Session II
Heat Stress in Industry
Abstracts 5-10

5 Physiological limitations of human performance in hot environments, with particular reference to work in heat-exposed industry

K. Rodahl and *T.* Guthe, Institute of Work Physiology, Oslo, Norway

Human performance depends on a variety of factors. Environmental temperature is one of them. Neuromuscular function and energy-yielding processes which are the basis for human performance are temperature dependent, reaching their optimum at temperatures above resting levels (see Aastrand and Rodahl, 1986). At higher temperatures both physical and mental performance may deteriorate. An association between heat stress and hypertension has been claimed (Kloetzel et al. 1973), but this is not confirmed. In extreme cases, however, acute heat stress may cause collapse, hyperthermia or even death.

During the past several decades, considerable effort has been devoted to refining methods for the assessment of environmental heat exposure, such as the Effective Temperature, Corrected Effective Temperature, Wet Bulb-Globe Temperature (WBGT) and the Wet Globe Temperature (WGT). All these methods are aimed at assessing the thermal load imposed by the environment. However, the environment is one thing, hut the human reaction to that environment is something else, and of far greater importance. For this reason, greater emphasis should be placed on the assessment of human response to the heat stress encountered by workers during the performance of their every day work at their actual work place. Without such information any discussion of safe or upper limits of exposure would seem meaningless.

During the east several years we have been involved in extensive studies of heat strain in several types of Norwegian heat-exposed industries, especially the el [illegible] industry. From our data it may be concluded:

For the purpose of assessing the heat load of the environment under the conditions of predominantly dry radiant heat encountered in our industry, the WGT may be preferable to the WBGT, in that the former uses a smaller inexpensive instrument which reacts more quickly. Furthermore, there is a good correlation between the two indices, especially in dry radiant heat. One can be converted to the other by a simple formula. At any rate, the recording of such environmental temperature with great accuracy (fractions of a degree) is often meaningless, since the environmental temperature may fluctuate by as much as 10 degrees from place to place. or from hour to hour in the same place.

For the assessment of the physiological reaction to the heat load imposed by the environment, we have routinely recorded on a continuous basis with the aid of portable recorders or loggers, deep body temperature and thigh skin temperature. Under moderate conditions we have found the thigh skin temperature, as proposed by Ramanathan (1964), to be close to mean skin temperature, and it may be used for the estimation of body heat content, to determine the rate of heat gain. Oral temperature may be a poor substitute for rectal temperature (Mairiaux et. al., 1983) and cannot always be easiiy recorded continuously in the field. Rectal temperature reflects, in our experience, body heat gain or loss when recorded over several hours. The skin temperature may also be used in the case of radiant heat as an indication of how close the worker is to the heat source, how often and for how long. We have also routinely recorded heart rate with the aid of the same portable recorder or logger, as an indication of combined work stress (work. heat and emotional stress).

Sweat rate has been determined by changes in body weight, taking into consideration food and fluid intake, and stool and urine output, and used to reflect fluid loss as part of the evaporative heat loss. In our experience this is a most valuable index of heat strain under the conditions studied, since it reflects the state of hydration, which in our experience is a key to the maintenance of homoeostasis and performance.

Blood samples were in some of the studies taken before, during and after the industrial heat exposure for the analysis of Na, Cl, K, creatinine, renin, hemoglobin and hematocrit. Urine samples were analysed with respect to epinephrine and nor-epinephrine.

The actual time of exposure was accurately recorded by time-activity logs.

The complexity of the assessment of heat stress in industrial operations is evident from the fact that in many of our field studies no direct relationship was found between the environmental temperature on the one hand and the different physiological responses to this temperature on the other

The American Conference of Government Industrial Hygienists (ACGIH, 1976) has recommended limit values tor industrial application. based on the WBGT. The limit values are based on the assumption that almost all acclimatized and fully-clothed workers with an apppropriate fluid and salt intake should be able to work under the given conditions without their body temperature rising above 38°C. There appears to be no valid physiological basis for this assumption, however, and there is no reason to believe that a rectal temperature above 38°C, in healthy people, is associated with any health hazard. On the contrary, physical performance improves with elevated body temperature, and this is the reason for the warming-up procedures practiced by athletes prior to athletic competitions.

In a study of workers at a ferry-alloy foundry, there was no significant difference in the blood pressure between heat exposed and non-heat exposed workers of similar age and duration of employment. Plasma renin concentrations were elevated during fhe work shift in the heat exposed foundry workers. but this was also the case in workers in the same company engaged in prolonged heavy physical work in a cool environment. The cause of elevated renin concentration in both cases may be a reduced kidney blood flow.

The results of the blood analyses were all within normal limits. The urinary catecholamine elimination showed no systematic correlation with heat exposure.

The solution to many of the problems associated with industrial heat exposure may be based on a combination of practical measures such as: shielding of the heat source, reducing each period of exposure to about 20 min, interspaced with brief 10 min. cooling off breaks, elimination of strenuous physical work close to the heat source, replacing exposed manual labor by mechanical aids, nursing the industrial process properly *ai* all times so **as** to avoid complications that will necessitate measures causing excessive exposure to heat stress. A key point is to avoid prolonged intense heat exposure, which will lead to profuse sweating. This will reduce the fluid loss, and thereby the need for fluid intake, mrrespondingly. The aim should be for the worker to leave the place of work fuiiy hydrated. able to enjoy his leisure time.

<u>References</u>

ACGIH (American Conference of Government Industrial Hygienists): Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with intended Changes for 1976". Cincinatti, Ohio, 1976.

Kloetzel. K., A. Etelvino de Andrade. J. Falleiros and J. Cota Pacheo: ...en Hypertension and ... Exposure to Heat. J. Occupational in..., 15 (11):878 1973.

Mairiaux, P., J.C. Sagot, and V. Caudas: Oral Temperature as an Index of Core Temperature during Heat Transients, Eur. J. Appl. Phusiol. 50: 331, 1983.

Ramanathan, L.N.: A New Weighing System for Mean Surface Temperature of the Human Body. J. Appl. Physiol. 19 (3): 531, 1964.

Astrand, P.-O., and K. Rodahl: Textbook of Work Physiology, 3. Edition. McGraw-Hill Book Company, New York, 1986.