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Reduction of Indoor Formaldehyde Concentrations and Subjective Symptoms in a Gross Anatomy Laboratory

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Formaldehyde, notorious as an irritant and a potential carcinogen (Horvath et al. 1988; Partanen 1993), is manufactured in very large quantities and used for various purposes (Fishbein 1992). One of the purposes is embalming or tissue presentation at medical schools (Pabst 1987). There are scarcely people who are more exposed to formaldehyde than anatomists, histology technicians, and medical students during their dissection course. In Japan, the Ministry of Health, Labour, and Welfare (MHLW) promulgated a guideline value (0.25 ppm = 307 $\mu g/m^3$ at 25°C) for the indoor formaldehyde concentration in workplaces, which handle materials emitting formaldehyde (MHLW 2002). If environmental measurement results exceed this value, it is needed to take effective measures to reduce the concentrations.

Many reports are available on environments in gross anatomy laboratories and possible symptoms in other countries, but not in Japan. In this survey, we conducted a measurement of the indoor formaldehyde concentrations in a gross anatomy laboratory and personal exposure concentrations of medical students during an anatomy dissecting course before and after installing ventilation fans in the laboratory, and also investigated whether the installation affected the increase of subjective symptoms experienced by the students.

MATERIALS AND METHODS

The gross anatomy laboratory and the students in a region of Japan were investigated in 2001 as a first phase and in 2004 as a second phase. Figure 1 illustrates the anatomy laboratory. Twelve sets of push-pull ventilation fans were installed in 2003 in the rectangular laboratory room (approximately 20.2 × 15.5 × 3.7 m). Each set of fans generates air flow at the rates of 1120 and 876 m^3/h for suction and exhaust, respectively. There were three doors which were closed when not in use. The room contained 36 dissecting worktables; 26 tables (first phase) and 24 tables (second phase) were actively used. The tables were spread evenly along the length of the laboratory in four rows. The anatomy dissecting course lasted for two months from May to July every year. The students worked on the

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cadavers on weekdays and served as their own controls for the duration of the course. They usually did not wear protective masks but gloves.

Indoor formaldehyde concentrations were measured at 9 points in the both phases, when the thoraxes of the cadavers were opened. Our environmental sampling method followed the standard methods, which were provided by MHLW (2000). That is, active sampling was undertaken for more than 10 minutes at each measurement point. Formaldehyde was collected from air onto 2,4-dinitrophenylhydrazine (DNPH) samplers. The derivatives in cartridges were eluted with acetonitrile before analysis with a high performance liquid chromatograph equipped with a UV detector. We also measured medical students' exposure to formaldehyde during an anatomy dissecting course, referred as personal exposure concentrations. Every four students worked on a cadaver together and 24 and 46 students for the first and second phases, respectively, volunteered to take part in this measurement. Formaldehyde was collected from air around the breathing zone onto DNPH samplers during dissecting operations (for 42–962 min and 100–540 min in the first and second phase, respectively). An analytical method was the same one as the described above.

A questionnaire survey was executed before and during the both periods of the anatomy course with the same self-administered questionnaire. The questions concerned individual characteristics (e.g., age, gender) and intensities of 25 subjective symptoms. The symptoms asked in the questionnaire are given in Table 1. Qualitative questions on these health complaints were asked on a four-point scale, in which responses were to be given: 1 (never), 2 (scarcely), 3 (sometimes), and 4 (always) and were required to refer to the respondents' experience at the time of the study. The recovery rates in this survey were summarized in Table 2. Seventy-eight and 79 students answered the questionnaires both before and during the anatomy course in the first and second phases, respectively. Then their answers were used in the following analysis.

RESULTS AND DISCUSSION

Table 3 shows the medians (ranges) of formaldehyde concentrations of indoor air and personal exposure. In the first phase our measured levels were generally higher than other studies (Chia et al. 1992; Kriebel et al. 1993; Akbar-Khanzadeh et al. 1994; Keil et al. 2001), which reported ambient air and breathing zone levels in gross anatomy laboratories had ranged from 780 to 2825 $\mu g/m^3$ and from 86 to 3611 $\mu g/m^3$, respectively. Both of the indoor air and the personal exposure formaldehyde concentrations significantly reduced after installation of ventilation fans ($P<0.01$). In the second phase, however, 88.9% of the indoor air and 82.6% of the personal exposure samples were exposed to formaldehyde in excess of the guideline value (307 $\mu g/m^3$) proposed by MHLW and the Occupational Exposure Limit (610 $\mu g/m^3$) by the Japan Society for Occupational Health (2004), respectively. It is not attributed only to ventilation performance because larger

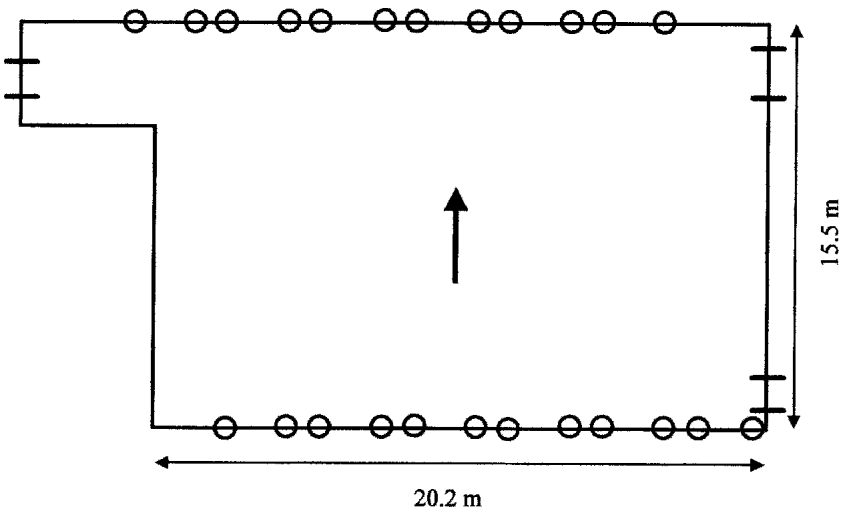

Figure 1. The layout of the gross anatomy laboratory
circle: ventilation fan; arrow: direction of air flow; bars: door

Table 1. Symptoms in the self-administered questionnaire used in this study.

Parts of body	Symptoms
Skin	eczema, itchy skin, flushed skin, swollen skin, dry skin, irritated skin
Eye	itchy eyes, irritated eyes, dry eyes, abnormal visual sensitivity to light, eye fatigue, eye congestion, watery eyes, poor vision
Nose	sneeze or runny nose or stuffy nose, itchy nose, changed sense of smell
Throat	sore throat, itchy throat, dry throat, difficulty swallowing, hoarseness, whistling throat, having a cold frequently, frequent cough

The possible scales of answers to the questions about frequencies of these individual subjective symptoms were: 1 = never, 2 = scarcely, 3 = sometimes, and 4 = always.

Table 2. Recovery of the questionnaire study.

Phase	Study period[a]	Recovery[b]	Analyzed questionnaire[c]
First	Before	89% (92/103)	78
	During	82% (84/103)	
Second	Before	96% (92/96)	79
	During	89% (80/90)	

[a] The questionnaires were distributed before and during the anatomy dissecting course.
[b] Numbers of returned and distributed questionnaires are in parenthesis.
[c] These questionnaires were answered by the same students before and during the course and introduced into the following analysis.

Table 3. Formaldehyde concentrations of indoor air and personal exposure.

Type of sample	Phase	n	Median (Range), $\mu g/m^3$
Indoor air	First	8[a]	259 (2108–3010)
	Second	9	729 (291–971)*
Personal exposure	First	24	3313 (2238–8909)
	Second	46	878 (396–3386)*

[a] One of the results was removed because of its abnormal low value.
* Significantly lower than the respective data of the first phase ($P<0.01$, Mann-Whitney test)

Table 4. Intensity of symptom change in the first and second phases.

Parts of body	Symptom	Symptom change index[a]	
		First phase (n = 78)	Second phase (n = 79)
Skin	eczema	0.13	−0.09*
	itchy skin	0.36	0.13
	flushed skin	0.17	−0.09
	swollen skin	0.05	−0.01
	dry skin	0.05	−0.24
	irritated skin	0.05	0.01
Eye	itchy eyes	0.74	0.27*
	irritated eyes	0.96	0.52*
	dry eyes	0.62	0.27
	abnormal visual sensitivity to light	0.09	0.03
	eye fatigue	0.68	0.20
	eye congestion	0.58	0.54
	watery eyes	1.42	0.46*
	poor vision	0.17	−0.27*
Nose	sneeze or runny nose or stuffy nose	0.22	0.15
	itchy nose	0.67	0.22*
	changed sense of smell	0.18	0.33*
Throat	sore throat	0.69	0.22*
	itchy throat	0.17	0.14
	dry throat	0.28	0.22
	difficulty swallowing	0.10	0.05
	hoarseness	0.10	0.14
	whistling throat	0.05	0.03
	having a cold frequently	0.09	−0.08
	frequent cough	0.06	−0.11

[a] How to calculate the index is in the text.
* There was a significant difference between first and second phases ($P<0.05$, Mann-Whitney test).

number of room-air exchanges does not always result in the lower concentration of formaldehyde vapors (Kerfoot and Mooney 1975). To overcome the difficulty, Coleman (1995) introduced a novel type of dissection table which could keep formaldehyde vapor levels in the range of 0.03–0.09 ppm (approximately 40–110 $\mu g/m^3$). Unfortunately this system is fairly expensive. The purchase price of each table is about $20,000, but the installation of the tables should be taken into account if finances allow.

Respondents of the analyzed questionnaires consisted of 57 males and 21 females (averaging 21.6 years old) in the first phase and 56 males and 23 females (averaging 21.7 years old) in the second phase. To quantify the intensity of a change in each subjective symptom, we subtracted "before anatomy training" from "during training" symptom scale which ranged from 1 (never) to 4 (always), and referred to the value as a symptom change level. Then, an average of symptom change levels of each subjective symptom was calculated by dividing the total of symptom change levels by the number of answers ($n = 78$ and 79 in the first and second phases, respectively). The average was referred to as a symptom change index (Table 4). Complaints involving the eye increased substantially in both phases compared to the others. The symptoms on the eye, skin, nose, and throat were common in former studies on people handling formaldehyde (Alexandersson and Hedenstierna 1989; Holness and Nethercott 1989; Akbar-Khanzadeh et al. 1994). In the first phase, the students complained about exacerbation of all the symptoms on average. The increase in 8 out of 25 symptoms was significantly reduced after installing general ventilation ($P<0.05$). Symptom change indices of almost all the other symptoms also had a decreasing tendency.

Ritchie and Lehnen (1987) demonstrated a positive dose-response relation between formaldehyde level and health complaints, Akbar-Khanzadeh et al. (1994) did not. In our study, Spearman rank correlation coefficients (r_s) were calculated between the personal exposure concentrations and the symptom change levels. Of the 25 subjective symptoms, the formaldehyde concentrations increased dose-dependently with the levels of itchy nose ($r_s = 0.471$) in the first phase and irritated eyes ($r_s = 0.308$) in the second phase with statistical significance ($P<0.05$). We need further improvement in assessing the formaldehyde effects on human health.

The results of this study indicated that indoor and exposure formaldehyde concentrations could be reduced by general ventilation fans and in consequence, the rise in the subjective symptoms was suppressed. The concentrations, however, were not sufficiently kept under the acceptable levels. That means it might be a better way to eliminate the source of release. Possible approaches are to use dissecting worktables equipped with local exhaust ventilation system or to develop a substitute for formaldehyde. We have to seek additional safety measures to maintain formaldehyde concentration below lowest feasible levels.

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