Original Article

Association between Blood Lead Level and Sleep Quality in Lead-Zinc Factories in Zanjan: A Cross-Sectional Study

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Abstract

Background and Objective: Adult lead poisoning commonly occurs due to workplace exposures. Neuropsychological symptoms such as insomnia are reported as the early symptoms of chronic lead intoxication. This study aimed to evaluate association between blood lead level (BLL) of workers from lead-zinc factories and their sleep quality.

Materials and Methods: A cross-sectional study was performed and 425 workers were enrolled with eligibility criteria of the study. BLL of workers were measured using atomic absorption spectrophotometry. Clinical assessment of workers was performed regarding their sleep problems through a self-administered questionnaire consisting of demographic characteristics, Insomnia Severity Index (ISI), Epworth Sleepiness Scale (ESS), and Pittsburg Sleep Quality Index (PSQI). Multiple linear regression and ANOVA tests were used for analysis of data.

Results: Among 425 workers studied, mean (±SD) BLL was 34.7(± 16.7) µg/dl. BLL was significantly associated with total scores of ISI, ESS, and PSQI questionnaires adjusted for age, sex, job experience, shift work, and body mass index (Adjusted R^2 was 0.19, 0.08, and 0.18, respectively; P<0.001). Difficulty with falling asleep, difficulty of staying asleep and waking up too early were more prevalent among workers with increased BLL (P<0.001).

Conclusions: Workers exposed to lead and with increased BLL may have more sleep problems including insomnia, excessive daytime sleepiness, and poor sleep quality. This warrants further attention toward different types of sleep problems in workers with lead exposure especially those with increased BLL.

Keywords: Blood lead level, Sleepiness, Insomnia

Introduction

Occupational exposure is one of the routes of lead exposure which occurs at greater magnitudes comparing to the general population contact (1). Adult lead poisoning commonly occurs due to workplace exposures (2). Lead intoxicates different organs among which central nervous system is the most notable (1,3). Neuropsychological symptoms such as insomnia, impaired concentration, and confusion are reported as the early symptoms of chronic lead intoxication (3,4). Furthermore, cognitive neuromotor deficits and mood disorders constitute other neuropsychological effects of lead exposure in workers of foundries, lead smelters, and battery plants (1). Pourabdian et al. have indicated more sleep problems in workers exposed to lead in comparison with non-exposed ones in a battery industry. They reported that the exposed workers with sleep problems had more Blood Lead Level (BLL) than their control group (2).

To our knowledge, frequency of sleep disorders is not studied in occupational settings with exposure to lead. Previous re-

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ports regarding sleep problems in workers with lead exposure are very scarce and limited to subjective complaints of participants regarding their disturbed sleep. Those studies have not addressed different types of sleep disorders, which may occur because of chronic lead intoxication, using standard questionnaires that measure various sleep disorders such as sleepiness, insomnia or poor sleep quality. The correlation between BLL and neuropsychological effects including various sleep disorders has not been well studied yet. Moreover, correlation between sleep characteristics of workers with lead exposure and their BLL is not assessed yet.

Limited available information on frequency of sleep disorders among lead-exposed workers, psychological effects of lead such as sleep problems because of their influence on worker's quality of life, and high possibility of lead exposure in lead-using factories warrant conducting further studies. Thus, current study was conducted to assess quality of sleep in workers of lead-zinc factories in Zanjan, and to measure BLL of exposed workers and find correlation between BLL and sleep quality of workers with lead exposure.

Materials and Methods

A cross- sectional study was conducted in four lead-zinc companies in Zanjan, Iran during 2012-2013. A total of 22 lead-zinc factories were in Zanjan of which 4 governmental ones accepted to participate in current study. The study was approved by the Ethics Committee of Tehran University of Medical Sciences.

All workers of selected factories except those met the exclusion criteria were recruited. Workers with following characteristics were excluded from the study: current smoking, alcohol consumption, having a child aged less than two years (since parents of this age group usually do not have regular sleep), history of physical or mental illness receiving treatment during past year, history of divorce or spouse's death during past year, and having a second job with night shift. A total of 458 workers were eligible to be enrolled in the study. Written informed consent was obtained from all the participants.

BLL was measured for all participants after blood sampling. Sleep quality of workers were assessed using self-administered questionnaires consisting of demographic characteristics, Insomnia Severity Index (ISI) (5), Epworth Sleepiness Scale (ESS) (6), and Pittsburgh Sleep Quality Index (PSQI) (7).

Blood sampling for measuring BLL was performed during the workers' periodic screening examination. Blood samples were collected at the workplace between 8-10 am from the cubital vein following thorough skin cleaning. Samples were stored at 4°C until the concentration of blood lead was measured using atomic absorption spectrophotometry at the laboratory of Baharloo hospital affiliated to Tehran University of Medical Sciences.

Four previously validated questionnaires including the demographic characteristics form, ISI, ESS, and PSQI were completed by workers for evaluation of their sleep quality. Excessive daytime sleepiness assessed by ESS questionnaire was considered as a score more than 10 and insomnia as a score ≥ 8 of ISI questionnaire. Those workers with a score ≥ 5 of PSQI were considered to have poor sleep quality.

The study participants were divided into three subgroups in terms of their BLL in μg/dl: <25, 25-55, and >55. The mean of ISI, ESS, and PSQI scores were compared between those three groups by using analysis of variances (ANOVA) technique. The data are presented as mean ± standard deviation (SD). Multiple linear regression and ANOVA tests were used for analysis of quantitative variables. P value ≤ 0.05 was considered statistically significant. Statistical analyses were performed using SPSS v.16.

Results

A total of 425 participants with eligibility criteria of the study accepted to complete the questionnaires (Response Rate: 92%). Men comprised 95.5% (n=406) of the participants. Mean age of workers was 34.1 ± 7.06 years and mean body mass index (BMI) (weight (kg) / square height (m^2), was 25.54 ± 3.56.

Eighty percent of workers were married. The mean duration of job experience at the factory was 4.5 years. Nearly half (50.6%) of the workers had shift work. The lowest BLL was 2.7 µg/dl, and the highest was 74 µg/dl with a mean of 34.7 ± 16.7 µg/dl.

A total of 343 (80.7%) of participants had no clinically significant insomnia (total score of ISI questionnaire ≤ 7), 72 (16.9%) had a score of 10 or more in ESS questionnaire indicating excessive daytime sleepiness, and 165 (38.8%) had poor sleep quality (PSQI score more than 5).

Insomnia, excessive daytime sleepiness and poor sleep quality of the workers studied were significantly correlated with their BLL ($P < 0.001$).

Table 1 shows that several characteristics of sleep disturbance including difficulty with falling asleep, difficulty of staying sleep, waking up too early, and shorter duration of sleep were significantly more common among workers with higher BLL. Mean BLL of workers also had significant association with mean total scores of ISI, ESS and PSQI questionnaires adjusted for age, sex, job experience, shift work, and BMI (Table 2).

A multiple regression was also performed to evaluate association between BLL with sleep quality, age, sex, BMI, job experience, and shift work included in the logistic regression model as covariates. None of the covariates had significant association with total scores of ISI, ESS, and PSQI questionnaires in separate regression models. However, BLL had significant statistical correlation with total scores of mentioned questionnaires ($P<0.001$). BLL was associated with insomnia, excessive daytime sleepiness, and poor sleep quality in adjusted regression models (Table 3).

Discussion

Current study showed BLL has a significant correlation with insomnia, excessive daytime sleepiness, and poor sleep quality indicated by higher total scores of ISI, ESS, and PSQI questionnaires in those with

Table 1. Association between BLL and characteristics of sleep problems of workers

	Number (%)	Mean BLL ± SD	*P* value
Difficulty with falling asleep			
Yes	216 (50%)	39.5 ± 16.82	<0.001
No	209 (49%)	30.05 ± 15.33	
Difficulty of staying sleep			
Yes	152 (35%)	40.20 ± 15.77	<0.001
No	273 (64%)	31.65 ± 16.52	
Waking up too early			
Yes	196 (46%)	37.88 ± 16.10	<0.001
No	229 (53%)	31.99 ± 16.84	

BLL: Blood Lead Level

Table 2. Mean scores of ISI, ESS, and PSQI questionnaires in different levels of blood lead

Test	BLL (µg/dl)			*P* value
	<25	25-55	55<	
	n=145	n=220	n=60	
ISI	2.68 ± 2.75*	7.78 ± 4.47	5.86 ± 4.58	<0.001
ESS	5.16 ± 3.57	8.07 ± 4.23	7.54 ± 4.18	<0.001
PSQI	3.95 ± 2.23	7.80 ± 3.70	5.51 ± 3.12	<0.001

*Mean ± SD

BLL: Blood Lead Level, ISI: Insomnia Severity Index, ESS: Epworth Sleepiness Scale, PSQI: Pittsburgh Sleep Quality Index

Table 3. Association between total scores of ISI, ESS, and PSQI and different covariates

Covariates	ISI		ESS		PSQI	
	B	P value	B	P value	B	P value
Sex	0.208	0.858	-0.032	0.477	0.011	0.989
JobExp.(year)*	0.049	0.302	0.034	0.472	0.065	0.059
BLL(µg/dl)	0.123	<0.001	0.076	<0.001	0.086	<0.001
Shift Work	-0.006	0.989	-0.182	0.645	0.063	0.828
Age (year)	0.001	0.965	0.028	0.360	0.012	0.596
BMI	-0.017	0.754	-0.040	0.479	-0.043	0.286
	R^2 = .205 Adjusted R^2= .191		R^2 = .098 Adjusted R^2= .083		R^2 = .198 Adjusted R^2= .184	

ISI: Insomnia Severity Index, ESS: Epworth Sleepiness Scale, PSQI: Pittsburg Sleep Quality Index, Job Exp: Job experience, BLL: Blood Lead Level, BMI: Body Mass Index

higher BLL, respectively.

Mean BLL of current study participants was 34.7µg/dl which is higher than standard recommendations (8) and could be associated with acute and chronic health effects; as the findings of this study showed. Thus, occupational health surveillance programs including periodic BLL measurement, clinical examination of workers regarding acute and chronic effects of lead exposure should be addressed. Implementing strategies for measurement of lead exposure at the work environment and reducing exposure by different methods including using appropriate personal protective equipment should also be considered by authorities of those plants.

Although no study has addressed sleep problems by focusing on sleep characteristics and quality in adults with exposure to lead at occupational settings, but consistent with current results, some studies have reported sleep disturbance as one of chronic neurobehavioral effects of lead (1,2).

Pourabdian et al. in a case-control study at a battery industry showed that workers with self-reported sleep disturbance and forgetfulness had higher BLL comparing to their non-exposed coworkers (2). The results are consistent with current findings which show more sleep problems including insomnia, excessive daytime sleepiness, and poor sleep quality in higher BLL.

A study conducted by Kordas et al. also has mentioned association of sleep problems including later waking and shorter duration of sleep with BLL (9). Mahmoudian et al. also found more neurological disorders such as insomnia and poor concentration in children with increased BLL (10). However, Kordas et al. and Mahmoudian et al. studies were conducted in non-occupational settings that generally have lower magnitudes of lead exposure comparing to workplace environments. Their studied age group was also different from current study (9,10). Thus, magnitude of lead exposure in this study can be associated with more sleep disorders than reported problems of chronic exposures of general population. Rather than general population studies, investigations conducted at workplaces including automotive garages, lead smelting, and lead-zinc mine have also mentioned more sleep disorders in lead exposed workers with high BLL (2,11-13). Adela et al. observed more sleep disorders in automotive garage workers with BLL of 19.75µg/dl (OR: 3.1). A case-control study on various workers indicated that lead exposed workers (Mean BLL: 77) report more psychiatric symptoms including insomnia, dizziness, and fatigue than non-exposed ones (12).

However, results regarding association of BLL and sleep disturbance are conflicting as Kirkby et al. found no more fatigue, headache, and sleep disturbance among lead smelting workers (14). Such results warrant conducting more objective studies using gold standard tests for diagnosis of sleep disorders regarding correlation of BLL and sleep.

Of 22 lead-zinc factories, 4 participated in current study which can be considered a limitation. Furthermore, random blood lead sample was obtained from exposed work-

ers; however, other methods of measuring lead exposure such as x-ray fluorescence may provide better estimation of body lead burden and magnitude of exposure. Measurement of Zinc Protoporphyrin (ZPP) and Erthrocyte Free Protoporphyrin (FEP) could be also helpful, but because of the high cost, these tests were not performed. Authors recommend conducting further studies to follow up those with sleep disorders using more objective sleep investigations including actigraphy or polysomnography which may reveal more information about effects of lead on sleep.

In conclusion, workers with higher BLL had more sleep problems including insomnia, excessive daytime sleepiness and poor sleep quality. This requires more objective follow-up studies in those with disturbed sleep. These findings along with behavioral effects of lead, emphasize the need for reducing environmental and occupational lead exposures through implementing appropriate strategies.

Increased prevalence of insomnia, excessive daytime sleepiness and poor sleep quality among workers with lead exposure warrants further attention toward different types of sleep problems in lead-exposed workers especially those with increased BLL.

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