ABSTRACT

Objectives The present study was performed to investigate the prevalence of olfactory dysfunction in workers exposed to hazardous substances in a variety of occupations in Korea.

Methods We designed a cross-sectional study. The exposed group (n=296) consisted of Korean workers in the automobile repair, printing, shoemaking and plating industries and was compared with office workers (non-exposed group, n=99). A self-report questionnaire was administered to the subjects for demographic characteristics. In addition, olfactory function was evaluated using the Korean version of Sniffin’s Stick (KVSS) I and II test, which has been reported to be valid and reliable in Korean subjects. KVSS I score ≥7 or KVSS II score ≥30 was classified as normal, KVSS I score <7 or KVSS II score <30 was classified as olfactory dysfunction. The statistical analyses were performed with olfactory dysfunction as a dependent variable to calculate prevalence ratio (PR) of the exposed group.

Results The prevalence of olfactory dysfunction was 21.2% in office, 45.1% in automobile repair, 69.7% in printing and 88.9% in shoemaking and plating workers. The adjusted PR was highest in plating (3.589, 95% CI 1.105 to 3.317), followed by printing (2.669, 95% CI 1.610 to 4.424) and automobile repair (1.914, 95% CI 1.105 to 3.317) workers.

Conclusions In comparison with office workers, the prevalence of olfactory dysfunction and the PR of olfactory dysfunction were very high in the four occupational groups. This finding could be an important basis for establishing the olfactory dysfunction prevention policy for workers who are exposed to hazardous substances or work in high-risk occupations.

INTRODUCTION

The human olfactory system modulates behaviour and interpersonal relationships and has been shown to have an important influence on nutritional status, eating satisfaction and quality of life.1-3 In addition to visual, auditory and vestibular function, the olfactory system also plays an important role in detecting changes in the environment, such as fire and gas leakage and olfactory dysfunction can, therefore, impact on safety.4 5

A variety of factors are known to be related to olfactory function. Olfactory dysfunction has been shown to decrease with age,6 8 with the decline in cognitive function (including olfactory function) progressing more rapidly in men than women.9 High body mass index (BMI),10 cigarette smoking,11 race,12 socioeconomic status12 13 and a history of head trauma14 have been associated with olfactory dysfunction. Occupational and environmental factors, such as exposure to certain metals (eg, lead,15 cadmium16 and manganese17), chemicals (eg, acetone,18 hydrogen sulfide,19 acrylate and methacrylate20) and pesticides (eg, chlorpyrifos21 and neonicotinoid22), can also impact on olfactory function.

Workers in certain industries are commonly exposed to multiple hazardous substances during the course of their work. While there have been several studies of the relationship between exposure to hazardous substances, such as metals and solvents and olfactory dysfunction, few have investigated olfactory dysfunction in specific occupational groups.23 In addition, many previous studies have had key limitations in their design, such as inadequate evaluation of exposure, small
subject numbers, lack of quantitative evaluation for olfactory function and inadequate control for confounding factors.25 We designed the cross-sectional study to investigate the prevalence of olfactory dysfunction in workers involved in various occupations and to evaluate the relationship between occupation and olfactory dysfunction.

METHODS

Subjects

Workers in automobile repair, printing, shoemaking and plating industries are known to be exposed to hazardous substances related with olfactory dysfunction. These workers were compared with non-exposed office workers.

An appropriate sample size was calculated with the Power and Sample Size Program V.3.1.2 and was calculated to be 250 in the exposed group and 82.5 in the non-exposed group, with a ratio for exposed and non-exposed group of 3:1. The initial number of subjects was 419. Subjects were excluded if there was sinusitis or sinus tumours associated with olfactory dysfunction (n=6) or if the olfactory function test was not adequately performed (n=26). The final number of subjects was n=99 in the non-exposed group and n=296 in the exposed group. The exposed group consisted of 82 automobile repair workers (27.7%), 142 printing workers (48.0%), 45 shoemaking workers (15.2%) and 27 plating workers (9.1%). Ethics was approved by the Institutional Review Board of Hanyang University. Informed consent was obtained from all study subjects.

Subjects and public involvement

The subjects were not involved the design, recruitment and conduct of the present study. The recruitment was performed to all workers in each industry and those who agreed to participate in the present study were included. The subjects were informed of the objective of the present study before questionnaire survey and of the results of olfactory function test right after the test.

Data collection

A self-report questionnaire was designed to capture demographic characteristics including age, sex, height, weight, alcohol drinking, smoking and working period. The researchers checked the questionnaires and asked the subjects to fill any missing data fields if found.

The Korean version of Sniffin’s Stick (KVSS) test has been shown to be valid and reliable for Korean subjects in comparison with the cross-cultural smell identification test (CC-SIT).24,25 KVSS I is a screening test that consists of eight pens for odour identification. The subject smells each pen and choose one out of four answers. The number of correct answers among the eight pens is considered to be the KVSS I score, with a KVSS I score ≥7 classified as normal, 5–6 indicating hyposmia and ≤4 indicating anosmia. KVSS II is an extended version of the test that includes an olfactory threshold test, odour discrimination test and odour identification test. The olfactory threshold test consists of 16 olfactory test pens with diluted butanol (n-butanol). The test starts from the pen with the lowest concentration and gradually increases the concentration of the pen to decide the threshold. The odour discrimination test consists of three pairs of 16 olfactory test pens, which include two of the same odour pens and one different odour pen. The subject is asked to smell three pens and choose a different odour pen. The odour identification test consists of 16 olfactory test pens containing odours familiar to the Korean population. The subject is asked to smell each pen and choose the right answer among four items. The score obtained after performing the three tests is referred to as the Threshold, Discrimination and Identification (TDI) score and is classified as follows: normal (TDI score ≥30), hyposmia (TDI score of 16–29) and anosmia (TDI score ≤15).

The exposed group was recruited in 2016 and tested using the extended olfactory function test (KVSS II). The non-exposed group were recruited in 2017, however due to time constraints were tested using the KVSS I. In addition, non-exposed group was considered as low-risk group for olfactory dysfunction, so we thought screening test (KVSS I) was appropriate for them. Subjects were classified as having normal or olfactory function according to the scores for KVSS I and II. In addition, the exposed group was classified further according to the score of odour identification test in KVSS II (≥13=normal, ≤12=odour identification impairment). The research was performed from May 2016 to July 2017.

Statistical analysis

Age was categorised as 20–29, 30–39, 40–49 and ≥50 in years. BMI was categorised as <23.0, 23.0–24.9 and ≥25.0 kg/m². Alcohol drinking was categorised as either ‘none or social’ or ‘moderate or heavy’. Moderate or heavy alcohol drinking was defined as drinking alcohol more than once a week. Working period was categorised as 0–9, 10–19, 20–29 and ≥30 years. Statistical analyses were performed with SAS Windows V.9.4. The demographic characteristics between the exposed and non-exposed groups were compared using a χ² test. The prevalence ratio (PR) of the exposed group was estimated with 95% CI using PROC GENMOD statement of SAS Windows V.9.4. Dependent variables were olfactory dysfunction and odour identification impairment and independent variables included age, sex, BMI, alcohol drinking and cigarette smoking. Age and BMI were treated as continuous variables and other variables were treated as categorical variables. The statistical significance level was set at p<0.05.

RESULTS

The demographic characteristics of all study subjects are shown in table 1. The mean age of subjects in the exposed group (45.8±10.5 years) was significantly higher than that of the non-exposed group (38.2±8.4 years, p<0.05). The proportion of obese subjects (BMI≥25 kg/m²) was
significantly higher in the non-exposed group (38.4%) than in the exposed group (24.6%, p<0.05). No significant differences were seen between the two groups with respect to alcohol drinking and smoking. More than half of the non-exposed group had <10 years working period (58.6%) compared with a third of the exposed group (33.8%).

Table 2 shows the prevalence of olfactory dysfunction and odour identification impairment. In the non-exposed group, the prevalence of olfactory dysfunction was 21.2%, which was lower than any of the occupations in the exposed groups (shoemaking and plating: 88.9% each; printing: 69.7% and automobile repair: 45.1%). The prevalence of odour identification impairment was highest in the plating group (96.3%), followed by shoemaking (86.7%), printing (82.3%) and automobile repair (54.9%).

Table 3 shows the association between occupation and olfactory dysfunction and odour identification impairment. The PRs of all occupations in the exposed group were significantly greater than 1.0. For olfactory dysfunction, adjusted PR was highest in plating (3.589, 95% CI 1.957 to 6.583), followed by shoemaking (3.136, 95% CI 1.763 to 5.579), printing (2.669, 95% CI 1.610 to 4.424) and automobile repair (1.914, 95% CI 1.105 to 3.317) workers.

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The present study was designed to investigate the prevalence of olfactory dysfunction in various occupations known to be exposed to hazardous substances and the relationship between occupation and olfactory dysfunction. In comparison with office workers, the prevalence of olfactory dysfunction was higher in the exposed occupational groups (45.1% in automobile repair group, 69.7% in printing, and 88.9% in shoemaking and plating versus 21.2% in office workers). All occupations in the exposed group exhibited elevated risk of olfactory dysfunction and odour identification impairment, with the risk being highest in plating, followed by shoemaking, printing, and automobile repair.

The reported prevalence of olfactory dysfunction in the general population has been shown to differ across a number of published studies and may vary depending on the target population and the method of testing. Schubert et al. performed odour identification test in 2838 participants aged 21–84 years and reported that the prevalence of olfactory impairment was 3.8%. In Korea, the prevalence of subjective olfactory dysfunction was 5.4%, which was derived from a self-reported questionnaire on 24990 participants aged 20–98 in the Korea National Health and Nutrition Examination Survey from 2008 to 2012. Among 2491 participants of old age (53–97 years), the prevalence of impaired olfaction using the San Diego Odor Identification Test (SDIOT) was 24.5%. Vennemann et al. measured the olfactory function using Sniffin’s Sticks test in 1312 participants (mean age 52.1 years) and reported that the prevalence of olfactory dysfunction was 18.0%. Brämerson et al. performed the Scandinavian Odor Identification Test in 1387 participants of all age groups (from 20 to >80 years) and reported that the prevalence of olfactory dysfunction was 19.1% (13.3% of hyposmia and 5.8% of anosmia).

There are many studies about the prevalence of olfactory dysfunction in the general population, but few studies have investigated the prevalence of olfactory dysfunction in specific occupational groups. Watanabe and Fukuchi conducted the olfactory function test in 33 workers in a chromate-producing factory, reporting that 54.5% exhibited olfactory dysfunction. Rose et al. examined 55 workers exposed to cadmium fumes in a brazing operation and reported that 56.4% exhibited olfactory dysfunction (43.6% mild hyposmia and 12.7% moderate or severe hyposmia). Mascagni et al. investigated olfactory function in 33 workers employed in cadmium fusion, sintering, and alloy lamination, reporting that 30.3% of study subjects exhibited olfactory dysfunction. Rydzewski et al. evaluated the olfactory function test in 73 workers in a cadmium–nickel battery plant and found that 45.2% had olfactory dysfunction (26.0% hyposmia, 17.8% parosmia, and 1.4% anosmia). Antunes et al. performed the University of Pennsylvania Smell Identification Test.

### Table 2
Prevalence for olfactory dysfunction and olfactory identification impairment.

<table>
<thead>
<tr>
<th>Job</th>
<th>Olfactory dysfunction*</th>
<th>Odour identification impairment†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office work</td>
<td>21 (21.2)</td>
<td>21 (21.2)</td>
</tr>
<tr>
<td>Automobile repair</td>
<td>37 (45.1)</td>
<td>45 (54.9)</td>
</tr>
<tr>
<td>Printing</td>
<td>99 (69.7)</td>
<td>117 (82.3)</td>
</tr>
<tr>
<td>Shoemaking</td>
<td>40 (88.9)</td>
<td>39 (86.7)</td>
</tr>
<tr>
<td>Plating</td>
<td>24 (88.9)</td>
<td>26 (96.3)</td>
</tr>
</tbody>
</table>

Data are shown as number (%).
*Evaluated with KVSS I (office work) or TDI score of KVSS II (automobile repair, printing, shoemaking and plating).
†Evaluated with KVSS I (office work) or odour identification test in KVSS II (automobile repair, printing, shoemaking and plating).

KVSS, Korean version of Sniffin’s Stick; TDI, Threshold, Discrimination and Identification.

### Table 3
The association between job and olfactory dysfunction and olfactory identification impairment.

<table>
<thead>
<tr>
<th>Job</th>
<th>Crude prevalence ratio (PR)</th>
<th>Adjusted PR*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olfactory dysfunction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office work</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Automobile repair</td>
<td>2.127 (1.245–3.634)</td>
<td>1.914 (1.105–3.317)</td>
</tr>
<tr>
<td>Printing</td>
<td>3.287 (2.052–5.263)</td>
<td>2.669 (1.610–4.424)</td>
</tr>
<tr>
<td>Plating</td>
<td>4.191 (2.333–7.527)</td>
<td>3.589 (1.957–6.583)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odour identification impairment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office work</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Automobile repair</td>
<td>2.587 (1.541–4.343)</td>
<td>2.386 (1.402–4.059)</td>
</tr>
<tr>
<td>Printing</td>
<td>3.884 (2.441–6.181)</td>
<td>2.979 (1.811–4.898)</td>
</tr>
<tr>
<td>Shoemaking</td>
<td>4.086 (2.404–6.945)</td>
<td>2.892 (1.630–5.129)</td>
</tr>
<tr>
<td>Plating</td>
<td>4.540 (2.554–8.068)</td>
<td>3.657 (2.015–6.635)</td>
</tr>
</tbody>
</table>

Data are shown as PR (95% CI).
*Adjusted for age, sex, body mass index, medical history, alcohol drinking and smoking.
(UPSIT) in 43 welders and matched control subjects, demonstrating that 88.0% of welders had a UPSIT score lower than their matched controls. According to the above researches, the prevalence of various occupations was reported to be 45.2%–88.0%, which is much higher than that of the general population from previous researches (3.8%–24.5%). In the present study, the prevalence of olfactory dysfunction in the exposed groups was much higher than that of the non-exposed group, which is consistent with the previous researches.

According to a review of olfactory toxicity and the long-term effects of occupational exposure, various metals and chemicals have been associated with olfactory dysfunction in exposed workers. Metals known to have an effect on the olfactory system include arsenic, cadmium, chromium, copper, mercury, nickel and zinc; chemicals include acetone, acrylate, methacrylate, benzene, toluene, trichloroethylene, xylene and solvent mixtures.23 However, few studies have assessed the magnitude of the risk associated with these hazardous substances or occupational groups. Schwartz et al investigated the risk of acrylate and methacrylate vapours on olfactory dysfunction, and reported the OR for acrylate and methacrylate exposure to be 3.1 (95% CI 1.2 to 7.7).20 They also reported a dose-response relationship between olfactory dysfunction and cumulative lifetime exposure to acrylates. Most studies have compared the subjective symptoms for olfactory dysfunction or the results of olfactory function testing between exposed and control groups, but did not investigate the relative risk or OR of hazardous substances or occupations on olfactory dysfunction.

In the present study, the adjusted PRs of all occupations in the exposed group were very high. A variety of potentially hazardous substances are used in the process of plating, that is, acids (sulfuric, hydrochloric and nitric), metals (zinc, nickel, chrome and copper) and solvents (trichloroethylene, ethylbenzene, xylene and toluene).33 34 Hazardous substances commonly used in the process of shoemaking include solvents, such as benzene, xylene, ethyl benzene, toluene and n-hexane.35 Solvents are also the main source of exposure in the printing process, with n-hexane, acetone, isopropyl alcohol, toluene and xylene being the most common substances used.36 In the process of automobile repair, workers may be exposed to solvents (toluene, xylene, acetone, isopropyl alcohol, methyl ethyl ketone and styrene) and metals (zinc, chrome, manganese and cadmium).37 38 Most workers are exposed to a variety of chemical substances rather than a single substance. In addition, occupational olfactory dysfunction may also likely occur due to an exposure of various chemical substances rather than a single substance. Therefore, future study about occupational olfactory dysfunction should focus on occupations which may have risk for olfactory dysfunction.

The present study has some limitations. First, the subjects of the present study were not representative for all workers. So, it is difficult to generalise the results of the present study. Second, the present study was cross-sectional, so the finding of the present study means the association, not causal relationship. Third, the KVSS I was used to assess olfactory function in the office worker group, while the KVSS II was performed in the occupational groups. KVSS I is a screening test that includes odour identification only, whereas KVSS II is an extended test that includes an olfactory threshold test, odour discrimination test and odour identification test. As the dependent variable of olfactory dysfunction was derived from different tests in the office workers and occupational groups, statistical analysis may be inappropriate. However, the correlation between the KVSS I, II and CC-SIT scores has been reported to be extremely high.25 We, therefore, consider that given the high correlation between KVSS I and II scores, the use of different tests was not a significant issue.

In conclusion, the prevalence of olfactory dysfunction was seen to be 21.2% in office workers, while notably higher rates were seen in the exposed group: 45.1% in automobile repair, 69.7% in printing and 88.9% in shoe-making and plating. In addition, the PR of olfactory dysfunction in the occupations of the exposed group was very high compared with office workers. To prevent the olfactory dysfunction in these occupations, it is recommended to inform workers about the health hazards of chemicals and metals, encourage them to wear protective equipment and provide periodic health examinations including olfactory function test. The findings of the present study could be an important basis for establishing an olfactory dysfunction prevention policy for workers who are exposed to hazardous substances or work in high-risk occupations.

Contributors S-JL Lee drafted the manuscript. E-MK Kim contributed to the questionnaire survey. S-IC Cho performed the olfactory function testing. JS contributed to the study design and interpretation of the manuscript. T-WJ contributed to the study design, statistical analysis, and revision of the manuscript. M-YL contributed to the statistical analysis and revision of manuscript.

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Patient consent Obtained.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data available.

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