Original Article

Psychomotor Effects of Mixed Organic Solvents on Rubber Workers

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Abstract

Background: Exposure to organic solvents is common among workers.

Objective: To assess neurobehavioral effects of long-term exposure to organic solvents among rubber workers in Tehran, Iran.

Methods: Across-sectional study was conducted on 223 employees of a rubber industry. The participants completed a data collection sheet on their occupational and medical history, and demographic characteristics including age, work experience, education level; they performed 6 psychiatric tests on the neurobehavioral core test battery (NCTB) that measure simple reaction time, short-term memory (digit span, Benton), eye-hand coordination (Purdue pegboard, pursuit aiming), and perceptual speed (digit symbol).

Results: Workers exposed and not exposed to organic solvents had similar age and education distribution. The mean work experience of the exposed and non-exposed workers was 5.9 and 4.4 years, respectively. The exposed workers had a lower performance compared to non-exposed workers in all psychomotor tests. After controlling for the confounders by logistic regression analysis, it was found that exposure to organic solvents had a significant effect on the results of digit symbols, digit span, Benton, aiming, and simple reaction time tests. No significant effect was observed in pegboard test.

Conclusion: Occupational exposure to organic solvent can induce subtle neurobehavioral changes among workers exposed to organic solvents; therefore, periodical evaluation of the central nervous system by objective psychomotor tests is recommended among those who are chronically exposed to organic solvents.

Keywords: Benzene; Toluene; Gasoline; Occupational exposure; Rubber; Neuropsychology

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Introduction

Organic solvents are a group of chemical liquids that have been widely used in chemical, food and pharmaceutical industries.[1,2] Exposure to organic solvents is therefore common among many workers.[3,4] Since organic solvents are lipid-soluble, they have an affinity for producing toxic effects in neural tissue in both the central and peripheral nervous systems. Long-term occupational exposure to organic solvents can cause a wide range of chronic central nervous system abnormalities, which have been described by various terms such as “chronic solvent intoxication,” “painter's syndrome,” “psycho-affective disorder,” and “neurasthenic syndrome.”[5,6] Several studies have so far shown the neurotoxic effects resulted from

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exposure to solvents.[7,8] A recent study in China has reported psychiatric changes in workers exposed for three years to ethyl-benzene.[9] Another study on shipyard painters chronically exposed to organic solvents has demonstrated increased incidence rates of adverse neurobehavioral effects.[10] These effects included memory problems, concentration difficulties, affective changes and decreased libido.[11]

In many instances, these effects have no obvious clinical signs or symptoms and cannot be found in routine medical surveillance; they could only be detected by psychomotor tests. Similar studies have used psychomotor tests for early diagnosis of the effects of exposure to neurotoxins such as heavy metals, solvents, and pesticides.[12,13] Neurobehavioral core test battery (NCTB) was recommended by World Health Organization (WHO) to evaluate the central nervous system disturbance of workers exposed to organic solvents at the workplace.[14] These tests are used to evaluate memory, concentration and reaction time, and are quite sensitive to neurotoxin effects.[11] Despite the large number of workers exposed to organic solvents, our literature review suggests that the aforementioned tests have not generally been included in routine occupational check-up.

We therefore, conducted this study to assess the neurobehavioral changes due to exposure to organic solvents in workers of a rubber industry in Tehran, Iran.

Materials and Methods

In a cross-sectional analytical study, all 223 employees of a rubber industry located in Tehran, Iran, were invited to participate in the study. Those who were working in tube curing and tire curing sections, where results of air samples showed excessive exposure to solvents such as benzene, toluene and gasoline, were considered as "solvent-exposed group." Solvent-exposed workers were working for a minimum of eight hours per day for at least three years in the working areas.[9] The unexposed group included workers from the same factory who were not working in areas with high concentration of solvents in the air.

The exclusion criteria included history of head trauma, convulsion, drug taking, previous mental illness, education level below eight years, alcohol consumption within the previous 24 hours of testing, and inadequate sleep the night before the test, according to self report. All the tests were carried out in the morning between 8:00 and 12:00 o'clock—before the workers entered the working area and became exposed to solvents.

All participants were asked about their age, work experience, education, and medical and occupational history. Psychomotor performance of the workers was assessed according to NCTB WHO recommendations. The test took 60 min per subject and was carried out by a trained occupational medicine resident in a silent environment, without any distractions. Simple reaction time for each subject was obtained by software according to WHO guidelines, as reported earlier.[15] This test consisted of 64 repetitive visual stimuli given at 1–10 sec interval while the subjects were asked to press a button with each stimulus.

To quantify the dexterity and coordination in subjects, a pursuit pegboard was used. This included a board with holes and some pegs. The subject had to fit the pegs correctly in the holes in three consecutive rounds—using only the left hand; only the right hand; and both hands simultaneously.

Digit span test from the Wechsler Adult Intelligence Scale (WAIS)[16] was used to evaluate short-term auditory memory and attention by forward and backward repeating of seven pairs of numbers whose length increased progressively.

Digit symbol test (WAIS)[16] also used

Table 1: Demographic characteristics of exposed and unexposed groups. Values are either mean±SD or frequency (%).

Variable	Exposed (n=95)	Unexposed (n=79)	p value
Age (yrs)	29.2±3.7	29.7±6.1	0.555
Education level (yrs)			
<12	26 (27%)	13 (17%)	0.086
≥12	69 (73%)	66 (84%)	
Work experience (yrs)	5.9±2.7	4.4±2.1	0.004
Smoking*	28 (30%)	19 (24%)	0.422

*Self reported

to evaluate the perceptual motor speed. This test consisted of nine symbols associated by numbers. The participants were instructed to fill the blank boxes with the symbols corresponding to the numbers in front of them in 90 sec.

Benton visual retention test was used to assess the short-term visual memory. This test consisted of 10 pairs of cards. A random drawing was shown to the subject who had to memorize the drawing and identify it among four similar looking drawings.

The pursuit aiming test was used to measure the ability to make quick and accurate movements. In this test, subjects were instructed to add a dot to the center of a number of circles as quickly as possible.

The exposure measurement was made according to the NIOSH standard method No. 2549, 1996. The concentration of organic solvents in the workplace air was measured by gas chromatography.

Statistical Analysis

The data was analyzed by SPSS® for Windows® ver18. *Student's t* test was used for comparison of the solvent effect on neurobehavioral function between two groups. Multiple logistic regression analysis was used for controlling the effect for age, education level, work experience, and smoking. A p value <0.05 was considered statistically significant.

Result

Of 223 workers who invited to participate in the study, 200 agreed (response rate of 89.7%). The exposed and unexposed groups consisted of 114 and 86 workers, respectively. Of the exposed and unexposed groups, 19 and 7 workers who met the above-mentioned exclusion criteria were excluded.

The distribution of age and education level was not significantly different between the exposed and unexposed groups. However, the mean±SD work experience in exposed workers (5.9±2.7 years) was significantly (p=0.004) more than that in unexposed workers (4.4±2.1 years, Table 1).

Table 2 shows the results of the psychomotor tests performed in the study groups. The exposed group had an inferior performance in psychomotor tests compared to unexposed group. There was a significant (p<0.05) decrease in the results for the digit symbol, digit span, aiming, Benton, and the pegboard tests for the exposed compared to unexposed group; the reaction time to the stimulus was significantly higher in the exposed compared to unex-

TAKE-HOME MESSAGE

- Organic solvents are a group of chemical liquids that have been widely used in chemical, food and pharmaceutical industries.
- Occupational exposure to organic solvents can induce subtle neurobehavioral changes among the exposed workers.
- Periodical evaluation of the central nervous system by objective psychomotor tests is recommended among those who are chronically exposed to organic solvents.

posed group (p=0.003) (Table 2).

Multiple logistic regression analysis revealed that exposure to organic solvents had a significant effect on the results of digit symbol, digit span, Benton, aiming and simple reaction time (p<0.05), but not on the pegboard test. Education level had a significant effect on the performance in digit symbol, aiming, and Benton (p<0.05). Age had a significant effect only on the result of Benton (p<0.05). Smoking and work experience did not affect any neurobehavioral performance (Table 3).

The concentration of organic solvents in the workplace air was measured by gas chromatography. The used threshold limit value-time weighted average (TLV-TWA) of the solvents was according to American conference of governmental industrial hygienists (ACGIH). The workplace concentration in air of benzene was 0.6 ppm (TLV-TWA: 0.5 ppm); toluene was 6.007 ppm (TLV-TWA: 20 ppm), and gasoline was 182.7 ppm (TLV-TWA: 300 ppm).

Table 2: Neurobehavioral function in workers exposed and unexposed to organic solvents. Values are mean±SD.

Test	Exposed (n=95)	Unexposed (n=79)	p value
Digit symbol	44.7±10.1	50±12.2	0.002
Digit span (forward+backward)	10.1±2.3	12.1±2.6	0.001
Pursuit aiming	106.8±22.6	117.1±24.7	0.005
Benton	6.7±1.5	7.5±1.3	0.001
Purdue pegboard			
Dominant hand	10.7±1.8	7.5±1.3	0.006
Both hands	17.2±2.5	18.6±2.9	0.001
Reaction time (ms)	330±56	305±55	0.003

Discussion

We found that exposure to organic solvents would affect the neuropsychological function in workers of a rubber industry who had no overt clinical signs and symptoms. A significant difference between test results for the exposed and unexposed groups were found in five of six psychomotor tests; none of these tests alone is nonetheless a really good predictor (Table 3). This would probably why WHO has not suggested using any of these tests individ-

Table 3: Results of multiple logistic regression analysis where for each model the neurobehavioral test is the dependent variable. 'B' represents the coefficient for each of the independent variables in the model. The p value shows the probability that the corresponding coefficient is really equal to zero; the values designated as ".00" represent values <0.001.

Independent Variable	Digit symbol		Digit span		Aiming		Benton		Reaction time		Pegboard	
	B	p	B	p	B	p	B	p	B	p	B	p
Constant	62.5	.00	14.5	.00	137.3	.00	7.6	.00	290.5	.00	11.1	.00
Exposure	–6.50	.00	–2.12	.00	–10.2	.02	–0.68	.00	25.73	.02	–0.49	.05
Age	–0.37	.07	–0.08	.07	–0.76	.21	–0.03	.03	1.39	.84	–0.00	.88
Education	9.47	.00	3.22	.17	20.05	.00	0.87	.00	–23.1	.12	0.86	.21
Experience	–0.39	.26	–0.14	.90	–1.1	.73	–0.06	.69	3.9	.05	–0.04	.42
Smoking	1.57	.37	0.13	.75	4.02	.31	–0.03	.89	–3.82	.69	0.55	.05
r^2	0.11		0.23		0.14		0.08		0.09		0.02	

ually. These results are consistent with the previous studies[17, 18] that reported the neurobehavioral functions of workers chronically exposed to solvents changed significantly.

Another study used a computer-based neurobehavioral test and suggested that occupational exposure to organic solvents could induce neurobehavioral changes in shipyard painters.[10] Another research demonstrated that traditional tests such as NCTB are as sensitive as computer-based methods in early diagnosis of psychomotor disorders.[19] Therefore, we adopted six tests of NCTB-WHO to assess the neurobehavioral performance of the workers. It has previously been shown that there were significant differences in neurobehavioral tests measuring manual dexterity between workers exposed to toluene and a control group.[20] In our study, exposure to the solvents had no significant effect on pegboard test. Follow-up of workers exposed to solvents may provide a better insight into this issue.

Level of education and age importantly affect the performance in NCTB tests.[22,23] However, we could not any significant difference in mean age and education level between the exposed and unexposed groups.

Those workers with an education level of ≤8 years were excluded from the study that would further reduce the effect of the education level on the results of our study. Tobacco smoking did not affect any of the neurobehavioral tests; this was consistent with other studies.[10,24] We believe that the exposed workers who had a mean work experience of 5.9 years, had had sufficient exposure to the solvents, the concentration of which was higher than the permissible levels even after the ventilation system had been improved in the same year the research was conducted. The concentrations were most likely higher during previous years.

In a recent study,[25] fMRI reveals structural changes at neuronal level due to exposure to a solvent. This could explain the inferior performance (memory and attention) of the exposed group. More research of objective measures of neurobehavioral function is thus essential, for providing further evidence, which may be used in setting standards for safe levels of exposure to neurotoxic chemicals in the workplace. Furthermore, use of more sophisticated equipment seems necessary in future studies for the early diagnosis of the psychomotor effects of the solvents on workers without any symptoms.

One of the limitations of our study was the likelihood of a biased choice of subjects, *ie*, the workers with diagnosed symptoms that have left the company prior to our study. Another limitation was that the test was not blinded enough. Therefore, it is possible that the subjects in the exposed group wanted to overstate the hardship of their working environment in doing the tests, either deliberately or unintentionally, that might have changed the results of their psychomotor tests.

In conclusion, occupational exposure to organic solvents can induce subtle neurobehavioral changes among the exposed workers. Therefore, periodical evaluation of the sign of involvement of the central nervous system by objective psychomotor test is recommended. We found that NCTB tests were successful in early detection of the signs. Considering the fact that these tests are simple and inexpensive, and that failure to early diagnosis of these symptoms could result in irreversible memory problems and difficulties in hand-eye coordination, we suggest including this battery of tests to the periodical occupational health surveillances of workers chronically exposed to organic solvents.

Conflicts of Interest: None declared.

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