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Occupational Lead Exposure: Blood Lead Levels of Apprentices in Bursa, Turkey

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Abstract: The aim of this cross-sectional study was to compare the blood lead levels of apprentices working in lead-related industries with those of non-apprentice controls and to evaluate the influence of such occupational exposure. The study was conducted between October 2004 and June 2005 in Bursa, Turkey. Subjects included 231 apprentices and 252 male controls, age ranging from 14–19 yr old. Inductively coupled plasma mass spectrometry (ICP-MS) was used to analyze blood lead levels. The overall mean blood lead level was 3.62 μg/dl (95% CI 3.39–3.85), the apprentice mean was 4.99 μg/dl (95% CI 4.60–5.38), and the control group mean was 2.37 μg/dl (95% CI 2.22–2.51). The blood lead level of apprentices was significantly higher than that of controls ($p<0.05$). Results show that occupational exposure increases the blood lead levels of apprentices, although the impact on their immediate health is low. Measurement of blood lead levels of apprentices should be taken periodically, and a regular medical surveillance program should be established.

Key words: Lead, Occupational lead exposure, Apprentice, Blood lead level, Turkey

Introduction

Exposure to lead can cause a number of diseases, including mild mental impairment and loss of IQ, increased blood pressure, anemia, and gastrointestinal problems. The exposure variable most often used is the population distribution of blood lead concentration. Blood lead concentrations of ~0.016 μg/dl measured in humans before industrialization indicate that the amount of natural lead in people is minimal[1)]. Estimates published recently suggest that the theoretical minimum risk may occur at blood lead concentrations as low as 0–1 μg/dl[1)]. Recent analyses suggest that health effects may become apparent at concentrations <5 μg/dl[2)], although no evidence exists for a threshold, even at concentrations of 1 μg/dl[3)].

There has been growing concern over the past 25 yr regarding the health effects of low-level lead exposure and the 'normal' body burden of lead. In an occupational context, the 'no effect' level of lead exposure is being scrutinized as increasingly sensitive measures of the physiological effects of lead are devised[4)].

Elevated blood lead levels in adults can damage the cardiovascular, central nervous, reproductive, hematological, and renal systems. The majority of cases are workplace-related[5)]. A wide variety of industrial populations is at risk of occupational exposure to lead. According to estimates made by the National Institute of Occupational Safety and Health, more than three million workers in the United States are potentially exposed to lead in the workplace[6)]. There are no statistical data in Turkey that show the number of workers at risk due to lead exposure.

Occupational exposure to lead occurs via inhalation of lead-containing dust and fumes as well as ingestion from contact with lead-contaminated surfaces. Symptoms of lead poisoning include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors and 'wrist drop'. Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, impotence, infertility, and reduced sex drive in both sexes. In most cases, an individual's blood lead level is a good indication of recent exposure

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to and current absorption of lead[7].

For lead industry workers in Turkey, the acceptable level of lead in blood is 70 μg/dl. A worker must be taken into medical care if she/he has a blood lead level >40 μg/dl[8]. In the workplace, however, there are no occupational lead poisoning prevention programs that cover all workers.

There are several surveys showing that people who work in lead-related industries have higher blood lead levels than other people. This is an expected condition. The importance of the present study is that we have measured the blood lead levels among apprentices who are in the early stages of their working lives.

The aim of this research was to determine the blood lead levels of apprentices at Bursa Vocational Education Centre and evaluate a link to workplace exposure by comparing the data with control subjects not working in the lead industry.

Subjects and Methods

This cross-sectional study was performed between October 2004 and June 2005 in Bursa, the fourth largest city of Turkey, population 2,125,140 (2,000 census). The labor force numbers show that 606,307 people are eligible for employment, 550,355 of whom are employed and the remaining 55,952 are unemployed[9].

Study sample

The study sample consisted of 256 apprentices receiving training in engineering, welding, electrical, and dye curricula at Bursa Vocational Education Centre. In Turkey, an apprentice is defined as one who receives knowledge, skills and on-the-job training in accordance with an apprenticeship agreement. An apprentice must be at least 14 yr old, a primary-school graduate, and healthy enough to meet the responsibilities and requirements of the workplace. An apprentice attends school one day per week and works five days a week.

In this survey, only 231 apprentices could be followed (90.2%) because 25 were absent during the survey period. The control group consisted of 252 children who live in the same neighborhoods as the apprentices but do not work in the lead industry. All apprentices and members of the control group were male.

Atmospheric lead levels could not be considered because there was no appropriate available research. Data concerning nutrition (which could affect blood count) was also unavailable.

Procedure

Questionnaires consisting of 33 questions for the controls and 39 questions for the apprentices were completed during face-to-face interviews. Both groups answered the same 33 questions regarding demographic data, socioeconomic status, habits, perceived health, and health complaints. The apprentices answered six additional questions regarding occupational lead exposure.

Height was measured to the nearest 0.5 cm by means of a portable stadiometer with the participants standing without shoes. Weight was measured to the nearest 0.1 kg with a calibrated scale with the subject wearing light clothing and in foot stockings. The body mass index was calculated from the formula weight (kg)/height (m^2).

Blood pressure was measured twice in succession with five minutes between measurements using a mercury sphygmomanometer on the right arm of seated participants according to World Health Organization criteria[10]. For the purposes of this study, hypertension was defined as an average systolic blood pressure >140 mmHg and/or average diastolic blood pressure > 90 mmHg. Individuals with normal blood pressure who were using antihypertensive medication were classified as hypertensive.

Two test tubes of venous blood samples were taken from all participants for lead and hematological analysis. Whole blood samples were taken in a lead-free plastic tube containing EDTA. Blood lead level was measured by ICP-MS in the Scientific and Technological Research Council of Turkey Bursa Test and Analysis Laboratory (TUBITAK-BUTAL; accredited by the international accreditation body, Deutsches Akkreditierungssystem Prüfwesen (DAP), with effect from July 9, 2001). Hemoglobin level was determined using a spectrophotometer BPC-PRIME in the Fethiye Public Health Centre's laboratory.

The study was accepted by the Ethical Committee of Uludag University's Faculty of Medicine (2003-14/12).

Statistical analysis

The data were evaluated by SPSS (Version 13.0) statistics software. In the statistical analysis, chi-square, student's *t*-test, correlations and logistic regression analyses were used. The median blood lead level was used as the variable in the logistic regression analysis. Dichotomy in the logistic regression model was established by dividing the sample into subjects with blood lead levels less than or equal to the median (≤2.81 μg/dl) or greater than the median (>2.81 μg/dl).

Results

The demographic characteristics of the subjects are shown in Table 1.

There was no significant difference in vehicular traffic densities in the neighborhoods. Significantly more apprentices (21.6% vs. 2.4% in controls) had at least one

Table 1. Demographics of study participants

Characteristics	Apprentices		Controls		p-value
	n	%	n	%	
Age					ns
14	13	5.6	20	7.9	
15	31	13.4	50	19.8	
16	54	23.4	60	23.8	
17	58	25.1	56	22.2	
18	64	27.7	54	21.4	
19	11	4.8	12	4.8	
Place of Birth					0.015
Bursa	91	39.4	127	50.4	
Other	140	60.6	125	49.6	
Father's education level					0.000
0–8 yr	219	94.8	109	43.3	
9+ yr	12	5.2	143	56.7	
Mother's education level					0.000
0–8 yr	228	98.7	166	65.9	
9+ yr	3	1.3	86	34.1	
Number of persons who live at home					0.000
1–4	104	45.0	169	67.1	
5+	127	55.0	83	32.9	
Family income per month (USD)					0.000
89–499	120	51.9	64	25.4	
500+	111	48.1	188	74.6	

ns: Not significant.

family member working in a lead-related industry (p<0.05).

The smoking rate was 57.1% among apprentices and 19.0% among the control group (p<0.05). Alcohol consumption was also greater among apprentices (12.6% vs. 4.8% among the control group) (p<0.05).

Fatigue, stomach-ache, and nervousness were statistically higher among apprentices (31.2, 12.6, and 44.6%, respectively) than among controls (16.3, 5.2, and 28.6%, respectively) (p<0.05). The differences between the rates of debility, lack of appetite, sleeping disorders, colic, nausea, vomiting, and constipation were not significant.

The body mass index of the apprentices (mean 21.90 kg/m^2 95% CI 21.5–22.3) was lower than that of the control group (mean 22.49 kg/m^2 95% CI 22.1–22.9) (p<0.05). There was no significant difference between systolic blood pressure (mean 112.25 mmHg 95% CI 110.82–113.68 vs. mean 112.14 mmHg 95% CI 110.70–113.59) or diastolic blood pressure (mean 71.09 mmHg 95% CI 70.02–72.17 vs. mean 71.35 mmHg 95% CI 70.26–72.44) between apprentices and controls, respectively.

Hematocrit values (44.01, 95% CI 43.62–44.40 vs. 44.86, 95% CI 44.49–45.23) and mean cell volume (MCV) (86.41 fl, 95% CI 85.74–87.09 vs. 87.48 fl, 95% CI 86.85–88.11) were both significantly different between the two groups (p<0.05). There were no differences between average hemoglobin levels, erythrocyte counts, and mean cell hemoglobin (MCH).

Table 2. Blood lead levels of subjects according to age

Age	Blood lead level		p-value
	Apprentices Mean μg/dl (95% CI)	Controls Mean μg/dl (95% CI)	
14	5.17 (3.79–6.54)	2.22 (1.74–2.69)	0.001
15	4.65 (3.62–5.68)	2.66 (2.33–2.99)	0.001
16	5.06 (4.30–5.81)	2.45 (2.09–2.80)	0.000
17	5.07 (4.33–5.81)	2.26 (1.97–2.56)	0.000
18	4.42 (3.85–4.99)	2.21 (1.95–2.47)	0.000
19	8.24 (3.61–12.86)	2.20 (1.48–2.93)	0.016
Total	4.99 (4.60–5.38)	2.37 (2.22–2.51)	0.000

In this survey, the overall mean blood lead level was 3.62 μg/dl (95% CI 3.39–3.85; median 2.81). The blood lead level of the apprentices was significantly higher than that of the control group (p<0.05). Blood lead levels according to age are given in Table 2.

Among the apprentices, those with a sleeping disorder had significantly higher blood lead levels than those without a sleeping disorder (5.85 μg/dl 95% CI 4.77–6.93 vs. 4.75 μg/dl 95% CI 4.35–5.15, respectively) ($p<0.05$).

There was a significant relationship between blood lead level and hemoglobin (r=–0.094, two-tailed, p=0.039), hematocrit (r=–0.108, two-tailed, p=0.018), MCV (r=–0.197, two-tailed, p=0.001) and MCH values (r=–0.136, two-tailed, p=0.003).

Apprentices had worked for an average of 33.42 months (95% CI 30.88–35.97). There was no significant difference in average working time among departments. The data for blood lead levels of the apprentices according to profession are presented in Table 3. The mean blood lead level of the dyers was found to be significantly lower than that of the others ($p<0.05$). There was no difference in blood lead levels between the apprentices working in electrical, engine repair, or welding departments.

The usage of personal protective equipment by apprentices ranged from 11.3% to 48.5% (Table 4). The blood lead level of workers who always used their masks was lower compared with other workers. This relationship was not found for any other personal protective equipment used.

The logistic regression analysis showed that being an apprentice had a significant impact on blood lead levels ($p<0.05$; OR=13.55, 95% CI 7.38–24.88).

Table 3. Blood lead levels of apprentices according to profession

Profession	n	Blood lead level		
		Mean μg/dl (95% CI)	Minimum	Maximum
Engine repairer	116	5.06 (4.49–5.63)	1.48	25.03
Welder	45	5.06 (4.19–5.93)	1.26	15.44
Dyer	34	3.53 (2.67–4.39)	1.21	13.45
Electrician	36	6.06 (5.06–7.05)	1.86	14.29

Discussion

Greater numbers of apprentices in this study tended to have been born outside of Bursa, to have less educated parents, to live in more crowded households, and to belong to lower income families compared to the controls (Table 1).

This social class difference between the apprentice group and the control group was not because of a selection bias on the control group; it reflects the prevailing conditions of apprenticeship in Turkey. Compulsory education lasts for eight yr, and adolescents who cannot continue school because of socioeconomic difficulties have to start work as apprentices. In 2004, 122,450 apprentices were trained in 359 institutions in Turkey[11]. Because of unregistered employment, however, it is estimated that the real number is much higher[12].

Smoking and alcohol consumption among apprentices was higher than in the control group ($p<0.05$). This difference in habits may be the result of starting work at earlier ages.

In this study it was found that the blood lead levels of apprentices were higher than those of the controls ($p<0.05$). In two other Turkish studies, carried out in Isparta[13] and Şanlıurfa[14], the blood lead levels of apprentices were also found to be higher than those of the control group ($p<0.05$). In research conducted in Portugal, however, no difference was found between the blood lead levels of apprentices and controls[15]. The results of the Portuguese survey may not be surprising, because apprentices were in the early stages of their working life. The results of the surveys in Turkey, however, could be a sign of prevalent unhealthy working conditions.

There are several surveys showing that people who work in lead-related industries have higher blood lead levels than other people[16–19]. This is an expected condi-

Table 4. The usage of the personal protective equipment

Personal protective equipment (n=231)	Usage status	%	Blood lead level Mean μg/dl (95% CI)	p
Work garments	Never	45.0	5.24 (4.56–5.93)	0.508
	Occasionally	6.5	4.88 (3.31–6.44)	
	Always	48.5	4.77 (4.29–5.24)	
Gloves	Never	59.3	5.26 (4.70–5.83)	0.245
	Occasionally	16.5	4.59 (3.77–5.41)	
	Always	24.2	4.58 (3.91–5.25)	
Mask	Never	76.2	5.29 (4.82–5.77)	0.016
	Occasionally	9.5	4.33 (3.29–5.37)	
	Always	14.3	3.78 (3.10–4.46)	
Safety eyeglasses	Never	76.2	5.14 (4.66–5.62)	0.352
	Occasionally	12.6	4.67 (3.80–5.54)	
	Always	11.3	4.30 (3.50–5.12)	

tion. What is interesting about the present study is the observation of high blood lead levels in apprentices who are in the early stages of their working life. This shows that not only lead factory workers but also apprentices are at risk for lead poisoning.

In this survey the mean blood lead level of the control group was 2.37 μg/dl. In two other Turkish surveys, which studied adults, the average blood lead levels were 3.65 μg/dl[20)] and 3.13 μg/dl[21)]. The blood lead level in our survey is lower, possibly because we studied only adolescent age groups.

Different trades have different levels of lead exposure. For example, one study found that exposure was lowest in painters and bakers[22)]. In our study of four trades—engine repairers, welders, dyers, and electricians—the dyers had the lowest blood lead levels (Table 3).

There are very few surveys related to lead exposure in Turkey. In a survey of traffic policemen in Bursa, the average lead blood level was 9.4 μg/dl[23)]. In another survey done among battery workers in Gaziantep, the average level was 36.83 μg/dl[19)]. In the present survey, the average level among apprentices was 4.99 μg/dl. In other Turkish surveys of apprentices, the average blood lead levels were 7.6 μg/dl (Isparta[14)]) and 27.8 μg/dl (Şanlıurfa[13)]). The lower average level in our survey could be related to differences in lead compounds in the workplace and in working conditions, however, further research on this topic is needed.

Many experimental animal studies have shown that chronic exposure to lead or cadmium can increase systolic and/or diastolic blood pressure in mammals, and several plausible theories for their role in the etiology of hypertension have been proposed. Human studies have generally provided less conclusive evidence for the role of lead and/or cadmium in hypertension[24)]. It has been reported that long-term occupational exposure is related to a slight increase in both systolic and diastolic blood pressure[25)]. As in similar studies evaluating the effect of lead exposure on blood pressure[26)], our study showed that there was no significant relationship between blood lead levels and systolic and/or diastolic blood pressure.

Hemoglobin levels did not correlate with blood lead levels. The discovery of anemia in a person with a blood lead level up to 80 μg/dl should be considered to be the result of lead toxicity only after other causes of anemia have been excluded. It has also been reported that periodic hemoglobin determinations are not useful indicators of lead exposure[27)]. In a study conducted in Japan, the group of workers whose blood lead levels were lower exhibited significantly lower hematocrit, hemoglobin, and erythrocyte values than the group of workers whose blood lead levels were higher[28)]. In our study a significant relationship was found between blood lead levels and low hemoglobin, hematocrit, MCH, and MCV levels. The relationship between blood lead levels and anemia varied according to exposure dose and time as well as lifestyle factors such as nutrition, smoking, and alcohol consumption. It is interesting to note that high blood lead levels in apprentices are associated with sleeping disorders. Sleeping disorders may be an indicator of high blood lead levels among risk groups[29)].

In developing countries, occupational exposure to lead is commonly unregulated and little monitoring of exposure is carried out[30)]. In Turkey, periodic inspections and blood lead level measurements were suggested by the Ministry of Labour, but there is no control mechanism to audit these measurements.

The use of protective clothing, gloves, and masks was low (Table 4). This is an important topic that needs attention. Of the personal protection items, the mask is the most effective against lead exposure. Workers at risk of lead exposure should therefore be encouraged to use them.

Workplace hygiene is also critical in the prevention of excessive lead exposure. Clean areas for eating should be provided. Cleaning of work garments and showering are mandatory, and should be provided at the plant. In processes that have the potential to generate airborne dust and fumes, respiratory protection should be provided for all staff[4)].

Although the levels are low, this survey clearly shows that occupational exposure causes an increase in blood lead level. Measurement of blood lead levels of apprentices must be taken periodically, and for lead industry workers, a regular medical surveillance system should be established.

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