

Olfactory function in painters exposed to organic solvents

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SANDMARK B, BROMS I, LÖFGREN L, OHLSON C-G. Olfactory function in painters exposed to organic solvents. *Scand J Work Environ Health* 1989;15:60–63. The olfactory receptor cells are in direct contact with the exterior environment, and some chemical agents can impair olfactory function. The olfactory function of 54 painters exposed to organic solvents was compared with that of 42 unexposed referents. A new clinical test validated for the sense of smell was used, the University of Pennsylvania Smell Identification Test. Age, smoking habits, exposure to organic solvents, and medical disorders of importance for the sense of smell were recorded. The painters had a somewhat lower test score than the referents. However, the influence of the exposure variable was not statistically significant in a multiple regression analysis including age and smoking habits. The exposure to organic solvents was low, and therefore an effect of high exposure on olfactory function cannot be ruled out. Since some of the painters had earlier been highly exposed, the effects of high exposure are likely to be reversible.

Key terms: olfactory function, organic solvents, smell test.

The olfactory epithelium is situated in the superior region of the nasal cavity, and the area is estimated to be 1 cm² on each side (1). The olfactory mucosa is exposed to all pollutants in the ambient air. A description of the human olfactory organ, clinical problems, and olfactory function testing has been given elsewhere (2–6). The olfactory receptor cells are the only neurons which have their cell bodies in direct contact with the exterior environment, and it is therefore not surprising that some chemical agents can impair olfactory function (7).

Organic solvents can impair the function of the central nervous system (8), and some chemical compounds can cause neuritis (9). Information on the influence of organic solvents on olfactory function is scarce (10, 11). Ekblom et al (12) studied the olfactory epithelium of the frog after exposure to styrene and toluene and observed morphological and electrophysiological changes. In a questionnaire study Danish electronic workers exposed to chlorinated solvents were asked about their sense of smell. Forty-nine percent reported a decreased sense of smell compared to 19 % of the unexposed workers (13). Ahlström et al (14) examined the odor perception of 20 tank cleaners exposed to petroleum products. The odor thresholds were increased for n-butanol and oil vapor but unaffected for pyridine and dimethyldisulfide 1 d after exposure. No changes in the odor thresholds were observed when the exposure stopped two or more days before the test.

In the present study it was hypothesized that, due to its direct contact with the exterior environment, the olfactory organ is the part of the central nervous system most vulnerable to organic solvents. The objective of this study was to examine the olfactory function of men occupationally exposed to organic solvents.

Methods

The University of Pennsylvania Smell Identification Test (UPSIT), a clinical test of olfactory function, was adopted (15, 16). It incorporates 40 diverse odors in an easily presented form. The test consists of four envelope-sized booklets, each containing 10 odors. The stimuli are embedded in 10- to 50-μm microcapsules fixed in a proprietary binder and positioned on brown strips at the bottom of the pages of the booklets.

Above each odorant strip is a multiple choice question with four alternative responses for each item, and the smell is released by scratching the strip with a pen. In an investigation of its usefulness, the UPSIT test appeared to be a highly reliable and internally consistent measure of the ability to identify odors. The correlation coefficient for the test-retest reliability was determined to be about 0.95 (17).

In the United States subjects with a normal sense of smell and between the ages of 20 and 50 years were found to have a mean test score of 36–38 correct answers. Subjects with total anosmia have only about 10 correct responses, and this accomplishment is to be expected by chance alone. The test score decreases with age, but the decrease seems not to be apparent before 50 to 60 years of age (18).

Most of the smell items are well known in the Swedish culture. Some of the items are however “typically

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American” and therefore not quite suitable in the Swedish version of the test but have similarities to other “Swedish odors.” Therefore, eight of the 40 items were provided with other alternative responses. The test has been applied in Japan, and it appeared that cultural factors play a role, since some of the odors were less familiar to the Japanese than to the Americans (19).

Some days before the test the subjects received a questionnaire on present and past work conditions and smoking habits, categorized as never smokers, current smokers (cigarettes/day) and ex-smokers (having given up smoking more than half a year ago). Furthermore, present and past disorders of importance for the sense of smell were inquired about, eg, head trauma, diabetes mellitus, neurological disorders, and allergies. The subjects were also asked about how they perceived their sense of smell, in terms of “good,” “impaired,” or “completely lost.”

An otorhinolaryngeal examination was performed immediately after the test so that the subjects with obstructive disorders like nasal polyps and sinusitis, as well as common colds, could be excluded from the calculations. The examinations were performed early in the morning, when the subjects had not been exposed to organic solvents for at least 12 h, during three weeks in late spring and one week in the summer.

Subjects

Male painters and spray painters younger than 60 years of age and employed at least one year were selected for the study. Painters who worked for three painting companies and were regularly exposed to organic solvents were invited to participate. According to information from a questionnaire survey three years earlier, they were exposed to organic solvents at least 2 h/d. As a consequence of the general awareness nowadays of the potential hazards of organic solvents, most painting work is done with water-based paints. The painters' current exposure to organic solvents was therefore estimated to be 20 % of their worktime.

All spray painters employed in a department of a mechanical workshop were selected. The spray painters were exposed every day to organic solvents, and their mean exposure levels were estimated to be moderate. This estimate was supported by a higher than expected prevalence of neuropsychiatric symptoms reported in a health examination carried out by the occupational health service. Every eligible subject selected for the study agreed to participate and received the questionnaire.

Referents, unexposed to organic solvents and younger than 60 years of age, were chosen from the staff of a military regiment. All eligible subjects participated.

Two exposed subjects were excluded from the calculations due to nasal polyps and chronic rhinitis. Among the referents one subject with known anosmia caused by cerebral trauma and four subjects who were

disturbed during the test procedure were excluded from the calculations.

The exposed subjects had a mean age of 39 years, and 35 % were current smokers. The corresponding figures for the referents were 36 years and 31 %. The study groups consisted of 54 subjects exposed to organic solvents (39 painters and 15 spray painters) and 42 unexposed referents.

Statistical methods

Differences between the mean scores were analyzed with Student's *t*-test. The influence of the exposure was analyzed with a linear multiple regression analysis under the assumption of a normal distribution of the dependent variable.

Results

The exposed subjects and the referents showed a difference of 1.4 in the crude mean test scores (table 1). This difference was almost statistically significant ($P = 0.05$).

The distribution by age and the proportion of smokers differed between the study groups, and therefore a multiple regression analysis was carried out in order to account for the possible confounding effect of these variables. With the test score as the dependent variable, exposure status (dichotomously as exposed/unexposed) was not statistically significant ($P = 0.16$, SE (b) = 0.70) nor was smoking habits ($P = 0.08$, SE (b) = 0.04) (ex-smokers = never smokers). Age, however, was statistically significant ($P < 0.01$, SE (b) = 0.03). The *F*-test value of the analysis was 6.98 ($P < 0.01$).

The subject's perception of his sense of smell (in terms of “good,” “impaired,” and “completely lost”) correlated well with the test score. A regression analysis with the test score as the dependent variable showed a significant influence on the perception of smell ($P < 0.01$, SE (b) = 0.87), corresponding to an *F*-test value of 24.5 ($P < 0.001$).

The influence of age and smoking habits on the test performance of the referents was further analyzed with a multiple regression analysis. The result was similar to that obtained from the study groups combined. The age effect was statistically significant ($P = 0.02$), and the smoking variable was almost statistically significant ($P = 0.05$). The following equation was obtained

Table 1. Mean test scores and standard deviations of the study groups.

	Exposed			Referents (N = 42)
	Painters (N = 39)	Spray painters (N = 15)	All (N = 54)	
Mean test score	35.2	35.2	35.2*	36.6*
Standard deviation	4.62	3.47	4.30	2.39

* Student's *t*-test = 2.07, $P = 0.045$, two-tailed.

for the referents: test score = $39.8 - 0.08 \times \text{age} - 0.08 \times \text{cigarettes/day}$.

Discussion

The exposed subjects had a somewhat lower mean test score than the referents, but the difference was not statistically significant after adjustment for age and smoking habits. The test scores were not normally distributed, and therefore the use of a linear regression model may be disputed. However, the distribution was not considered so skewed as to invalidate the regression analysis. One exposed subject had a test score of 12, and this extremely low value had a marked influence on the mean value for the group. However, it was not considered appropriate to exclude this value because it may be the strongest indication of an effect of solvent exposure.

Participation in this study was voluntary, and, even though all eligible subjects accepted, the study groups cannot be regarded as representative of exposed and unexposed populations in general. The differences in relevant determinants or confounding variates, eg, age and smoking habits, were however considered in the multiple regression analysis. The exclusion of three subjects with organic disorders likely to affect the olfactory function and four subjects disturbed during the test was done without knowledge of the individual test scores and should not have introduced any major bias.

The current exposure to organic solvents was low or moderate, and no one seemed to have been recently exposed to high levels, ie, the occupational exposure limit or higher. This lack of variability in the exposure variable restricted the statistical analysis, which had to be done with the exposure variable dichotomized. A cumulative measure of exposure (ie, intensity $\times$ time) was not considered proper, as exposure time is strongly correlated with the age of the painters. Most painters enter their profession after school and seldom change jobs. Furthermore, the painters and the spray painters had different types of exposure, but the number of subjects was too low to justify separate regression analyses.

The reliability of the test is considered good (17) and is reflected in the relatively small standard deviation shown in table 1 (corresponding to a coefficient of variation of about 10 %). As a consequence, a study of this size had a power ($\alpha = 0.05$, $1 - \beta = 0.90$) sufficient to detect a difference of at least two test score units with the assumptions of unbiased comparison and a normal distribution of the variable. The painters and the referents were alternately examined on the same days during two weeks but in different offices. The spray painters were examined three months later. However, no major variations in the test procedures are believed to have influenced the comparability between the study groups.

The test measures the ability to recognize various odors, and the test score can therefore be expected to correlate well with the subjects' perception of smell, which in fact was the case in this study. The test measures neither thresholds nor odor intensity. Other modalities of olfactory function may have been more relevant to the issue of olfactory dysfunction caused by organic solvents. Odor threshold tests are commonly used to test the sense of smell. Therefore we also examined all the subjects except the spray painters with a commercial pyridine threshold test (20). The result of this test did not however differ between the exposed painters and the unexposed referents, and there was a statistically nonsignificant correlation with the subjective perception of smell.

In conclusion, this cross-sectional study of painters, spray painters, and military staff did not demonstrate any statistically significant decrease in olfactory function after exposure to organic solvents. The exposures to organic solvents were low to moderate, but some of the painters had, without doubt, been exposed previously to high levels of organic solvents. If high exposure has an effect on olfactory function, it is likely to be reversible.

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References

1. Moran D, Rowley C, Jafek B, Lovell M. The fine structure of the olfactory mucosa in man. *J Neurocytol* 1982; 11:721-46.
2. Doty R. A review of olfactory dysfunctions in man. *Am J Otolaryngol* 1979;1:57-79.
3. Douek E. The sense of smell and its abnormalities. Edinburgh & London: Churchill Livingstone, 1974.
4. Engen T. The perception of odors. New York, New York: Academic Press, 1982.
5. Meiselman H, Rivlin R. Clinical measurement of taste and smell. New York, New York: Macmillan, 1986.
6. Valcke H. Olfaction. *Acta Otorhinolaryngol Belg* 1986;40:97-119.
7. Amoore J. Effects of chemical exposure on olfaction in humans. In: Barrow C, ed. *Toxicology of the nasal passages*. Washington, DC: Hemisphere Publishing Corp, 1986:155-90.
8. WHO Working Group. Organic solvents and the central nervous system. Copenhagen: WHO Regional Office for Europe/Nordic Council of Ministers, 1985. (Environmental Health 5.)
9. Baker EL. Neurological disorders. In: Rom WN, ed. *Environmental occupational medicine*. Boston, Massachusetts: Little, Brown and Company, 1983.
10. Emmet E. Parosmia and hyposmia induced by solvent exposure. *Br J Ind Med* 1976;33:196-8.
11. Naus A. Olfactory properties of industrial matters. Prague: Charles University, 1975.
12. Ekblom A, Flock Å, Hansson P, Ottosson D. Ultrastructural and electrophysiological changes in the olfac-

- tory epithelium following exposure to organic solvents. *Acta Otolaryngol* (Stockh) 1984;98:351—61.
13. Rasmussen K, Bjerre A, Petersen R, Sabroe S. Health complaints caused by working with chlorinated solvents in the electronic industry. *Ugeskr Læger* 1985;147: 1053—7.
 14. Ahlström R, Berglund B, Berglund U, Lindvall T, Wennberg A. Impaired odor perception in tank cleaners. *Scand J Work Environ Health* 1986;12:574—81.
 15. Doty R, Shaman P, Dann M. Development of the University of Pennsylvania Smell Identification Test: a standardized microencapsulated test of olfactory function. *Physiol Behav* 1984;32:489—502.
 16. Doty R, Shaman P, Kimmelman C, Dann M. University of Pennsylvania Smell Identification Test: a rapid quantitative olfactory function test for the clinic. *Laryngoscope* 1984;2:176—8.
 17. Doty R, Newhouse M, Azzalina J. Internal consistency and short-term test-retest reliability of the University of Pennsylvania Smell Identification Test. *Chem Senses* 1985;10:297—300.
 18. Doty R, Shaman P, Applebaum S, Giberson R, Sikorski L, Rosenberg L. Smell identification ability: changes with age. *Science* 1984;226:1441—3.
 19. Doty R, Applebaum S, Zusho H, Settle R. Sex differences in odor identification ability: a cross-cultural analysis. *Neuropsychologia* 1985;23:667—72.
 20. Amoore J, Ollman B. Practical test kits for quantitatively evaluating the sense of smell. *Rhinology* 1983; 21:49—54.

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