

# BMJ Open Risk of olfactory dysfunction of the workers in the automobile repair, printing, shoemaking and plating industries in Korea: a cross-sectional study

Soo-Jin Lee,<sup>1</sup> Eun-Mi Kim,<sup>2</sup> Seok-Hyun Cho,<sup>3</sup> Jaechul Song,<sup>4</sup> Tae-Won Jang,<sup>4</sup> Mi-Young Lee<sup>5</sup>

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<sup>1</sup>Department of Occupational and Environmental Medicine, Hanyang University Medical Center, Seoul, Korea

<sup>2</sup>Graduate School of Public Health, Hanyang University, Seoul, Korea

<sup>3</sup>Department of Otolaryngology, Hanyang University College of Medicine, Seoul, Korea

<sup>4</sup>Department of Occupational and Environmental Medicine, Hanyang University College of Medicine, Seoul, Korea

<sup>5</sup>Occupational Health Research Bureau, Occupational Safety and Research Institute, Ulsan, Korea

## Correspondence to

Dr Tae-Won Jang;  
om1024@hanmail.net

## 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  $\geq 7$  or KVSS II score  $\geq 30$  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 1.957 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.

**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.<sup>1–3</sup> In addition to visual, auditory and vestibular function, the olfactory system also plays an important role

## Strengths and limitations of this study

- The study investigated the prevalence of olfactory dysfunction in various occupational groups.
- Olfactory function testing with high validity and reliability was performed using the Korean version of Sniffin's Stick (KVSS); confounding factors associated with olfactory dysfunction were controlled.
- Different tests were performed on subjects in the two groups: KVSS I in non-exposed group and KVSS II in the exposed group.

in detecting changes in the environment, such as fire and gas leakage and olfactory dysfunction can, therefore, impact on safety.<sup>4,5</sup>

A variety of factors are known to be related to olfactory function. Olfactory dysfunction has been shown to decrease with age,<sup>6–8</sup> with the decline in cognitive function (including olfactory function) progressing more rapidly in men than women.<sup>9</sup> High body mass index (BMI),<sup>10</sup> cigarette smoking,<sup>11</sup> race,<sup>12</sup> socioeconomic status<sup>12,13</sup> and a history of head trauma<sup>14</sup> have been associated with olfactory dysfunction. Occupational and environmental factors, such as exposure to certain metals (eg, lead,<sup>15</sup> cadmium<sup>16</sup> and manganese<sup>17</sup>), chemicals (eg, acetone,<sup>18</sup> hydrogen sulfide,<sup>19</sup> acrylate and methacrylate<sup>20</sup>) and pesticides (eg, chlorpyrifos<sup>21</sup> and neonicotinoid<sup>22</sup>), 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.<sup>23</sup> 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.<sup>23</sup> 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).<sup>24 25</sup> 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  $\geq 7$  classified as normal, 5–6 indicating hyposmia and  $\leq 4$  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  $\geq 30$ ), hyposmia (TDI score of 16–29) and anosmia (TDI score  $\leq 15$ ).

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 ( $\geq 13$ =normal,  $\leq 12$ =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  $\geq 50$  in years. BMI was categorised as  $< 23.0$ , 23.0–24.9 and  $\geq 25.0$  kg/m<sup>2</sup>. 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  $\geq 30$  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  $\chi^2$  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 $\pm$ 10.5 years) was significantly higher than that of the non-exposed group (38.2 $\pm$ 8.4 years,  $p < 0.05$ ). The proportion of obese subjects (BMI  $\geq 25$  kg/m<sup>2</sup>) was

**Table 1** Demographic characteristics of study subjects.

	Non-exposed (n=99)	Exposed (n=296)	P values
Age (years)	38.2 ± 8.4	45.8 ± 10.5	<0.0001
20 – 29	15 (15.2)	24 (8.1)	
30 – 39	48 (48.5)	61 (20.6)	
40 – 49	23 (23.2)	92 (31.1)	
≥50	13 (13.1)	119 (40.2)	
Sex			0.0570
Male	89 (89.9)	242 (81.8)	
Female	10 (10.1)	54 (18.2)	
BMI (kg/m <sup>2</sup> )			0.0266
< 23	34 (34.3)	134 (45.3)	
23 – 25	27 (27.3)	89 (30.1)	
≥ 25	38 (38.4)	73 (24.6)	
Alcohol drinking			0.3324
Non-drinker or social drinker	25 (25.3)	61 (20.6)	
Moderate or heavy drinker <sup>*</sup>	74 (74.7)	235 (79.4)	
Smoking			0.1960
Non-smoker or ex-smoker	43 (43.4)	107 (36.1)	
Current smoker	56 (56.6)	189 (74.9)	
Working period (years)			<0.0001
0–9	58 (58.6)	100 (33.8)	
10–19	24 (24.2)	74 (25.0)	
20–29	16 (16.2)	63 (21.3)	
≥30	1 (1.0)	59 (19.9)	
Job			<0.0001
Office work	99 (100.0)	0 (0.0)	
Automobile repair	0 (0.0)	82 (27.7)	
Printing	0 (0.0)	142 (48.0)	
Shoemaking	0 (0.0)	45 (15.2)	
Plating	0 (0.0)	27 (9.1)	

Data are shown as mean±SD or number (%).

<sup>\*</sup>Drinking alcohol more than once a week.

BMI, body mass index.

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. For odour identification impairment, adjusted PR was highest in plating (3.657, 95% CI 2.015 to 6.635), followed by printing (2.979, 95% CI 1.811 to 4.898), shoemaking (2.892, 95% CI 1.630 to 5.129) and automobile repair (2.386, 95% CI 1.402 to 4.059).

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

Job	Olfactory dysfunction*	Odour identification impairment†
Office work	21 (21.2)	21 (21.2)
Automobile repair	37 (45.1)	45 (54.9)
Printing	99 (69.7)	117 (82.3)
Shoemaking	40 (88.9)	39 (86.7)
Plating	24 (88.9)	26 (96.3)

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.

## DISCUSSION

The present study was designed to investigate the prevalence of olfactory dysfunction in variety of 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*<sup>13</sup> 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.<sup>26</sup> Among 2491 participants of old age (53–97 years), the prevalence of impaired olfaction using the San Diego Odor Identification Test (SDOIT) was 24.5%.<sup>8</sup> Vennemann *et al*<sup>11</sup> 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*<sup>27</sup> 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<sup>28</sup> conducted the olfactory function test in 33 workers in a chromate-producing factory, reporting that 54.5% exhibited olfactory dysfunction. Rose *et al*<sup>29</sup> 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*<sup>30</sup> 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*<sup>31</sup> 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*<sup>32</sup> performed the University of Pennsylvania Smell Identification Test

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

Job	Crude prevalence ratio (PR)	Adjusted PR*
<b>Olfactory dysfunction</b>		
Office work	1.000	1.000
Automobile repair	2.127 (1.245–3.634)	1.914 (1.105–3.317)
Printing	3.287 (2.052–5.263)	2.669 (1.610–4.424)
Shoemaking	4.191 (2.471–7.106)	3.136 (1.763–5.579)
Plating	4.191 (2.333–7.527)	3.589 (1.957–6.583)
<b>Odour identification impairment</b>		
Office work	1.000	1.000
Automobile repair	2.587 (1.541–4.343)	2.386 (1.402–4.059)
Printing	3.884 (2.441–6.181)	2.979 (1.811–4.898)
Shoemaking	4.086 (2.404–6.945)	2.892 (1.630–5.129)
Plating	4.540 (2.554–8.068)	3.657 (2.015–6.635)

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.<sup>23</sup> 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).<sup>20</sup> 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).<sup>33,34</sup> Hazardous substances commonly used in the process of shoemaking include solvents, such as benzene, xylene, ethyl benzene, toluene and n-hexane.<sup>35</sup> 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.<sup>36</sup> 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).<sup>37,38</sup> 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 study, 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.<sup>25</sup> 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 shoemaking 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-HC 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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