MODEL OF THERMOREGULATION FOR PARAPLEGICS

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ABSTRACT

The authors evaluated the model of thermoregulation in paraplegics. The main interest was in paraplegics with problems in maintaining normal body temperature in their environment. In the morning, at noon and in the evening, in nineteen hot summer days, we measured the rectal and sublingual temperature. We selected fifteen paraplegics, and we measured also: the skin temperature on four places, blood pressure and heart rate. We estimated the perspiration above the injury and below it, the amount of clothes they wore. The questionnaire for personal feeling and comfort was designed. The combined influence of the weather, (temperature, humidity, wind and radiation) was estimated through an effective temperature, discomfort index and an equivalent temperature. We estimated the physical manifestations on the body, influenced by the weather, through reports of weather fronts objectively. The statistical methods pointed out that though thermoregulation is a very effective system for the maintenance of our intern environment, paraplegics do suffer many disturbances.

INTRODUCTION

Body temperature in man is maintained constant by physiological mechanisms and behaviourial responses (Weihe 1987). Behaviourial responses provides the conditions to live in different and extreme climatic environments (Yousef 1987, Astrand 1986).

Many authors studied the effect of different climatic stresses on the thermoregulatory processes of healthy people (Wagner 1974, Mathew 1981, Buget 1987, Sharma 1987, Kamen 1971, Sen Gupta 1984, Ookouchi 1987, Haskell 1981 and Issing 1986), the influence of aging (Mathew 1986) and body mass (Toner 1986).

Paraplegics with complete spinal cord transection have the main problem with their physiological thermoregulatory mechanisms (temperature receptors, central control and effectors). They have intersection of axons conducting the impulses from peripheral receptors to higher centers and the axons conducting in the opposite direction. The difficulty in regulating body temperature vary according to the time after injury, the level of the cord transection and relationship between deep and superficial temperature change (Downey 1971).Guttmann (1976) stated that paraplegics with spinal cord transection above T_8 at environmental temperatures above 35° C and below 20° C suffered from a condition of partial poikilothermia.

We developed a model of thermoregulation in paraplegics. The aim of the model is to see what kind of problems in maintaining the normal body temperature is associated with the environmental changes.

MATERIAL AND METHODS

Fifteen paraplegics were selected for our study: 14 men and one woman, aged between 18 and 56 years (mean age 37 years), with the body surface between 1.2 - 1.74m^2 (mean 1.37m^2), motor level of cord lesion C_5-L_5, median T_7, sensibility level C_7 - L_4, median T_{10} and time after injury 0.1 - 10 years (mean 1.56 years).

The body surface was calculated using the formula (DuBois 1916):

$$P = 71.84 \,.\, h^{0.425} \,.\, m^{0.725} \; /m^2/$$

We measured the rectal and sublingual temperature, as well as, the skin temperature on four places, blood pressure, heart rate, and estimated the perspiration above and below the injury. On the side we recorded the amount of clothes they wore, while the persons filled a questionnaire about their personal feeling of comfort.

Core temperature was measured by mercury thermometers in the rectum at the depth 7 cm and in the mouth under the tongue and skin temperature by platinum resistance thermometer Pt100 (surface 30x19 mm). Four position on the skin were: forehead, sternum, thigh and calf.

The combined influence of the weather (temperature, humidity, wind and radiation) was estimated through an effective temperature, discomfort index and an equivalent temperature (Plesko 1983, Angouridakis 1982), which were calculated using formulas:

Effective temperature $Tef = t - 0.4(t - 10)(1 - U\%/100)$

Discomfort index $DI = 0.4(t + t_1) + 4.8$

Equivalent temperature $Teq = t + 1.5\, emb$,

where: t - temperature of dry thermometer, t_1 - temperature of wet thermometer, $U\%$ - relative humidity and emb water vapour pressure in millibar.

The statistical analysis of data and the model of thermoregulation for paraplegics was tested by LISREL program, which provides an efficient estimation procedure for the causal effects and causal theories.It is based on the relationship between the measures of covariation between variables (covariance and correlation) and the causal effects (Sarris 1984).

RESULTS AND DISCUSSION

9-35 measurements (mean 21) were made in each person. Tables 1, 2 and 3 show the results.

The results						
	x1	#1	x2	#2	x3	#3
Tc	31.7	0.92	32.7	3.76	32.5	0.88
Tp	32.0	0.11	32.8	0.98	32.8	1.11
TN	31.9	0.78	32.8	1.98	32.6	0.84
Tn1	29.9	0.95	30.1	1.38	30.6	1.27
Tn2	29.7	0.86	29.9	1.39	30.2	1.19
TS	29.8	0.84	30.0	1.34	30.4	1.16
D	2.1	0.80	2.8	2.06	2.2	1.17
T	36.7	0.34	37.1	0.44	37.3	0.46
TE	17.8	2.61	22.1	3.24	20.0	1.90
DI	18.8	2.11	22.2	2.76	20.4	1.62
RS	122	13.1	122	13.2	123	14.30
RD	77	9.57	78	9.92	78	10.33
F	76	12.9	82	14.38	80	12.91

Table 1: x1-mean values in the morning, #1-standard deviation in the morning, x2-mean values at the noon , #2-standard deviation at the noon, x3-mean values in the evening, #3-standard deviation in the evening , Tc-skin temperature on forehead /°C/,Tp-skin temperature on sternum /°C/, TN-temperature of sentient portion /°C/, Tn1-skin temperature on thigh /°C/, Tn2-skin temperature on calf /°C/, TS-temperature of insentient portion /°C/, D=TN-TS, T-core temperature /°C/, TE- effective temperature, DI-discomfort index, RS-systolic blood pressure /mmHg/, RD-diastolic blood pressure /mmHg/, F-pulse

c	morning		noon		evening	
	Tef	DI	Tef	DI	Tef	DI
minimum	11.1	13.4	12.8	14.5	16.5	17.4
maximum	21.7	22.0	22.2	25.7	22.4	22.6
mean	17.8	18.8	21.1	22.2	20.0	20.4
	± 0.5	± 0.4	± 0.6	± 0.5	± 0.4	± 0.3

Table 2 : Minimal, maximal and mean values of effective temperature and discomfort index in all three measurement times

SO	morning	noon	evening
0	11	3	9
1	6	13	10
2	2	3	0
3	0	0	0

Teq	SO
< 49	0 - no stress comfort
59 > SO > 49	1 - stress for ill and weak people
> 59	2 - stress also for healthy people
> 59 + stressed day before + all night or emb > 18mb	3 - severe stress

Table 3: Distribution of values of sultriness (SO) in the morning, noon and evening and the relation between the effective temperature (Teq) and stage of sultriness

From tables 2 and 3, we concluded that weather stresses were not great and serious. Sultriness never reached the stage three and only five times stage two. Discomfort index, also, never reached the maximal discomfort (100%), only effective temperature was six times (always at the noon) higher than 24.5 - very hot. In ten years, July temperatures (eight days) and August (eleven days) were above or equal to the average. The number of sunny hours was also only just above the average.

For every day and every measurement time the hypothesis that the mean skin temperatures on forehead and on sternum (thigh and calf) are equal was tested by "t" test. The differences between two skin temperatures measured at the had should be greater, because of a small number of samples. Only in eight from 34 examples tested we got the statistical significant differences between temperatures on forehead and sternum and only in six from 26 for temperatures on thigh and calf. Because the differences (divergences(were of the opposite sign, it was even more difficult to say that those hypothesis are not true.

As we did not get statistical significant differences between skin temperatures on forehead and sternum neither between temperatures on thigh and calf we calculated from them the temperature of sentient portion ($TN=(Tc+Tp)/2$) and temperature of insentient portion ($TS=(Ts+Tg)/2$) with which we operate in further analyses.

Because of diurnal variation of body temperatures for further analyses the values were distributed in three samples: sample of morning measurements (morning n=95), sample of noon measurements (noon n=96) and the sample of evening measurements (evening n=90). A unit in those samples was measurement made in one person. The detailed measurements in specific person provided better sampling of some variables (age, level of lesion, body surface, time after injury). The detailed information was included in the model, thus their influence on results was eliminated (Sarris 1984).

For all measurements, the model was tested by LISREL program (Figures 1-3).

Arrows between the variables present the expected causal effects. The numbers on them are the parameters of the LISREL model. They showed, the amount of variable change, at which the arrow points, due to the one unit change of the variable where the arrow origins.

This model differs from the model in healthy human, when relationship of various body temperatures is studied. The adjusting temperature is the core temperature. This is in healthy men adjusted by skin temperature. This is acting as a puffer(Hoppe 1987). In paraplegics the skin surface above the lesion is not involved in the termoregulation, therefore the temperature below the lesion influences the core temperature.

Also, the arrow from the skin temperature of sentient portion to the temperature of insentient portion is a sign of disturbance of termoregulation in paraplegics. If the skin surface above the lesion is too small for maintaining an adequate core temperature, than the warmer blood comes in the skin below the lesion. This influence the skin temperature, together with the environmental warmth. This influence is strong in the morning, even stronger at noon, while in the evening it drops down.

The thermoregulation has been most disturbed at noon as the biothermal influences were the biggest. At noon an arrow from skin temperature appears of sentient portion to the core temperature. In our opinion, the surface of the skin below the lesion was to small to maintain an adequate core temperature. The disturbance was great and the influence could be seen. Not only that the skin temperature below the lesion was different, but also core temperature was higher. With those variables 43% of total variance of core temperature could be explained.

In the morning there was no thermal stress, the environment was in an termoneutral range. The percentage of explained variance of core temperature was also appropriately small, only 13%.

In evening, the biothermic influences were not large, but at this daytime the body temperature reaches the highest values in the daily cycle. Therefore, at this time the heat is not well tolerated, as humans are more sensitive for higher environmental temperatures.

The whole model was tested by the LISREL program by "hi" square test. The hypothesis is that data ideally fit the model. If hi square value is big the hypotheses and model can be rejected (with certain risk or significance level).

Hi-square value was the smallest at noon and the biggest in morning, thus, our morning data didn't fit the model very well. In our opinion, this is a consequence of too small climatic stresses in the morning and of an ideal thermal conditions in patients beds. The patients were only ten minutes nude before morning measurements and this time was too short to get the true influence of environment on the temperatures.

CONCLUSION

Termoregulation is an important neurophysiological process in humans. Though thermoregulation is a very effective system for maintenance of our intern environment, paraplegics suffer disturbances if the influence of temperature, humidity, wind and radiation is large. This can be diminished by proper control of clothes, the choice of environment, cooling or warming.

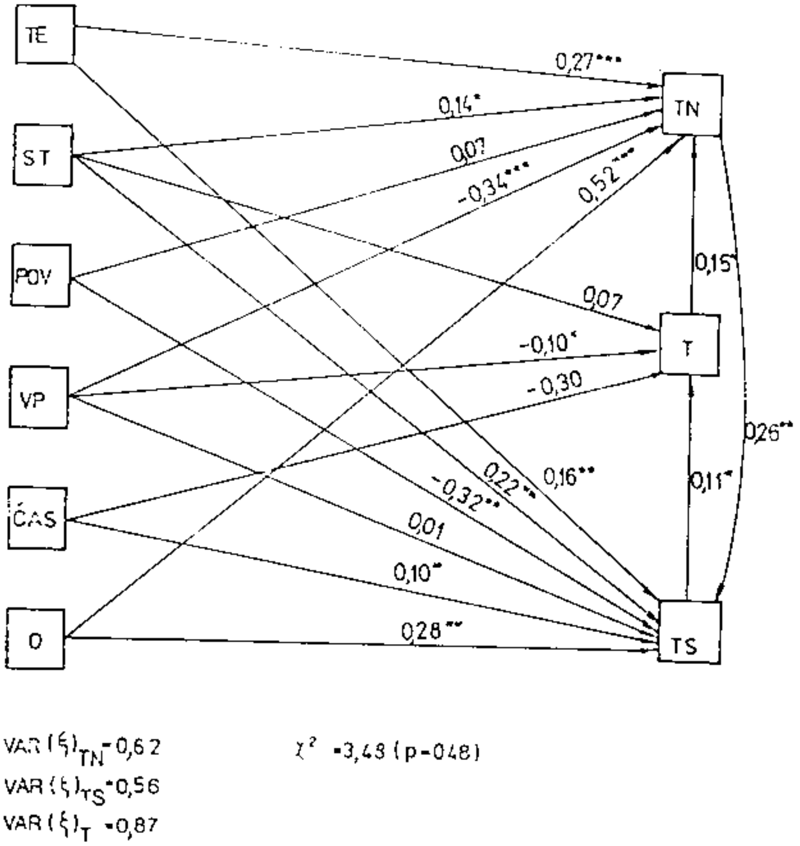

Figure 1. Linear structural model of thermoregulation (in the morning) with percentage of unexplained variance for core temperature, skin temperature above and below the lesion and value. (TE-effective temperature, ST-age, POV-body surface, VP- sensitive level of cord transection, CAS-time after injuries, O-clothes)

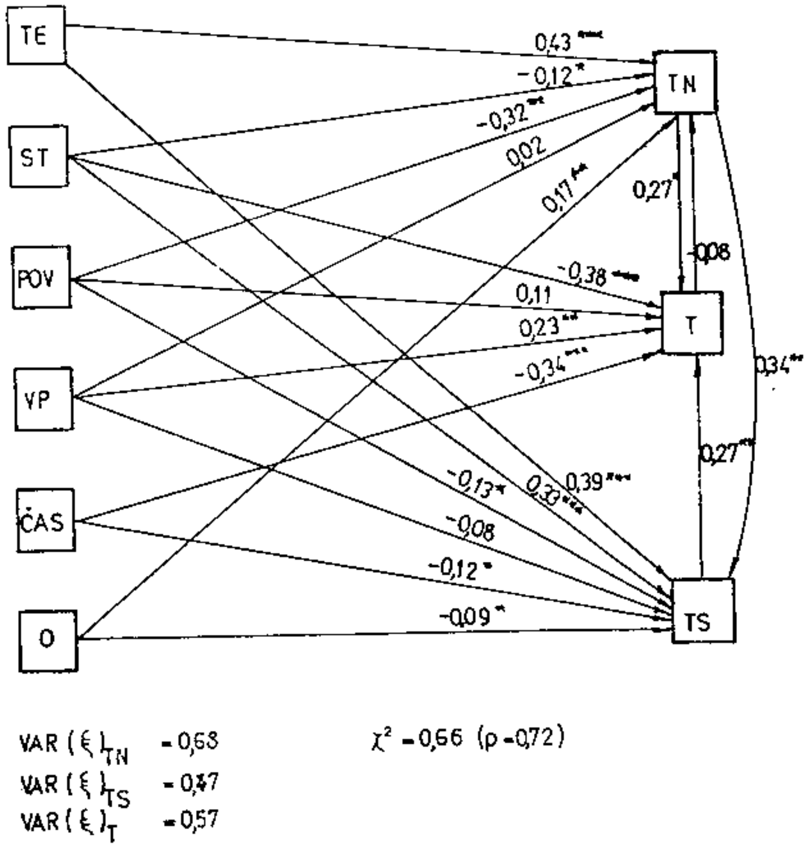

Figure 2. Linear structural model of thermoregulation (in the noon) with percentage of unexplained variance for core temperature, skin temperature above and below the lesion and value. (TE-effective temperature, ST-age, POV-body surface, VP- sensitive level of cord transection, CAS-time after injuries, O-clothe)

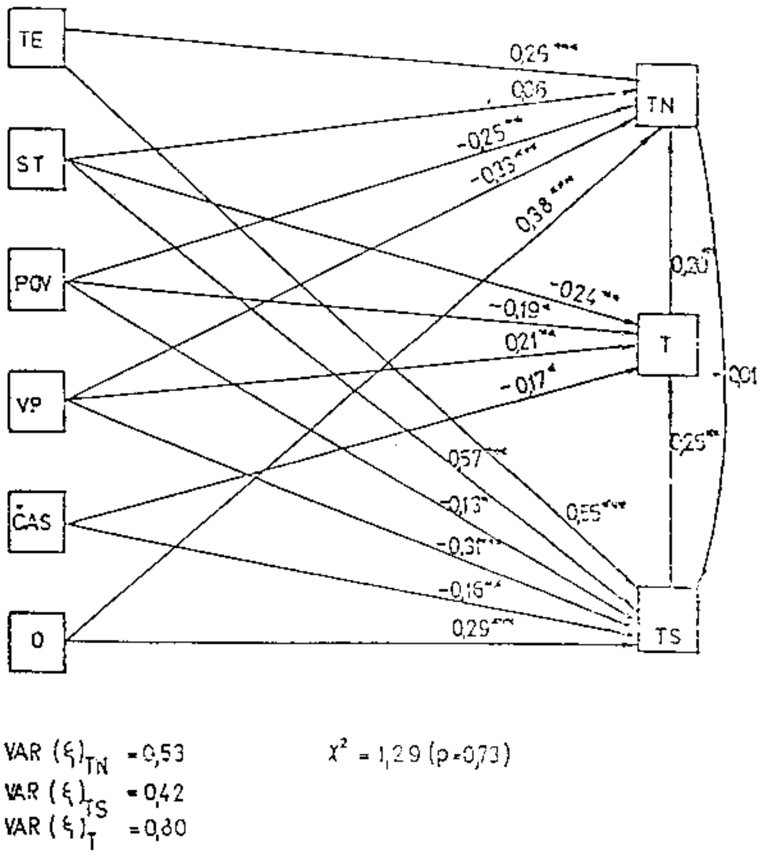

Figure 3. Linear structural model of thermoregulation (in the evening) with percentage of unexplained variance for core temperature, skin temperature above and below the lesion and value. (TE-effective temperature, ST-age, POV-body surface, VP- sensitive level of cord transection, CAS-time after injuries, O-clothes)

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