Neurological Disorders In Shoe-Makers And The Role Of Some Trace Elements

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Abstract: Workers in shoemaking industry are exposed to various risk factors which can result in many health hazards. They include CNS affection, other system abnormalities and biochemical derangements. The aim of this study is to investigate the possible neurological disorders among shoe makers, determinate the levels of Cu, Zn and Se in the workers, and correlate the environmental concentrations of respirable dust, heavy metals, and organic solvents contents in the workplaces with the detected neurological disorders. The study included 62 shoe makers and 72 control subjects who were matched for age, sex and socioeconomic status. Questionnaire and clinical neurological examination were done for all subjects. Serum trace elements (Cu, Se and Zn) were determined. Air samples were collected for environmental monitoring of volatile organic compounds (VOCs), respirable dust and its heavy metal content such as (Cu, Pb, Cr and Ni). Results showed that VOCs level in the ambient air of the workplaces were found to be lower than the OSHA standard. Respirable dust and heavy metal concentrations were found to be significantly lower than the Egyptian standard. The results of neurological examination revealed that 61% of the shoe makers had neurological disorders, while all the control subjects were normal. Nearly half the shoe makers with neurological abnormality had combined cranial and spinal neurological disorders (47.4%). Olfactory and auditory nerves recorded the highest frequency of affection. Among motor abnormalities, sensory abnormalities and disturbances in micturation reported in workers, muscular weakness had the highest frequency of occurrence. Duration of exposure in shoe makers with combined cranial and spinal abnormalities, and spinal alone were significantly longer than that in normal shoe makers and those with cranial problems while there was no significant effect of the age on the incidence of neurological abnormalities. On comparing levels of the trace elements between the shoe makers and controls, Se was significantly lower in the shoe makers, while levels of Cu and Zn levels were not significantly different between the two groups. No significant difference in levels of Cu, Se, and Zn between neurologically normal and abnormal shoe makers. In conclusion, Occupational exposure to organic solvents and other chemicals in shoemaking industry was found to have hazardous effects on nervous system both cranial and spinal. The protective role of trace elements has been suggested. Levels of Se were decreased in shoe workers, while, the exact role of Zn and Cu are not clarified in the development of neurological abnormalities and needs further study.

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Introduction

Shoemaking is one of the oldest professional industries. Various risk factors contribute to occurrence of health hazards in shoemakers. These include leather dust, noise, vibration, stress, ergonomic problems beside exposure to solvents, metals and other chemicals (Elci et al. 2007).

Although many processes are now completely automated, hand manufacture is still present in small scale industrial workshops (Hassan et al. 2001). Among the raw materials used in the manufacturing process and the most occupational hazardous materials are adhesives and dyes. These include natural solid and liquid adhesives and adhesive solutions based on organic solvents (Parmeggiani 1989). Polyurethane is one of the most commonly used adhesives in the studied workshops in the present work.

Synthetic adhesives used in shoemaking industry composed mainly of synthetic polymers (e.g. styrene, chloroprene, acrylonitrile) dissolved in a special mixture of organic solvents. These solvents are mainly n-hexan, benzene, xylene, ethylbenzene and toluene. Other constituents such as resins, catalysts, monomers, magnesium and zinc may be present as adhesives constituents (Hassan et al. 2001). Due to volatility of these organic solvents, inhalation is considered the main route of exposure, besides there is dermal absorption and may be ingestion. When solvents are used in mixture, the effects may be additive, synergetic or potential.

Adverse health effects which can occur in shoe workers include short term effects such as irritation of the eyes, nose and throat, headaches, dizziness, confusion, fatigue and nausea. Dermatitis and sensitization reactions can also occur in workers exposed to adhesives containing epoxyresins (wikipedia, 2009). The longer term effects include reproductive problems (ROM, 2007), neurological and psychological disorders (Elci et al., 2007). Hematological changes, lung, liver and kidney damage and increased risk of malignancy are also considered as long term hazardous problems in workers exposed to adhesives (Hassan et al., 2001).

The incidence of neurological disorders in shoe makers can be attributed to various factors including occupational exposures to organic solvents, metals and other chemicals. They include derangement of levels of neurotransmitters, enzymes, essential and trace elements inside the body (Alpay et al., 2004)

Copper, zinc and selenium and other trace elements are required in the formation of vital molecules and normal functions of many enzymes inside various body cells. Also they are essential for integrity and optimum function of the immune system. Cu is necessary for the manufacture of the neurotransmitter noradrenaline. Deficiency of Copper leads to anemia, liability to infections, osteoporosis, thyroid gland dysfunction, heart disease as well as nervous system problems (Clinical Neurophysiology, 2006).

Patients with amyotrophic lateral sclerosis are proved to have an essential trace element imbalance in the form of decrease CSF and serum Cu levels, increased serum manganese levels, while serum zinc and magnesium levels were unchanged (Kapaki, 1997). Moreover, Zn and Se are considered as essential antioxidant trace elements that have protective effects against the damaging effects of organic solvents in shoe makers (Hussein et al., 2008).

Therefore, a link between changes in serum levels of trace elements with neurological disorders caused in shoe makers is the hypothesis of this study. This relationship may be causal or an end result.

Usually, environmental monitoring of levels of pollutants in workplaces has been conducted in several studies to correlate between health risks and levels of these pollutants. Saad et al. (2008) found that levels of BTEX were measured in car spray painters' workshops to associate their levels with the neuropsychatric disorders among these workers. In another study, Sanni et al. (2002) correlated the levels of workplace organic solvents, airborne particles, SVOCs and noise in shoe repair shops with the self reported health effects such as musculoskeletal disorders, hearing loss, neurological disorders and allergic symptoms.

Therefore, the current study aims to investigate the possible neurological disorders among shoe makers, determinate the levels of Cu, Zn and Se in the workers, and correlate the environmental concentrations of respirable dust, heavy metals, and organic solvents contents in the workplaces with the detected neurological disorders.

Subjects and methods

Study Design:

This study is a cross sectional comparative study between shoe makers and control subjects.

The principal steps of shoemaking are:

a- Making the uppers from natural leather or other materials. Leathers are prepared, arranged and cut according to prepared designs.

b- The leather parts are then sewn or glued together.

c- For making the bottom stock (soles or heels), leather is cutout, and then heels are made by compression of leather or wood strips. The stock is trimmed, shaped, scoured and stamped.

d- The uppers and bottom stock are assembled and then stitched or glued together.

e- Finally the shoe waxed, colored, sprayed, polished and packed.

Environmental Monitoring:

Air samples were collected for analysis of respirable particulate matter, heavy metal and organic solvents.

Determination of respirable particulate matter was done by using a vacuum pump with a rate of 2 liters/minute. Membrane filter paper was used for the collection of respirable particulates. On sampling, the membrane filter was weighted in the laboratory and then transported carefully to the field. It was mounted on open filter holder.

The air was a spirited on the weighted filter, and the reading of the gasmeter was recorded before and after sampling period. The membrane filter was reweighted after the sampling time (8 hours) and the difference in weight before and after sampling was recorded as the weight of respirable particulate matter. The volume of air was calculated from the gasmeter readings. The concentration of respirable particulates was calculated and expressed in µg/m3.

Determination of heavy metals in respirable particulates, by using Atomic Absorption Spectroscopy (Jackson, 1973, Yasser, 2000).

Air samples were collected for volatile organic compounds (VOCs) (Activated Charcoal Tube Adsorption Method, ASTM Annual Book of ASTM Standards, Vol 11.03) aspirating air at a known rate through sampling tubes (Supelco ORBO 32 large) containing activated charcoal.

Subjects:

The present study included 62 shoe makers from six small scale workshops. The mean working daily hours ranged from 8 -10 hours. All steps of shoemaking were done at the same workplace in all the included workshops. A comparable group of 72 control subjects were also recruited in the study. They were matched for age, sex and socioeconomic status with the examined shoe makers. Non of the participants had a history of alcohol intake, nor a history of previous neurological problem.

Ethical approval was obtained from the National Research Center ethical committee prior to the clinical part of the study, and written consents were obtained from all examined subjects. Inclusion in the study was on volunteer bases.

Questionnaire and clinical examination:

All members of the study were interviewed and a full personal, occupational and medical histories were taken. A detailed neurological history and examination were carried out also for both the workers and their controls.

Laboratory:

A blood sample (5 ml) was obtained from all the examined subjects. The blood samples were centrifuged to separate sera which were kept at -20°C until analyzed. Serum trace elements (Cu, Se and Zn) were determined according to AOAC (1995), using Atomic Absorption Spectrophotometer (SOLAAR-UNICAM 989).

Statistical analysis:

The results were computerized. Statistical analysis was done through SPSS version 14.0. One sample t-test, Independent t-test, Pearson's Chi-square (χ^2), Likelihood Ratio, and Analysis of Variance (ANOVA) and the least significant difference (LSD) as a post-hoc test were used in the analysis of the results. P-value ≤ 0.05 was considered significant.

Results

Table (1) revealed that environmental monitoring of total workshops' respirable particulate matter concentration was found to be significantly lower than the Egyptian standard set for indoor workplace environments. Again, heavy metals inside workplaces revealed that the concentration of copper (Cu), lead (Pb) chromium (Cr), and nickel (Ni) were significantly lower compared to the Egyptian standards. The total VOCs was in the range 0.074-0.082 mg/m^3 (0.078±0.01 mg/m^3).

Table (1) Indoor Environmental Concentrations

	Mean	Egyptian standard	One sample t-test	P-value
Respirable particulates (µg/m^3)	1930±28.28	3000	53.5	P< 0.01
Heavy Metals				
Cu (µg/m^3)	10.5±2.08	1000	950.7	P< 0.0001
Cr (µg/m^3)	17.75±3.09	500	311.6	P< 0.0001
Pb (µg/m^3)	20.75±4.65	50	12.59	P= 0.001
Ni (ug/m3)	9±1.83	1500	1633.3	P< 0.0001
Volatile Organic Compounds (VOCs)				
Total VOCs (mg/m^3)	0.078±0.01			

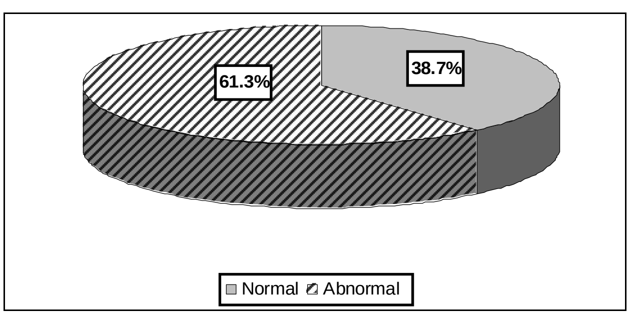
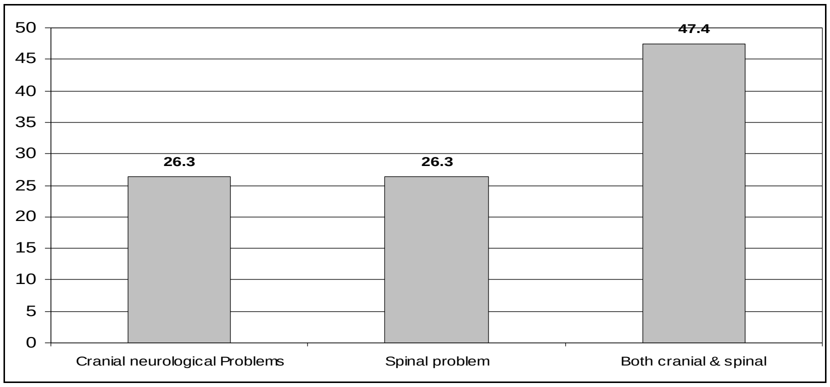


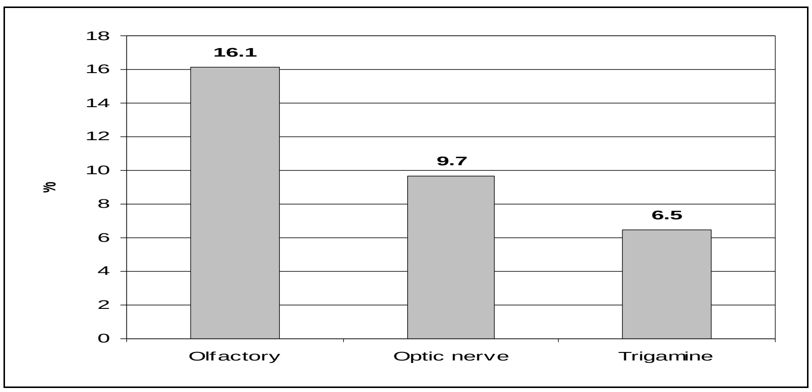
Figure 1. The percent of neurological health problems in the workers

The included subjects were all males. There was no significant difference between the shoe makers and their controls according to their age (35.4±12.0 and 37.8±9.23 years respectively) and according to their smoking index (8.83±3.02 and 3.58±1.39 package/year respectively). The duration of exposure of all the examine shoe makers were above 10 years (mean = 20.8±14.7 years).

Neurological examination revealed that 61% of the shoe makers had neurological disorders (Figure 1). While, all the control subjects were normal.

Figure (2) shows that nearly half the shoe makers with neurological abnormality had combined cranial and spinal neurological disorders (47.4%). The details of neurological abnormalities were illustrated in Figures 3, 4, and 5.





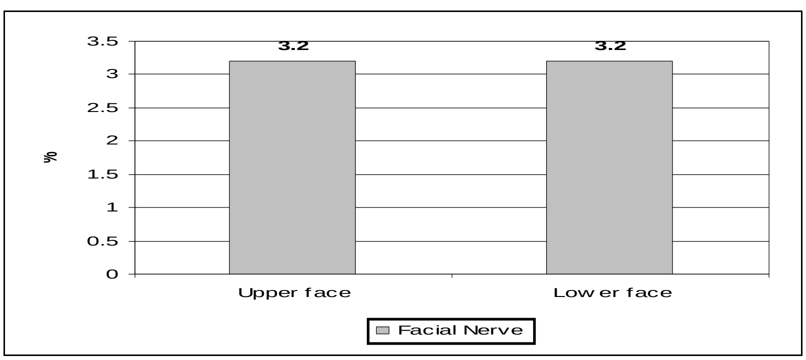


Figure 2. Percent of shoe makers according to the neurological examination

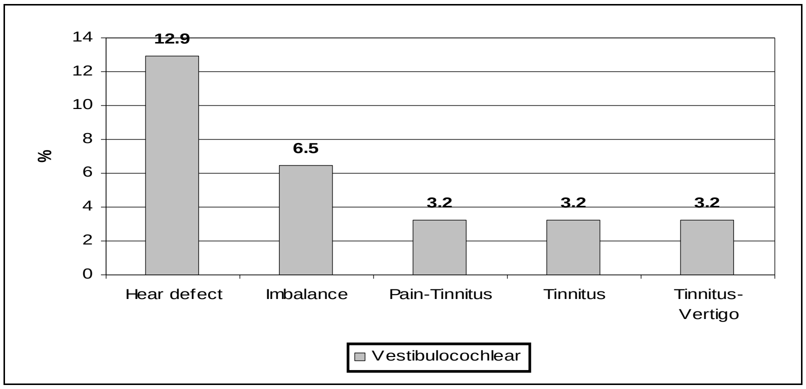


Figure (3) Percent of shoe makers with abnormalities in the cranial nerves

Figure 4. Percent of shoe makers with abnormal movement

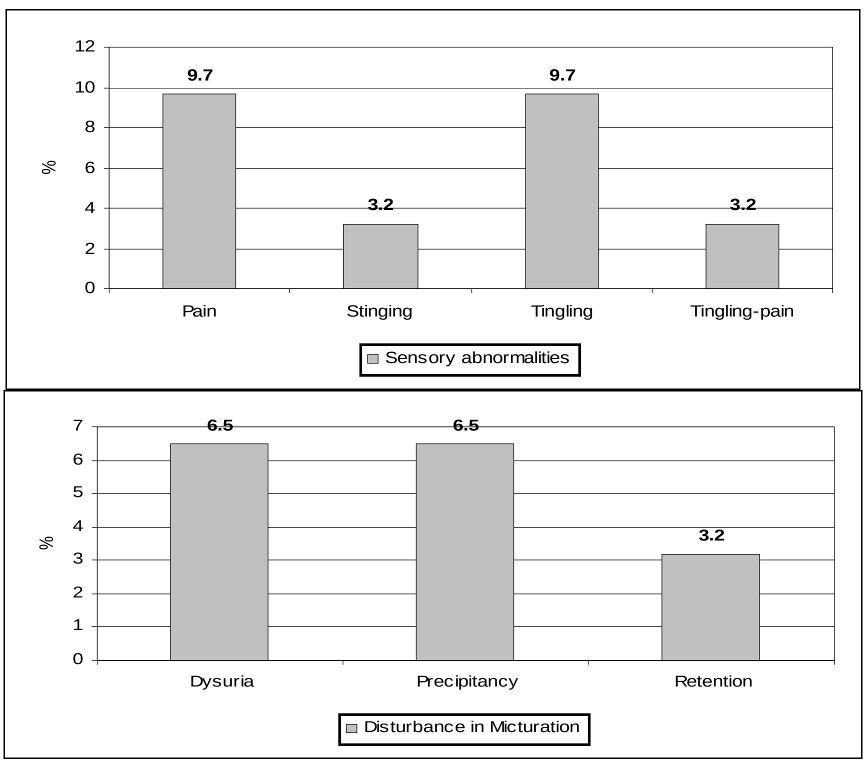


Figure 5. Percent of shoe makers with sensory abnormalities and disturbance in micturation

There were no significant effects of the age on the occurrence of neurological abnormalities among the examined shoe makers. Duration of exposure in shoe makers with neurological abnormalities both combined cranial and spinal and spinal alone were significantly longer than that in normal shoe makers and those with cranial problems (Table 2).

Table (2): Role of age, SI and duration of exposure on the neurological health problems in the workers

	Age		Duration of exposure	
	Mean	SD	Mean	SD
Normal (24)	31.8	13.40	17.1	15.24
Cranial problem (10)	33.6	8.40	15.8	10.01
Spinal problem (10)	42.4	9.18	31.8	11.02
Both cranial & spinal (18)	37.1	11.50	22.3	15.01
ANOVA	1.019		10.715*	
P-value	NS		P< 0.01	

*Kruskal Wallis Test

On comparing the levels of the trace elements between the shoe makers and their controls, Se was significantly lower in the shoe makers than in the control subjects, while levels of Cu and Zn levels were not significantly different between the two groups (Table 3).

Table (3) Comparison between the levels of Cu, Se, and Zn in the shoe makers and their controls

	Workers (62)		Controls (72)		Independent t-test	
	Mean	SD	Mean	SD	t-test	P-value
Cu (ppm)	4.19	0.69	2.88	0.15	0.559	NS
Se (ppm)	0.038	0.003	0.403	0.26	4.991	P< 0.0005
Zn (ppm)	0.130	0.01	0.147	0.08	0.201	NS

Table (4) showed that there was no significant difference between the levels of Cu, Se, and Zn in the shoe makers with normal and abnormal neurological signs and symptoms detected through examination.

Table (4) Comparisons between the levels of Cu, Se, and Zn in the shoe makers with normal and abnormal neurological signs

	Cu (ppm)		Se (ppm)		Zn (ppm)	
	Mean	SD	Mean	SD	Mean	SD
Normal (24)	3.24	0.12	0.04	0.01	0.11	0.04
Cranial problem (10)	3.2	0.16	0.02	0.01	0.17	0.05
Spinal problem (10)	3.24	0.15	0.04	0.02	0.08	0.02
Both cranial & spinal problems (18)	6.59	2.37	0.04	0.02	0.08	0.02
ANOVA	43.032		1.948		0.653	
P-value	NS		NS		NS	

Discussion

Employees in shoe manufacture are routinely exposed to a mixture of organic solvents used in cleaning and as diluents in glues, primers, and degreasers (Emara et al., 1996). Metals such as chromium can be present in the work environment from the tanned leather used in shoe manufacture. (Saad and Beshir, 2007; Saad et al., 2008). Lead, copper and nickel from dyes and varnishes used in painting and polishing of the shoes (Rom, 2007).

Exposure to organic solvents and other chemicals in shoe factories has been reported to increase the risks for acute and chronic health problems in shoe-makers (Alpay, 2004). Environmental monitoring of indoor workplace pollutants is routinely carried out in many studies in order to correlate levels of pollutants with health effects. Levels of many types of pollutants are measured in shoemaking and shoe repair workshops in previous studies.

In the current study, the concentrations of total VOCs and metals (Cu, Pb, Ni and Cr) as well as respirable particulate matter concentrations were measured in air of the selected workshops. Environmental concentration of total VOCs seemed to be not so high in the air of the selected shoemaking workshops, but there is no Egyptian Standard to compare with. According to US Occupational Safety and Health Administration (OSHA, 2004), the concentration of VOCs in the selected workshops (0.078±0.01) was within the safe limits, as OSHA has set 3.19 mg/m^3 as workplace time weighted average regulation limit for a normal 8-h work day.

According to law 4 for 1994 of Egyptian standards, that modified in the year 2005 it has set a maximum limit of 50 $\mu g/m^3$ for Pb, 1000 $\mu g/m^3$ for Cu. In case of chromium, it is 500 $\mu g/m^3$ for Cr metal and trivalent Cr compounds, and 50 $\mu g/m^3$ for hexavalent compounds. Lastly it is 1500 $\mu g/m^3$ for Ni. OSHA has set a permissible exposure limits (PEL) of 50 $\mu g/m^3$ averaged over 8 hours for Pb. For Cu copper dust and mists 1000 $\mu g/m^3$, and 1000 μg cr/m^3 for chromium metal and insoluble compounds. Divalent and trivalent chromium compounds has PEL 500 $\mu g/m^3$, while it is reduced to 5 micrograms for carcinogenic hexavalent Cr compounds. While for Ni, it is 1500 $\mu g/m^3$ for the inhalation fraction of metal. (OSHA2006). American Conference of Governmental Industrial Hygienists (ACGIH) and NIOSH (2005) have set similar values for these metals as TLVs and PELs. So, it is obvious that indoor metal levels measured in the selected workshops in the present study were below the PEL for all of them (ATSDR, 2010)

In agreement with the present study, the study of Sanni et al. (2002), which detected very low concentrations of insoluble and hexavalent Cr in shoe repair workshops in Finland (0.10 – 0.32 $\mu g/m^3$ for insoluble Cr and 0.01 – 0.08 $\mu g/m^3$ for hexavalent Cr). Levels of airborne particles sampled in front of finishing machines ranged from 70 – 1010 $\mu g/m^3$, which is comparable to our results. However, there was high concentrations of a mixture of organic solvent vapors (1.1-13.2) times the occupational exposure limit value.

The present study revealed increased incidence of neurological problems among shoemakers compared to the controls. Both cranial and spinal problems occurred. Affection was more evident in cranial nerves I, VII, VIII, while spinal problems were in the form of muscular weakness, increased sensory abnormalities and micturition disturbances. This was in accordance with many studies which examined neurological or neuropsychatric abnormalities in shoemakers or shoe repair workers. For example, in the study of Elci et al. (2007), they found that muscular leg cramps, imbalance in walking and hand tremors were the most prevalent neurological symptoms among shoemakers in Turkey. Gobba (2006) found in his study occupationally-related olfactory impairment in workers chronically exposed to industrial chemicals such as some metals as cadmium, chromium, manganese, arsenic, mercury, and organic lead, and to other chemicals as acrylates, styrene, and solvent mixtures. This was in agreement with the present study which found that the most affected cranial nerve among our workers was the olfactory nerve (figure 3).

Previously, outbreaks of a disease known as shoemakers paralysis have appeared in a number of footwear factories, presenting with a clinical picture of sever form of flaccid paralysis, localized to the limbs and gives rise to osteotendinous atrophy with areflexia. The condition was explained by functional inhibition or injury of lower motor neurons of the pyramidal tract (Parmeggiani, 1989).

And, in the study of Langauer et al. (1983) on women workers exposed to glue solvents in a shoe factory, Cortical organic changes and subclinical neuropathy were significantly more frequent in workers exposed to high concentrations of extraction naphtha and toluene.

Another group of workers exposed to solvents such as dockyard painters reported significantly higher neurological problems than controls. They were in the form of problems in buttoning and unbuttoning, hands trembling and feeling weak or unsteady in the arms or legs (Chen, 1999).

However, in contrast to these results, Sanni et al. (2002) found in their study that self reported neurological disorders of shoe repair workers in Finland were low (1%) compared to other work related diseases like musculoskeletal disorders, dermatitis, rhinitis and asthma.

The present study revealed no significant effect for age on the incidence of neurological disorders. But, the duration of exposure was significantly increased in the shoe makers with spinal neurological abnormalities compared to the normal workers and those with cranial abnormalities. Similarly, Elci et al. (1) found that the rate of peripheral neuropathy was increased by duration of work, but this was insignificant statistically. Additionally, Hassan et al. (2001) and Emara et al., (1996) proved that the incidence and the severity of neurological and psychiatric symptoms were related to the duration of exposure to neurotoxic solvents in shoemaking and other industries.

The present study revealed no increase in air concentrations of heavy metals (according to the Egyptian standards) in the shoemakers' workshops despite the presence of neurological abnormalities. Some previous studies correlated exposure to chromium, lead, aluminum, manganese and other metals in various industries with neuropsychatric abnormalities in their workers. Examples are the study of Sjogren et al (1990) which was among welders exposed to metal fumes, and the study of Gobba (2006) which detected olfactory dysfunction due to affection of neuroepithelium in workers chronically exposed to industrial metals. So, our suggestion is to revise the present standards, concerning heavy metals, trying to lower their levels to a safer values for CNS functioning.

Analysis of trace elements in the biological fluids became nowadays an important clinical diagnostic test in human diseases (Hussein et al, 2008). Among them are Zn and Se which have an antioxidant effect, that is protective against cellular injury in general and neurological diseases caused by exposure to solvents (Viegas et al., 2000)

In the present study there was no statistically significant difference between the shoe makers and their controls regarding the levels of Cu and Zn. In agreement with the present results, Andrzejak et al. (1992) and El-Gazzar et al. (1997) found no significant variations in levels of Cu and Zn between workers exposed to benzene and toluene and their control subjects. While, Dundaroz et al. (2002) revealed a decrease in plasma levels of Zn due to chronic inhalation of volatile organic solvents.

While, Se of the shoe makers in the current study was significantly lower than the controls. Hussein et al. (2008) attributed the significant decrease in the Se of shoe makers compared to their controls to the exhaustion of the Se as an antioxidant against the oxidative effect of chronic exposure to organic solvents. Contradictory, Georgieva et al. (2002) found that Se was not significantly changed in workers exposed to a mixture of hydrocarbons.

Currently, in the present study, on comparing the levels of Cu, Se and Zn in normal shoe makers with the neurologically affected workers revealed no statistically significant difference between them. Moreover, no difference was found between the groups of workers with cranial, spinal or combined problems.

This findings could be explained the fact that exposure to organic solvents affected the levels of Se in all the exposed workers, but due to individual variation and / or genetic susceptibility, some workers were affected by neurological abnormality while others still are not. Those normal workers may be affected later on with aging or increasing dose and duration of exposure to solvents as both factors have deleterious effects on central nervous system.

Previously, Niels et al. (1981) found that in patients with parkinson's disease and amyotrophic lateral sclerosis the levels of Se were normal. Kapaki et al., 1997 in their study on amyotrophic lateral sclerosis patients, they detected that the serum Zn were unchanged, while, CSF and serum Cu levels were decrease.

Conclusion

Occupational exposure to organic solvents and other chemicals in shoemaking industry was found to have hazardous effects on nervous system both cranial and spinal. The protective role of trace elements has been suggested. Levels of Se were decreased in shoe workers, while, the exact role of Zn and Cu are not clarified in the development of neurological abnormalities and needs further study.

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