Original Article

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TANAFFOS

Evaluation of Occupational Exposure of Shoe Makers to Benzene and Toluene Compounds in Shoe Manufacturing Workshops in East Tehran

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Background: Shoe making is among the oldest traditional occupations. Hazardous chemical substances such as adhesives containing benzene and toluene are used in the manufacturing process. Due to the lack of studies on exposure of shoemakers to benzene and toluene in Iran, this study was organized aiming at evaluating occupational exposure and risk assessment in shoemakers.

Materials and Methods: Overall, 48 shoemakers (12 workshops) in East Tehran were selected randomly for this study. Personal exposure of shoemakers in four different task groups of cutting, modeling, fitting and finishing was examined during three consecutive months (October, November and December) with different climatic conditions. Sampling and analysis of samples were based on an OSHA method (Method No.12).

Results: The results of personal monitoring of subjects' exposure to benzene and toluene in each of the three consecutive months (Mean ± standard error) were 1.10± 0.11, 1.37 ± 0.14 and 1.52 ± 0.18ppm , 11.78 ± 1.77, 14.87 ± 1.71 and 16.08 ± 2.31ppm respectively. Due to climatic temperature changes from October to December and restriction of air flow due to closure of windows and shut down of general ventilation systems, a general trend of increased exposure was noticed. However, the difference among these three examinations was not statistically significant. Shoemakers in four task groups did not have statistically significant differences in exposure to benzene and toluene. The severity of shoemaker's exposure to toluene was significantly correlated with the number of manufactured shoes and the amount of glue used for the process.

Conclusion: Considering the magnitude of personal exposure of task groups to benzene and toluene which was higher than TLV-TWA and unacceptably high risk of cancer and non-cancerous diseases in these subjects, improvement of work conditions for shoemakers seems imperative.

Key words: Benzene, Toluene, Personal Monitoring, Risk assessment, Shoemakers

INTRODUCTION

Shoe manufacturing is one of the oldest occupations and mass production of shoes was not started until late 19th century. Although the shoe production processes changed in the 20th century, working conditions and related health problems have yet to be controlled, especially in developing countries (1, 2). The raw material used in the manufacturing processes such as adhesives and

paints contain organic solvents. Solvents mainly consist of benzene, xylene, ethyl benzene, toluene and n-hexane. Due to their volatility, the main routes of exposure are through inhalation and skin absorption. Oral intake has also been reported in some cases (3, 4). Solvents in benzene are reported to cause various respiratory diseases, neurotoxicity and cancer (5). Benzene is classified as a group 1 carcinogen (6-8). Epidemiological studies have reported excess mortality due to leukemia in shoemakers exposed to benzene (9-11). Chinese shoemakers were reported to have high levels of exposures to benzene, toluene and other toxic solvents. There are a number of workers at risk for aplastic anemia, leukemia and other health problems (12).

In Chinese shoemakers, the prevalence of aplastic anemia was 12.1/100,000 compared to the prevalence rate in general population of Mudanjiang (in north east of China) which was 2.1/100000 (13). Also, incidence of leukemia was 13 per 100,000 in shoemakers in Turkish which is greater than the rate in general population which was 6/100,000 (14). Standardized mortality ratios (SMR) for all hematolymphopoietic malignancies and leukemia were estimated for Italian shoemakers to be 1.4, 3.7, 3 and 7 for benzene cumulative exposure of <40, 40–99, 100–199, and >200 ppm-years, respectively (11).

One of the newest approaches of toxicology is risk assessment, whereby scientific information on the hazardous properties of toxic agents and the extent of exposure results in a statement as to the probability that exposed populations will be effected. This process is a scientific attempt to identify and estimate the true risks (15, 16). Carcinogenic risk assessments justify preventive provisions (17). This cross-sectional study aimed at monitoring Iranian shoemakers' exposure to benzene and toluene.

MATERIALS AND METHODS

In this study, 12 workshops were selected randomly among the shoemaking workshops of East Tehran. The production processes were semi-automated and manual requiring a skilled labor force. Shops were not equipped with local exhaust ventilation and no personal protective equipment (PPE) was used. In all workshops, shoemaking consisted of four different tasks including: cutting, modeling, fitting and finishing operations. Monitoring of 48 workers in 12 different shops was carried in three consecutive months (October, November and December) with different atmospheric conditions. Number of subjects in each task was 12. Ambient temperature in the first monitoring was similar to summer season. The second monitoring ambient temperature was much cooler and the third one was conducted in cold winter climate. It must be mentioned that air conditioning systems were used in the first trial of monitoring, but, in the second and third trials no cooling or heating devices were used and all doors and windows were closed. Information about age, work experience, education, working hours, production of shoes and consumption of adhesives, were obtained from all subjects using a questionnaire.

Personal Monitoring: Sampling and analysis of samples were done according to the optimized OSHA method No.12 (18). Gas Chromatograph (GC-17A, SHIMADZU) equipped with flame ionization detector was employed for experimental analysis in this study. A capillary column from Agilent Technologies 30 m x 0.32mm ID-HP-1, 0.25 was used .Column temperature was initially programmed at 45°C for 4 minutes and temperature was increased at the rate of 30°C/min to 105 °C for 2 minutes. Chromatographic retention times of benzene and toluene were validated by GC-Mass analysis equipped with column and GC parameters.

Risk assessment: Incidence of leukemia in terms of odds ratio (OR) for all individuals exposed to benzene was determined according to Rinsky's model (19).

$$OR=\exp(0.0126\times ppm\text{-}years)$$

Also, risk assessment of cancer incidence per reference population due to benzene exposure and 30 years of work history of all subjects were computed according to Yimrungruang formula (20).

$$I= (C\times ET\times EF\times ED) / AT$$

where I is the inhalation intake (µg / m^3), C is the concentration of the compound in the personal air sample (µg / m3), ET is the exposure time (hr / day), EF is the exposure frequency (days / year), ED is the exposure duration (years), and AT is an average lifetime (years).

ACGIH additive effect of Benzene and Toluene exposure for non-carcinogenic effect is calculated by the following formula:

$C_1 / T_1 + C_2 / T_2 = N$

Where C_1 indicates the observed atmospheric concentration and T_1 is the corresponding threshold limit and N should be less than one (21).

Statistical analysis: Mean and standard error values were determined for all exposures and the results were expressed as Mean ± SE. Repeated measures linear model was used for difference in exposure levels between the three tests and four tasks. Also, Pearson test was used for determination of the correlation of data. All statistical calculations were performed using SPSS version 18.0 software.

RESULTS

Age and work experience of shoemakers (mean ± SD) were 37±14.5 and 18±14.9 years respectively. Information about workshops in terms of their production level and consumption of glue are reported in Table 1. OSHA method NO.12 was optimized in the laboratory and this method was validated in this study by determining the coefficient of variation of intra-day and inter-day and recovery measurements of benzene and toluene which are shown in Table 2. The results of personal monitoring of subjects for benzene and toluene exposure in each of the three consecutive months (mean ± standard error) were measured and a trend of exposure increase was noticed; however, the difference between any two periods of monitoring was not statistically significant ($p>0.05$) (Table 3). Occupational exposure of four different task operational groups of cutting, modeling, fitting and finishing to benzene and toluene was not significantly different ($p>0.05$) (Figures 1 and 2).

Table 1. Information about workshops

Workshop	1	2	3	4	5	6	7	8	9	10	11	12
Area (m^2)	20	19	18	26	12	18	24	24	10	13	18	24
Shoe production (number/month)	1296	540	675	2160	540	675	2700	1890	810	1296	2160	1944
Glue use (kg/month)	128	120	168	320	80	132	500	320	128	140	340	212

Table 2. Precision and accuracy of the improved method No.12 for benzene and toluene analysis

compound	Conc. µg/ml	Intra-day Variation %CV	Inter-day Variation %CV	Accuracy (Recovery)
Benzene	25	7.13	8.26	100±6
Benzene	150	3.10	1.03	100±5
Benzene	300	1.12	1.85	100±3
Toluene	25	3.8	5.2	100±5
Toluene	150	1.06	2.8	100±4
Toluene	300	0.95	1.5	100±3

Table 3. Occupational exposure of 48 shoemakers (mean ± standard error) as ppm

Time period of monitoring	Benzene	Toluene
October	1.10± 0.11	11.78 ± 1.77
November	1.37 ± 0.14	14.87 ± 1.71
December	1.52 ± 0.18	16.08 ± 2.31

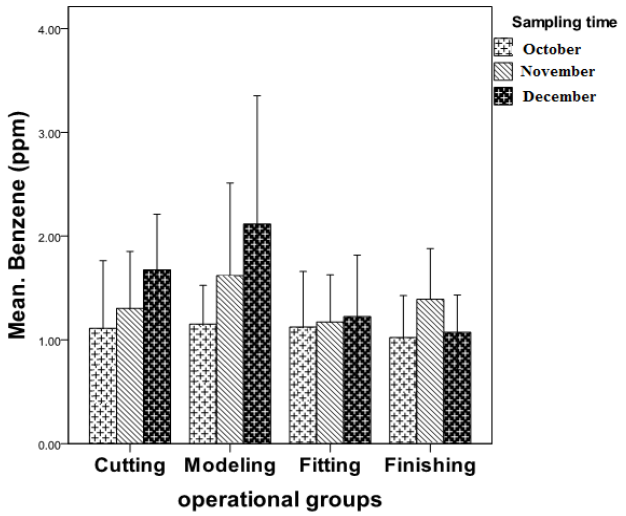

Figure 1. Occupational exposures of operational groups to Benzene in the three months

Percentage of correlation of different occupational groups' exposure to Benzene with TLV was determined and, a general trend of increased exposure to the two compounds was observed in the three months (Table 4).

Odds ratio of cancer incidence due to benzene exposure was calculated for all subjects and additive effect of Benzene and Toluene was also determined for shoemakers (table5).

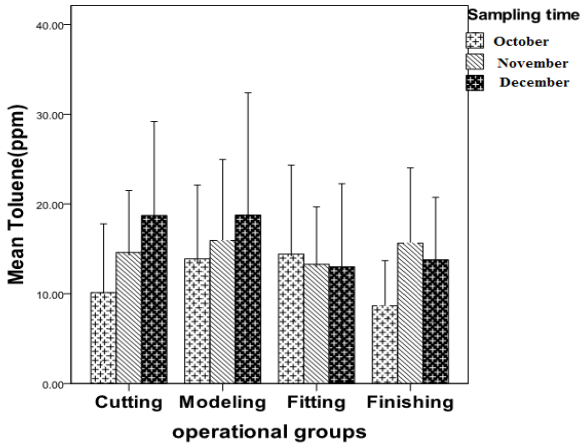

Figure 2. Occupational exposure of operational groups to Toluene in the three months

Table 4. Percentage of occupational group exposures (n=12) higher than TLV *

Occupational Group	Benzene TLV=0.5ppm			Toluene TLV=20ppm		
	October	November	December	October	November	December
Cutting	83.3%	100%	100%	16.7%	50%	50%
Modeling	100%	91.7%	100%	41.7%	50%	50%
Fitting	100%	100%	91.7%	33.3%	41.7%	33.3%
Finishing	83.3%	100%	100%	16.7%	50%	41.7%

* Threshold limit value (TLV) based on the ACGIH criteria for chemical substances

Table 5. Risk assessment for benzene exposure and additive effect of mixed exposure to toluene for non-cancerous diseases

Operational group \ Model risk assessment	Cancer effect (benzene)		ACGIH additive effect of Benzene and Toluene
	Rinsky *	Yimrungruang ** (per thousand)	
Cutting	1.8	17	4.31
Modeling	2.3	21	5.11
Fitting	1.6	15	3.74
Finishing	1.6	15	3.68

* Odds ratio

** Number of patients per thousand reference population

Application of Pearson statistical test revealed a significant positive correlation between the amount of glue used and the level of exposure to toluene (r=0.75,p=0.005). Also, a significant positive correlation was found between the production level and level of exposure to toluene (r=0.79,p=0.002). The Pearson test showed a significant positive correlation between exposure to toluene and benzene (p<0.001)

DISCUSSION

Benzene and Toluene were sampled in three consecutive months from early autumn to early winter. Due to climatic temperature changes from October to December and restriction of air flow due to closure of windows and shut down of general ventilation systems, a general trend of exposure increase was noticed. In the Vermeulen study similar results were observed in Chinese shoemakers that had similar working conditions to the present study (22).

The results of individual monitoring of shoemakers in three different monitoring sessions in this study indicated that almost all exposures to benzene were higher than TLV set by ACGIH. Similar results even with higher magnitude of exposures were reported by Chinese and Turkish authors for shoemakers (14, 23). Similarities of Iranian shoemakers with their peers abroad were: workers sitting in close proximity of each other and handling shoemaking processes semi-automatically without local exhaust ventilation.

Twenty seven percent of occupational groups in the first month, 48% in the second month and 44% in the third month had higher exposure to toluene than TLV set by ACGIH (20 ppm). Chinese and Mexican shoemakers also had similar exposures to toluene as in our study (22, 24). It is apparent that exposure to toluene and benzene could be a risk factor for all shoemakers.

In the present study, exposures of shoemakers in direct contact with adhesives (fitting, modeling and finishing phases) were compared with exposure rate of subjects who had indirect contact with these substances (cutting), and significantly higher exposure rates to benzene were detected in the former group; however, this finding was not seen for toluene. This phenomenon might be due to the higher volatility of benzene compared with toluene. It should be noted that all shoemakers were working in small workshops with an area of 10 to 26 square meters. No partitions were used to separate different working groups from each other and the workers worked in stations in close proximity of each other. Generally, Chinese workshops had similar conditions to the present study with almost the same results (22).

In the present study, there was a significant positive correlation between exposure to toluene and benzene .This result was also observed in Chinese shoemakers (22), but in a study by Gonzalez it was reported that exposure to benzene was very low close to the detection limit and only toluene exposure was higher than the standard limit (24). However, significant concentration of benzene even in solvent free benzene was reported by Jafari et al, (25).

Based on epidemiological studies regarding various rates of cancer prevalence among Italian, Chinese and Turkish shoemakers, they showed higher rates than general population. In this study, due to the lack of epidemiological studies in Iran, risk assessment of cancer incidence of shoemakers was conducted according to Rinsky (19) and Yimrungruang models (20). Odds ratio of leukemia incidence for Iranian shoemakers (cutting, modeling, fitting and finishing) according to Rinsky's model was 1.8, 2.3 and 1.6, 1.6, respectively which were higher than the general population. Cancer incidence of Iranian shoemakers (cutting, modeling, fitting and finishing) according to Yimrungruang model for cumulative exposure to benzene and 30 years of shoe manufacturing work was 17, 21, 15 and 15 per one thousand, respectively which were higher than the acceptable risk set by OSHA (26).

The present study was a cross sectional experimental study for determination of actual exposure to benzene and toluene and their respective risk assessments which is recommended by some epidemiological studies (9, 17). In

this study exposure monitoring was done according to OSHA's improved method which was validated in our laboratory and chromatographic peaks for benzene and toluene were confirmed by GC-Mass. It must be mentioned that the majority of exposure assessments of shoemakers to benzene in other countries were conducted by simple direct reading method (14), which may not be as accurate as our method. Generally, Iranian shoemakers had lower exposures to benzene than their foreign counterparts (14, 22), which might be due to accuracy of the method applied in this study. Considering the fact that Iranian shoemakers had exposure levels higher than TLV-TWA and also the unacceptable levels of risk for cancer and non-cancerous diseases, control measures such as management control and engineering control measures are imperative for shoemakers.

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