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Occupational Exposure to Formaldehyde and Its Association with Physical Health Symptoms in Pathology Laboratory Staff: A Cross-Sectional Study

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ABSTRACT

Objective: To evaluate the relationship between occupational formaldehyde exposure and physical health symptoms among pathology laboratory workers.
Method: This cross-sectional study was conducted between May and September 2016, and included 98 healthcare workers. Formaldehyde exposure was measured using a badge method during an eight-hour shift, and the Formaldehyde Exposure Index (FAI) was calculated. Participants completed a structured questionnaire covering sociodemographic characteristics, occupational factors, and physical symptoms. The Mann-Whitney U test and correlation analyses were used for statistical evaluation.
Results: The mean age of participants was 40.06 ± 9.09 years. The median formaldehyde measurement was 0.030 ppm (range: 0.004–4.400). Formaldehyde levels were significantly lower in laboratories with local and general ventilation systems ($p < 0.05$). A total of 89.8% of participants reported at least one physical symptom; the most common were unpleasant odor (75.3%), headache (61.3%), and watery eyes (58.1%). The mean FMI of those reporting at least one symptom (513.83 ± 381.16) was significantly higher than that of those without symptoms (15.35 ± 11.05) ($p = 0.001$).
Conclusion: The incidence of physical symptoms increased with higher formaldehyde exposure indices among pathology laboratory workers. These findings highlight the critical importance of effective ventilation systems, personal protective equipment use, and regular exposure monitoring in protecting worker health.
KEYWORDS: Formaldehyde, occupational exposure, pathology, symptoms, health worker

INTRODUCTION

Pathology laboratories are critical workspaces for the preservation and microscopic analysis of biological tissue samples. In these processes, formalin containing a 10% formaldehyde solution is widely used as the gold standard for tissue fixation (Inglezakis et al., 2020). Formaldehyde is a volatile, colorless aldehyde with a pungent odor and can cause serious adverse effects on human health through inhalation or dermal contact (IARC, 2012; OSHA, 2019). Acute exposure can irritate the eyes, nose, throat, and skin, while long-term exposure can cause certain cancers such as nasopharyngeal cancer and asthma (Kim et al., 2011). A cohort study found that both high-dose and cumulative lifetime exposure can impair cognitive function (Letellier et al., 2022).

Various epidemiological and experimental studies have shown that formaldehyde exposure among technicians, pathologists, and trainees in pathology laboratories can lead to both biological and symptomatic health effects. Field studies in Iran found formaldehyde exposure to be associated with asthma-like respiratory symptoms such as coughing, burning eyes, and wheezing, as well as an increased cancer risk (Safari et al., 2013). Key factors that elevate exposure levels include inadequate ventilation, lack of protective equipment, and high workload (Marongiu et al., 2016).

The aim of this study was to determine the physical symptoms associated with formaldehyde exposure among pathology laboratory personnel working in public and private hospitals in Mersin Province, and to evaluate the risk factors influencing exposure levels.

MATERIAL AND METHODS

This study is a cross-sectional study. The population of the study consisted of 88 healthcare professionals working in pathology laboratories of six public hospitals in Mersin province between May 18 and September 28, 2016 and 11 healthcare professionals working in a private pathology laboratory, totaling 99 individuals. It was planned to include all individuals in the population in the study without selecting a sample. However, one participant could not participate in the study and the analyses were conducted on 98 participants.

A structured questionnaire form was used as a data collection tool. The questionnaire consisted of six sociodemographic questions and 30 questions about occupational characteristics, work environment and exposure. In order to evaluate the validity of the data form, a pilot study was conducted in a group of five people and necessary adjustments were made in line with the feedback received. The questionnaires were administered by the researcher using face-to-face interview method.

Formaldehyde exposure assessment was performed by means of a formaldehyde badge named "ACS Badge Company, 04-006 Formaldehyde Monitoring Badge"

placed near the respiratory area of the employees. With this method, workers' exposure to formaldehyde was measured during an eight-hour shift. After the measurement, the badges were sent to Sensors Safety Products Laboratory (ID 176760), an American Industrial Hygiene Association (AIHA) accredited laboratory, and analyzed.

Only one formaldehyde exposure measurement was taken from each employee. The legally accepted eight-hour time-weighted average (TLV-TWA) exposure limit value in Turkey is 0.75 ppm (Turkish Ministry of Health, 2021). Based on this limit value, formaldehyde exposure was evaluated on the basis of duration and dosage.

In order to evaluate formaldehyde exposure in a more holistic manner, the Formaldehyde Exposure Index (FAI) was used in line with similar studies in the literature (Wang et al., 2015). This index is calculated by multiplying the formaldehyde measurement result (ppm) determined by the badge, daily exposure time (hours) and annual exposure time (years).

FMI = Badge measurement result (ppm) × Daily exposure time (hours) × Annual exposure time (years)

Frequency, percentage distribution, mean, standard deviation, median, minimum and maximum values were used in descriptive statistics. The conformity of continuous variables to normal distribution was evaluated by Kolmogorov-Smirnov test. Since working time, formaldehyde exposure (collar card measurement result) and FMI variables did not show normal distribution, median, minimum and maximum values were used in the analysis of these variables.

Mann-Whitney U test was used to analyze the difference between groups, and Pearson and Spearman correlation tests were used to evaluate the correlations between variables.

RESULTS AND DISCUSSION

The mean age of the health care workers included in the study was 40.06±9.09 years (lowest=21, highest=64) and the mean duration of employment was 13.95±9.43 years (lowest=0.2, highest=35). Of the healthcare workers included in the study, 62 (63.3%) were female, 72 (73.5%) were married, 50 (51.0%) were university/high school graduates, 87 (88.8%) were employed in the public sector, and 44 (44.9%) were laboratory technicians (Table 1).

Table 1. Distribution of sociodemographic characteristics of healthcare workers according to employment in public and private sectors

Variables	Public		Special		Total	
	n	%	n	%	n	%
Gender						
Woman	53	60.9	9	81.8	62	63.3
Male	34	39.1	2	18.2	36	36.7
Level of education						
Primary School	3	3.5	1	9.1	4	4.1
Middle School	2	2.3	1	9.1	3	3.1
High School	10	11.5	2	18.2	12	12.2
University	45	51.7	5	45.4	50	51.0
PhD	27	31.0	2	18.2	29	29.6
Profession						
Pathology specialist	26	29.9	2	18.2	28	28.6
Laboratory Technician	39	44.8	5	45.4	44	44.9
Medical Secretary	16	18.4	3	27.3	19	19.4
Cleaning staff	6	6.9	1	9.1	7	7.1
What he does						
Microscopy	24	27.6	2	18.2	26	26.5
Macroscopy	9	10.3	2	18.2	11	11.2
Staining, sectioning	30	34.5	4	36.3	34	34.7
Secretariat	18	20.7	2	18.2	20	20.5
Cleaning	6	6.9	1	9.1	7	7.1

The median formaldehyde exposure index was 0.287 "year x hour x ppm" (lowest= 0.001, highest= 140.800) (Table 2). It was determined that two of the measurements (2.1%) were higher than the eight-hour threshold values for formaldehyde (1.6 ppm and 4.4 ppm) and the other measurement results were normal. The formaldehyde measurement result was found to be above the accepted exposure limit value in one institution (14.2%).

Table 2. Distribution of the duration and amount of formaldehyde exposure of healthcare workers

Variable	Median	Lowest	Highest
Total formaldehyde exposure time (years x hours)	10.5	0.1	203.5
Formaldehyde badge measurement result (ppm)	0.030	0.004	4.400
Formaldehyde exposure index (years x hours x ppm)	0.287	0.001	140.800

It was determined that formaldehyde measurement result was lower in laboratories with local and general ventilation systems and in public hospitals ($p<0.05$) (Table 3).

Table 3. Formaldehyde measurement result and evaluation of associated factors

Variables	n	Median	Distribution Range	Test Value	p
Local ventilation system					
There is	67	0.030	0.004-4.400	723.5	0.016*
No	31	0.035	0.004-1.600		
General ventilation system					
There is	72	0.030	0.004-4.400	672.5	0.034*
No	26	0.036	0.004-0.150		
Institution					
Public	87	0.030	0.004-4.400	175.5	0.001*
Special	11	0.110	0.020-0.150		

*Mann Whitney U Test

The mean number of physical symptoms due to formaldehyde use was 7.8±5.9 (minimum= 0.0, maximum= 24.0) and 89.8% of the healthcare workers had at least one symptom. The most common physical symptoms experienced by healthcare workers due to formaldehyde use were unpleasant odor (75.3%), headache (61.3%), watery eyes (58.1%), nasal irritation (44.1%) and itching (43.0%) (Table 4).

The mean formaldehyde exposure index of the participants who reported at least one symptom (513.83 ± 381.16) was significantly higher than those who did not report symptoms (15.35 ± 11.05) ($p=0.001$).

Table 4. Physical symptoms due to formaldehyde use

Variables	Yes		No.	
	n	%	n	%
Disturbing odor	70	75.3	23	24.7
Headache	57	61.3	36	38.7
Watery eyes	54	58.1	39	41.9
Nasal irritation	41	44.1	52	55.9
Itching in the eye	40	43.0	53	57.0
Eye irritation	35	37.6	58	62.4
Runny nose	34	36.6	59	63.4
Cough	34	36.6	59	63.4
Sore throat	32	34.4	61	65.6
Irritation in the throat	32	34.4	61	65.6
Cracking in the hands	32	34.4	61	65.6
Difficulty breathing	32	34.4	61	65.6
Pain in the eye	29	31.2	64	68.8
Blurred vision	28	30.1	65	69.9
Nasal congestion	28	30.1	65	69.9
Itching in the hands	27	29.0	66	71.0
Dizziness	23	24.7	70	75.3
Skin irritation	23	24.7	70	75.3
Pain in the nose	21	22.6	72	77.4
Skin rash	17	18.3	76	81.7
Nausea	14	15.1	79	84.9
Allergic skin reaction	14	15.1	79	84.9
Wheezing	8	8.6	85	91.4
Chest pain	5	5.4	88	94.6

This study demonstrated that pathology laboratory workers exposed to formaldehyde reported a wide range of physical symptoms, with prevalence approaching 90%. The most common complaints included unpleasant odor, headache, watery eyes, and nasal irritation, consistent with irritant effects even at low concentrations. Our finding that the Formaldehyde Exposure Index (FAI) was significantly higher among symptomatic workers underlines the exposure–response relationship.

Consistent with earlier work (Safari et al., 2013; Marongiu et al., 2016), our results highlight the critical importance of engineering controls such as local and general ventilation systems. In our study, the presence of both types of ventilation systems was significantly associated with reduced formaldehyde concentrations. This supports current occupational hygiene recommendations, which prioritize engineering controls over administrative measures or personal protective equipment alone (World Health Organization [WHO], 2022).

Recent global reviews have reinforced these conclusions. For example, WHO (2022) has emphasized that controlling indoor air concentrations of formaldehyde is a key strategy to prevent mucosal irritation and potential carcinogenic effects. In a 2023 study of hospital laboratory settings in Europe, Pérez-López et al. (2023) reported that multi-level interventions combining ventilation upgrades, workflow redesign, and worker training reduced formaldehyde exposures by over 60%.

Importantly, formaldehyde remains classified by the International Agency for Research on Cancer (IARC) as a Group 1 human carcinogen (IARC, 2012; IARC, 2024). While most measurements in our study were below Turkey's 8-hour TWA limit (0.75 ppm), we identified outliers exceeding 1.6 ppm and even 4.4 ppm in individual samples. These peak exposures may contribute disproportionately to symptom burden (Occupational Safety and Health Administration [OSHA], 2023). Therefore, periodic monitoring remains essential, especially in settings with variable workloads or inadequate engineering controls.

Furthermore, recent studies have expanded concerns beyond irritant and cancer risks to include neurotoxicity. For example, Letellier et al. (2022) reported cognitive impairment associated with cumulative occupational formaldehyde exposure in a longitudinal cohort. Similarly, Xu et al. (2023) found evidence of formaldehyde-induced oxidative stress and neuroinflammation in experimental models at concentrations relevant to occupational exposure, underscoring the need for long-term preventive strategies.

Sectoral differences also emerged in our study, with higher exposure levels observed in private laboratories. This disparity may reflect differences in regulatory enforcement, resources, and safety culture. Similar inequalities have been noted in other middle-income contexts (Zhang et al., 2022), highlighting the importance of equitable enforcement of occupational health standards.

Overall, our findings support a multi-faceted approach to exposure reduction. This includes regular environmental monitoring, engineering controls (ventilation, enclosure), administrative measures (work rotation, task allocation), personal protective equipment use, and worker education (European Agency for Safety and Health at Work [EU-OSHA], 2023). Recent guidance suggests integrating these elements into comprehensive workplace safety plans tailored to local conditions (International Labour Organization [ILO], 2023).

CONCLUSIONS

This study systematically investigated formaldehyde exposure levels and the associated physical symptom profiles among healthcare personnel in pathology laboratories in Mersin Province. While most measured values were below legal

limits, some samples exceeded these limits, and widespread irritative symptoms were reported.

These findings highlight the critical role of engineering controls—particularly local and general ventilation systems—in reducing exposure. Future multicenter and longitudinal studies are recommended to provide a more comprehensive understanding of the long-term health effects of formaldehyde exposure.

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