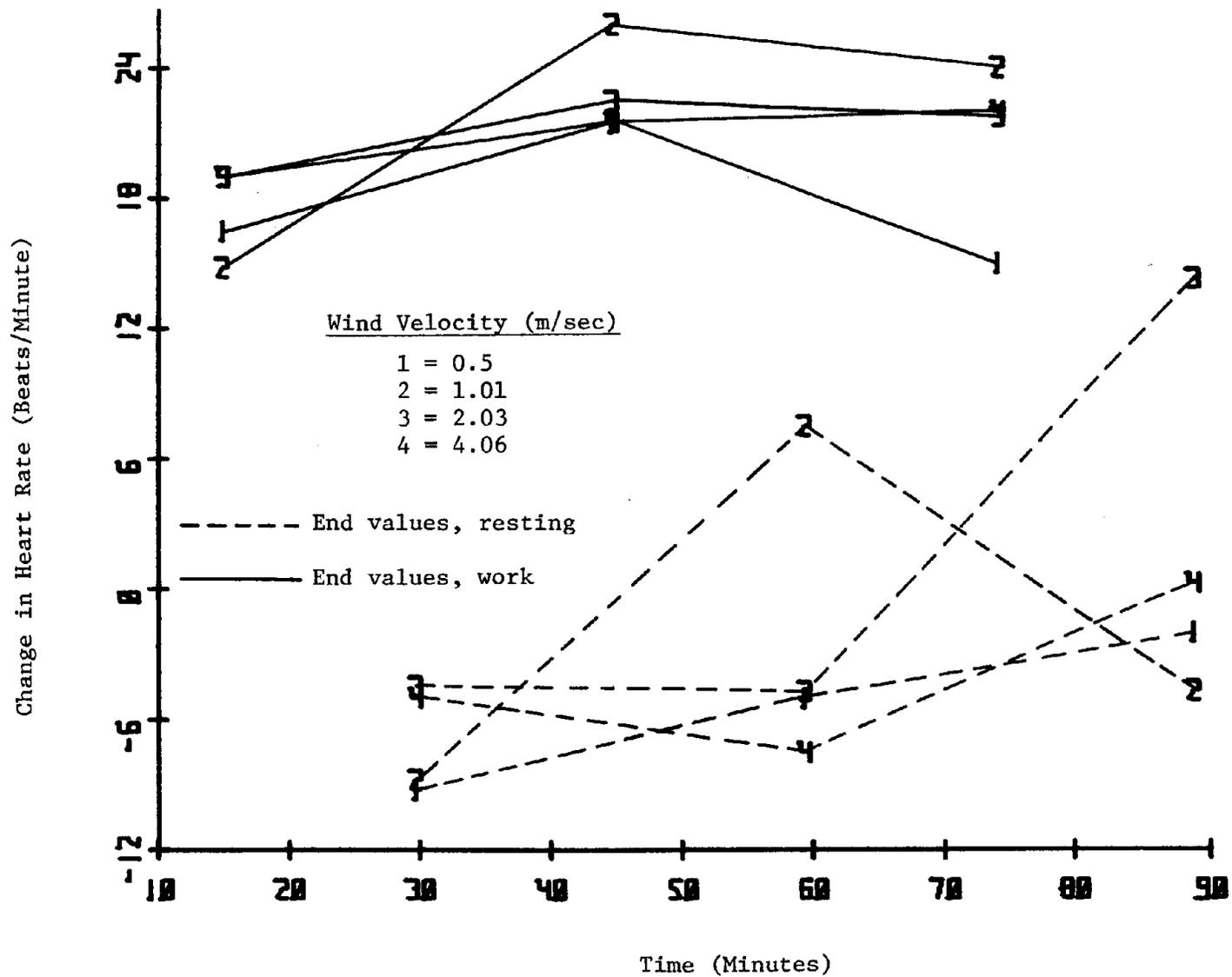
Figure 12. Time course of heart rate changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 200 kcal/hr. (N = 4)
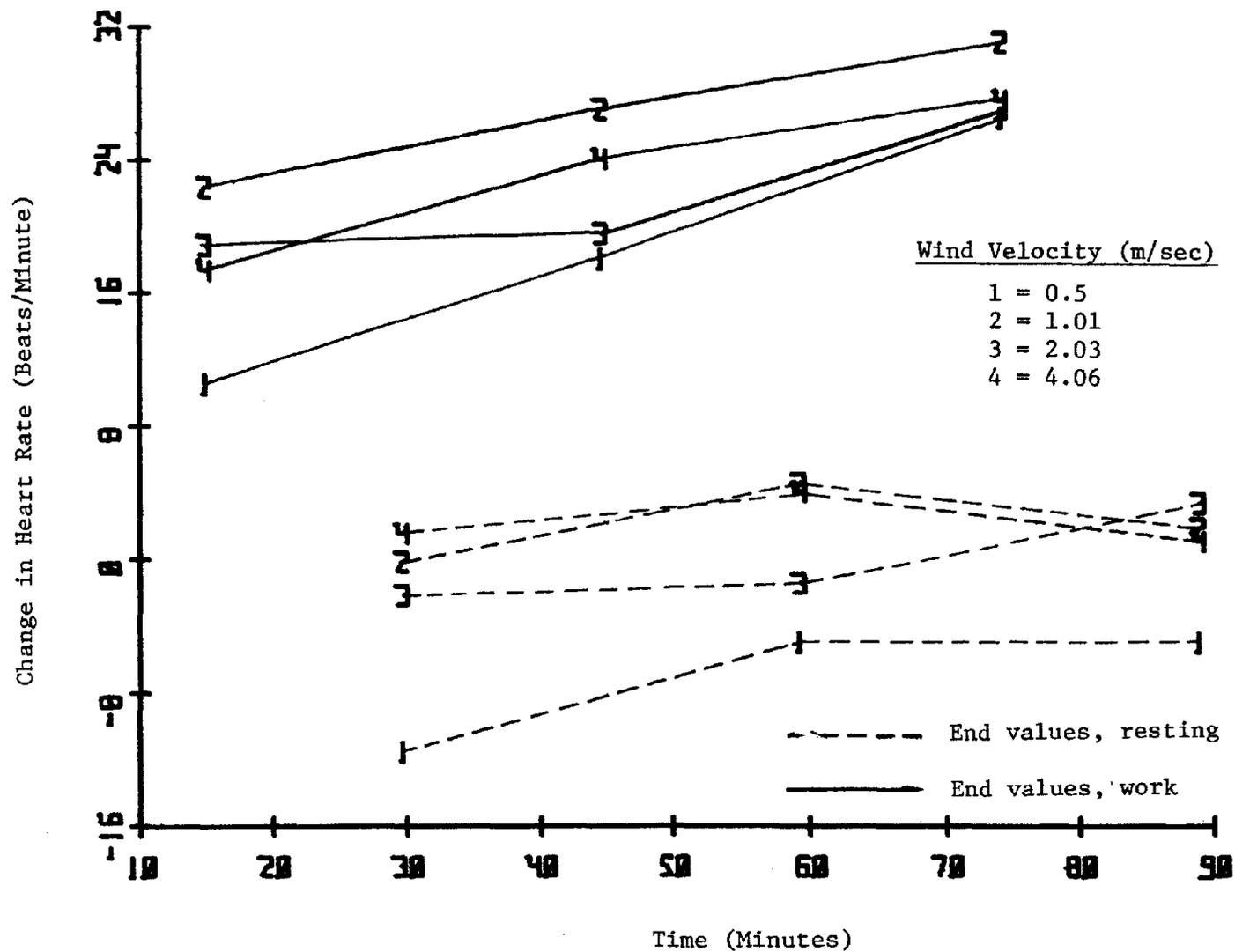
Figure 13. Time course of heart rate changes as a function of wind velocity for WBGT 34.4°C and metabolic rate of 200 kcal/hr. (N = 4)
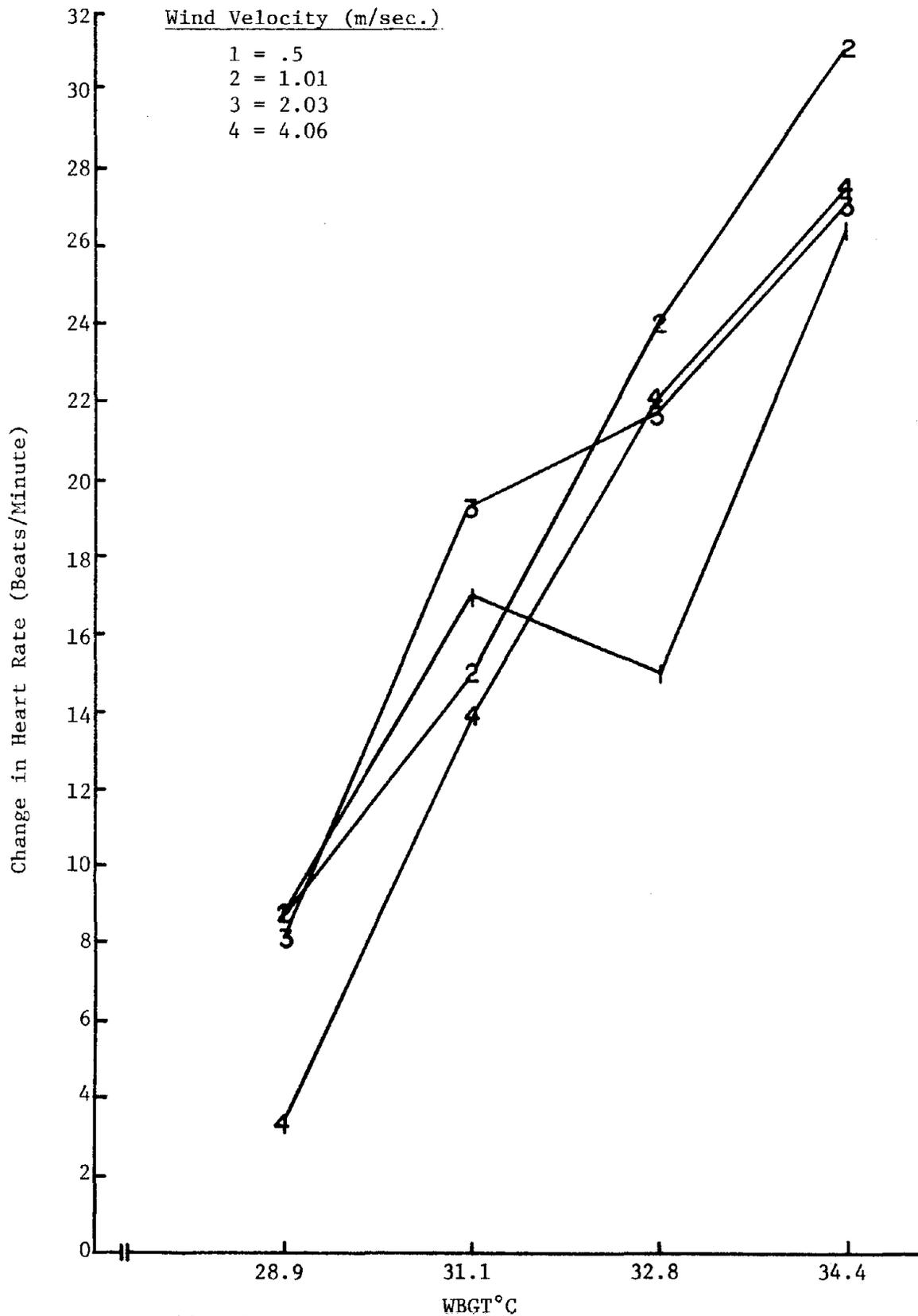
Figure 14. Change in heart rate as a function of WBGT for different wind velocities (M = 200 kcal/hr). Mean values for 4 subjects.
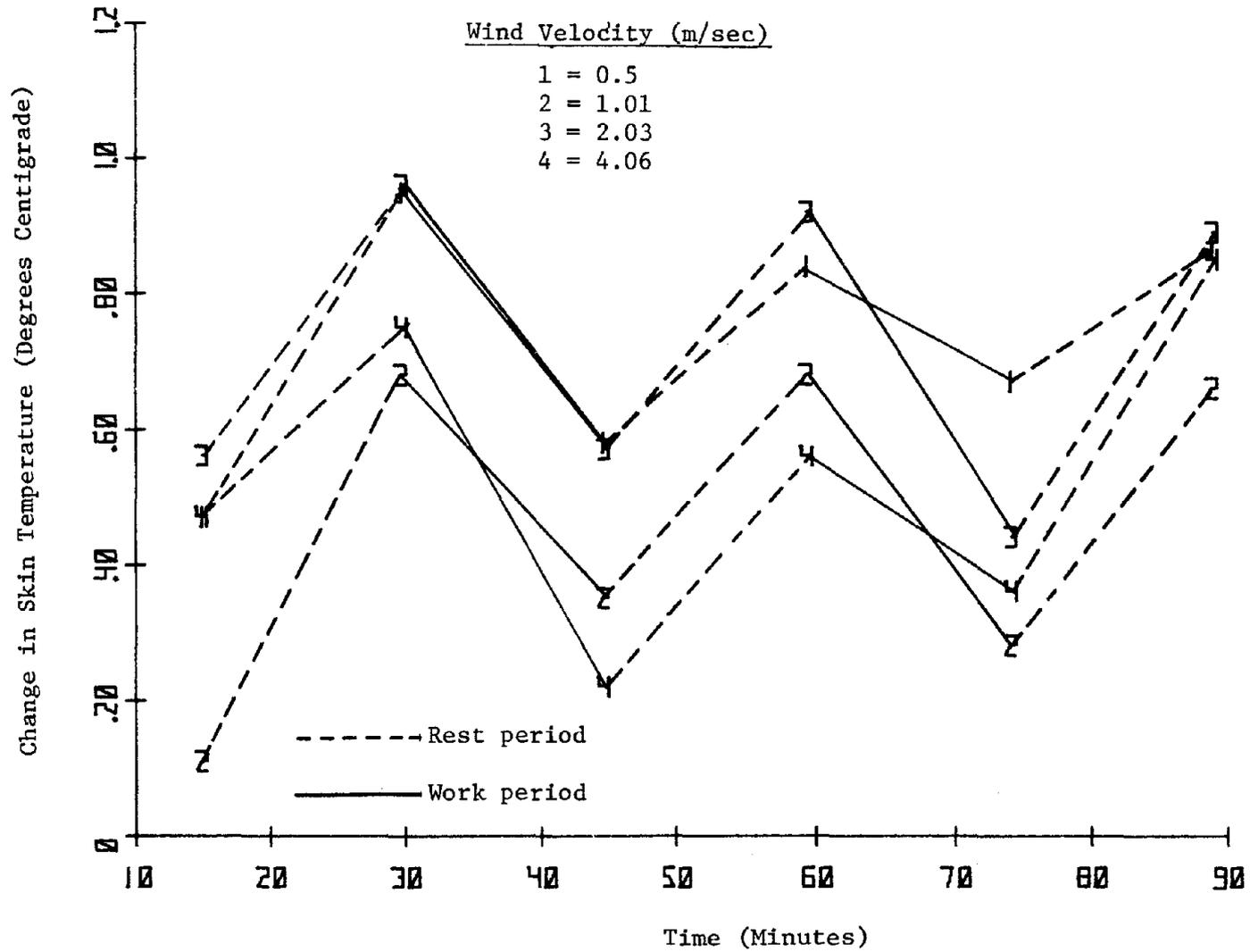
Figure 15. Time course of skin temperature changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 200 kcal/hr. (N = 4)
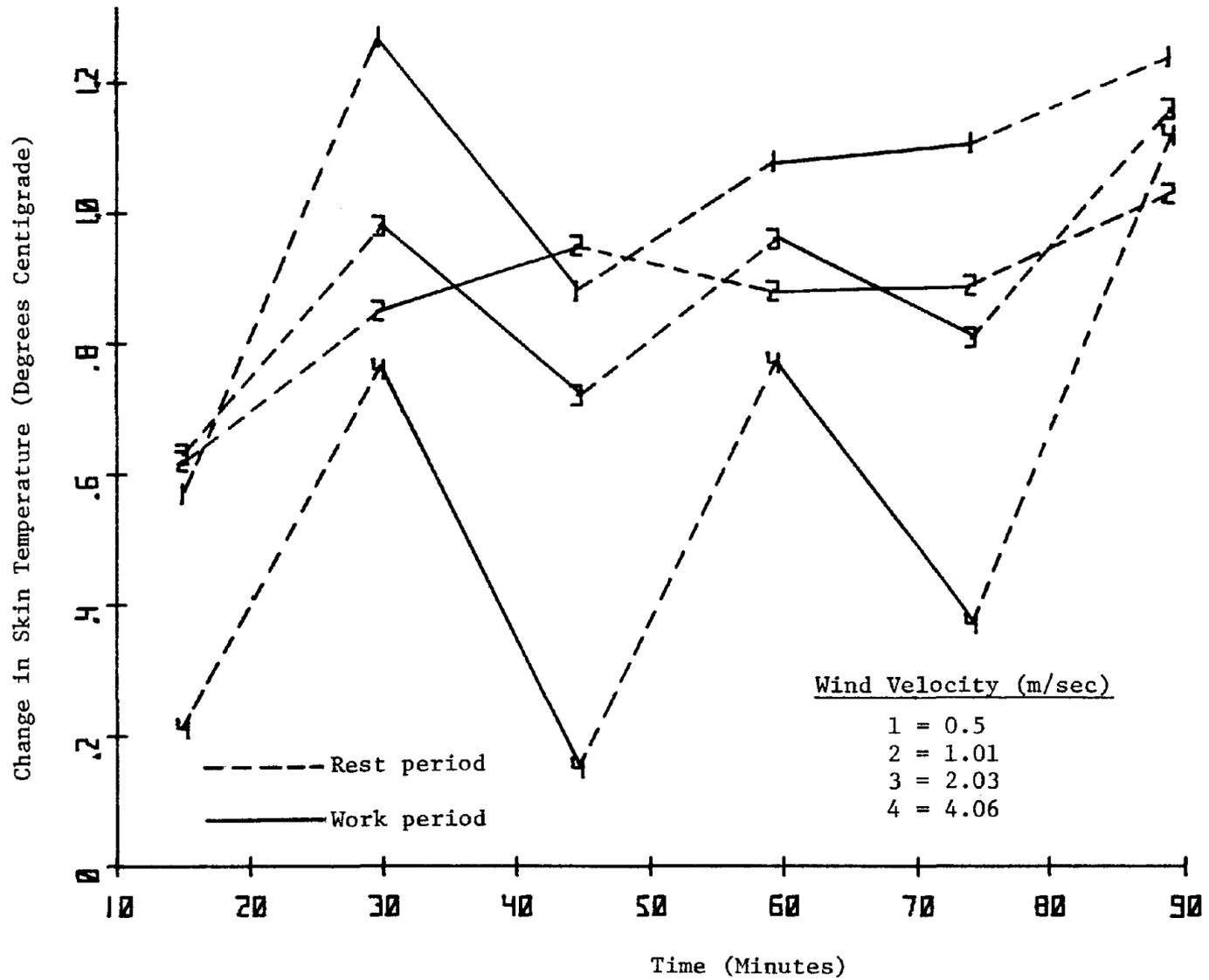
Figure 16. Time course of skin temperature changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 200 kcal/hr. (N = 4)
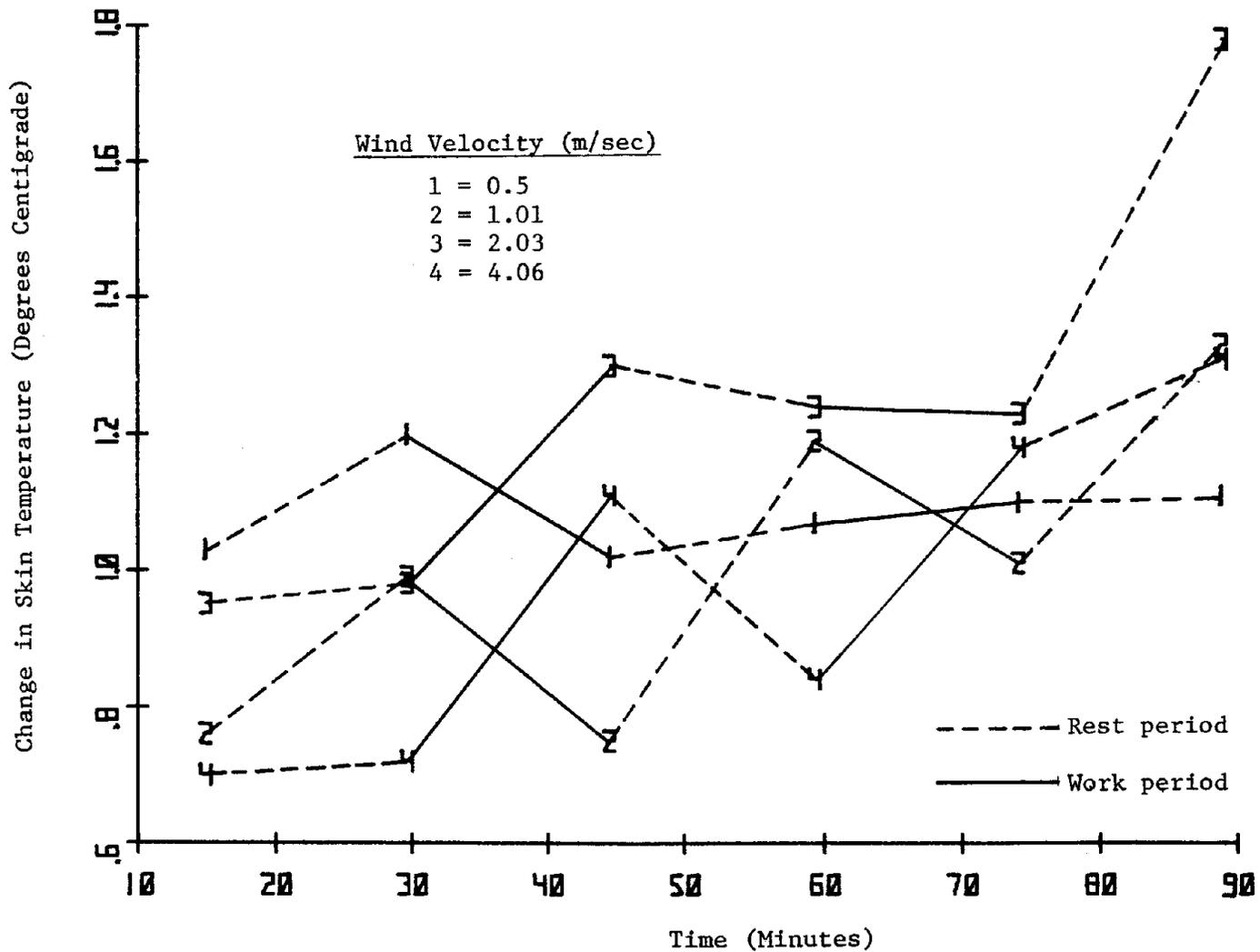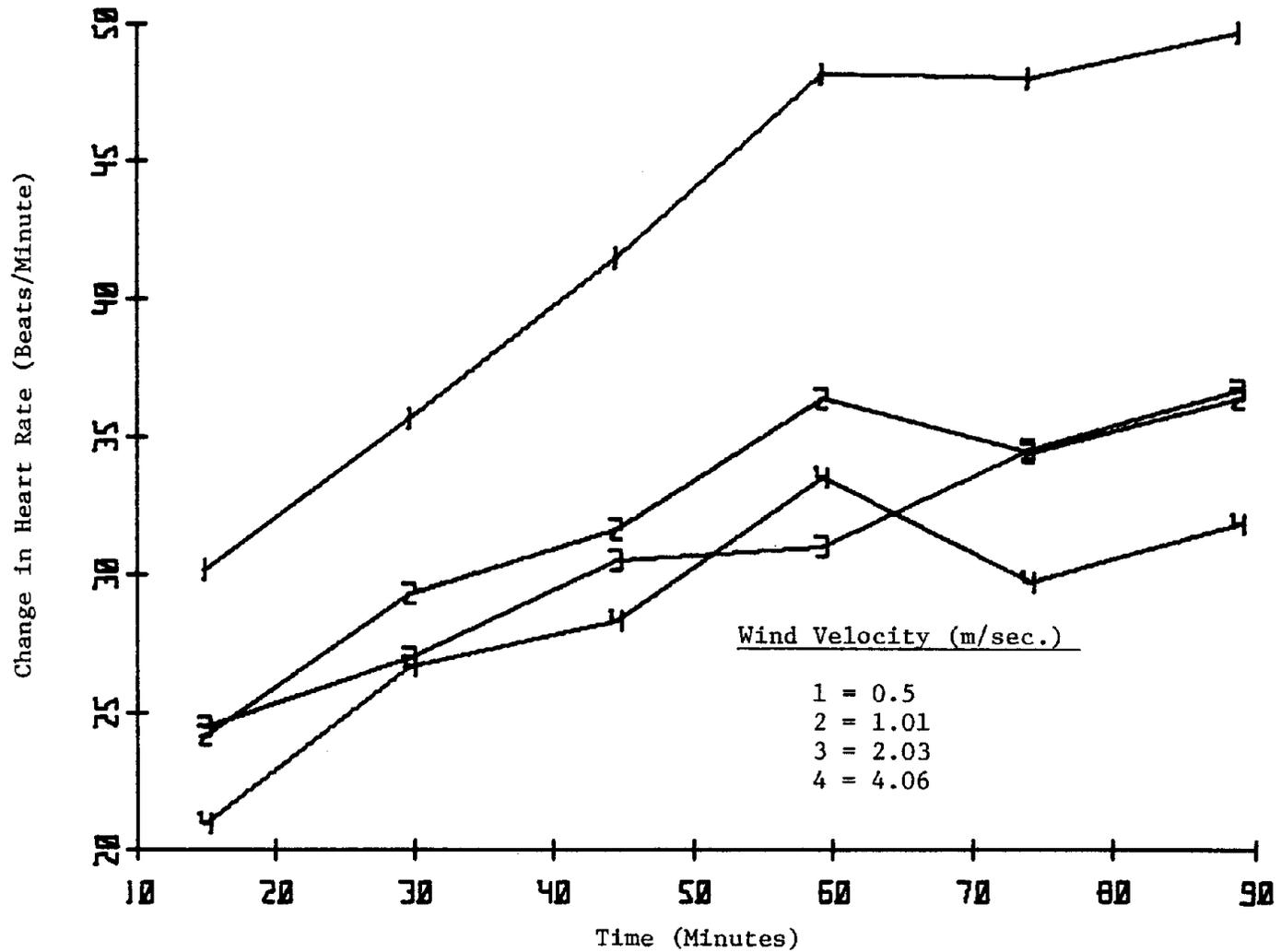
Figure 17. Time course of skin temperature changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 200 kcal/hr. (N = 4)
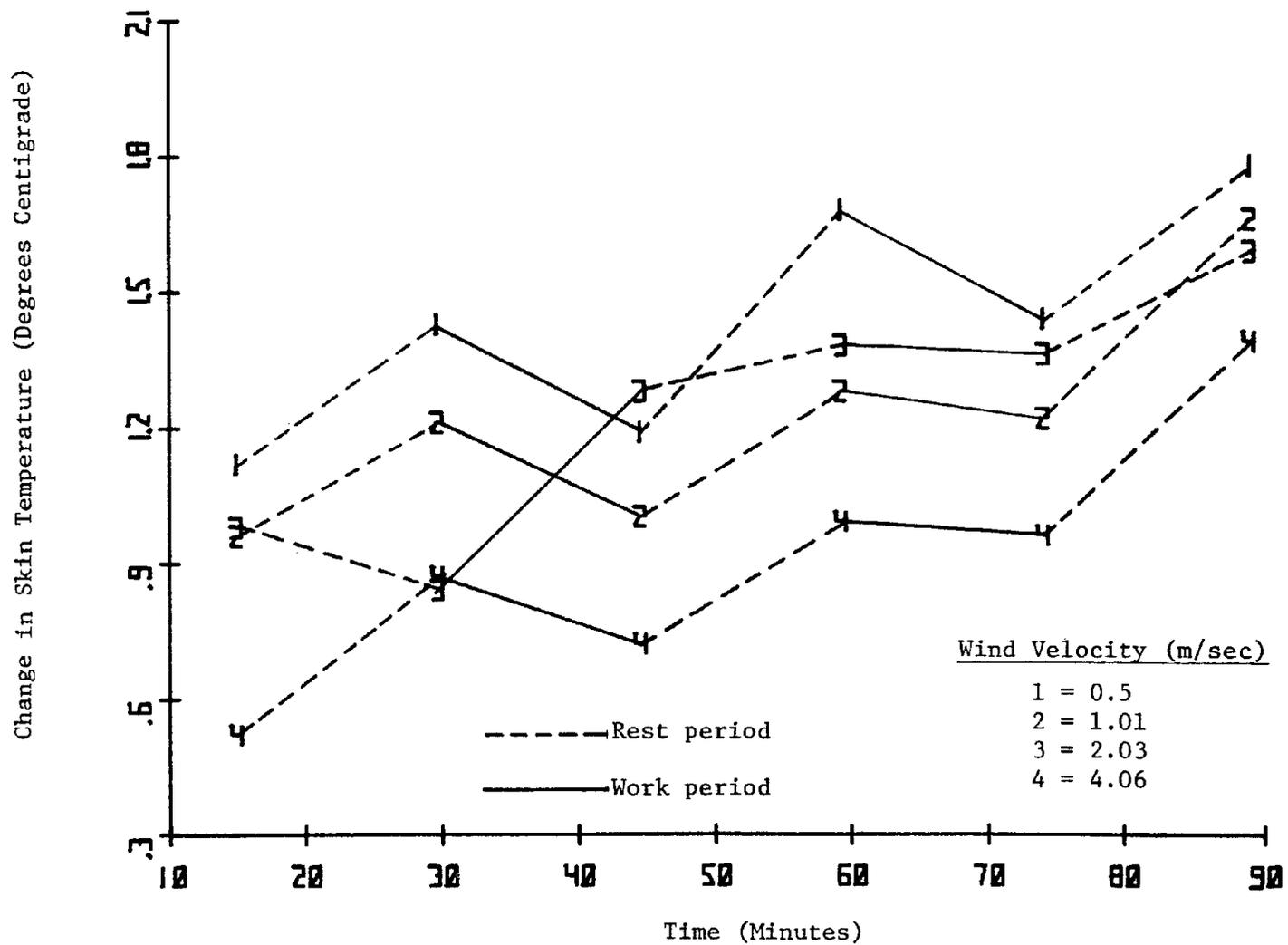
Figure 18. Time course of skin temperature changes as a function of wind velocity for WBGT 34.4°C and metabolic rate of 200 kcal/hr. (N = 4)
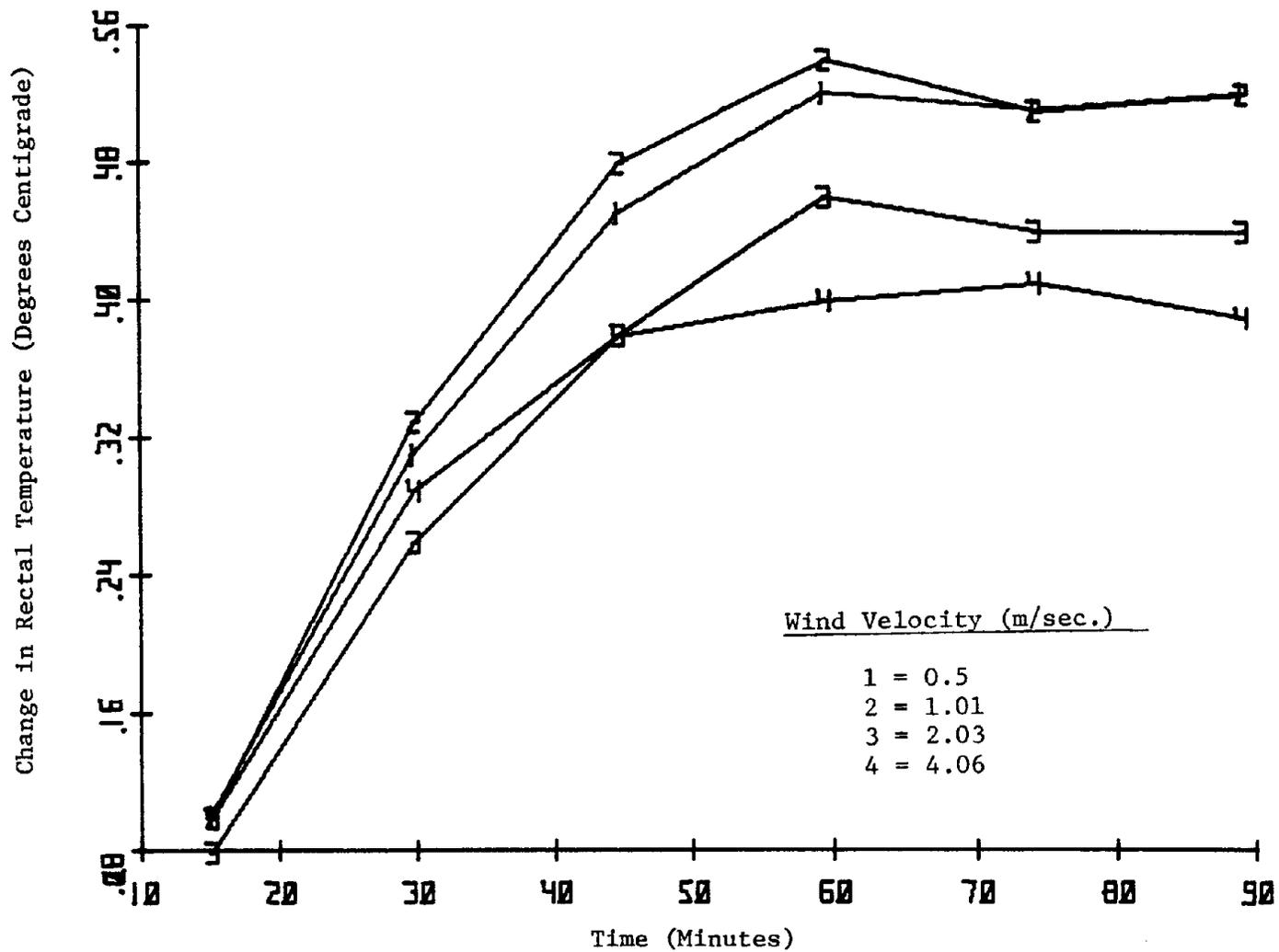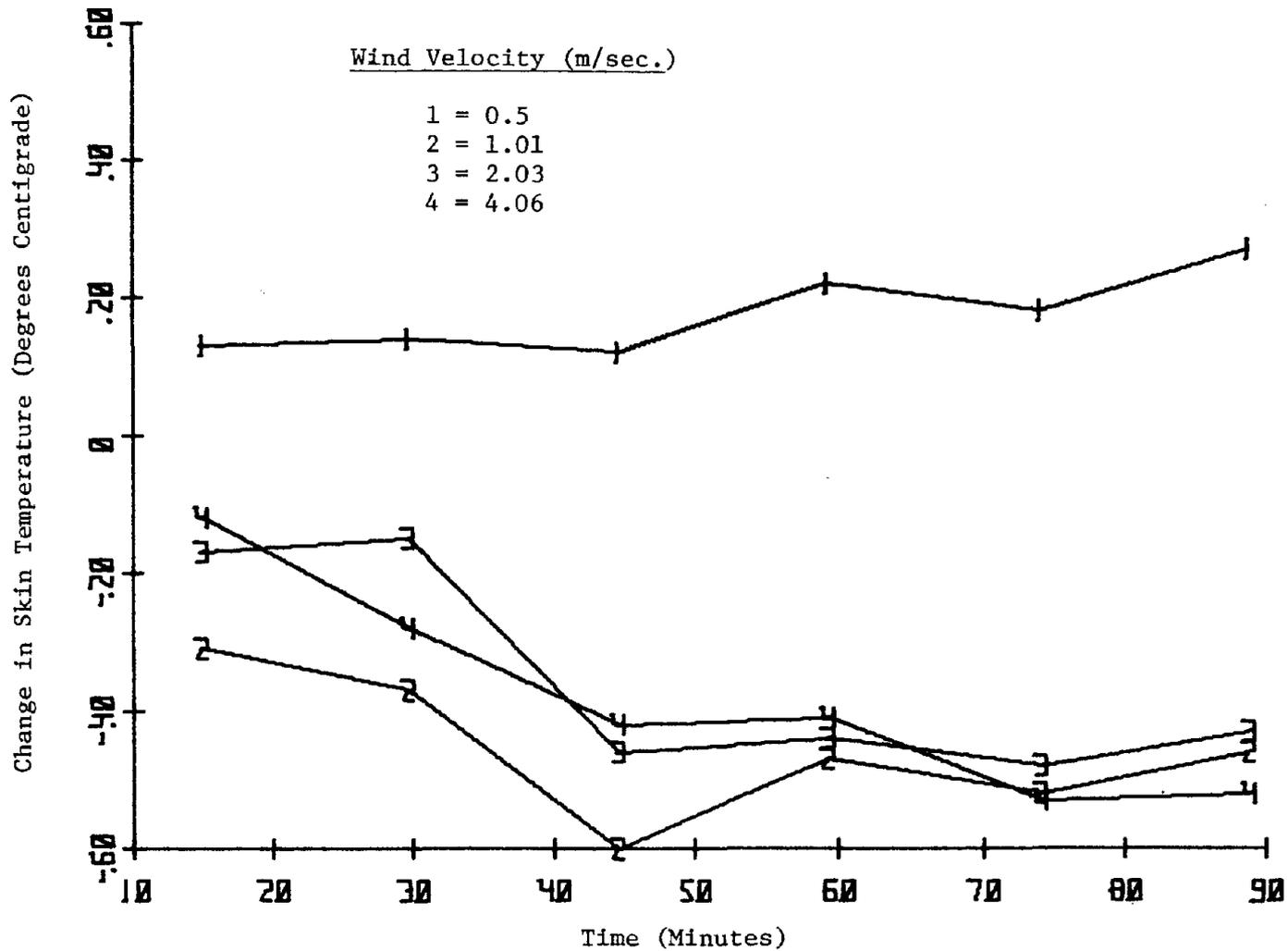
Figure 19. Time course of rectal temperature changes as a function of wind velocity for WBGT 27.2°C and metabolic rate of 300 kcal/hr. (N = 6)
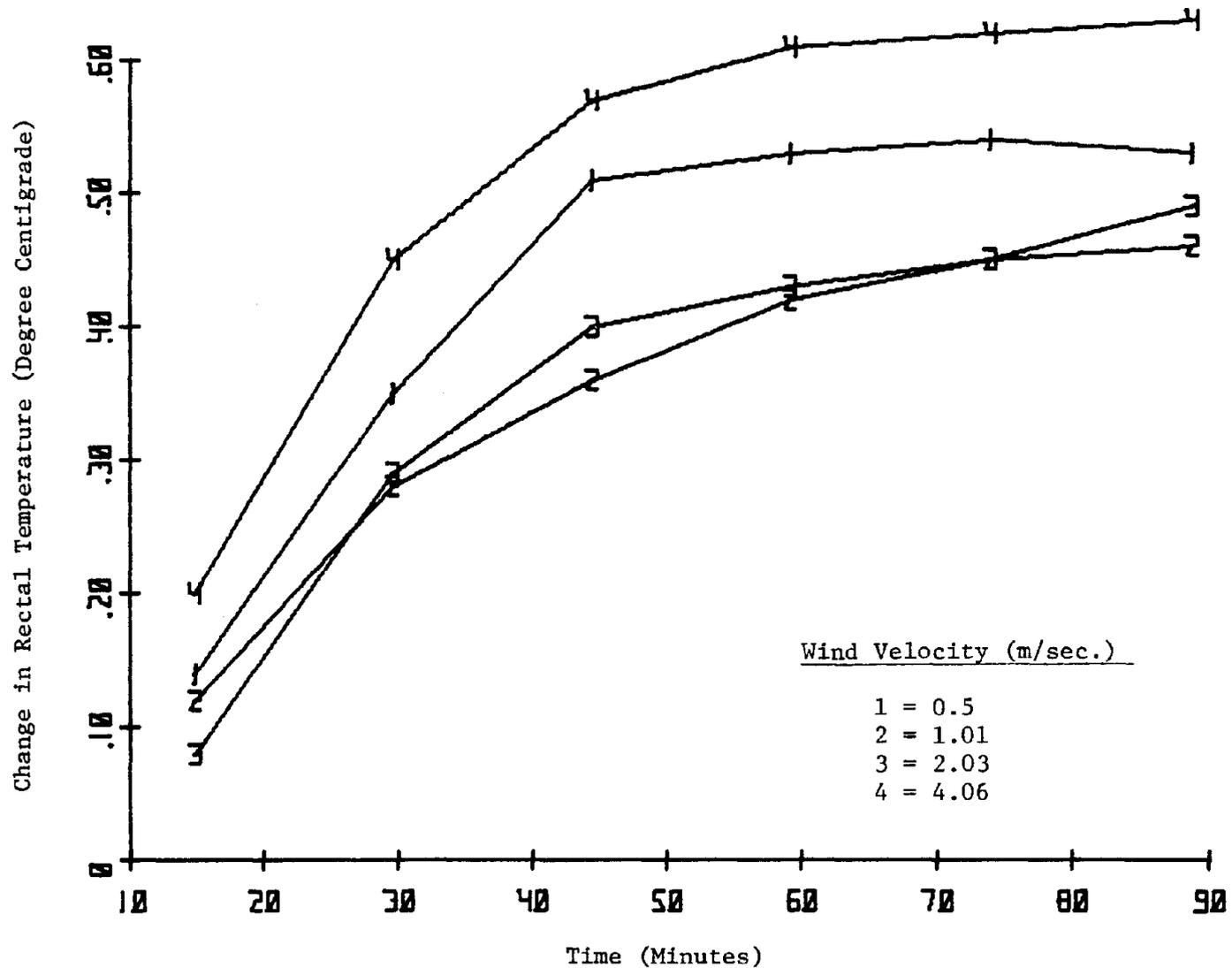
Figure 20. Time course of rectal temperature changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 300 kcal/hr. (N = 6)
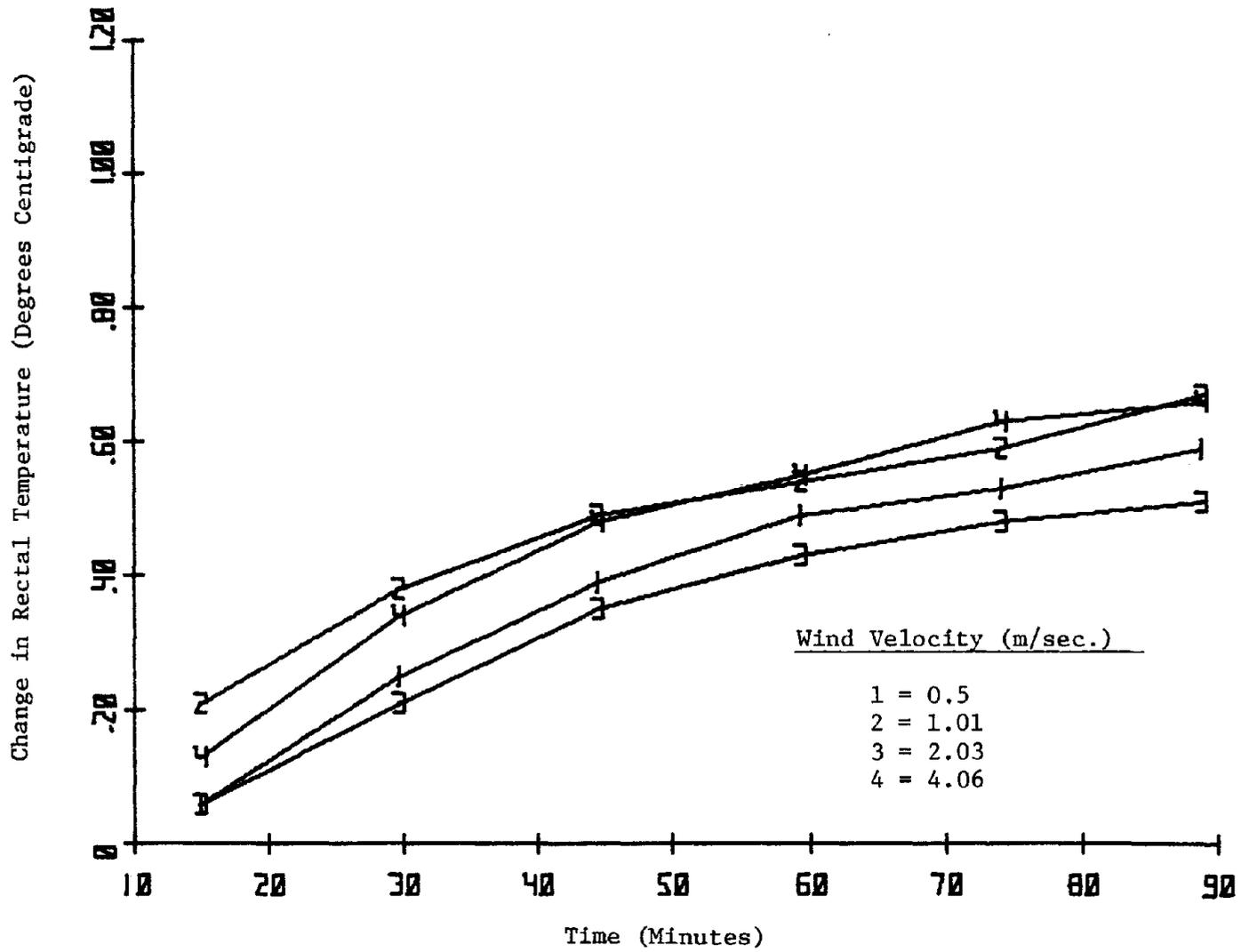
Figure 21. Time course of rectal temperature changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 300 kcal/hr. (N = 6)
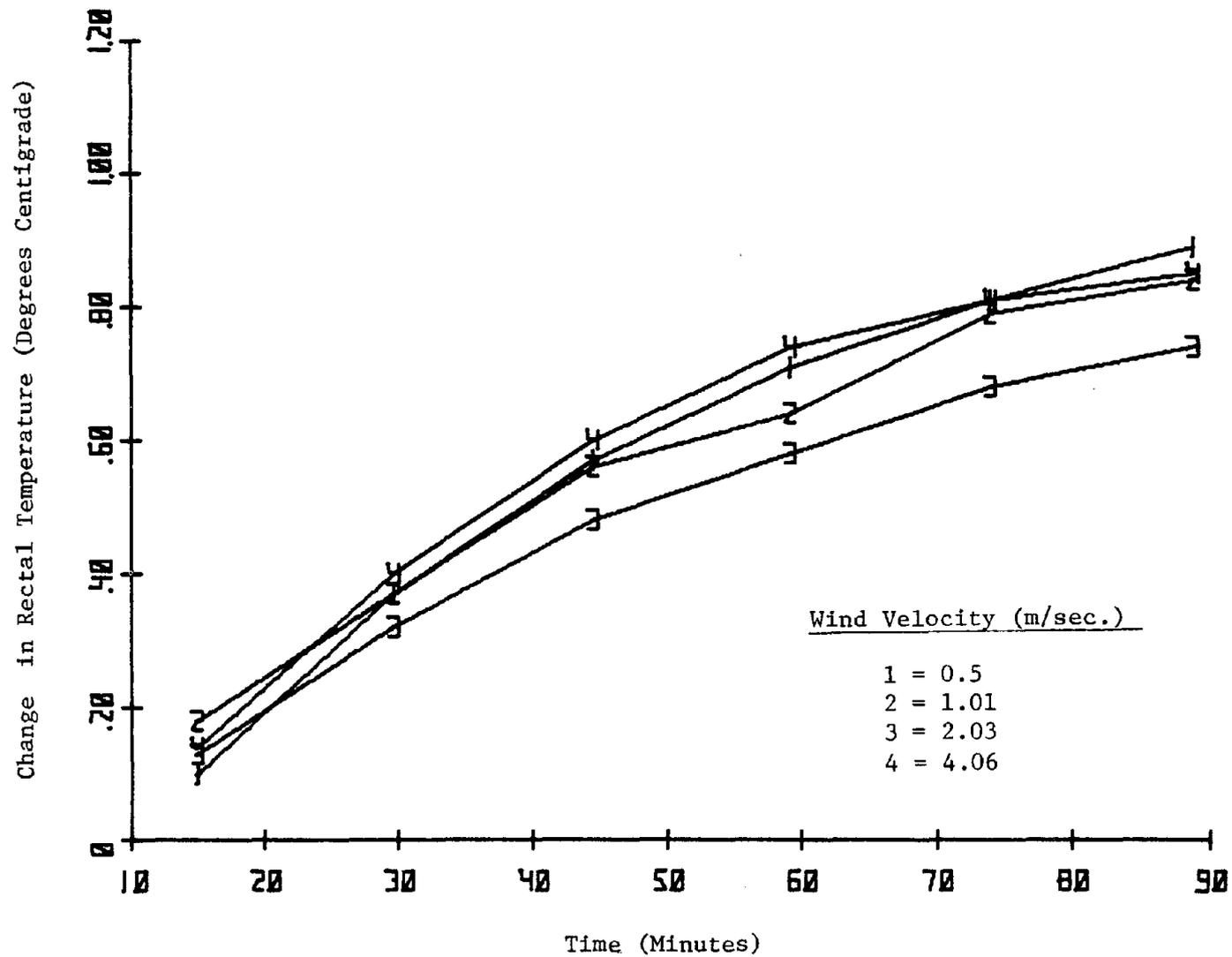
Figure 22. Time course of rectal temperature changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 300 kcal/hr. (N = 6)
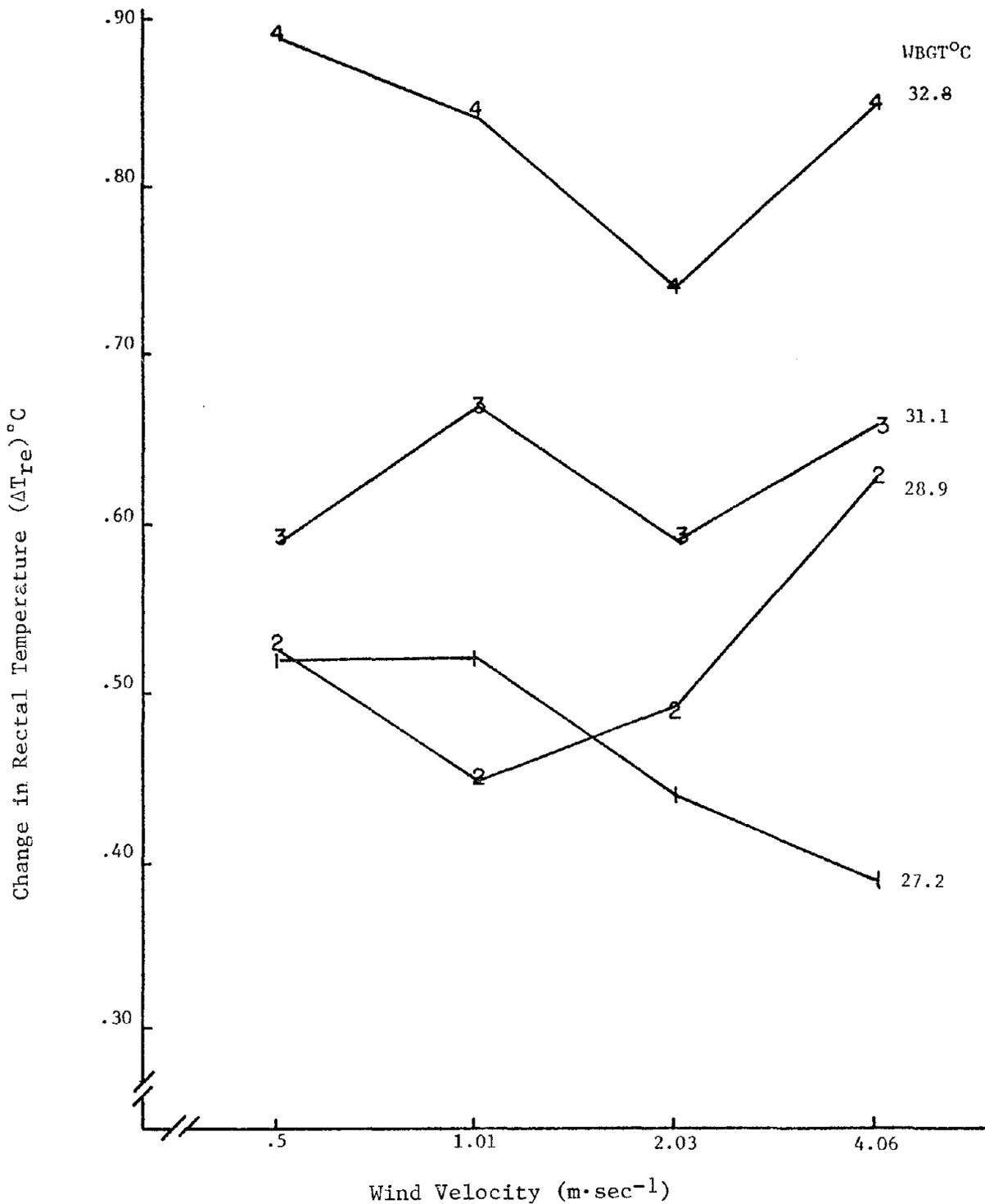
Figure 23. Change in T_{re} over 90 minute exposure as a function of wind velocity for the four WBGT values. (N = 6)
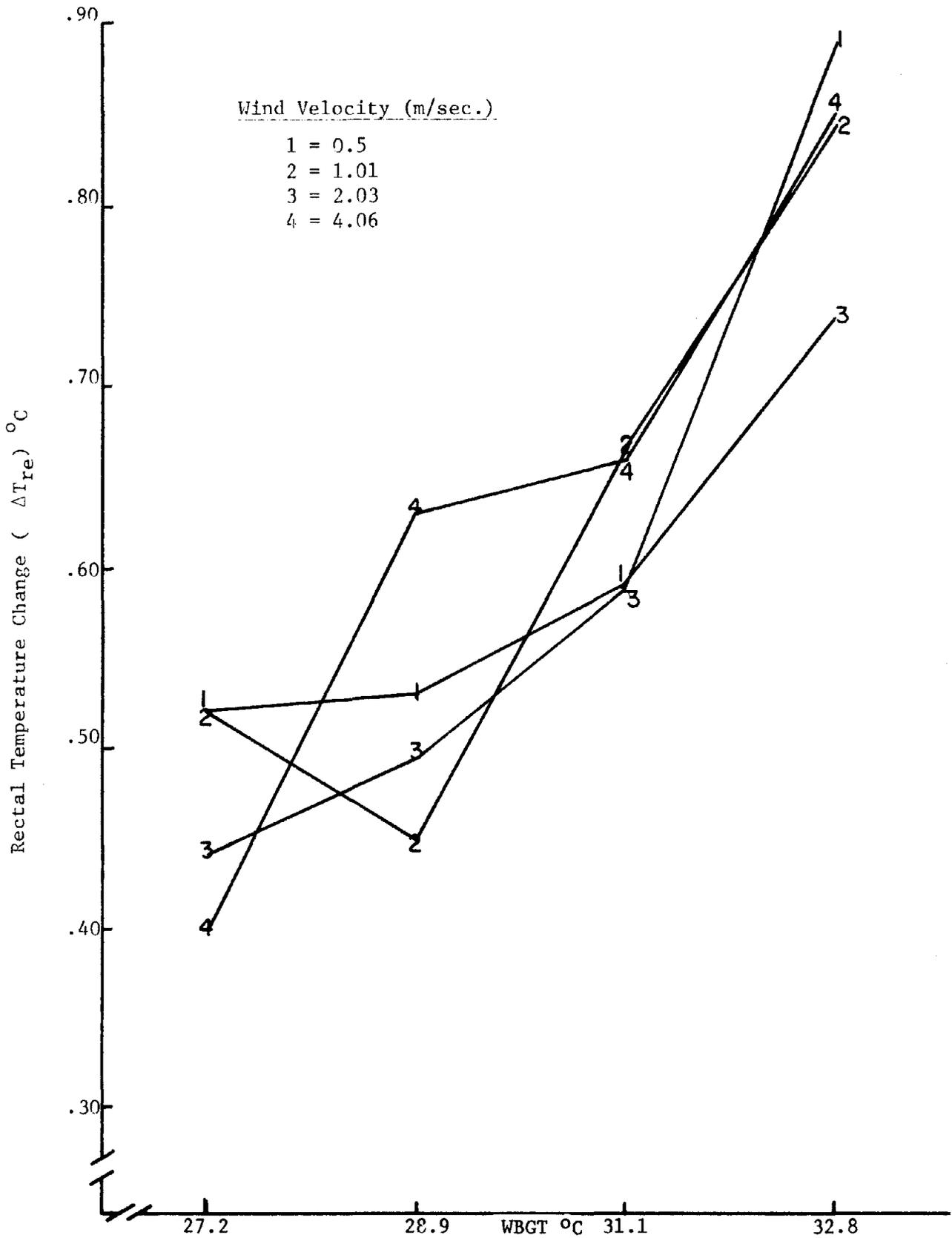
Figure 24. Change in T_{re} over 90 min. exposure as a function of WBGT for four wind velocities. (N = 6)

Figure 25. Time course of heart rate changes as a function of wind velocity for WBGT 27.2°C and metabolic rate of 300 kcal/hr. (N = 6)

Figure 26 . Time course of heart rate changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 300 kcal/hr. (N = 6)
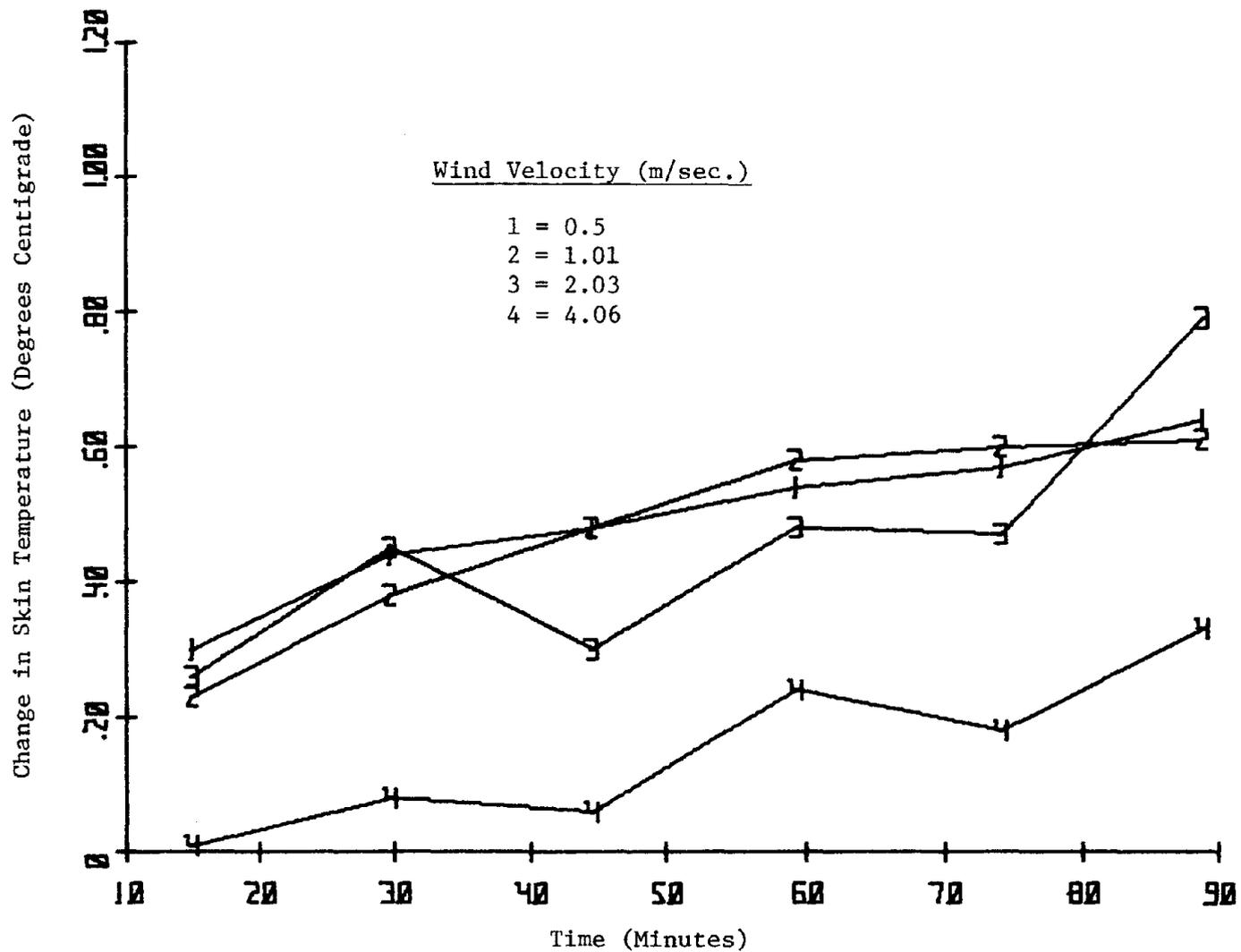
Figure 27. Time course of heart rate changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 300 kcal/hr. (N = 6)

Figure 28. Time course of heart rate changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 300 kcal/hr. (N = 6)

Figure 29. Time course of skin temperature changes as a function of wind wind velocity for WBGT 27.2°C and metabolic rate of 300 kcal/hr. (N = 6)
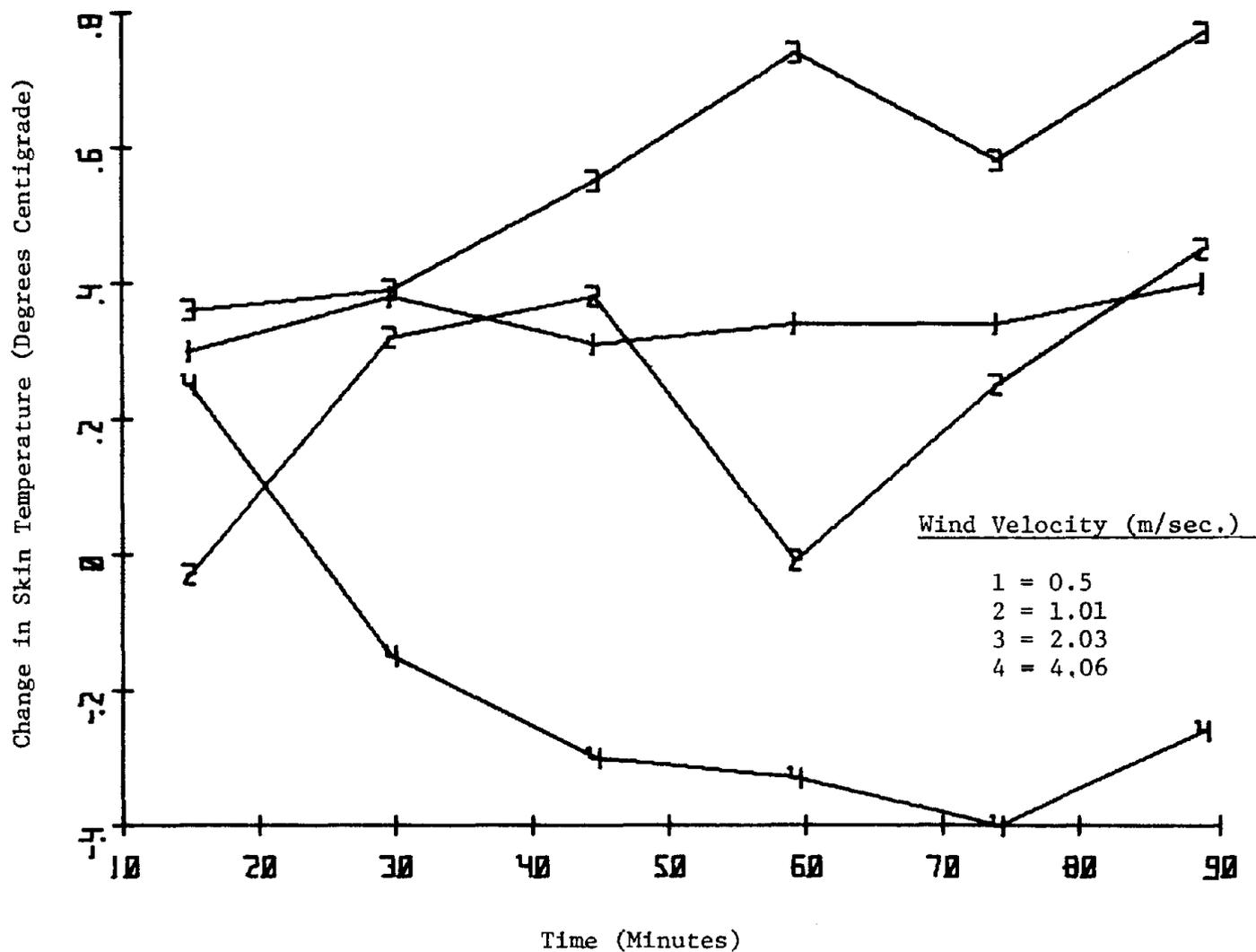
Figure 30 . Time course of skin temperature changes as a function of wind velocity for WBGT 28.9°C and metabolic rate of 300 kcal/hr. (N = 6)
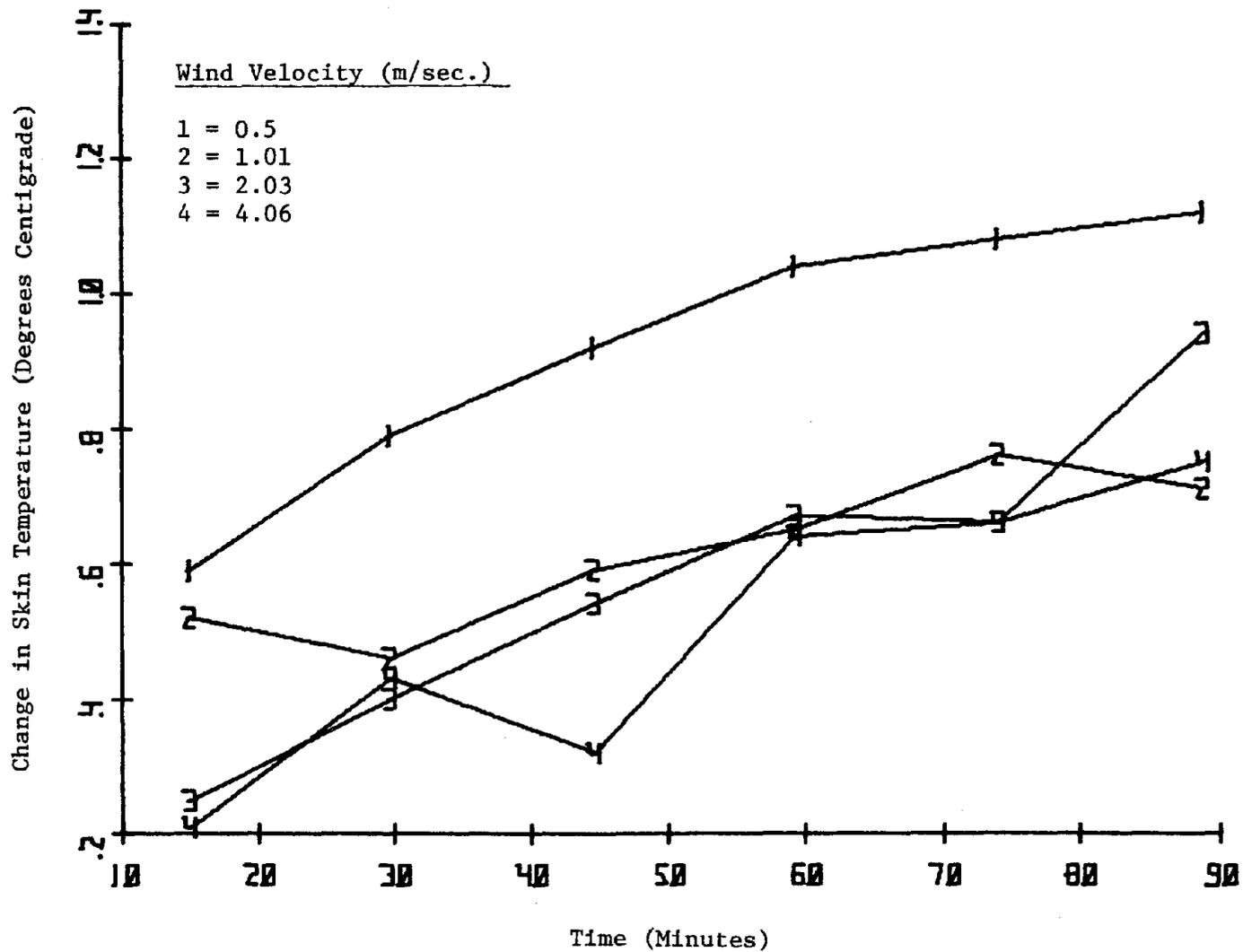
Figure 31. Time course of skin temperature changes as a function of wind velocity for WBGT 31.1°C and metabolic rate of 300 kcal/hr. (N = 6)

Figure 32 . Time course of skin temperature changes as a function of wind velocity for WBGT 32.8°C and metabolic rate of 300 kcal/hr. (N = 6)

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			6.
7. Author(s) Eliezer Kamon, Ph.D.; Arnold Goldfuss, Ph.D.; James L. Hodgson, Ph.D.; Joseph L. Loomis; Francis N. Dukes-Dobis, M.D.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Noll Laboratory for Human Performance Research Pennsylvania State University University Park, PA 16802			10. Project/Task/Work Unit No.
			11. Contract/Grant No. 210-75-0002
12. Sponsoring Organization Name and Address National Institute for Occupational Safety and Health 4676 Columbia Parkway Cincinnati, Ohio 45226			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

Four heat acclimated college student volunteers were exposed for 90 minutes at each of the following combinations of work-heat conditions: 1) metabolic level (M) of 200 kcal·hr -1, and Wet Bulb Globe Temperature (WBGT) of 28.9°C, 31.1°C, 32.8°C and 34.4°C. Each of these had 32 exposures to the combinations of the above two M levels, four WBGT conditions and wind velocities of: 0.5m·s -1 (100 ft.min -1), 1 m·s -1 (200 ft. min -1), 2 m·s -1(400 ft.min -1) and 4 m·s -1 (800 ft.min -1). 2) M of 300 kcal·hr -1, and WBGT of 27.2°C, 28.9°C, 31.1°C and 32.8°C. Two additional heat acclimated college student volunteers were exposed for 120 minutes to the second combination of work-heat conditions. These two volunteers were exposed for 120 minutes to 16 of the combinations at M of 300 kcal·hr -1 only.

This study was used to examine the effectiveness of increased wind velocity in reducing strain at each of the conditions described. The criteria for strain were the following physiological responses: rectal temperature, mean skin temperature, heart rate, evaporation and sweating rates. The physiological responses were measured at intevals throughout each exposure.

There were differences in the physiological responses during the different WBGT conditions, there were no significant differences due to increased wind velocities under these conditions.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
	20. Security Class (This Page) UNCLASSIFIED	22. Price