AIRWAY HYPERREACTIVITY IN THE ELECTROCERAMIC INDUSTRY

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Received November 30, 1993

Seventy-four female shift workers employed in the oxide ceramics industry were examined; a group of 36 workers from the press workshop and a group of 38 controls from the mounting workshop from the same factory. The two groups did not differ by age, years of employment, smoking habit or height. Persons with extreme constitution and serious respiratory disease were excluded from the study. Interstitial lung disease was eliminated by X-ray examinations. All subjects underwent a clinical examination and completed a questionnaire. Measurements of ventilatory lung function demonstrated no difference between the groups; lung function values were normal. Non-specific airway reactivity was expressed as $\text{PCO}_2 \cdot \text{RI}$ i.e. 50% increase in resistance in relation to the value measured after inhalation of the physiological solution. A significant difference was found for $\text{PCO}_2 \cdot \text{RI}$ between the exposed and control workers during ($P<0.001$) and outside working hours ($P<0.01$). Significantly different $\text{PCO}_2 \cdot \text{RI}$ values were also established within the group of exposed workers as well as within the group of exposed workers during and outside working hours ($P<0.014$ and $P<0.0015$ respectively). The majority of hyperreactive persons were workers from the press workshop ($n=17$) when measurements were performed during working hours. For early detection of respiratory diseases in workers employed in the oxide ceramics industry preemployment examinations and regular check-ups aiming to determine non-specific airway reactivity are suggested as necessary.

Key terms
airway hyperreactivity, clinical examination, occupational exposure, oxide ceramics, ventilatory lung function, working environment

The manufacture of clay products can be traced back through the history of mankind. Technological progress has enabled the use of such products in atomic and aeronautical industries, biomedicine and machine engineering. Such a product is the spark plug, a product of high technology, consisting of a ceramic insulator and fuse. The development of the spark plug insulator dates from the discovery of the Otto motor.

* Valing postgraduate student.
The spark plug insulator is produced from oxide ceramics—a high density material, resistant to high temperatures. It is produced by a dry method and has the characteristics of hard synthetic porcelain. The basic raw material is a type of clay α alumina. A thinner is added to the α alumina (flintstone, oxide titanium, barium, magnesium, manganese, chromium), plasticizer (bentonite), defloculants, ammonia salts, additives for lowering the melting point (calcium carbonate, manganese oxide, magnesium hydroxide), polyvalent alcohols, wax, paraffins, paint and glaze (1). Insulators are manufactured in phases: grinding, mixing, drying, shaping, sintering and mounting of the insulators and fuse.

In spite of the modern technological process, which is partly an enclosed system, the pollution of the working environment originates in specific microclimatic conditions in the plant, with the exception of the assembling and packing departments.

During the manufacture of oxide ceramics the worker's respiratory system can become affected. For this reason health control, both before employment and periodically during employment, is obligatory, in accordance with WHO recommendations (2). Medical examinations are intended for persons working in exposure to respirable dusts, free silica, hard metals, dusts of organic origin, allergenic substances, and airway irritants.

Non-specific airway reactivity (NAR) is a pluri-component phenomenon comprising numerous factors (3). Firstly, there are endogenous factors, particularly the inherited tendency to airway hyperreactivity. Then, there are exogenous factors pertaining to the environment (smoking, respiratory infections) (4, 5). Inhalation of allergenic substances and occupational irritants can also influence airway reactivity (6, 7).

In healthy populations altered NAR is a known temporary phenomenon that occurs in exposure to specific substances. Consequently, the borderline between normal and impaired reactivity is not sharply defined (8).

During the manufacture of spark plug insulators, particularly in the course of preparation of raw material casts, excessive values of free SiO₂ were determined in the working environment. This, along with the other components in the manufacture, may have caused an irritative cough and altered NAR (9).

The purpose of this study was to examine the phenomenon of an irritative cough observed over the previous two years, both during and outside working hours, in workers employed in the press workshop. Workers from the mounting workshop were chosen to serve as controls. Periodic check-ups in accordance with WHO recommendations were included in the study, in addition to non-specific airway challenge.

SUBJECTS AND METHOD

The subjects in the study were 74 female workers: 38 from the press workshop and 36 controls from the mounting workshop. They had not previously been employed in any other work organization. All subjects were smokers. The groups did not differ by age, duration of work service in the factory, smoking habit and
height (Table 1). Analysis of health status over the previous five years in both groups did not indicate atopic constitutions, skin disease or serious respiratory disease (pleurisy, tuberculosis, pneumonitis). Chest X-rays did not reveal interstitial lung disease. In the previous six weeks the workers had not suffered from any respiratory disease or a disease which could have induced non-specific bronchial reactivity.

Table 1  Anthropometric characteristics of compared groups of workers

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age</th>
<th>Total work service</th>
<th>Height</th>
<th>Smoking index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>SD</td>
<td>X</td>
</tr>
<tr>
<td>Press workshop</td>
<td>38</td>
<td>32.5</td>
<td>5.6</td>
<td>12.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Mounting workshop</td>
<td>38</td>
<td>34.4</td>
<td>5.1</td>
<td>14.1</td>
<td>3.1</td>
</tr>
</tbody>
</table>

All workers underwent a physical examination and were administered a questionnaire, with emphasis on upper respiratory airway infections (10). The occurrence of chronic, irritable cough in the previous two-year period was verified in all workers employed in the press workshop, where a large number of workers were found to have respiratory infections and reported having dyspnoea during exertion (Table 2).

Table 2  Upper respiratory airway disease frequency and PCon Rt in examined workers

<table>
<thead>
<tr>
<th>Disease</th>
<th>Press workshop</th>
<th>Mounting workshop</th>
<th>T-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Rhinopharyngitis</td>
<td>11</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>Polysinusitis</td>
<td>12</td>
<td>31.7</td>
<td></td>
</tr>
<tr>
<td>Respiratory infection</td>
<td>23</td>
<td>60.5</td>
<td></td>
</tr>
<tr>
<td>Dyspnoea during exertion</td>
<td>7</td>
<td>18.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

Measurements of ventilatory functions (FVC, FEV1, MEF25, MEF50) followed by NAR testing were carried out during the work process. Ventilatory functions were measured during the first two hours of work in October 1989 using a Pneumoscreen I, Jaeger, Germany. The values measured were compared to a nomogram (11). In both groups of workers ventilatory parameters were within normal ranges and no difference was found between the examined groups (Table 3).

Non-specific reactivity of airways was determined by the method of Tjwa and co-workers and Takashima and co-workers, with checked reproducibility of the methods (12-14). An Astograph-TCK-6100H, Chest Corporation, USA was used, consisting of an automated inhalation unit with 12 nebulizers, for measuring lung resistance by the oscillation method. Histamine diphosphate (Sigma, USA)
was used as a provocation agent, in doses of 0.5–16.0 mg/ml. The inert agent was non-buffered saline. PC_{50} Rt denotes the provocation concentration during increase in lung resistance greater than 50% of that measured after saline inhalation. Chosen as a status of reactivity PC_{50} Rt was calculated by logarithmic interpolation from dose-response. Usual cautionary measures were respected (15).

**Table 3   Ventilatory functions in the exposed and control groups of workers**

<table>
<thead>
<tr>
<th>Ventilatory functions (%)</th>
<th>Press workshop workers (n=38)</th>
<th>Mounting workshop workers (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
</tr>
<tr>
<td>FVC</td>
<td>94.8</td>
<td>11.1</td>
</tr>
<tr>
<td>FEV_{1}</td>
<td>93.8</td>
<td>14.0</td>
</tr>
<tr>
<td>MFF_{10}</td>
<td>130.6</td>
<td>56.8</td>
</tr>
<tr>
<td>MEF_{50}</td>
<td>83.5</td>
<td>22.2</td>
</tr>
<tr>
<td>MEF_{25}</td>
<td>77.0</td>
<td>27.1</td>
</tr>
</tbody>
</table>

In all subjects NAR testing with histamine diphosphate was carried out on two occasions: during working hours, regardless of shift, and after a three-week annual leave of absence the following year, within two hours of the work shift. The latter was considered to be non-exposure reactivity.

In the press workshop microclimatic conditions were disturbed by increased temperature, dry air and low level of humidity (14, 16). Statistical analysis was performed by parametric and non-parametric analyses of the results for testing small independent samples, and by Spearman’s test for correlation ranges (17).

**RESULTS**

The NAR values are presented in tables and graphs, in cumulative dose units of histamine diphosphate (Tables 4 and 5, Figure). Table 4 shows the PC_{50} Rt reactivity in the examined groups.

PC_{50} Rt values were obtained at significantly lower levels of the applied provocation agent in workers in the press workshop during working hours than after a leave of absence. Likewise, PC_{50} Rt values recorded in the press workshop were the result of significantly lower levels of the provocation agent than those registered among the mounting shop workers (Figure). A cumulative histamine dose <8 mg/ml was registered in as many as 17 workers in the press workshop and in 14 workers after a leave of absence, and in only two mounting workshop workers.
Table 4  \( PC_{50} \) Rt during and outside working hours in workers from the press and mounting workshops

<table>
<thead>
<tr>
<th></th>
<th>During work ( PC_{50} ) Rt*</th>
<th>Outside work ( PC_{50} ) Rt*</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Press workshop</td>
<td>8.83 (5.76)</td>
<td>10.72 (6.13)</td>
<td>P&lt;0.01400</td>
</tr>
<tr>
<td>Mounting workshop</td>
<td>12.32 (4.89)</td>
<td>14.27 (4.04)</td>
<td>P&lt;0.00185</td>
</tr>
<tr>
<td>Statistical significance</td>
<td>P&lt;0.001</td>
<td>P&lt;0.01</td>
<td></td>
</tr>
</tbody>
</table>

* Cumulative dose of airway provocation agent (histamine diphosphate) at which \( PC_{50} \) Rt was obtained

Table 5  \( PC_{50} \) Rt during working hours in workers from the press and mounting workshops

<table>
<thead>
<tr>
<th></th>
<th>Press workshop ( PC_{50} ) Rt*</th>
<th>Mounting workshop ( PC_{50} ) Rt*</th>
<th>T-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhinopharyngitis</td>
<td>9.0 (4.3) 11 (20.4)</td>
<td>14.0 (0.3) 5 (13.0)</td>
<td>NS</td>
</tr>
<tr>
<td>Polysinusitis</td>
<td>8.8 (5.2) 12 (37.7)</td>
<td>12.5 (2.1) 8 (22.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Respiratory infection</td>
<td>9.5 (3.5) 23 (60.5)</td>
<td>14.8 (5.3) 12 (37.3)</td>
<td>P&lt;0.01</td>
</tr>
<tr>
<td>Dyspnea during exertion</td>
<td>13.5 (4.2) 18 (4.4)</td>
<td>9.8 (1) 1 (2.7)</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Cumulative dose of airway provocation agent (histamine diphosphate) at which \( PC_{50} \) Rt was obtained

Table 5 shows the number of workers with regard to obtained \( PC_{50} \) Rt values matched by data from the questionnaire on dyspnoea, sinusitis, respiratory infections and rhinosinusitis over the previous two years. \( PC_{50} \) Rt obtained at a lower level of provocation agent was found in workers with previous respiratory infections in the press workshop.

![Cumulative dose of histamine diphosphate for obtaining \( PC_{50} \) Rt in examined groups of workers](image)
A multiple correlation matrix was drawn up for all subjects for the predictors: FFV₁, MEF₂₅ and MEF₅₀, dose of histamine diphosphate, years of employment, smoking index and PC₅₀ Rt values. No correlation was found between PC₅₀ Rt and/or cumulative dose of histamine diphosphate, and age, work service and smoking index.

DISCUSSION

Industrialization and high technology have confronted man with new diseases. It is therefore surprising that we have failed to find any reports in available literature on the oxide ceramics industry, oxide ceramics being an essential component in many modern technologies. On the other hand certain components in the manufacture of oxide ceramics have been thoroughly analysed during investigations of diseases of the respiratory system, although their possible synergistic and/or additive effect is still unknown (10–23). Pirić examined NAR in workers in the ceramics industry, but failed to find any difference between the exposed and control workers (24).

Oxide ceramics contains numerous components that can affect the respiratory system. It could be speculated that dispersed free silica dioxide, verified in excessive amounts (6.8–49.34 mg/m³) in the ambient air of the press workshop, could not be the only cause of the irritative cough and/or altered NAR. Inert chemical pollutants can interact with toxic pollutants and microbial toxins. Their additive and/or synergistic effect indicates an uncertain relationship between the toxic and the allergic effects (25–27). However, the crystal structure of a alumina could be responsible for such an effect, i.e. sl'epine chimiques (28). Inhalation of floating particles (from the raw material of the cast) may cause a chain of interactions, such as epithelial inflammation, damage to smooth muscles and effect of polygenetic factors. No definite opinions, however, have been presented with regard to the etiopathogenesis of non-specific reactivity (29).

Our investigation, apart from indicating the occurrence of altered NAR in workers employed in the manufacture of oxide ceramics, also emphasizes the need for TLV measurements of its various components, other than free SiO₂, which was analysed in this study. The need for improving personal protective devices as well as the working environment is also apparent.

Further research into the mineral structure of certain components in the manufacture of oxide ceramics is called for, with special reference to the components that are added to obtain high quality products.

The results point out the need for further investigation of NAR in the oxide ceramics industry as a possible early indicators of respiratory impairment, and as a useful indicator during periodic examinations and preemployment examinations of workers for specific workplaces and working conditions. The phenomenon that a healthy population may also have altered NAR (8, 20, 30) indicates the need for including NAR testing in examinations of workers employed in the oxide ceramics industry.
Acknowledgement

This study was carried out within the framework of Project No. 301-130 with the Croatian Ministry of Science and Technology, Zagreb, Croatia.

REFERENCES


Sažetak

HIPERREAKTIVNOST BRONHIJA U ELEKTROKERAMIČKOJ INDUSTRIJI

Ispitano je 74 radnika zapošlenih u tvornici okvirene keramike (34 radnice zaposlene u prejašnici i 38 kontrolnih radnica iz montažno hala). Skupine se nisu razlikovale po dob, trajanju radnog staža, visini i težini čulini. Niti jedna od radnica nije imala znakove atopolŏki konstitucije, a na rendgenskoj snimi pluća nisu utvrđene promjene plućnog intersticijuma. Obje skupine ispitane podignute su kliničkim pregledom i ispitane su na ocjeni standartonog upitnika. Izmjerene su i ventilacijske funkcije pluća na uređaju Pneumosciren I. Jaeger, Njemčka. U obe skupine vrijednosti PVC, FVC, MEF25, MEF50 i MEF75 bile su u granicama normalnih. Ispitivanje nespesificne reaktivnosti dječjih putova provedeno je histaminom otocatnom na uređaju Astrograph, Chest Corporation, SAD. Za izraz nespesificne reaktivnosti koristen je PC20 Rt i, porast rezistencije za 50% u odnosu na izmjerenu vrijednost nakon učinjenog fiziolŏkog testa na pluća. Razlika u izrazi nespesificne reaktivnosti između radnica prejašnice i montaža izmerene s UVZom ali i izvan radnog vremena (P>0,01) ali i radnica u montaži (P>0,01). U skupini radnica prejašnice tjekom radnog vremena utvrđeno je 17 uzroka s PC20 Rt dobivenim s manje od 5 mg/m3 histamin dišofasta. U radu se naglašava potreba za sustavnim pre MainMenu nespesificne reaktivnosti dječjih putova u keramičkoj industriji.

Ključne riječi: studijski pregled, profesionalna izloženost, hyperreactivity dječjih putova, okvirena keramika

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