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INFLUENCE OF EXTREMAL HEAT WAVES ON MAN

Abstract: Advections of subtropical air masses in Central Europe bring heat waves mainly during summer and also in spring and autumn. At summer heat waves the air temperature reaches up to 35-38°C. They effected the human organism both, the functioning of thermoregulation system as well as the human health and well being. The paper presents the results of thermophysiological and medical observations carried out during extremal heat waves in Poland in July 1989 and July 1994. They influenced the human heat balance and human health.

Key words: human heat balance, MENEX model, heat load, heat waves.

1. Introduction

Adaptation of the human organism to hot environment produces specific reactions of thermoregulation system (Hensel 1981; Ingram, Mount 1975). The most important is activation of sweat glands (Klonowicz, Kozlowski 1970). Sweat evaporation increases the heat elimination from the body and decreases the skin temperature (Błażejczyk 1993, 1997; Malchaire 1991). Intensive regulation of the body temperature in the hot leads to great load of circulatory and respiratory systems of an organism (Błażejczyk et al. 1999a; Givoni, Goldman 1973; Smolander 1987). The intensive work of heart and respiratory system in the hot effected the rates of circulatory as well as respiratory diseases and depths (Błażejczyk et al. 1999b; Kuchcik 2000; Matzarakis, Mayer 1991).

The aim of the paper is to present some results of common, climatological as well as thermophysiological and medical research carried out in Poland in July 1989 and in July 1994.

2. Materials and Methods

Climatological and thermophysiological investigations were carried out in North-eastern Poland in July 1989. The full complex of meteorological elements (solar radiation, air temperature and humidity, wind speed, cloudiness) as well as physiological parameters (skin temperature, sweat secretion) were observed simultaneously every hour from 6:30 a.m. till 8:30 p.m. (Błażejczyk 1993).

Climatological and medical research were carried out in Warsaw from July 1994 till December 1995. The meteorological elements (air temperature and humidity, wind speed, cloudiness) were observed on the weather station of Warsaw University. Simultaneously, the physicians from outpatient surgery in Warsaw have noted every day amount of patients suffering respiratory, circulatory, digestive and skeleton system diseases. The most frequently respiratory and circulatory patients have visited the surgery. For the present paper July and August 1994 were taken into consideration (Błażejczyk et al. 1999b).

The human heat balance was calculated with the use of the MENEX model (Błażejczyk 1994). The general equation of the heat balance has the following form:

$$M + R + E + C + L + Res = S$$

where: M is metabolic heat production (assumed as 70 W m^{-2}, which is typical for standing man), R – solar radiation absorbed by man, E – evaporative heat loss, C – heat exchange by convection, L – heat exchange by long wave radiation, Res – respiratory heat loss, S – net heat storage, i.e. changes in body heat content. The S is resultant value of heat exchange between man and his surroundings. For long periods (24 hours or longer) S can be considered as equal to zero, i.e. heat gains are equilibrated by heat losses. However, in particular moments the S has positive or negative values. In this case accumulation of heat in the body or body core cooling occur.

3. Results

In July 1989 short but very intensive heat wave reached North-eastern Poland. In the beginning of the period daily air temperature was 25-30°C and in the last day it was about 38°C. Air humidity was relatively low and wind speed did not exceed 2.5 m s^{-1}. Physiological observations pointed to very intensive sweating of subjects. Their skin temperature was very high and it varied from 30 up to 35°C, i.e. in some situations it was lower then air temperature. It effected additional heat gains by convection. 8 July convective flow transferred up to 20 W m^{-2} of heat from the air to the body. Its value was similar to heat gain by absorbed solar radiation. High skin temperature activated sweat gland and heat loss by evaporation was the main way of heat elimination from the body. This process was especially effective in the midday hours, when intensity of evaporative heat loss reached up to 70-80 W m^{-2}. Amount of absorbed solar radiation was similar at whole studied period. However, it strongly fluctuated during the day. The lowest R values were observed at midday hours what is caused by solar geometry. In the high Sun altitudes in spite of great intensity of solar beams their values absorbed by man were relatively low. In an effect of low absorption of solar radiation and of intensive evaporative heat loss the net heat storage was the smallest during midday hours. It protected an organism against strong heat accumulation in the body core (Fig. 1).

The heat stroke caused by subtropical air mass can be assesed by two indices: SW, which indicates amount of water lost by evaporation (in grams per hour), and HL, which indicates heat load caused by absorbed solar radiation and net heat storage. HL values varied from 0.82 at 4 July (cloudy conditions) up to 1.46-1.49 at 7 and 8 July (sunny conditions). However, more then 50% of observations indicate slight, small or moderate hot stress (Tab. 1).

It means that during the studied period thermoneutral conditions or not great heat load in man occurred. Relatively soft thermal conditions are confirmed by SW index. Its value did not exceed 208 grams per hour. The alert SW value for unacclimated subject is 260 g h^{-1} (Fig. 2). The results point to great acclimatisation abilities of man which can eliminate the physiological hazard of heat waves.

Tab.1. Frequency of heat load intervals during heat wave in North-eastern Poland, July 1989.

HL	Heat load in man	Frequency (%)
< 0.750	very strong cold stress,	-
0.751 – 0.810	great cold stress,	-
0.811 – 0.870	moderate cold stress,	4.0
0.871 – 0.930	small cold stress,	4.0
0.931 – 0.970	slight cold stress,	8.0
0.971 – 1.080	thermoneutral,	33.4
1.081 – 1.185	slight hot stress,	29.3
1.186 – 1.415	small hot stress,	16.0
1.416 – 1.600	moderate hot stress,	5.3
1.601 – 1.750	great hot stress,	-
> 1.750	very strong hot stress.	-

In the light of above analysis very interested seem to be the results of medical observations made in Warsaw during advection of subtropical air mass in the Summer 1994. The heat wave has started about 4 July with air temperature (ta) of about 25°C and the highest ta (30-35°C) occurred from 25 July till 7 August. High air temperature effected high intensity of net heat storage in man (up to 65 W m^{-2}). The heat wave influenced daily amount of respiratory and circulatory patients in different ways.

Mean, daily summer number of respiratory patients is about 10 per day. In July-August 1994 it varied from 4 up to 18 per day. Significant increase in respiratory patients was observed mainly in the beginning of heat wave (10-18 patients per day). After acclimatisation to new weather conditions respiratory problems occurred less frequently (4 to 10 patients per day during culmination of heat wave). Increase in respiratory patients was observed 2-3 days after temporal, short decrease in air temperature (Fig. 3).

Mean daily amount of circulatory patient (30 per day) was relatively constant over all the year. Significant increase in circulatory patients (up to 45 per day) was observed in the second week of heat wave. Next, significant increase in circulatory patients was observed about 2 weeks after the heat wave (Fig. 4).

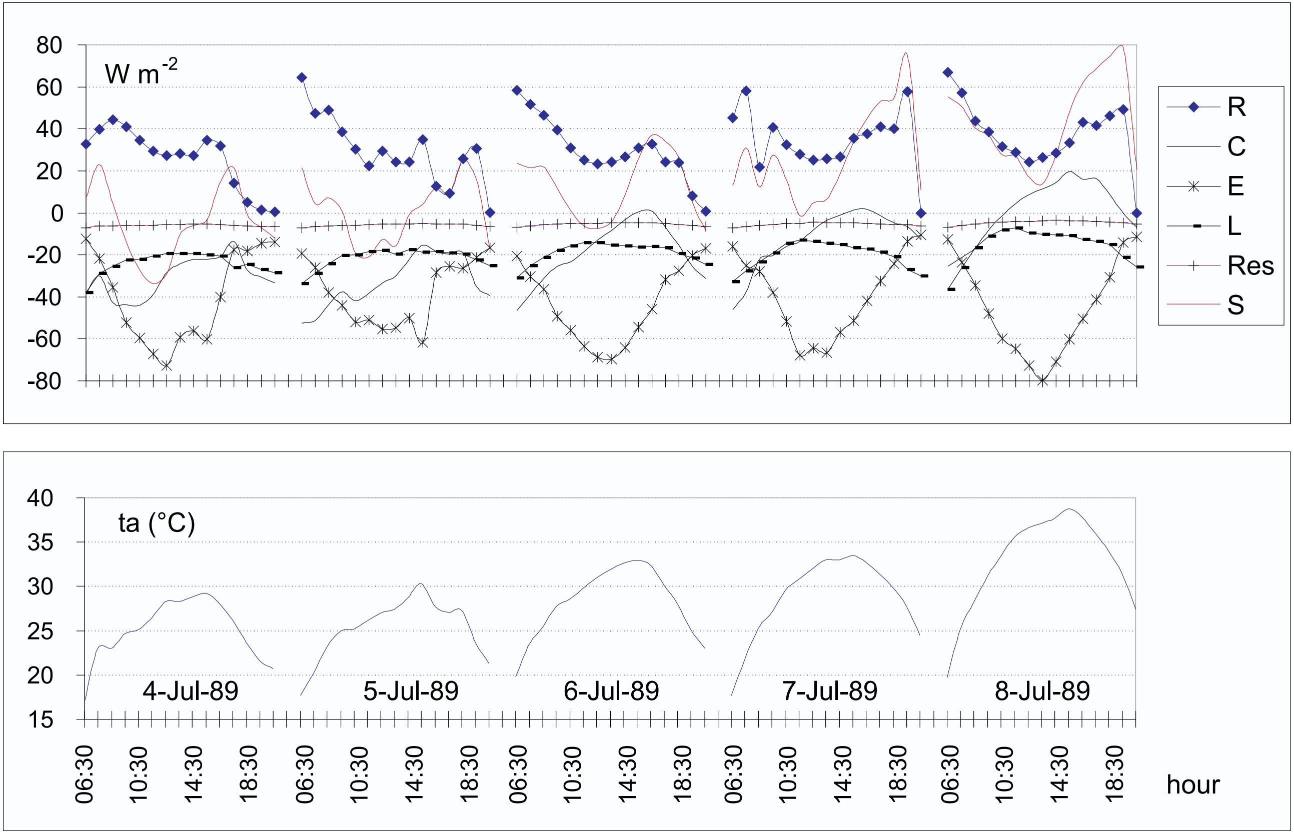

Fig. 1. Daily courses of human heat balance components (upper panel) and air temperature (ta – lower panel) during the days with advection of hot-dry subtropical air mass, North-eastern Poland, 4-8 July 1989.

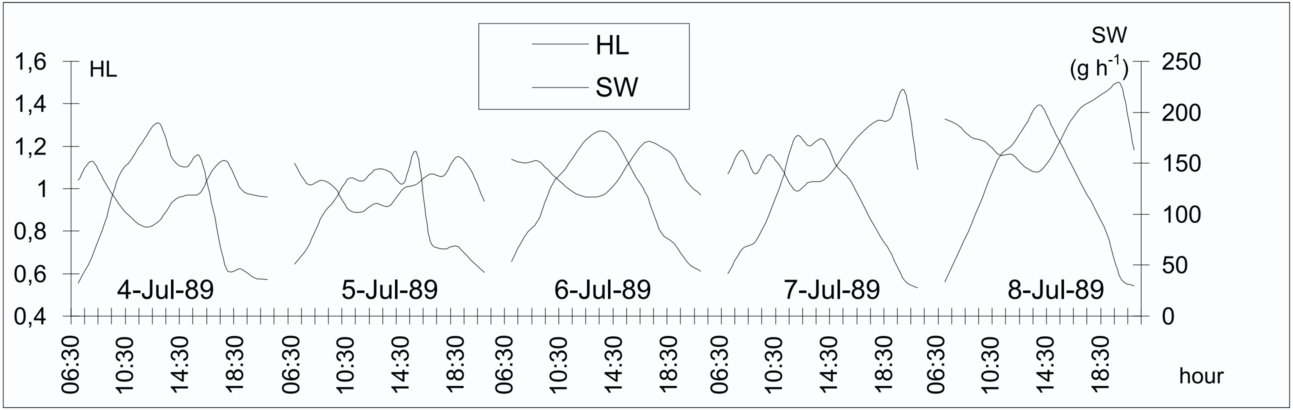

Fig. 2. Daily courses of heat load (HL) and water loss (SW) indices during the days with advection of hot-dry subtropical air mass, North-eastern Poland, 4-8 July 1989.

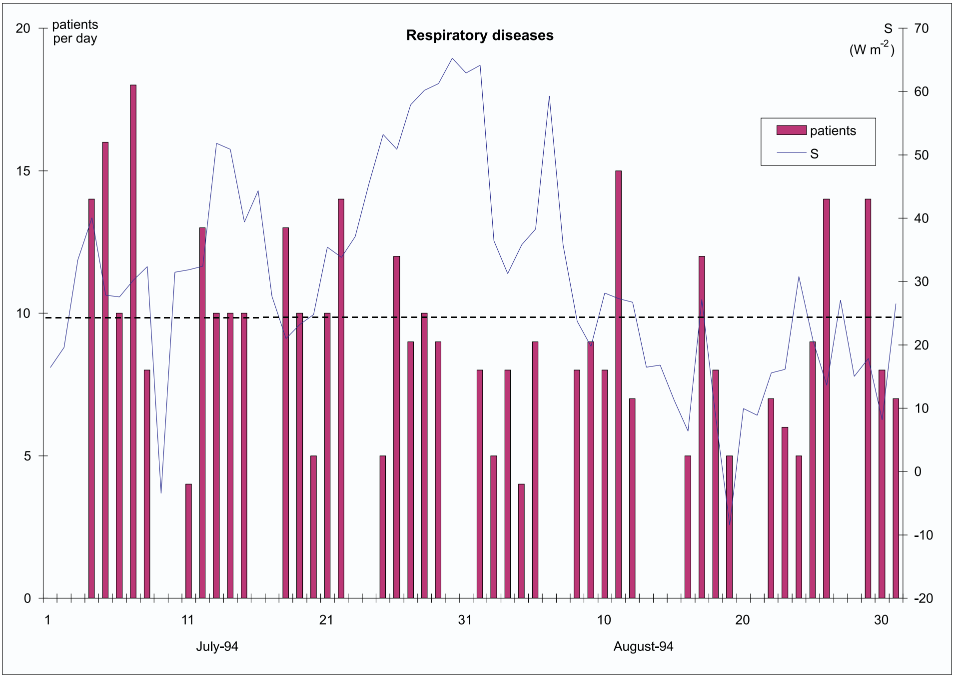

Fig. 3. Changes in respiratory patients and net heat storage in man (S) during advection of hot dry subtropical air mass, Warsaw, July-August 1994.

4. Discussion

Heat waves and their influence on man (its mortality and morbidity) were studied in Greece (Matzarakis, Mayer 1991), Portugal, Germany and United States (personal communications). In Poland changes in mortality in man were studied by Kuchcik (2000). All studies indicate the influence of heat waves on circulatory and total mortality.

The studies reported in the paper point to great acclimatisation abilities in man. Even very intensive heat waves did not disturb physiological processes in an organism. Physiological thermal regulation in man seems to be very effective and does not involve heat overload and respiratory disturbances. However, circulatory costs of acclimation to heat seem to be considerable. After the long period of intensive heat wave the significant increase in circulatory problems occurred.

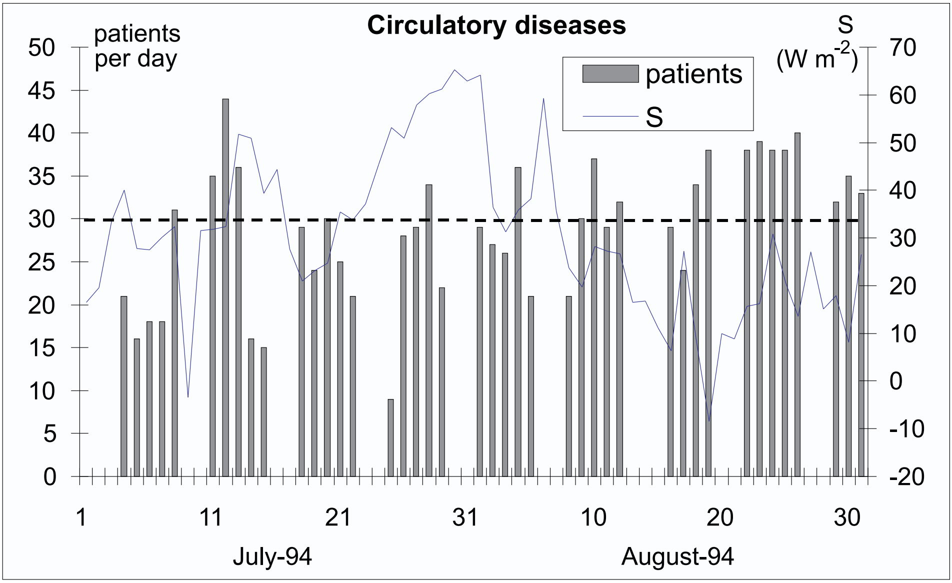

Fig. 4. Changes in circulatory patients and net heat storage in man (S) during advection of hot dry subtropical air mass, Warsaw, July-August 1994.

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