HEAT STRESS IN TWO MANUFACTURING UNITS

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Summary. The hygienic norms for microclimate are often neglected. The purpose of the study was to assess stress in workers exposed to overheat in the hot period of the year. The microclimate components and wet bulb globe temperature (WBGT) were measured in two units: glass manufacturing unit and iron foundry. Stress was estimated in 15 males, exposed to heat and in a control group of 15 men from each unit. Stress hormones were followed up on three-hour intervals during the early morning shifts: cortisol was assessed using RIA kits, cathecholamines – with spectrofluorimetric method. The heart rate was followed up too. The psychosocial factors were assessed by the questionnaire “My job”. The microclimate parameters and WBGT indicated a high heat load in glass manufacturing unit, and a moderate one, mainly due to infrared radiation in the iron foundry. A highly significant increase in the secretion of the stress hormones in the exposed to heat workers in both units was found, more pronounced and considerable in the glass manufacturing unit. The overheat rises a considerable increase in the activity of the stress system, more expressed with high heat load. In view of the possible health hazards, better control and measures for reduction of heat load and a prophylactic program are recommended.

Key words: *stress hormones, overheat, psychosocial factors*

INTRODUCTION

Intense hot environments are prevalent in the iron, steel, glass and ceramic units, rubber foundries, coke ovens, mines and other industries. The hygienic normes for microclimate are well defined, but often neglected in our country.

The physiological changes reflect the combined effect of industrial heat exposure and the climatic one, i.e. the total heat stress. The stress hormones cortisol and noradrenaline are found to be sensitive indices of heat stress [5, 7, 11]. It is well known that the repeated exposures to heat and exercise produce acclimation, improving the tolerance to heat stress. However, high intensity exposures without enough long periods for recovery even highten the response pattern and it may gradually become chronic. The chronic elevation of stress hormones may cause functional disturbances, increasing the risk for cardiovascular, immune, infectious diseases [3, 4, 10].

The **purpose** of the study was to investigate the physiological adaptation in workers exposed to overheat during the hot period following the excretion rates of stress hormones and heart rate.

METHODS

The study was carried out during the hot period in glass manufacture and iron foundry. The microclimate components (air temperature, air velocity and relative air humidity) were measured twice at 18 heat exposed work places in the glass manufacture and in 13 ones in the iron foundry with Testoterm 452 followed by BSS [1]. The microclimate at 10 unexposed work places at each unit was followed, too. The Wet Bulb Globe Temperature (WBGT), defined as

$$WBGT = 0.7t_{WB} + 0.3t_{GT},$$

where t_{WB} is wet bulb temperature and t_{GT} is globe temperature, was calculated for heat exposed indoor locations.

15 male heat exposed operators and control group of 15 subjects from each enterprise were studied (Table 1).

Table 1. Age and length of service of the investigated groups

Enterprise	Heat exposed groups		Control groups	
	Age	Length of service	Age	Length of service
Glass manufacture	35.5 ± 11.3	15.9 ± 11.4	39.5 ± 11.5	18.3 ± 10.2
Iron foundry	38.5 ± 7.7	17.6 ± 8.2	43.6 ± 10.5	20.3 ± 12.5

The shift system 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.

The stress hormones were followed up on three-hour intervals (7.00-10.00 and 10.00-13.00) during the second and the third day of the four early morning shifts. Cortisol was assessed by RIA kits (Orion Diagnostica, Finland), catecholamines by spectrofluorimetric method [12].

The heart rate was followed by Sport Tester and mean values were calculated for both periods.

The psychosocial factors were assessed by the questionnaire “My job” [9], containing 5 subscales. The working condition scale contains items about working pose, lighting, noise, vibrations, temperature, humidity, flow, dust, odours, etc. The job content scale sums 18 items (monotony, tasks, requiring intense concentration, time pressure, work organization, etc.). The job control scale (10 items) includes questions about novelties at work, ability to influence the pace, methods of work, professional realization, etc. The work related social support scale sums 10 items: 5 ones concerning support from coworkers and 5 from supervisors. Health complaints scale is the sum of 16 items (physical and mental exhaustion, cardiovascular problems, headache, sleep disorders, etc.).

One-way analysis of variance (ANOVA) and correlation analysis were completed.

RESULTS

The microclimate parameters and WBGT (Table 2) indicated high heat load in the glass manufacture. In the iron foundry, the air temperature did not exceed the hygienic norms, but WBGT indicated overheat, mainly due to infrared radiation.

Table 2. Components of microclimate and WBGT in heat exposed work places in glass manufacture and iron foundry during the hot period

Indices	Glass manufacture	Iron foundry	Hygienic normes by BSS 14776-87 and ISO 7243-1989
Air temperature,oC	38.7 ± 3.7	28.9 ± 3.3	to 31 when outside temperature>25°C
Air velocity, m/sec	0.91 ± 0.58	0.52 ± 0.28	0.2 – 0.5 for 1st and 2nd category
Relative air humidity, %	17.2 ± 2.8	24.9 ± 3.6	30 – 55 when air temperature> 28°C
WBGT, oC	36.9 ± 4.0	33.4 ± 4.6	28°C

Cortisol excretion (Fig.1) retained the normal circadian rhythm in the heat exposed groups, but with very high rates in the glass manufacture operators and high ones in iron foundry operators, significantly higher in comparison with the control groups. The adrenaline and noradrenaline excretion (Fig. 2 and 3) was significantly higher with the heat exposed groups, too, especially during the second half of the shift. The highest adrenaline and noradrenaline values were measured during the second half of the shift in the heat exposed operators in the glass manufacture.

In the glass manufacture, the heart rate of heat exposed operators was significantly higher than that of the control group ($F = 6.554$, $p < 0.01$ and $F = 14.748$, $p < 0.001$ for the first and second half of the shift respectively), while in the iron foundry the increase did not reach significance. In both cases, the mean group heart rate did not exceed 120 beats/min-1.

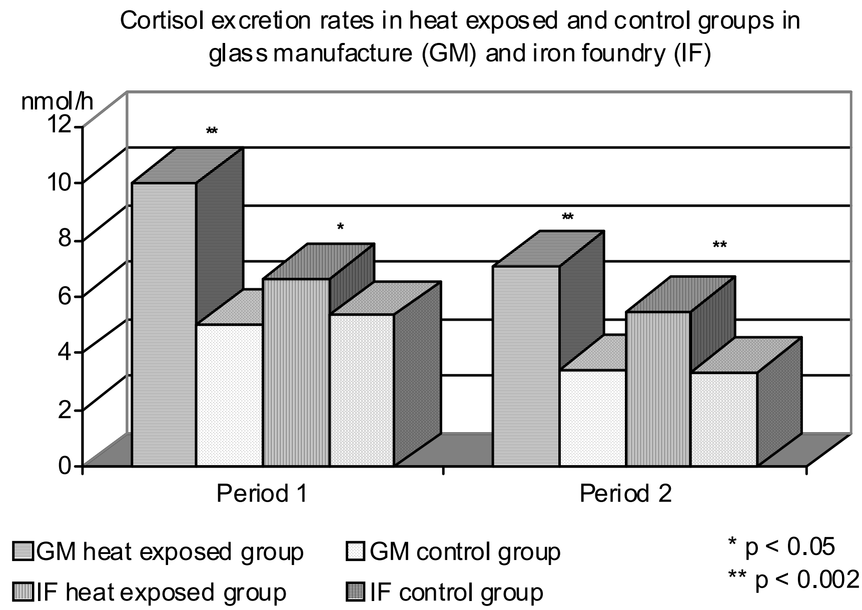

Fig. 1. The excretion rates of cortisol in heat exposed workers and control group in glass manufacturing unit and iron foundry during the early morning shifts.

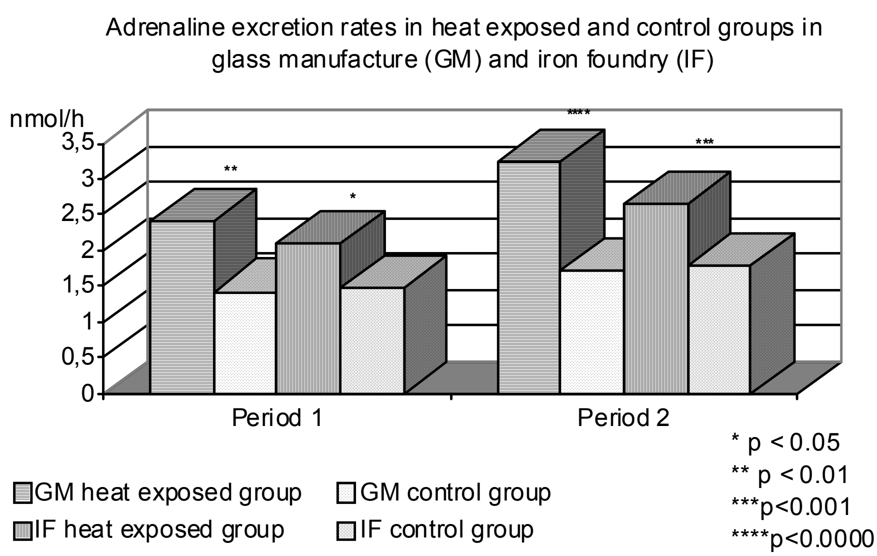

Fig. 2. The excretion rates of adrenaline in heat exposed workers and control group in glass manufacturing unit and iron foundry during the early morning shifts.

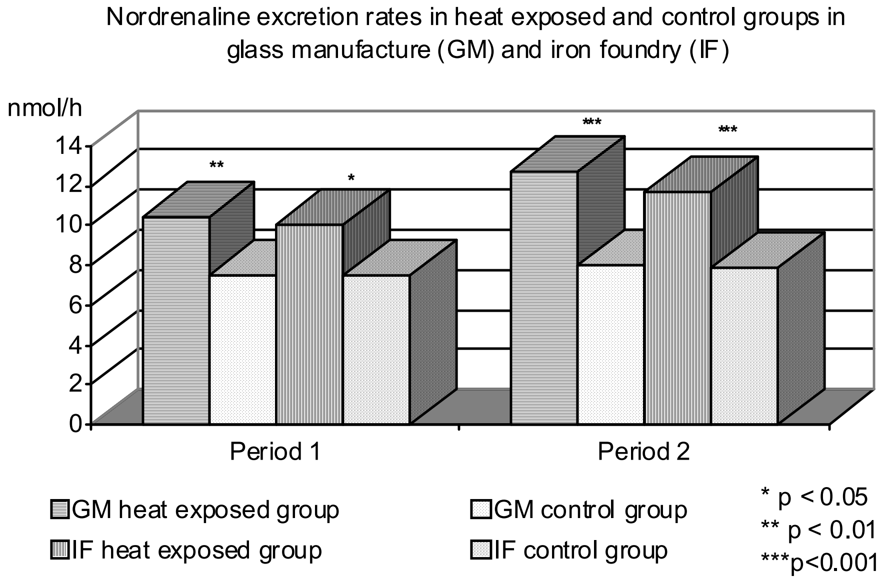

Fig. 3. The excretion rates of noradrenaline in heat exposed workers and control group in glass manufacturing unit and iron foundry during the early morning shifts.

Table 2. Psychosocial factors of heat exposed operators and control groups of glass manufacture and iron foundry

Enterprise/Scale		Work conditions	Work content	Control	Social support	Psychoso-matic complaints
Maximal scores		13	16	10	10	16
Glass Manufacture	Heat exposed group	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	6.00 ± 1.96	3.66 ± 1.44	10.07 ± 3.63
Iron Foundry	Heat exposed group	8.91 ± 2.87	8.95 ± 3.15	4.95 ± 2.85	3.28 ± 2.47	7.39 ± 4.55
	Control group	8.70 ± 2.83	7.70 ± 3.97	4.75 ± 2.86	2.87 ± 2.29	8.25 ± 5.77

No significant differences in the psychosocial factors between the heat exposed and the corresponding control groups were found (Table 2). The working conditions were described as poor and dangerous (intensive noise, unsatisfactory lightening, high pollution, danger of accidents, etc. and very high temperature for the heat exposed groups). Work consisted of short rapidly repeated operations, requiring concentration, and often carried out under time pressure. The control at work was low. The main psychomatic complaints were physical exhaustion, fatigue, apathy, musculoskeletal disorder, etc. The working conditions correlated with catecholamine excretion rates, the work content with cortisol values and control at work with adrenaline secretion.

DISCUSSION

In our country, regular measurements for microclimate are established [1] and the hygienic norms are well defined [2, 8]. However, after finding the presence of heat load, even high one, the workers continue their usual shifts. In some cases the measuring laboratories even fail to find the presence of overheat because of the lack of ability to calculate the WGBT or measure the infrared radiation.

We followed up the physiological adaptation in parallel to the heat indices in two enterprises. Our data show very high activation of the stress system in the glass manufacture heat exposed operators and high in the iron foundry ones. The increase in the secretion of stress hormones can not be attributed to confounding factors, i.e. the psychosocial factors, as they were controlled. The increase in stress hormones is dose-dependant, very high under high heat load and high under heat load with WGBT > 33°C, more pronounced during the second half of the shift in both cases. The found increase in the secretion of stress hormones may have implications on health because of the effect of glucocorticoids and catecholamines on the cardiovascular system [3, 6, 14, 15], the immune system [4], etc. Our earlier data show high cardiovascular risk in workers exposed to overheat [12, 13, 14].

In conclusion, our data show the lack of acclimation to work under overheat with WGBT > 33°C with considerable activation of the stress system. In view of the possible health hazards, better control of heat exposed work places, countermeasures for reduction of heat load and active profilactics are recommended.

REFERENCES

1. B S S 16686-87. [Labour protection. Methods for measurement of air temperature, relative humidity, air velocity and heat radiation.]
2. B S S 14776-87 [Labour protection. Working places in industrial buildings. Hygienic normes for air temperature, relative humidity, air velocity and heat radiation.]
3. C h r o u s o s, G. P. The role of stress and the hypothalamic-pituitary-adrenal axis in the pathogenesis of metabolic syndrome: neuroendocrine and target tissue-related causes. – Intern. J. Obesity, **24**, 2000, Suppl. 2, S50-S55.
4. E l e n k o v, I. Stress, cytokine patterns and susceptibility to disease. – Bailliere's Clin. Endocrin. Metab., **13**, 1999, № 4, 583-595.
5. F o l l e n i u s, M. et al. Cortisol as a sensitive index of heat-intolerance. – Physiol. Behav., **29**, 1982, 509 -513.
6. G o l d s t e i n, D. S. Plasma catecholamines and essential hypertension. An analytical review. – Hypertension, **5**, 1983, 86-99.
7. H o f f m a n, R. J. et al. Effects of hydratation state on plasma testosterone, cortisol and catecholamine concentrations before and during mild excercise at elevated temperatures. – Eur. J. Appl. Physiol., **69**, 1994, 294-300.

8. I S O 7243-1989. Hot environments – estimation of the heat stress on working man, based on the WBGT-index.
9. K o m p i e r, M. et L. Levi. Stress at work: causes, effects and prevention. A guide for small and medium sized enterprises. Geneva, European Foundation for Improvement of Living and Working Conditions, 1994.
10. R o s m o n d, R., M. F. Dallman et P. Bjorntorp. Stress-related cortisol secretion in men: Relationships with abdominal obesity and endocrine, metabolic and hemodynamic abnormalities. – J. Clin. Endocrinol. Metab., **83**, 1998, 1853-1859.
11. S o n n e n t a g, S. et C. Fritz. Endocrinological Processes Associated with Job Stress: Cathechlolamine and Cortisol Responses to Acute and Chronic Stressors. – Res. Occupat. Stress Well Being, **5**, 2006, 1-59.
12. V a n g e l o v a, K. Method for assessment of catecholamines adrenaline and noradrenaline in urine. – Methods Invest. Hygiene, **2**, 2000, 2-4.
13. V a n g e l o v a, K. et C. Deyanov. Blood pressure and serum lipids in industrial workers under intense noise and hot environments. – Rev. Environ. Health, **22**, 2007, № 4, 303-311.
14. V a n g e l o v a, K. et C. Deyanov. Serum lipids and cardiovascular risk in workers exposed to convection overheat. – Acta Med. Bulg., **26**, 1999, 3-7.
15. V r i j k o t t e, T. G. M., L. J. P. van Doornen et E. J. C. de Gues. Work stress and metabolic and hemostatic risk factors. – Psychosom. Med., **61**, 1999, 796-805.

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