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 norms 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 heighten 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 overheating 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 workplaces in the glass manufacture and in 13 ones in the iron foundry with Testoterm 452 followed by BSS [1]. The microclimate at 10 unexposed workplaces 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

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Heat exposed groups</th>
<th>Control groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>Length of service</td>
</tr>
<tr>
<td>Glass manufacture</td>
<td>35.5 ± 11.3</td>
<td>15.9 ± 11.4</td>
</tr>
<tr>
<td>Iron foundry</td>
<td>38.5 ± 7.7</td>
<td>17.6 ± 8.2</td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Enterprise/Scale</th>
<th>Work conditions</th>
<th>Work content</th>
<th>Control</th>
<th>Social support</th>
<th>Psychosomatic complaints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximal scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass Manufacture</td>
<td>Heat exposed group</td>
<td>9.72 ± 2.54</td>
<td>9.35 ± 2.36</td>
<td>6.10 ± 2.17</td>
<td>3.75 ± 1.48</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>8.60 ± 2.64</td>
<td>8.00 ± 2.23</td>
<td>6.00 ± 1.96</td>
<td>3.66 ± 1.44</td>
</tr>
<tr>
<td>Iron Foundry</td>
<td>Heat exposed group</td>
<td>8.91 ± 2.87</td>
<td>8.95 ± 3.15</td>
<td>4.95 ± 2.85</td>
<td>3.28 ± 2.47</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>8.70 ± 2.83</td>
<td>7.70 ± 3.97</td>
<td>4.75 ± 2.86</td>
<td>2.87 ± 2.29</td>
</tr>
</tbody>
</table>

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


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