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THE EFFECT OF HEAT EXPOSURE ON CORTISOL AND CATECHOLAMINE EXCRETION RATES IN WORKERS IN GLASS MANUFACTURING UNIT

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SUMMARY

The aim of the investigation was to study the effect of long term repeated heat exposure on the excretion rates of stress hormones of workers in glass manufacturing unit. Sixteen operators, exposed to heat, were studied during the hot period and compared to a control group of 16 subjects, working in the same manufacturing unit. Both groups had moderate work load. The microclimate components and the Wet Bulb Globe Temperature were used for defining the heat exposure. The excretion rates of cortisol, adrenaline and noradrenaline were followed during the early morning shifts on three hour intervals using RIA and fluoriphotometric methods. Heart rate was followed, too. The psychosocial factors were measured by the "My job" questionnaire. Highly significantly higher cortisol, noradrenaline and adrenaline values were measured in the heat exposed operators compared to the control group, while significant differences of the psychosocial factors between the two groups lacked. Even if the heart rate was in the safe limits, the found alterations in the stress system are considerable and indicate heat stress. The work in conditions of overheat is associated with considerable heat stress and the possible health implications need to be clarified.

Key words: heat stress, occupational exposure, stress hormones, psychosocial factors

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INTRODUCTION

Intense hot environments are prevalent in the iron, steel, glass and ceramic units, rubber, foundries, coke ovens, mines and other industries, however the heat is often neglected as an occupational hazard. The physiological changes reflect the combined effect of industrial heat exposure and the climatic exposure, i.e. the total heat stress. And the effects vary widely in different seasons in our country. The maximum temperatures in Bulgaria range from about 30 °C to 40 °C. Heat stress occurring due to work in hot environments during the summer months is augmented for workers involved for longer periods of time close to furnaces. Glass manufacturing unit is one such work environment, where some workers are continuously exposed to high temperature during the 8-hour shifts.

Stress is well known to increase the activation of the hypothalamic-pituitary-adrenal axis. Several investigations show a significant increase in cortisol and catecholamine values during mild exercise at elevated temperatures of about 30-33 °C (1-6). Cortisol is found to be a sensitive index for heat stress and heat intolerance in a study of a passive heat exposure of 120 - 180 min at ambient temperature of 43 - 48 °C (7). The repeated exposure to heat and exercise produce acclimatization, changes in physiological function by which the tolerance to heat stress is improved (5, 6). Our study (8) confirms these data investigating thermoelectric station operators, exposed to comparatively high ambient temperature during the cold period.

However, there are no data concerning the stress system under occupational exposures to intense heat environments in summer months. It is known that repeated exposures to stressors without periods for recovery could heighten the response pattern and it may gradually become chronic. The chronic elevation of catecholamines (CA) and glucocorticosteroids (GCS) may cause functional disturbances, leading to disease. The influence of elevated CA and GCS on cardiovascular system is shown in several studies (9, 10). Further the GCS possess suppressive effect on the immune function, thus increasing the risk of infectious diseases and cancer (11, 12).

The aim of the investigation was to study the effect of long term repeated heat exposure on the excretion rates of stress hormones of workers in glass manufacturing unit.

The investigation is a part of a complex study of risk assessment of occupational heat exposure.

METHODS

The increased heat level exposure operations in glass manufacture are associated with work around the furnaces and the hot part of the flow lines, forming the final product. In the present study the effect of heat exposure on stress hormones only of flow line operators was studied, and compared with a control group of heat unexposed workers from the same manufacture. The study was carried out during the hot period of the year.

The microclimate components were measured with Testoterm 452 (air temperature from -20 °C to +70 °C, air velocity 0 - 10 m/s, relative air humidity 0 - 100%) according to BGS (13, 14). The measurements were carried out twice at 18 working places with heat exposure and 10 working places without heat exposure. The mean air temperature 38.9 °C (32.7 - 47.3 °C), air velocity 0.84 m/s (0.33 - 2.25 m/s), relative humidity of 17.5 % (12.8 - 22.2 %) were measured for the heat exposed working places. In the working place without heat exposure the mean air temperature was 31.4 °C (29.0 - 32.7 °C), air velocity 0.37 m/s (0.09 - 0.60 m/s) and relative humidity 22.7 % (17.6 - 26 %). The Wet Bulb Globe temperature (WBGT), defined as

$$WBGT = 0.7\, WB + 0.3\, GT,$$

where WB is the wet bulb temperature and GT is the globe temperature, was calculated for the heat exposed indoor locations. The mean WBGT was 36.9 °C (29.3 - 41.7 °C) for the studied heat exposed work places.

16 heat exposed operators aged 35.9 ± 11.3 years with length of service 15.9 ± 11.4 were studied and compared to a control group of 16 subjects, working in the same manufacturing unit, aged 39.5 ± 11.5 years with length of service 20.3 ± 12.5 years. The shift system of both groups comprised four consecutive early morning shifts (6.30 - 14.30), two days off, four afternoon shifts (14.00 - 22.00), followed by two days off. Both groups had moderate work load.

The excretion rates of cortisol, adrenaline and noradrenaline were followed on the second and third day of four consecutive early morning shifts. The investigated subjects were asked to void at 7.00. Urine samples were collected at three hour intervals (10.00 and 13.00). Urine aliquots were stored at -20 °C and the subsamples for catecholamine assay were acidified to pH 3 with 6 N HCl prior refrigeration. Urine free cortisol was measured by using RIA kit (Orion Diagnostica, Espoo, Finland): intraassay CV 1.7, 2.8, 3.5% and interassay 5.2, 5.2, 6.1% for low, mean and high value urine samples. Free urine adrenaline and noradrenaline were measured by our adaptation (15) of the fluoriphotometric method (16).

Heart rate was followed by Sport Tester during the early morning shift and mean values were calculated for the period 1: 7.00 - 10.00 and period 2: 10.00 - 13.00.

The psychosocial factors were measured by the Questionnaire "My job" (17). It contains five subscales with 80 items. The working conditions scale (18 items) includes items about working pose, lighting noise, vibrations, temperature, humidity, flow, dust, odour, etc. The job content scale sums 18 items (cyclical work, monotony, intense concentration, time pressure organization of work/ work schedules, problems with the equipment, etc.). The job control scale (10 items) includes questions about novelties at work, choice how to perform work, etc. The work related social support scale sums 10 items: 5 ones concerning the support from coworkers and 5 from supervisors. Health complaints scale is the sum of 16 items (physical and mental exhaustion, heart troubles, headaches, sleep disorders, etc.)

Data Analysis

One-way analysis of variance (ANOVA) was used to assess the effect of heat on the investigated variables. Correlation coefficients were calculated and the level of significance was set at 0.05.

RESULTS

Significantly higher cortisol values were measured in the heat exposed operators compared with the control group (Fig. 1) during both measurements ($F = 20.344$, $p = 0.002$ and $F = 9.927$, $p = 0.0037$ for period 1 and period 2, respectively). Cortisol excretion retained the normal circadian rhythm with higher values in the period 1 compared to period 2 in both groups.

The adrenaline excretion (Fig. 2) was significantly higher during period 1 in the heat exposed operators ($F = 7.269$, $p = 0.0135$). It increased during period 2 in both groups, but the increase in the heat exposed group was greater and with significantly higher adrenaline values ($F = 23.502$, $p = 0.0000$). The noradrenaline followed the same trend (Fig. 3). Higher noradrenaline values were measured during period 1 ($F = 3.735$, $p = 0.06$) and significantly higher ones during period 2 ($F = 16.344$, $p = 0.0003$) in the exposed group.

Significantly higher heart rate was registered in the heat exposed operators ($F = 8.918$, $p = 0.0087$ and $F = 14.748$, $p =$

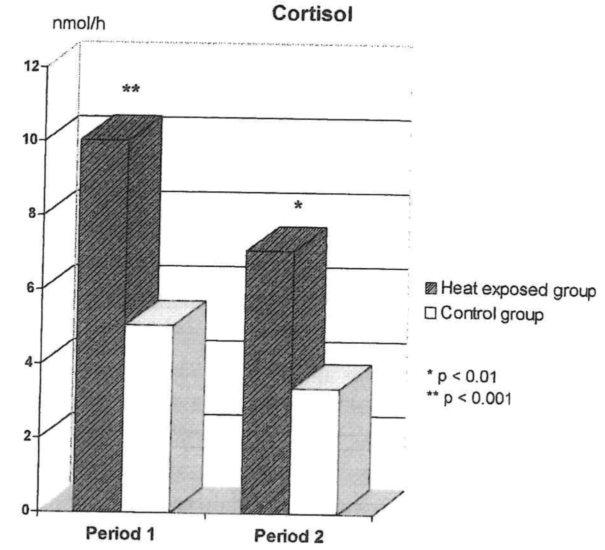

Fig. 1. Excretion rates of cortisol in heat exposed operators and control group in glass manufacturing unit.

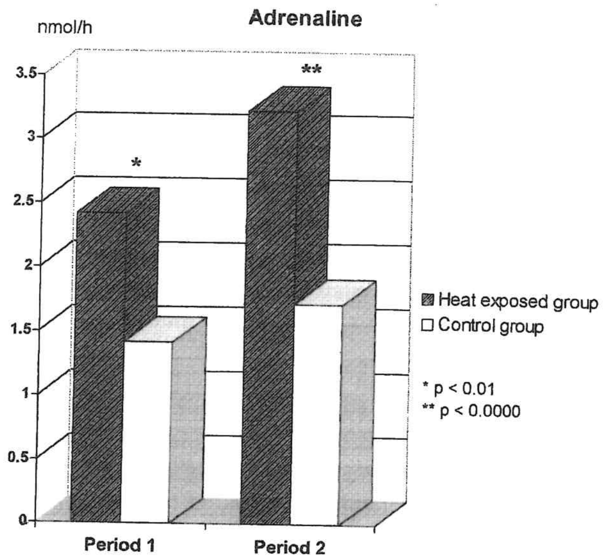

Fig. 2. Excretion rates of adrenaline in heat exposed operators and control group in glass manufacturing unit.

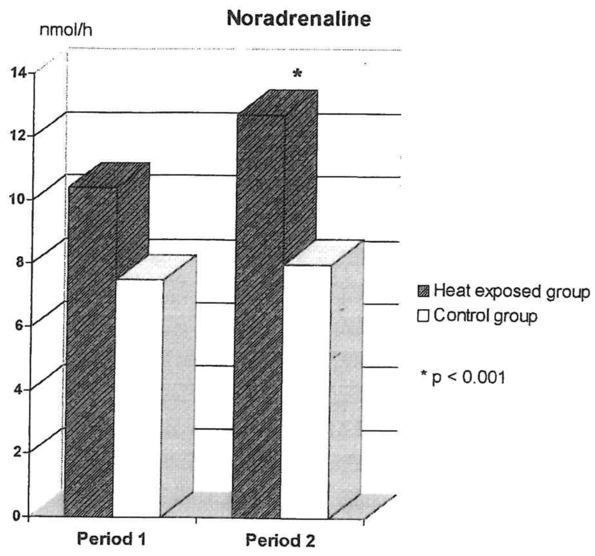

Fig. 3. Excretion rates of noradrenaline in heat exposed operators and control group in glass manufacturing unit.

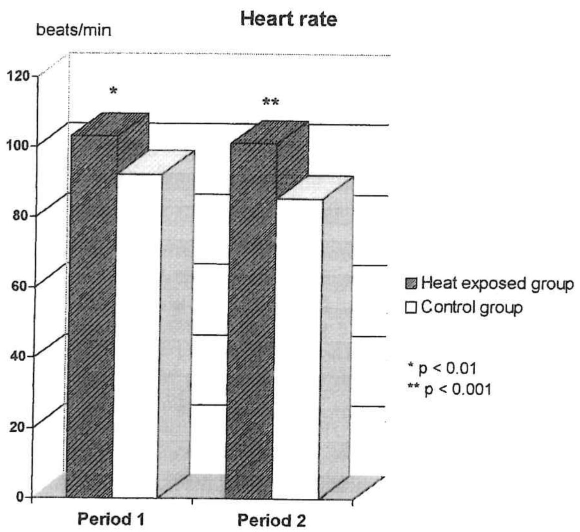

Fig. 4. Heart rate in heat exposed operators and control group in glass manufacturing unit.

0.0009 for period 1 and period 2, respectively), but did not exceed the safe limit of 120 beats.min^{-1} during the both studied periods.

The studied catecholamines excretion rates correlated highly significantly during both periods ($r = 0.91$, $p = 0.0001$ and $r = 0.85$, $p = 0.0009$). The cortisol excretion during period 1 was associated in the frame of trend with the adrenaline ($r = 0.53$, $p = 0.09$) and correlated with the adrenaline values during period 2 ($r = 0.66$, $p = 0.02$). Cortisol, adrenaline and noradrenaline excretion during both studied periods correlated with the heart rate for the corresponding period. The cortisol excretion during period 2 was associated in the frame of trend with the length of service in the conditions of overheat ($r = 0.51$, $p = 0.1$), but not with the all length of service.

No significant differences in the psychosocial factors (Table 1) between the two groups were found. The working conditions correlated with the catecholamine excretion during period 2 ($r = 0.64$, $p = 0.03$ and $r = 0.63$, $p = 0.03$ for adrenaline and noradrenaline respectively), while the work content correlated with the cortisol values during the same period. The job control correlated with adrenaline excretion during period 1 ($r = 0.67$, $p = 0.02$) and was in the frame of trend during period 2 ($r = 0.48$, $p = 0.1$).

DISCUSSION

The air temperature and WBGT exceeded the safe limits (18) for moderate work load at all the working places and for great part of them both were very high.

Our data show highly significant cortisol excretion in heat exposed operators for both studied periods of the early morning shift, the second showing a trend for correlation with the length of service in overheat, but not with the whole length of service. The considerable increase in the cortisol excretion can not be explained with the psychosocial factors. They did not differ significantly between the heat exposed operators and the control group. The mean of the working conditions scale was slightly higher with the heat exposed operators, but it should be noted that it included questions about the microclimate as temperature, humidity, etc. The job content of the studied group was slightly poorer and correlated with the cortisol excretion during period 2. The job control and the work related support did not differ between the two groups, while the health complaints were even lower in the exposed group. The found cortisol response to heat is in agreement with previous investigations (7, 19). Both of them used passive heat exposures of non acclimatized volunteers, and the former besides with comparable ambient temperature (43 - 48 °C) was with shorter duration of about 120 - 180 min. Our operators have a long experience in hot environments, but showed considerable increase in cortisol secretion.

At the same time we found high excretion rates of the measured catecholamines adrenaline and noradrenaline. Noradrenaline is known as a sensitive marker of exercise heat stress (3) and our data show that it responded in a very sensitive manner to work in heat. It is well known that the major role of noradrenaline is to maintain cardiovascular homeostasis. During exercise in heat the peripheral vasodilatation is compensated by increased vasoconstriction in other vascular beds, mediated by noradrenaline. The heart rate during the study was elevated, but did not exceed the safe limits. Cardiac stress

Table 1. Psychosocial factors of heat exposed operators and control group in glass manufacturing unit

Subscales/Groups	Working conditions	Job content	Job control	Social support	Health complaints
Heat exposed operators	9.72 ± 2.54	9.35 ± 2.36	6.10 ± 2.17	3.75 ± 1.48	9.24 ± 4.06
Control group	8.60 ± 2.64	8.00 ± 2.23	6.10 ± 1.96	3.66 ± 1.44	10.1 ± 3.63

in hot environments is also related to the work load (20), but it was moderate with the investigated workers. Later Rastogi (21) found that the heart rate did not exceed the safe limits even in workers near the main melting furnace (globe temperature 53.8 ± 3.0 °C) in glass bungle industry during the hot period in India.

Our data also show a significant and considerable increase in adrenaline excretion, especially in the second half of the shift, measurable with the increased values of noradrenaline. Most of the investigations show significantly lower increase in adrenaline compared with noradrenaline (3, 5, 6), but all of them are carried out in conditions of lower ambient temperature and shorter duration. Both adrenaline and noradrenaline excretion during period 2 correlated with the working conditions and adrenaline values for the same period with the job control, too.

Besides the heart rate within the safe limits, our data show pronounced stress reaction with sustained secretion of glucocorticoids and severe increase in the secretion of catecholamines, especially during the second half of the working shift. However, we studied only the work shifts and have no data on the recovery period, but even thus the increase in the investigated stress hormones was considerable and could rise some health effects. It is well known that the chronic elevation of glucocorticoids and catecholamines may cause functional disturbances, which, in turn may lead to disease. The effects of catecholamines on cardiovascular system are well defined (9, 10). Recent studies clearly show interaction between diurnal cortisol secretion related to perceived stress and anthropometric, endocrine, metabolic and hemodynamic variables (22, 23, 24). Our earlier data (25, 26) show high rate of dyslipidemias and overweight in faience industry workers exposed to overheat, more pronounced in men, especially in those exposed to radiation heat. Several investigators (27, 28) associate higher mortality from cardiovascular diseases, particularly sudden death and hypertension - related diseases, with occupational heat exposure. Further the glucocorticoids possess suppressive effects on several functions of the immune system (11, 12).

Summing up, our data show highly significant increase in secretion of stress hormones in heat exposed operators in the glass manufacturing industry, indicating considerable heat stress. Besides the heart rate within the safe limits, the possible health hazards associated with the found alterations in the stress system need to be clarified. Further, counter measures to reduce work stress under heat exposure would help to reduce health risk and promote work safety.

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