TRANSVAAL AND ORANGE FREE STATE CHAMBER OF MINES

RESEARCH ORGANISATION

REPORT

ON

THE ASSESSMENT OF HEAT STRESS IN WORKING PLACES UNDERGROUND IN THE MINES.

PART 3

AN EXAMINATION OF THE EXTENT TO WHICH METABOLIC RATE IS TAKEN INTO ACCOUNT BY THE P_4SR INDEX.

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S Y N O P S I S

In a previous report in this series (No. 62/66) it was shown that the P_4SR index does not take accurate account of one or more of the various heat stress factors which it is said to take account of.

In this report a detailed analysis is made of the effect of different metabolic rates, corresponding to light, moderate and hard work, on the rectal temperatures, heart rates and sweat rates of 13 highly-acclimatised subjects under experimental conditions in which 45 different combinations of wet bulb temperatures, wind velocities and work rates were used.

By fitting separate regression lines to data for each of the three metabolic rates and calculating 78 per cent confidence limits to these lines, it is shown that the regression lines for the highest rate of work is significantly higher than those for the two lower rates of work and that in some cases the regression lines for the two lower rates of work are also significantly different from each other.

From the results of the analysis it is quite clear that the P_4SR index does <u>not</u> take accurate account of the effects of different rates of work and, therefore, one of the main advantages claimed for this index, that it takes account of different rates of work, whereas the Effective Temperature Scale and the Wet Kata Cooling Power do not, is negated.

1. INTRODUCTION

In Part 2 of this series (1) rectal temperature, heart rate and sweat rate responses of individual subjects were shown plotted against the corresponding values of the P_4SR index for the various combinations of the various environmental parameters (temperature of the water vapour, saturated air, wind velocity and work rate). Attention was drawn to the fact that certain arrays (sets of response values corresponding to subjects exposed at the same P_4SR level) appeared to be displaced relative to arrays corresponding to similar P_4SR levels. The anomalies were referred to as "slippages" amongst the arrays.

In this report possible causes of these "slippages" are examined, the analysis being confined to data obtained on the 13 highly-acclimatised subjects used in the investigations referred to in Part 2 of this series of reports.

2. METHODS

The methods are outlined in previous reports in this series (1).

3. RESULTS

3.1 Regression of sweat rate, heart rate and rectal temperature on P_4SR

In Figures 1, 2 and 3 the sweat rate (in litres per 4 hours) of each individual is shown plotted against the corresponding P_4SR value of environments for which the wind velocities were 400, 150 and 50 feet per minute respectively. The different work rates, 100, 150 and 240 Cals/m^2/hour are identified by the symbols (X), (●) and (O) respectively.

The slippages mentioned above are also clearly in evidence. For example, the arrays at 2.9 and 6.1 which

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correspond to a work rate of 100 cals/m^2/hour, are displaced downwards relative to the arrays at 3.1 and 6.2 respectively; the latter array corresponds to a work rate of 240 cals/m^2/hour.

In Figures 4, 5 and 6 the mean heart rate (over a 4-hour period) of each individual is shown plotted similarily against the corresponding P_4SR value. The regression is clearly non-linear in each case. As in the case of sweat rate, the obvious "slippages" will be seen to involve arrays corresponding to different metabolic rates.

In Figures 7, 8 and 9 the mean rectal temperature (over the 4-hour period of exposure) of the individuals is shown plotted against the corresponding P_4SR values of the environments for which the wind velocities were 400, 150 and 50 ft/min respectively. While the regressions are clearly linear in this case, "slippages" are again evident where the members of adjacent pairs of arrays correspond to different metabolic rates.

3.2 Curves describing the regression of physiological reaction on P_4SR for different metabolic rates

In view of the above indications that there are differences between the regressions, on P_4SR, of the physiological reactions of men working at different rates, the data corresponding to the different metabolic (or work) rates were treated separately (with no distinction between sets of data relating to different wind velocities) and regression curves were fitted to each of the reactions (sweat rate, heart rate and rectal temperature).

Curves of the form

$Y = ax^b$
$Y = K(1 - ae^{bx^m})$
$Y = ax + b$

} Where Y is the average response to exposure at a P_4SR level of x and a, b and m are unknown contents which vary from one reaction to another.

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were employed in the cases of sweat rate, heart rate and rectal temperature respectively.

The fitted curves together with the original data are shown in Figures 10, 12 and 14 respectively.

In Figures 11, 13 and 15 the same regression curves are shown respectively, together with 78 per cent confidence intervals for the points of the curves. This level of confidence was chosen as a test of the significance (at the 5 per cent level) of the difference between the values. At a given level of P_4SR, a test of significance of difference between the curves, corresponding to two different metabolic rates, may be effected by simply examining whether or not the confidence intervals overlap at that point.

It will be clear from Figure 11 that it is reasonable to claim a significant difference between the sweat rate curves corresponding to metabolic rates of 100 and 240 cals/m^2/hour, the former lower than the latter. The curve corresponding to a metabolic rate of 150 cals/m^2/hr, which lies between the other two, may be claimed to differ significantly from them for P_4SR values less than 4.0.

Similarly, reference to Figure 13 will support the claim that the heart rate curve corresponding to the highest metabolic rate is significantly higher than the curves corresponding to either of the two other metabolic rates. While the curve relating to the middle metabolic rate lies between the other two no claim may be made on the basis of the test of significance, regarding the difference between the former and that corresponding to the lowest metabolic rate.

The only positive conclusion which may be drawn from the significance test illustrated in Figure 15 is that in the case of rectal temperature, as in the case of heart rate, the regression curve corresponding to the greatest metabolic rate is significantly higher than that corresponding to the other two rates.

4. DISCUSSION

The significance tests provide conclusive evidence that

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the physiological reaction regression curves (on P_4SR) corresponding to the highest metabolic rate differs from those corresponding to the lower metabolic rates. The fact that in all cases the curve corresponding to the middle metabolic rate lies between the other two curves leads to the conclusion that there are real differences between the regression curves relating to all three metabolic rates.

In the lower range of P_4SR values the conclusion is confirmed by the significance test in the case of sweat rate - which is known to be a sensitive indicator of physiological strain.

These results, which are based on the measured physiological reaction (sweat rate, heart rate and rectal temperature) of acclimatised men exposed at P_4SR levels which cover a wide range of air temperatures(air saturated with water vapour), wind velocities and metabolic rates, indicate that metabolic rate is inadequately taken into account in the P_4SR index.

It is certainly true that the most striking evidence in support of this claim involves a metabolic rate of 240 cals/m^2/hr which is outside the range for which the index was designed (viz. up to 200 cals/m^2/hr). The results relating to this high metabolic rate, are also present at the lower metabolic rates, even if this effect is less dramatic. This suggests that the P_4SR does not take accurate account of the influence of metabolic rate.

Clearly, where two arrays of data relating to men working at different rates under the same wind velocity and similar P_4SR values, the air temperatures corresponding to the two arrays must differ substantially. This is so for the data shown in Figures 1 to 9. Thus, whereas the slippages are attributed to incorrect weighting of metabolic rate, the possibility exists that the effect is due to incorrect weighting of air temperature. This possibility was examined by distinguishing points relating to different air temperatures. No clear pattern emerged.

Similar comments apply to wind velocity as a possible cause of the "slippages." While these points will be

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examined in more detail in a subsequent report it is concluded at this stage that incorrect weighting of metabolic rate, in the construction of the P_4SR index, represents the primary cause of the observed "slippages."

REFERENCE

1. C.H. Wyndham, N.B. Strydom J.F. Morrison, A.H. Munro and H. Sichel.
The Assessment of the Heat Stress in Working Places, underground in the Mines.
Part 2: The Relationship between certain Physiological Reactions and P_4SR Values.
C.O.M. Research Report No. 62/66, Chamber of Mines, Johannesburg, 1966.

FIGURE 1

Observed Mean Actual Sweat Rate values vs. P_4SR values

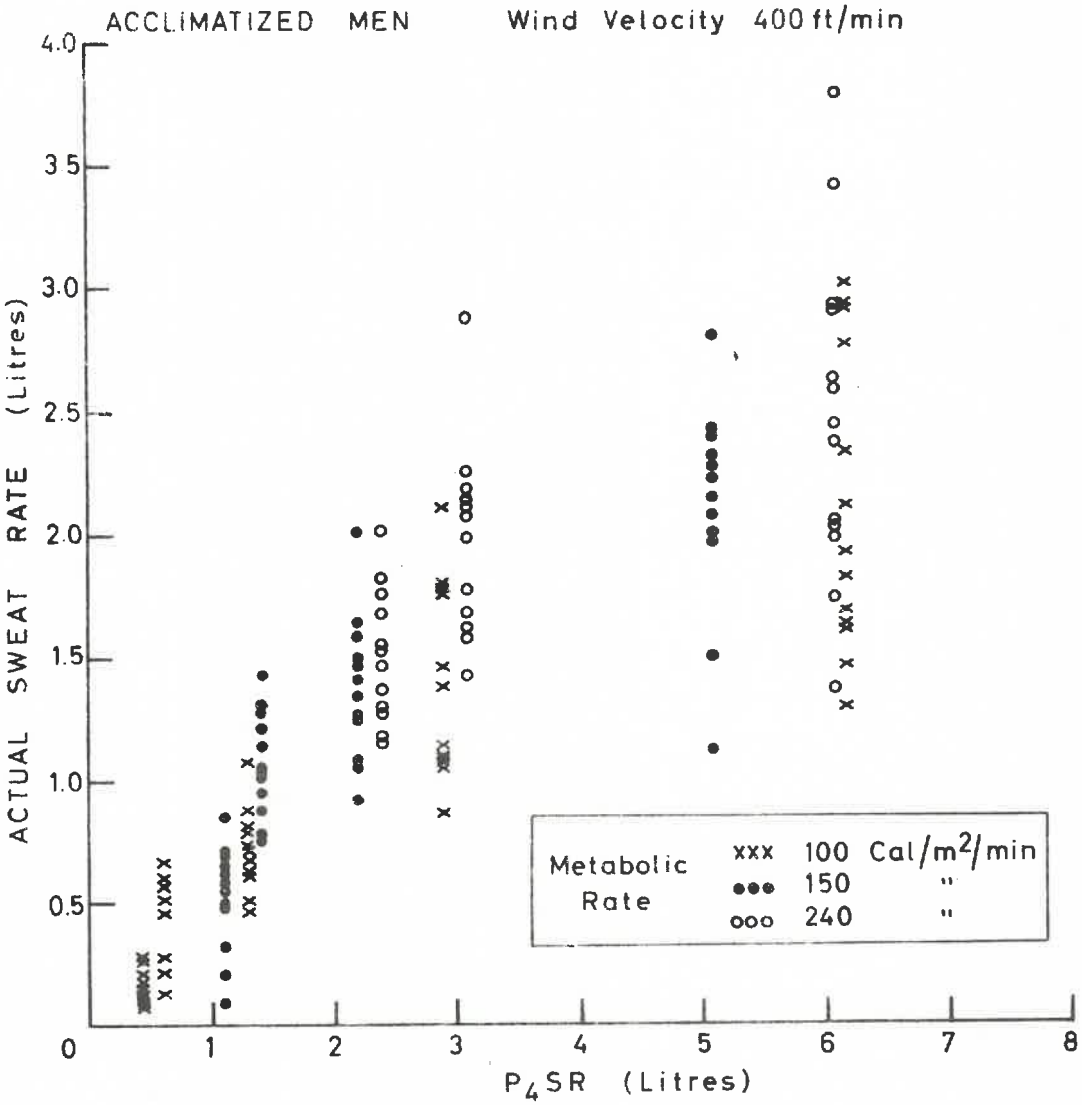

FIGURE 2

Observed Mean Actual Sweat Rate values vs. P_4SR values

ACCLIMATISED MEN

Wind Velocity 150 ft/min

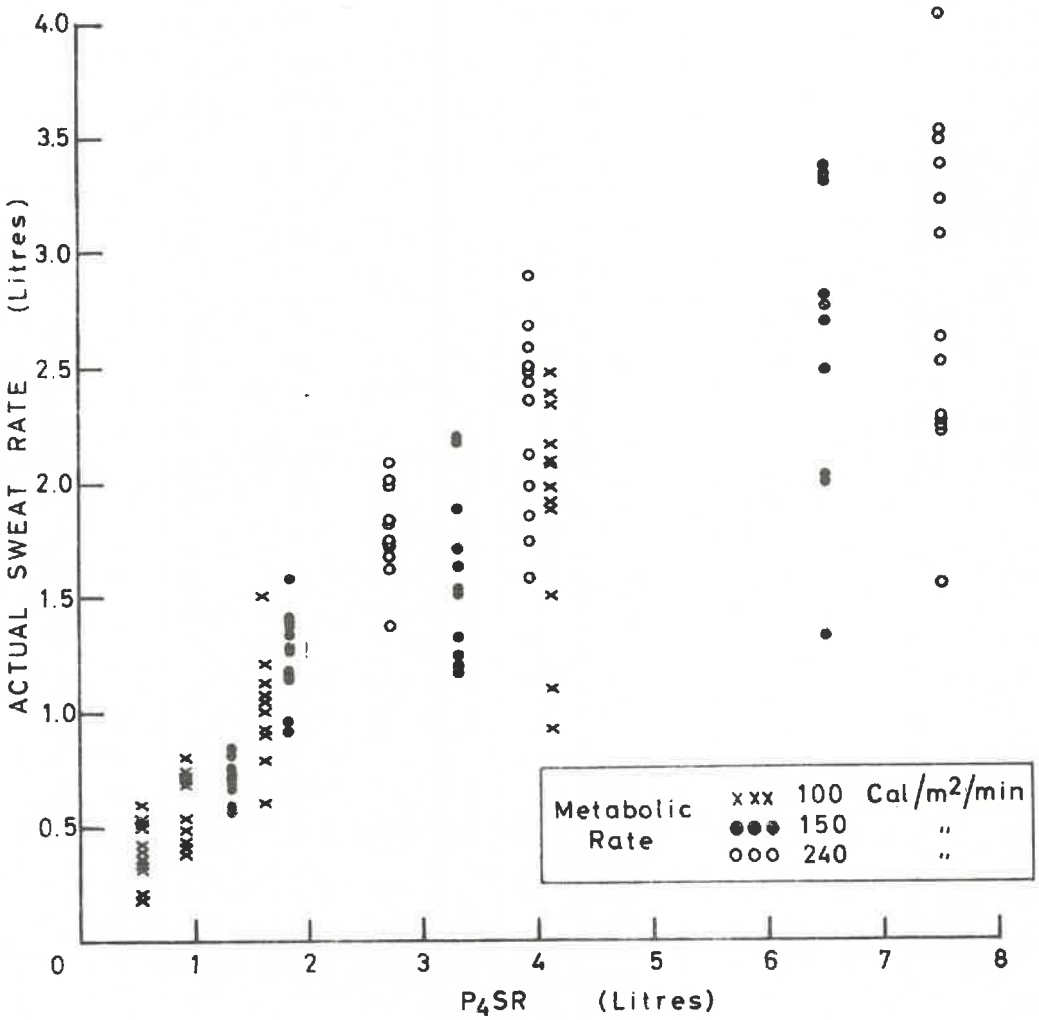

FIGURE 3

Observed Mean Actual Sweat Rate values vs. P_4SR values

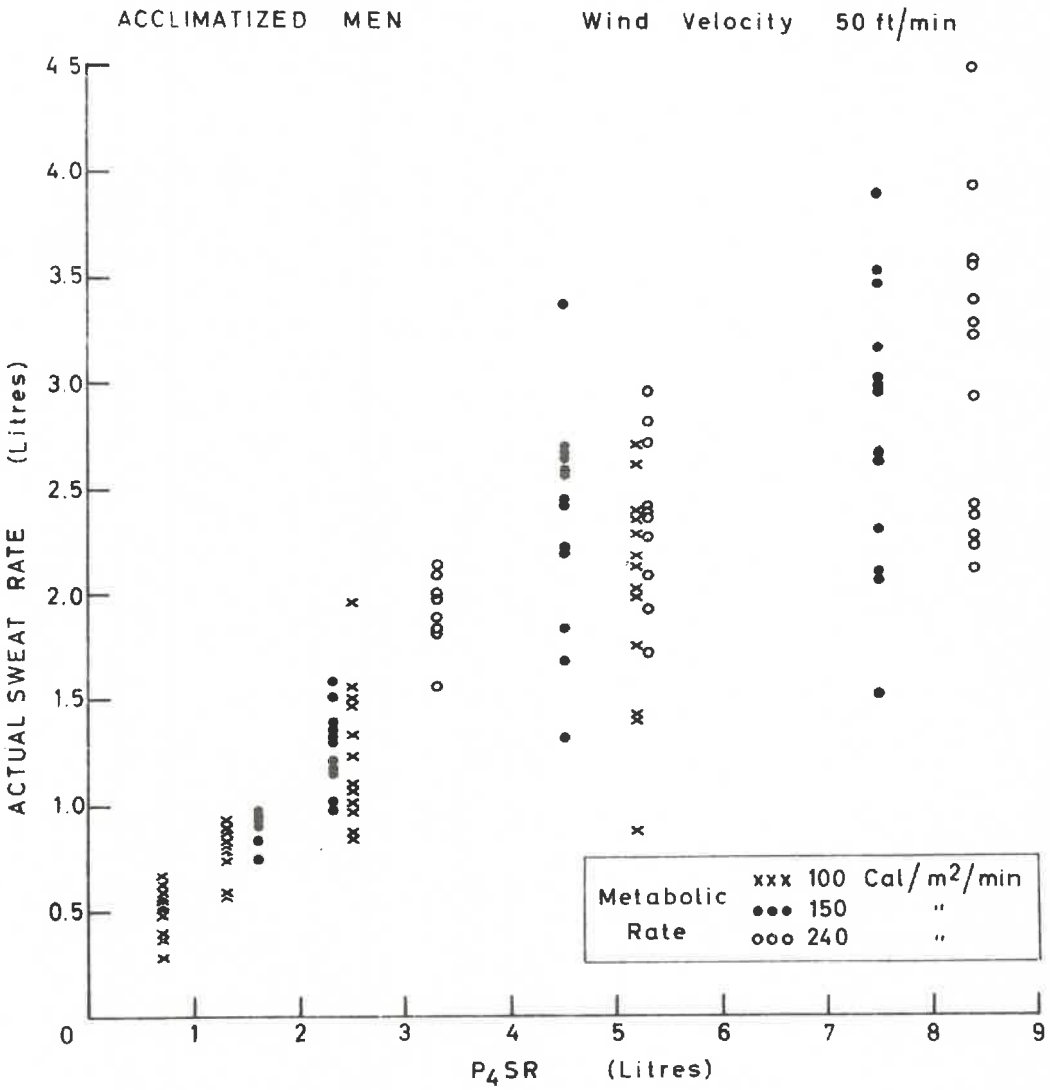

FIGURE 4

Observed Mean Heart Rate values vs P_4SR values

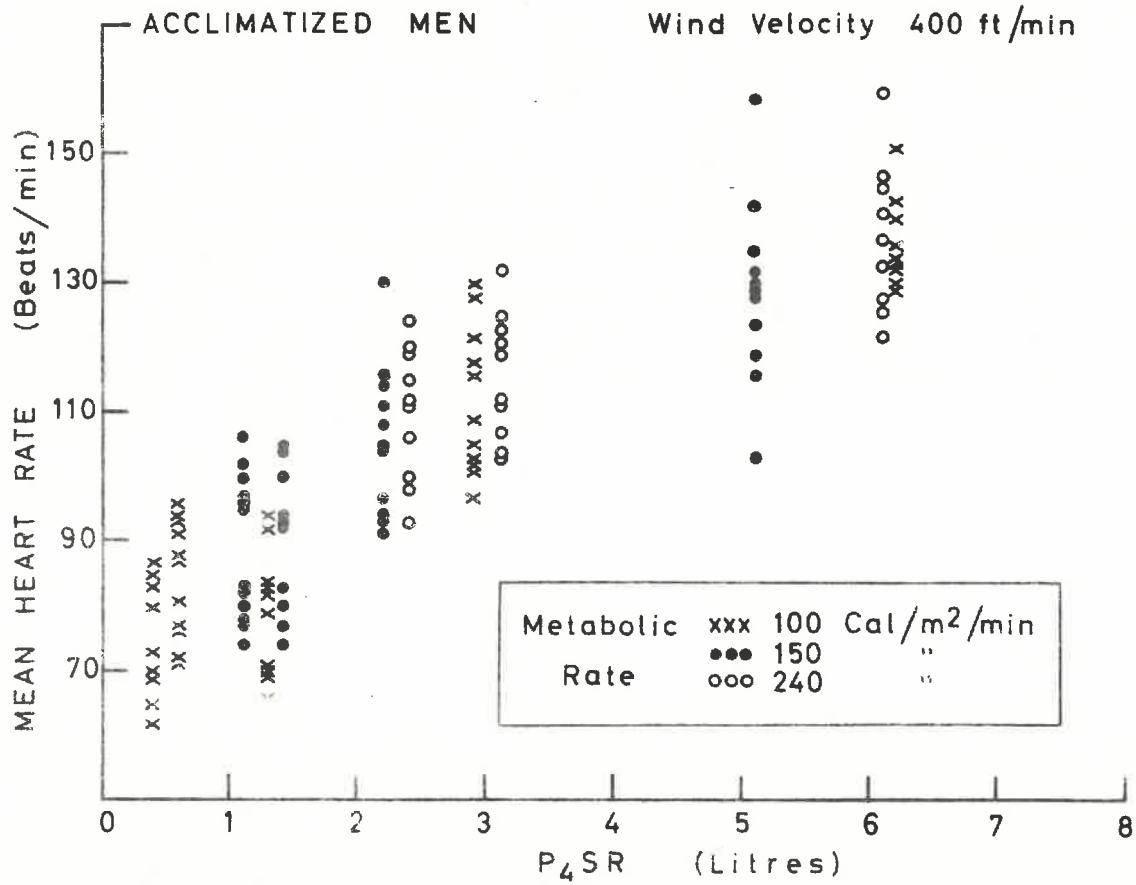

FIGURE 5

Observed Mean Heart Rate values vs. P_4SR values

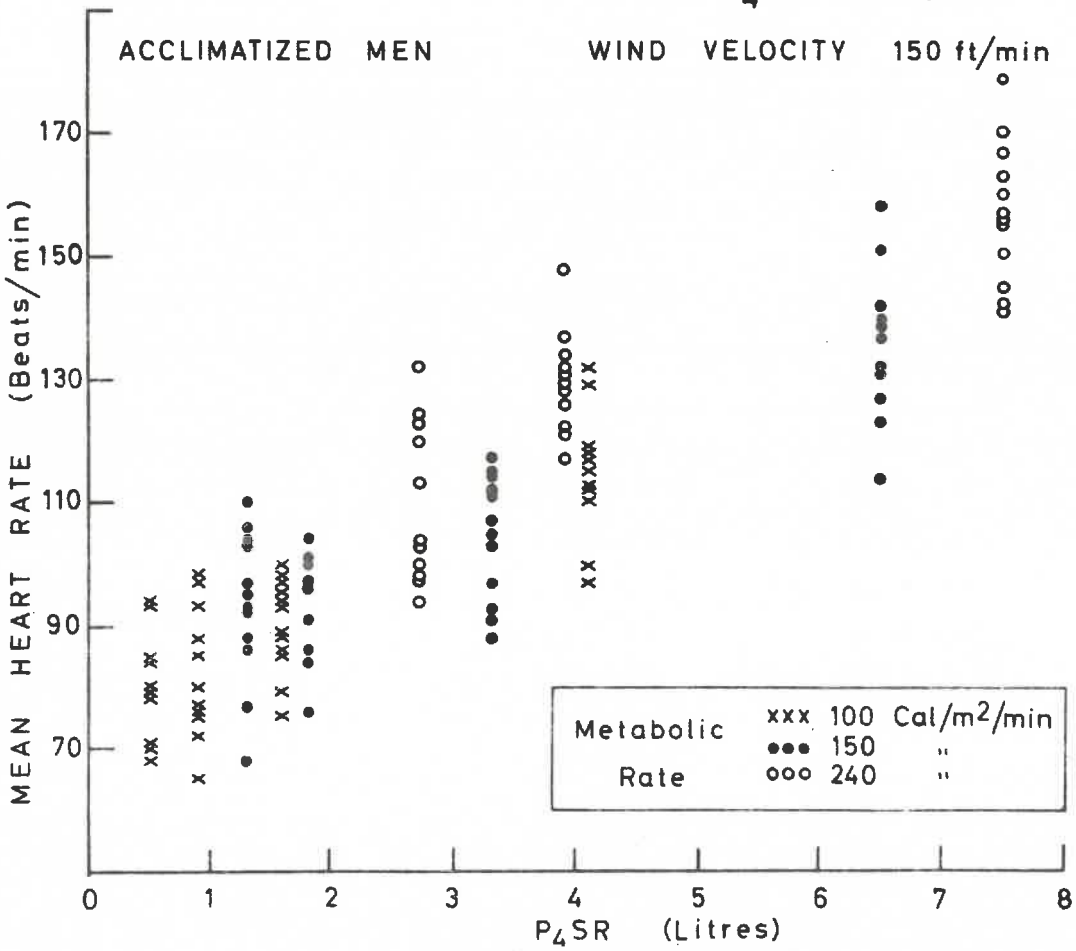

FIGURE 6

Observed Mean Heart Rate values vs. P_4SR values

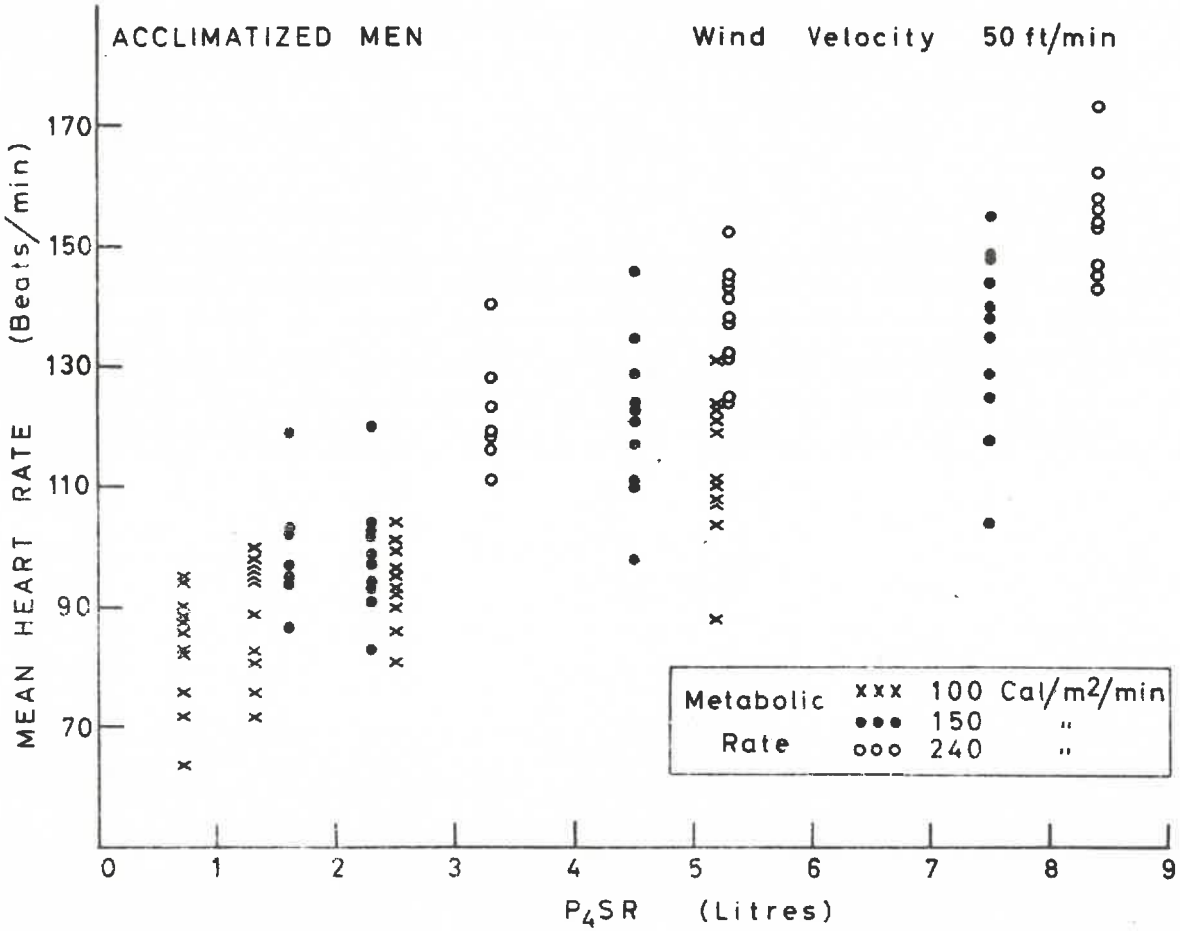

FIGURE 7

Observed Mean Rectal Temperature values vs. P_4SR values

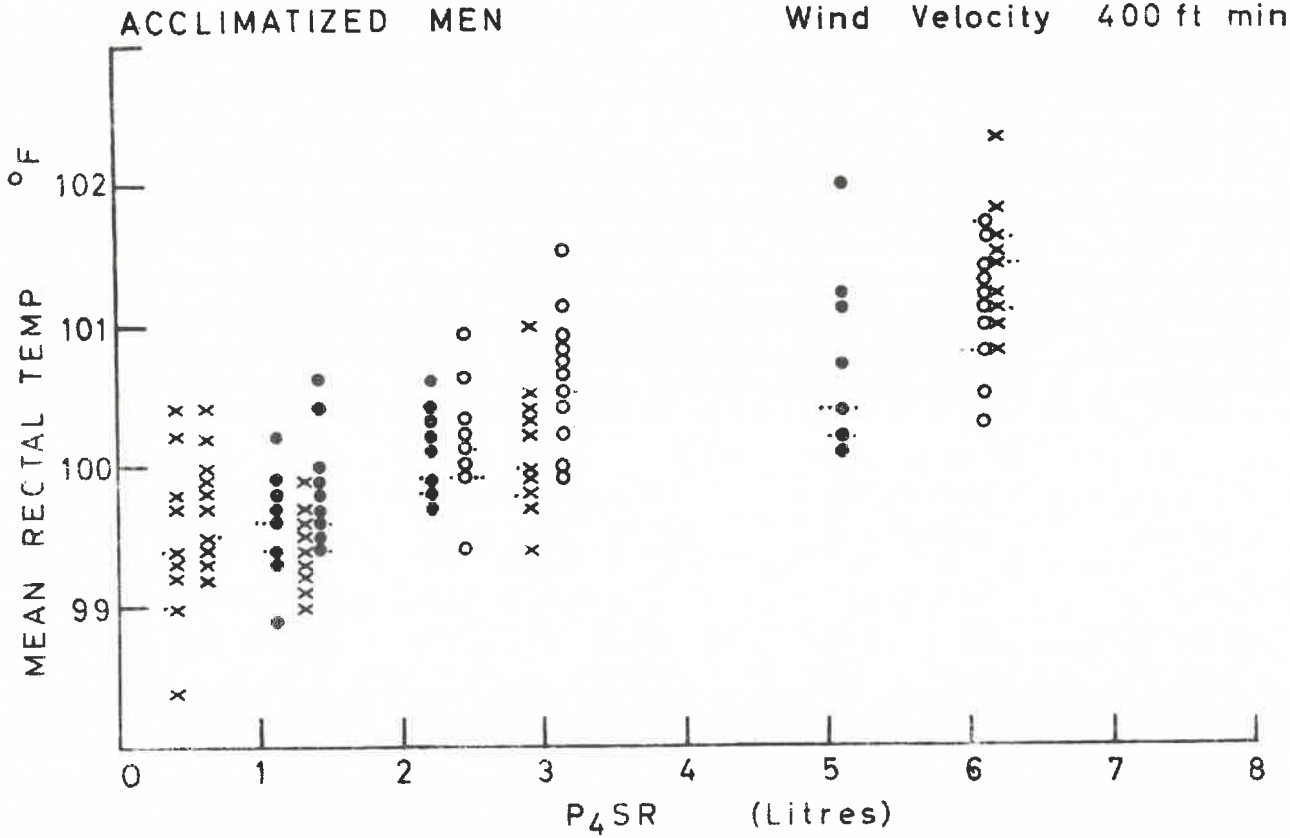

FIGURE 8

Observed Mean Rectal Temperature values vs. P_4SR values

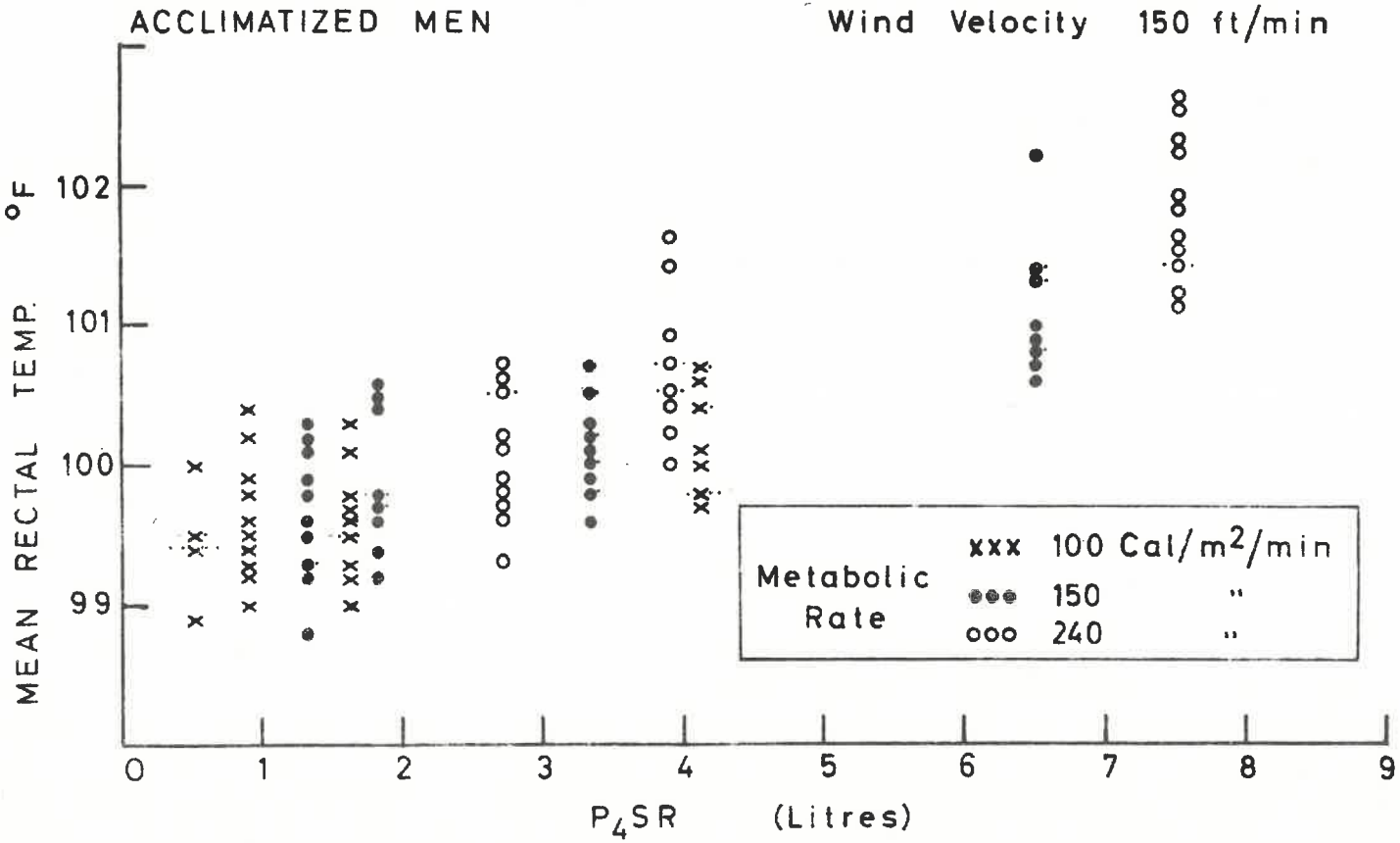

FIGURE 9

Observed Mean Rectal Temperature values vs. P_4SR values

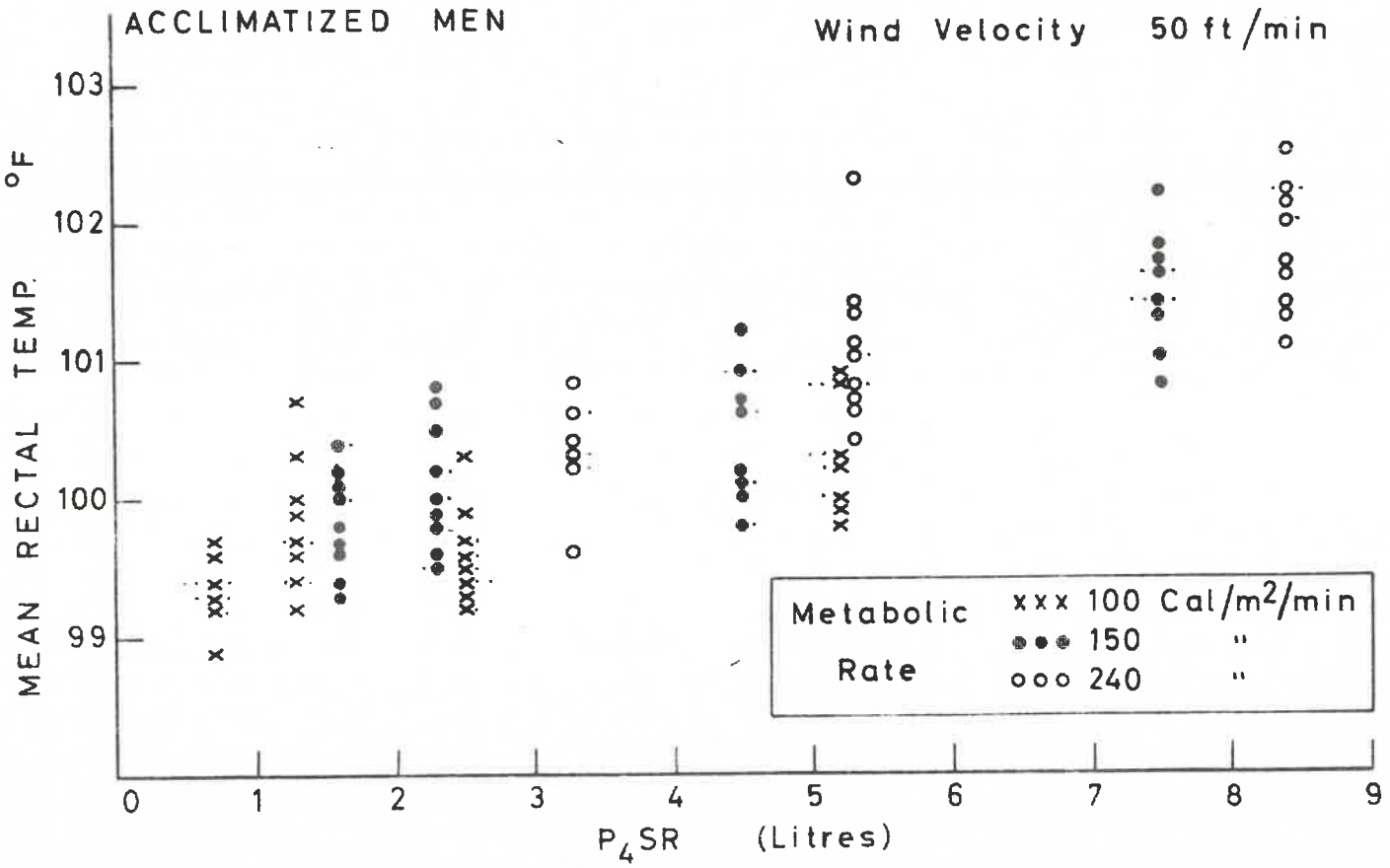

FIGURE 10

Regression of Mean Actual Sweat Rate on P_4SR

ACCLIMATIZED MEN

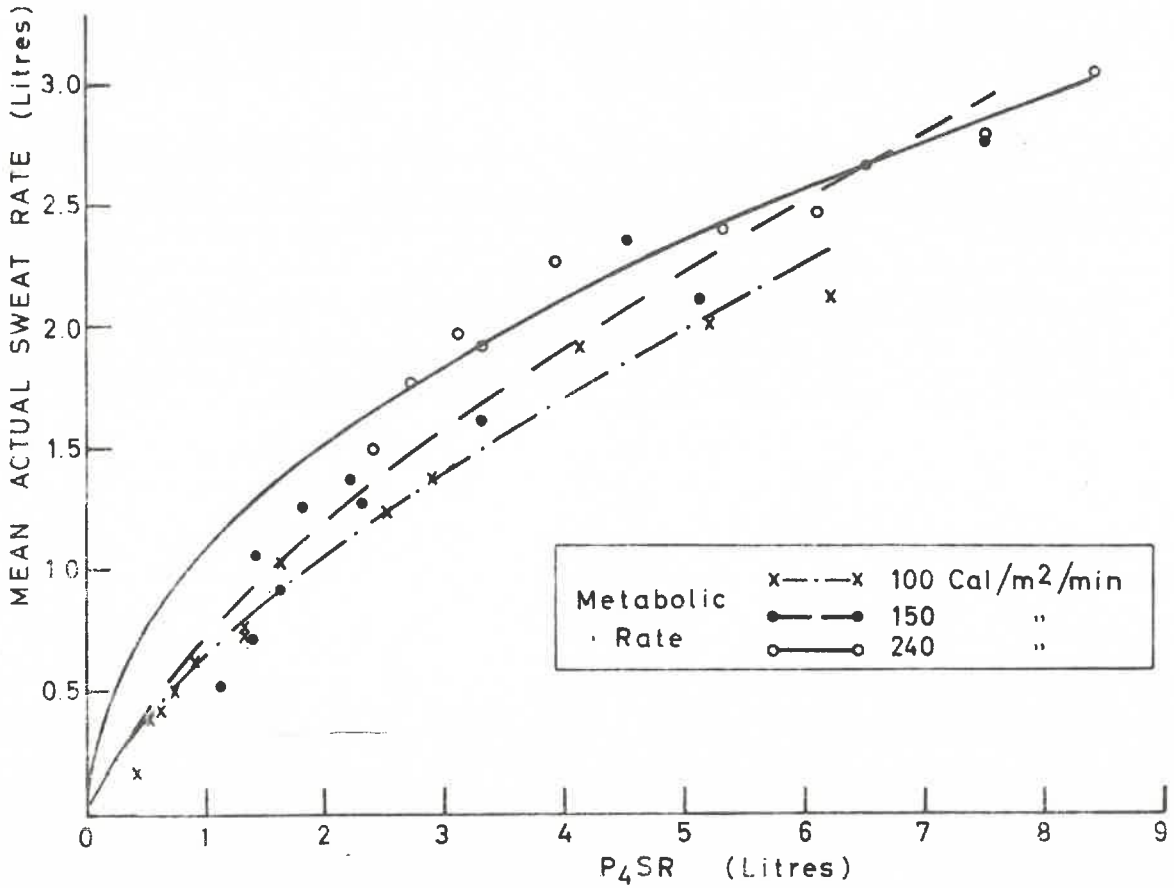

FIGURE 11

Regression Curves at the 5% level of Sweat Rate vs. P_4SR

ACCLIMATIZED MEN

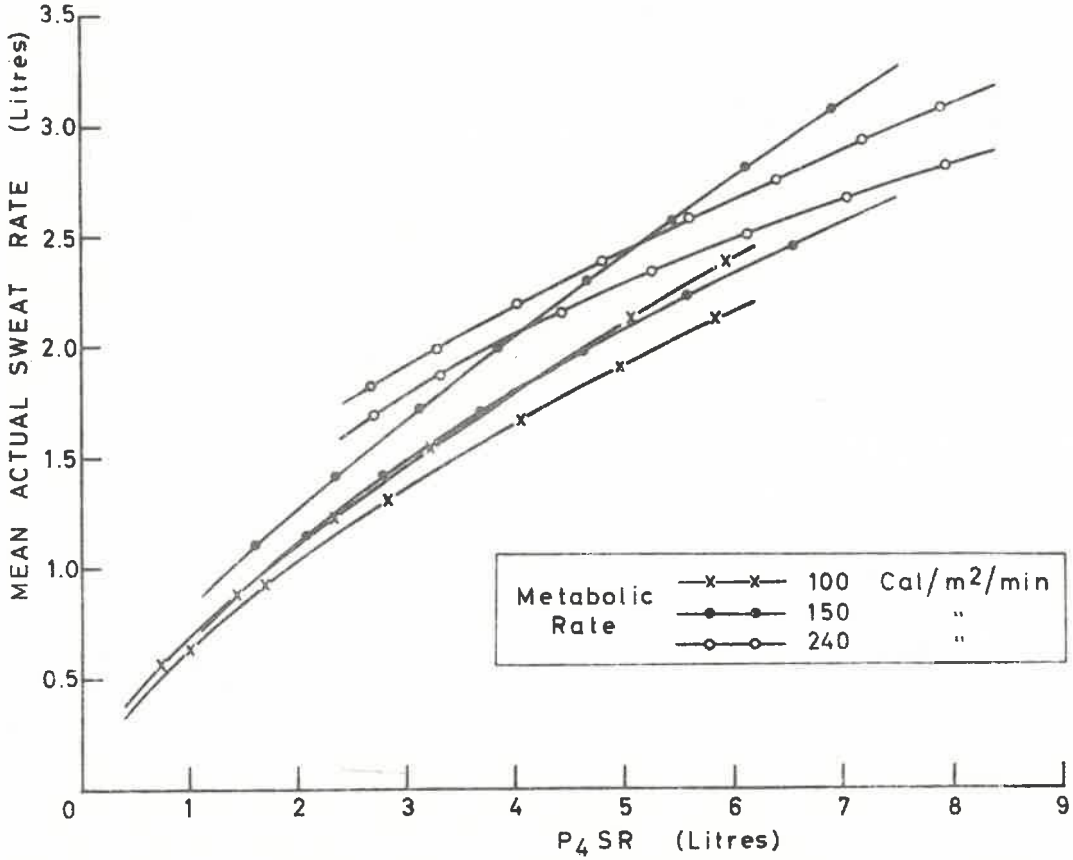

FIGURE 12

Regression of Mean Heart Rate on P_4SR

ACCLIMATIZED MEN

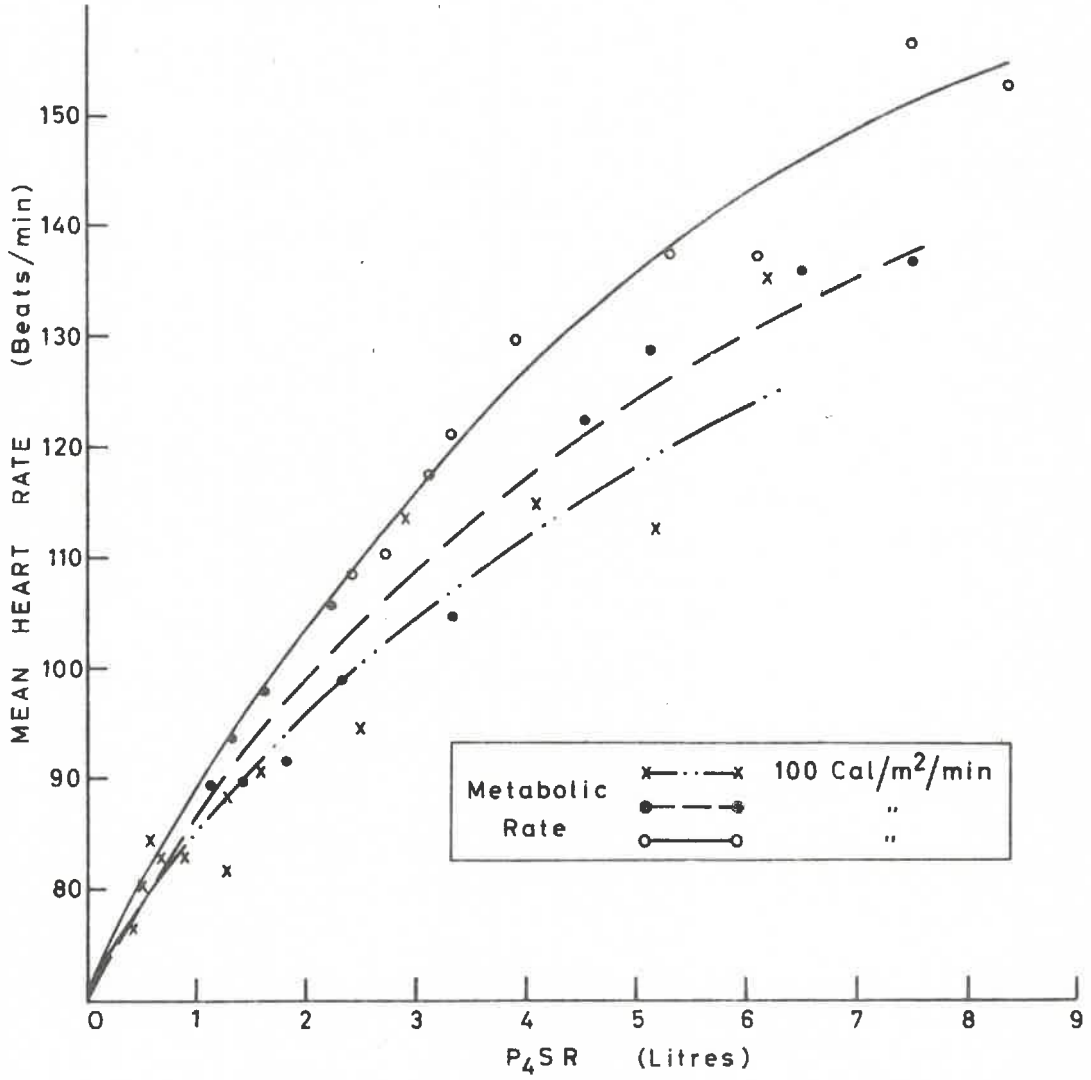

FIGURE 13

Regression Curves at the 5% level of Heart Rate vs P_4SR

ACCLIMATIZED MEN

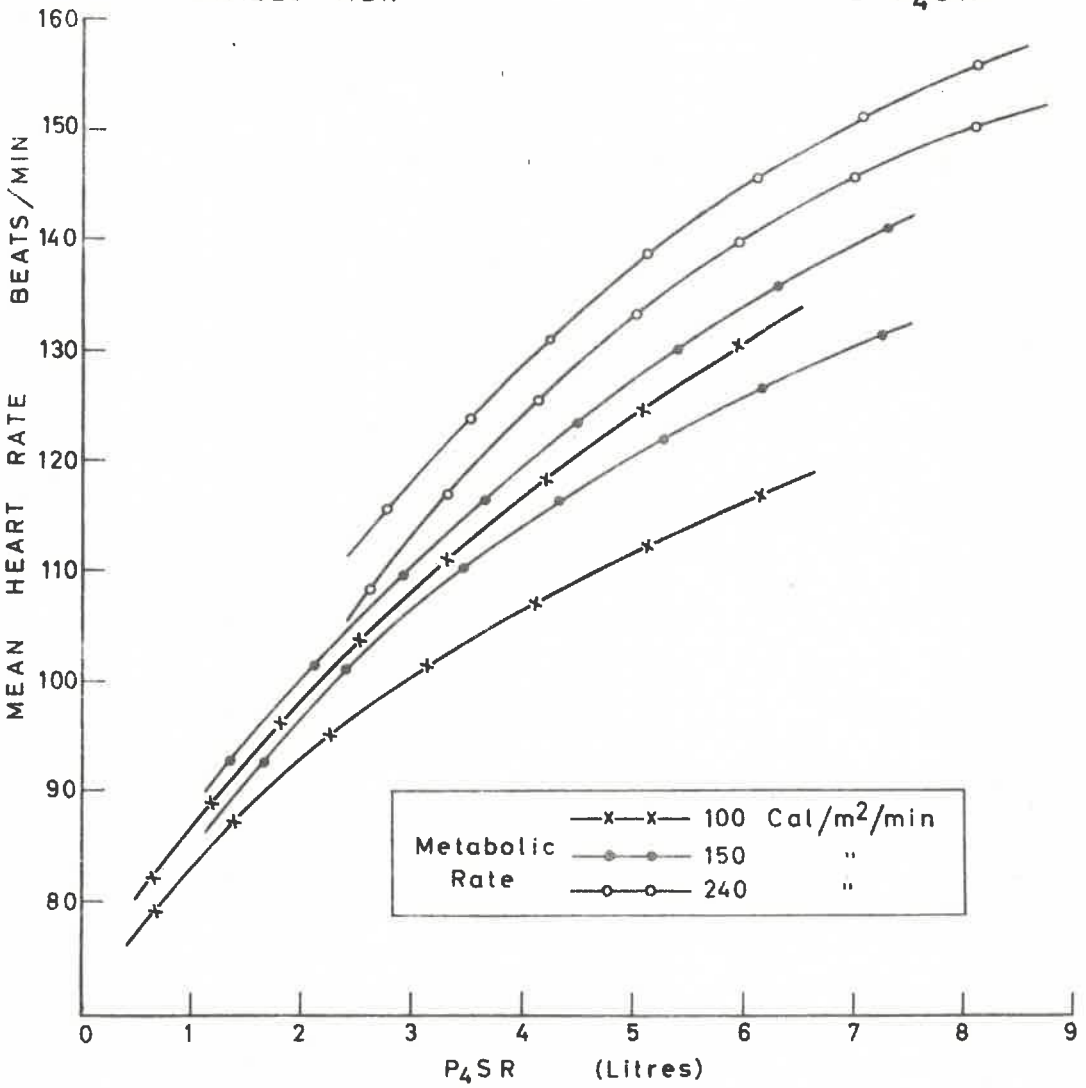

FIGURE 14

Regression of Mean Rectal Temperature on P_4SR

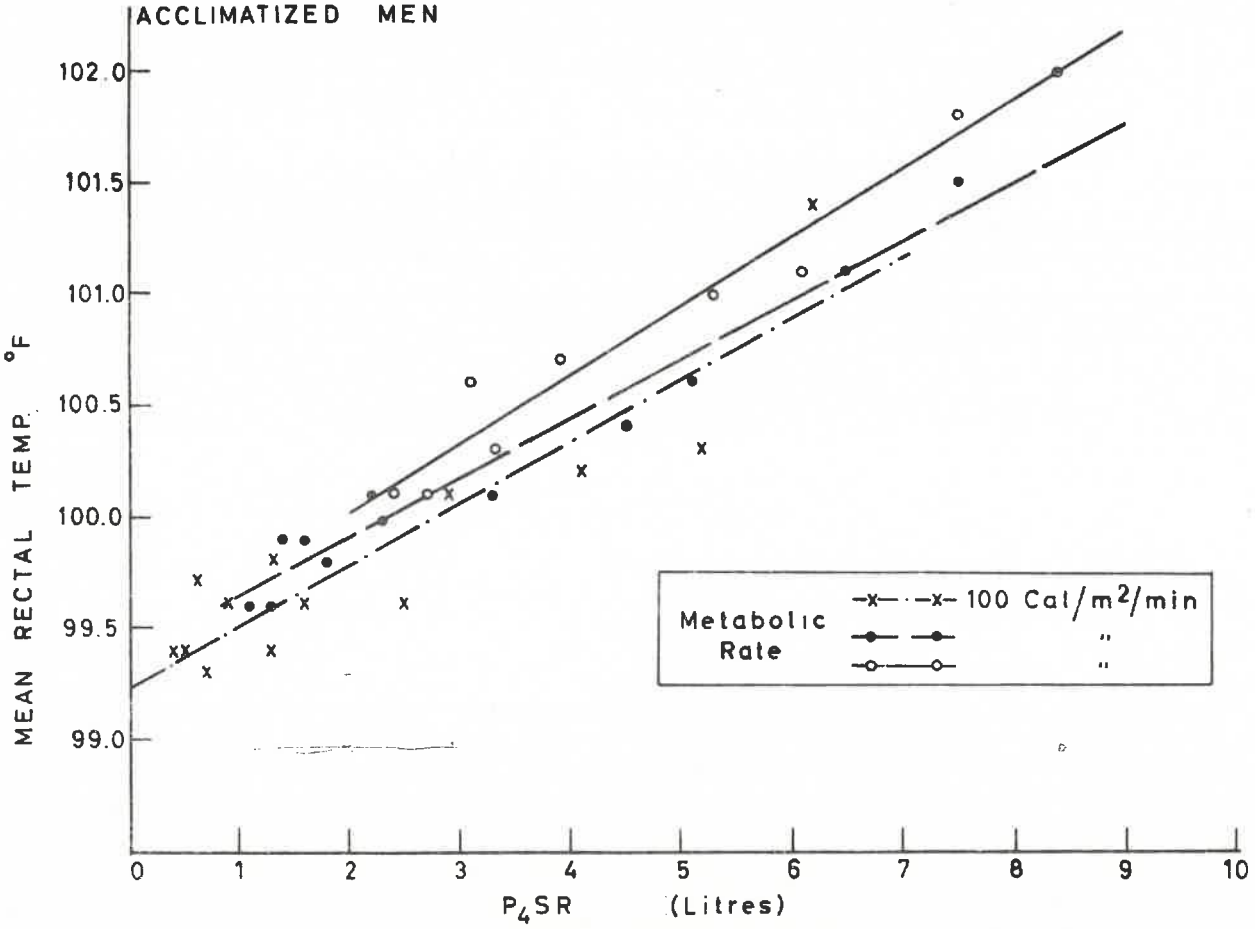

FIGURE 15

Regression Curves at the 5% level of Rectal Temp. vs P_4SR