The Effects of Solvent Exposure on Memory and Motor Dexterity in Working Children

Basema Saddik, MPH[a,b,c]
Ann Williamson, PhD[d]
Iman Nuwayhid, MD, DrPH[b]
Deborah Black, MStat, PhD[c]

SYNOPSIS

Objectives. Children working in vehicle spray-painting, mechanical, and other trade workshops are at significant risk of exposure to organic solvents and, as a result, may be at significant risk of developing clinical and subclinical signs of neurotoxicity. This study reports on the association between exposure to solvents and neurobehavioral performance on a number of non-computerized tests for working children exposed to solvents in comparison with nonexposed working children and nonexposed children at school.

Methods. A convenience cross-sectional sample of 300 male children aged 10–17 years was recruited for study. The exposed working group and the two nonexposed groups (working and nonworking school) were matched, as far as possible, on geographic location of residence and age. Neurotoxic effects were assessed through a questionnaire and the child's performance on a selection of neurobehavioral tests.

Results. Exposed working children scored worse on the overall neurotoxicity symptoms score (mean=6.8; standard deviation [SD]=3.6) compared with the nonexposed working children (mean=1.3; SD=2.0) and school children (mean=1.2; SD=1.8). Analysis of the non-computerized neurobehavioral tests demonstrated that exposed working children performed significantly worse than the two nonexposed groups on the motor dexterity and memory tests. Results of the mood test showed that exposed working children were more angry and confused than the nonexposed groups.

Conclusion. There is an association between exposure to solvents and lower neurobehavioral performance, with significant neurobehavioral deficits among children exposed to solvents in comparison with working children not exposed to solvents and nonworking school children. Memory and motor dexterity appear to be particularly affected in solvent-exposed working children.

[a]School of Health Information Management, Faculty of Health Sciences, The University of Sydney, Sydney, Australia
[b]Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon
[c]School of Public Health and Community Medicine, The University of New South Wales, Sydney, Australia
[d]NSW Injury Risk Management Research Centre, The University of New South Wales, Sydney, Australia
Address correspondence to: Basema Saddik, MPH, School of Health Information Management, Faculty of Health Sciences, Univ. of Sydney, P.O. Box 170, Lidcombe NSW 1825, Australia; tel. 61-2-9351-9193; fax 61-2-9351-9672 ; e-mail <b.saddik@fhs.usyd.edu.au>.
©2005 Association of Schools of Public Health

Child labor is a social problem in Lebanon, especially in the underserved urban neighborhoods of the major cities and in rural areas.[1] This phenomenon is attributed to poverty, loss of or injury to parents during the civil war, low educational status of parents, lack of recreational activities for children, divorce, and loss of work opportunities for parents. In addition, an increasing number of students are leaving their schools for economic reasons or lack of interest.[2] A report indicates that, in spite of several national laws and international agreements that ban child labor, more than 40,000 children younger than 18 years of age are active participants of the labor force in Lebanon—comprising 4.6% of the total work force.[1] Most of the 10- to 14-year-old working children are full-time paid workers and the majority of males are employed in metal works, handicrafts, and artisan production.[3,4] Children working in mechanical and other trade workshops are at significant risk of exposure to organic solvents and, as a result, may be at significant risk of developing clinical and subclinical signs of neurotoxicity.

Previous studies have investigated the magnitude of developmental neurotoxicity and the effects on children of environmental exposure to lead,[5–7] methylmercury,[8–10] pesticides,[11,12] and other toxins. To our knowledge, there have been no published studies that have investigated the association between neurotoxicity and solvent exposure of children in the workplace. Research on solvent exposure among children is still limited to glue sniffers and solvent abusers, who often have other confounders, such as alcohol use and malnutrition.[13] However, exposure to solvents has been associated with several neurobehavioral effects among working adults, such as loss of dexterity, delayed reaction time, lack of concentration, and loss of memory.[14] One study specifically reports neurotoxic signs in visual attention, perceptual speed, and memory functions in paint manufacturing workers exposed to low-level organic solvents.[15] Many studies have shown clear dose-effect relations between the degree of exposure and the magnitude of the associated neurobehavioral deficits.[16] Paint manufacturing workers, chronically exposed to mixed solvents at levels less than the recommended threshold limit value, have been reported to exhibit poorer neurobehavioral performance and diminished digital sensitivity to vibration.[17] Similarly, another study compared a group of Korean painters exposed to a mixture of solvents to nonexposed controls.[18] Solvent workers performed significantly more poorly than controls on the Benton Visual Retention (BVR) test, digit symbol test, and the Santa Ana Dexterity Test.[18] However, when adjusted for age, alcohol intake, and smoking, only the BVR remained significant.[18]

In an earlier article, present author Saddik and colleagues reported from findings in Lebanon that working children exposed to solvents performed worse than the nonexposed groups (working and nonworking school) on reaction speed for the choice reaction time, symbol-digit, and dual task tracking tests; however, accuracy of performance was not affected on these tests.[19] Children in the exposed working group also complained of more headaches, loss of concentration, memory deficits, and higher irritability. This article reports further analyses from the same study and examines the effect of exposure to solvents on neurobehavioral performance, specifically on measures of attention, memory, mood, and complex motor and cognitive function from the Neurobehavioral Core Test Battery (NCTB).[20] The effect will be assessed for working children exposed to solvents in vehicle spray painting, mechanical, and furniture painting workshops compared with groups of nonexposed working children and nonexposed nonworking school children.

METHODS

Subject selection

A total of 300 male children aged 10–17 years were recruited to this convenience cross-sectional study. The study sample consisted of 100 working children exposed to organic solvents at work (the exposed subject group), 100 working children not exposed to organic solvents at work (the positive control group), and 100 nonworking school children (the negative control group). Children were recruited to the study by means of walk-through surveys within the cluster of industrial areas of the city of Tripoli and its environs in North Lebanon. These areas are known for their small industrial establishments and the relatively high rates of working children.

Children working in places with potentially high exposures to solvents were identified during the walk-throughs and approached at work. The high exposure places consisted of automotive spray painting, mechanical repair, and furniture painting workshops. During initial contact at the workplace, the objectives of the study were explained to each child and to the child's employer. After securing the consent of the child and his employer, the child was visited at home where the consent of the guardian also was obtained. Similarly, the nonexposed working children were selected by means of walk-through surveys. The workplaces approached for this group were in the vicinity of those from which the exposed group was recruited, but these places were without the potential for exposure to solvents. They included barbershops, butcheries, and retail convenience stores. The nonworking school children were recruited from the residential neighborhoods of the working children. Because of the nature of the workplaces selected for this study, all working children in the study were male, and since gender matching was required, all the school children controls were also male. The three groups of children were frequency matched, as far as possible, on age and area of residence.

Data collection

Questionnaire. Each child was interviewed at home in the presence of his parents using a standardized questionnaire. General sociodemographic data were collected, as well as information on the work history and social habits of the child. General health and neurotoxic symptoms also were recorded. Because the questionnaire was interviewer-administered, the child was prompted rigorously regarding the type of work he did, actual tasks he performed, and any other information that would help determine his levels of exposure to solvents. The neurotoxic symptom questions were derived from the Swedish Q16 Neurotoxic questionnaire developed to monitor effects on the central nervous system among workers exposed to solvents.[21] This questionnaire contains 16 short questions with yes or no response alternatives on symptoms commonly described by workers

exposed to solvents.[22] For the purposes of this study, these questions were modified to make them more applicable and comprehensible to children. Specifically, the questions on changes in sex life were deleted and questions pertinent to an illiterate population were added. These questions included items such as, "Do you understand meanings of things watched on TV?" In the end, a total of 17 questions were asked. A neurotoxicity score was developed for each child by adding up the number of positive responses to the 17 symptoms (range: 0 to 17).

Neurobehavioral tests. A set of neurobehavioral tests was selected for the study from a number of different test batteries previously used in other studies. Particular emphasis was placed on the selection of performance (rather than verbal) tests that were specifically developed or tailored for a non-English-speaking and illiterate population in an attempt to reduce the effect of cultural differences on test performance. Tests also were selected on the basis that they assessed specific neurobehavioral functional domains and modalities that have been shown to be affected by solvents in previous studies. The selected tests included computerized and manual non-computerized tests. We reported on the computerized tests in a previous article.[19] This article will report on the non-computerized tests from the NCTB, specifically tests of mood (Profile of Mood States [POMS]), manual dexterity (grooved pegboard), and short-term memory and attention (Wechsler Intelligence Scale for Children–Revised [WISC-R] Digit Span).[20] In addition, the Draw a Person (DAP) test was used in an attempt to estimate complex cognitive function or intelligence and to obtain an indicator of premorbid intellectual abilities.[23] Details of these tests are briefly described below.

The Profile of Mood States (POMS) test. This is a non-verbal analogue profile of mood test used to determine the mood of the child. This test has been previously used on children to assess mood states.[8] Cartoon pictures of faces portraying various mood states (happy, tired, afraid, angry, energetic, sad, confused, and tense) were presented with a nonverbal response scale consisting of a horizontal 10 centimetre (cm) line between the neutral face and the one portraying a mood state. In the original test, a vertical line was used and the cartoon faces were on the bottom and top of the page.[8] Following a pilot study conducted using this test, the vertical line was changed to a horizontal line of the same measurement with the faces on the right and left hand sides of the page. In this test, the child was asked to indicate on the scale how they felt as they were presented with the eight stimuli (mood states). The score for each stimulus is the distance in cm from the neutral face. Two composite scores were computed for the two positive (happy, energetic) and the remaining six negative feelings.

Draw a Person (DAP) test. The DAP test was used in this study because it is a nonverbal, nonintrusive, and easy to administer estimate of intelligence with inherent appeal to most children.[23,24] The children were asked to draw pictures of a man, a woman, and then themselves. To draw each picture, they were given five minutes—or less, if they felt that they had nothing else to add to the picture. A separate page was used for each picture drawn. To test inter-rater reliability, each picture was evaluated by three scorers for content and complexity, and scored using cognitive criteria identified in the test manual.[23] In this system, 14 features (arms, attachment, clothing, ears, eyes, feet, fingers, hair, head, legs, mouth, neck, nose, and trunk) are rated on scales that range from 0 to a maximum of 3, 4, 5, or 7 points. Raw scores were converted to standard scores and age-equivalent scores using tables for individual drawings supplied in the test manual.[23] DAP standard scores from only one scorer were used in the data analyses because no significant differences were found among the three scorers.

Grooved pegboard. In this test, the child was presented with small pegs with grooves on one side and a board with holes. The child was asked to fill the holes in the board with the pegs as quickly as possible using only one hand to pick up, rotate, and fill the holes in a structured manner (left to right or right to left, depending on the hand used). The dominant hand was used first and then the non-dominant hand. A total of 25 pegs filled the board. The child's time for each hand was recorded.

Wechsler Intelligence Scale for Children—Revised (WISC-R) Digit Span. In this test, a series of digit spans of increasing length starting from a combination of two numbers between one and nine were presented to the children verbally in Arabic. The task of the child was to repeat the sequences in the same order as they were given in the digits forward test and in the reverse order they were given in the digits backward test. The trial was discontinued when the child failed both sequences of the same length (for example, if both sequences of five digits were failed). The score was the total number of correct trials.

Procedure

The interviewing and testing components of the study were carried out on separate days. Parental consent and administration of the questionnaire were done on the first visit, followed by neurobehavioral testing on the subsequent visit. All the children were tested at home and were introduced to the non-computerized tests, followed by the computerized tests. The test session took approximately 40 to 45 minutes; in most cases, the parents were present during the testing of the child. A thorough verbal introduction was given at the beginning of testing. The POMS test was administered, followed by the DAP test, the grooved pegboard test, and the verbal WISC-R Digit Span. The sequence of testing was the same for all children in the study, regardless of exposure status.

Data analysis

We compared sociodemographic characteristics, personal habits, occupation, neurotoxicity score, and neurobehavioral performance among the three groups of children. Data were analysed using SPSS Version 11 for windows.[25] One-way analysis of variance (ANOVA) using Bonferroni post-hoc tests, *t*-tests, and chi-square analysis were used to test for statistical significance, set α at 0.05, for both continuous and categorical variables. A Bonferroni adjustment was used where multiple tests were done. For example, if eight comparisons were made, the alpha level was reduced to 0.006 for each

test. We used one-way analysis of co-variance to adjust for variables that showed statistically significant differences among the three groups of children, namely, child's age, education, parental education, smoking, coffee drinking, substance sniffing, and head injury with loss of consciousness less than 15 minutes.

RESULTS

Table 1 compares the sociodemographic, work, and health characteristics of the three groups of children. Nonworking school children were slightly younger in age than the other two groups, and the nonexposed working children and their parents had a lower education level than the exposed working and nonworking school children and their parents. None of the children reported that they drank alcohol, but the working children reported a higher frequency of smoking (p=0.02), coffee drinking (p=0.005), and substance sniffing (p=0.004) than the nonworking school children. No differences were found among the three groups of children regarding their reports of chronic health problems. The exposed working children reported on average working 1.3 years longer than the nonexposed working children and were significantly younger than the nonexposed working children when they started work.

During the walk-through surveys, children were found to be working in very poor hygienic conditions and performing the same duties as adults with no protective or safety measures in place. The solvents that were identified from the walk-through surveys included benzene, xylene, toluene, hexane, styrene, and methyl ethyl ketone.

Table 2 shows that exposed working children scored significantly higher on the neurotoxicity score compared with the two other groups, both before and after adjusting for

Table 1. General characteristics of the 300 exposed and nonexposed children

	Working exposed to solvents (n=100)	*Working not exposed to solvents (n=100)*	*School children (n=100)*	p *value*[a]
Demographic				
Age of child (years)				
9–14	50	39	52	
15–17	50	61	48	
Mean (SD)	14.5 (1.6)	14.7 (1.6)	14.0 (2.0)	0.021
Years at school				
Mean (SD)	3.8 (1.9)	6.3 (1.9)	7.6 (2.5)	<0.001
Education of father in years				
Mean (SD)	3.4 (2.8)	5.3 (3.4)	5.7 (4.0)	<0.001
Education of mother in years				
Mean (SD)	2.8 (2.9)	5.2 (3.8)	6.2 (4.0)	<0.001
Work history				
Current work				
Spray painter	45	—	—	
Mechanic	32	—	—	
Furniture painter	23	—	—	
Barber	—	90	—	
Butcher/Baker/Other	—	10	—	
Years at work				
Mean (SD)	3.7 (2.0)	2.4 (1.5)	—	<0.001
Age started work				
Mean years (SD)	10.8 (2.2)	12.3 (1.7)	—	<0.001
Social habits				
Current smoker	10	6	1	0.022
Intake of alcohol	0	0	0	NS
Intake of coffee	13	8	1	0.005
Substance sniffing	7	1	0	NS
Health conditions				
Peripheral vascular disease, central nervous system disorder, psychiatric illness, diabetes mellitus	0	0	0	—
Head injury with loss of consciousness <15 minutes	5	1	0	NS

[a]Values determined using one-way ANOVA and t-tests for continuous variables, and chi-square analysis for categorical variables; values significant at $p<0.05$.

SD = standard deviation

NS = not significant

Table 2. Comparison of scores on the neurotoxicity symptoms questionnaire

	Working exposed	*Working nonexposed*	*School children*	*Unadjusted analysis*[a]		*Analysis adjusted for potential confounding variables*[b]	
	Mean (SD)	*Mean (SD)*	*Mean (SD)*	F	*p-value*	F	*p-value*
Total neurotoxic symptoms	6.8 (3.6)	1.3 (2.0)	1.2 (1.8)	148.79	<0.001	55.09	<0.001

[a]Using ANOVA and significant at $p<0.01$

[b]Controlling for child's age, education, parental education, smoking, coffee drinking, substance sniffing, and head injury using ANCOVA

SD = standard deviation

potential confounders or child's age, education, parental education, smoking, coffee drinking, substance sniffing, and head injury.

Table 3 compares neurobehavioral performance on the non-computerized tests across the three groups. The multiple comparisons and alpha level for each test were set at $p<0.003$. Educational level was a possible confounder for performance on these tests, given the significant differences in levels of education among the groups. Analysis using general linear models (ANOVA and ANCOVA) was undertaken, first with only group as a fixed factor, then again with age, educational level, parental education, smoking, coffee

Table 3. Performance on non-computerized neurobehavioral tests amongst the three groups

	Working exposed	*Working nonexposed*	*School children*	*Unadjusted analysis*[c]		*Analysis adjusted for potential confounding variables*[d]	
	Mean (SD)	*Mean (SD)*	*Mean (SD)*	F	*p-value*	F	*p-value*
Digit span—(WISC-R)							
Forward	6.53 (1.5)[a]	7.96 (1.4)	8.18 (1.7)	34.46	<0.001	11.07	<0.001
Backward	3.56 (1.3)[a]	4.41 (1.4)	4.73 (1.6)	17.07	<0.001	2.25	0.108
Total	10.08 (2.16)[a]	12.36 (2.4)	12.9 (2.9)	35.08	<0.001	8.49	<0.001
Grooved pegboard							
Dominant hand	85.76 (17.0)[a]	70.58 (11.7)	71.31 (10.6)	40.38	<0.001	26.07	<0.001
Non-dominant hand	93.61 (22.9)[a]	76.01 (11.9)	78.60 (14.2)	31.01	<0.001	16.89	<0.001
Profile of Mood States							
Happy	68.60 (31.0)	75.90 (24.5)	79.40 (25.9)[b]	4.00	=0.019	0.37	0.692
Not sad	80.05 (25.7)	78.80 (25.9)	86.61 (24.8)	2.72	=0.068	2.30	0.103
Energetic	79.44 (25.2)	79.73 (21.9)	90.65 (19.8)[b]	8.10	<0.001	5.90	0.003
Not tired	74.38 (29.2)	76.68 (26.3)	90.38 (20.7)[b]	11.34	<0.001	4.33	0.014
Not angry	74.55 (22.2)[a]	84.42 (22.6)	88.58 (22.3)	10.22	<0.001	6.19	0.002
Not confused	76.93 (20.9)[a]	88.18 (20.3)	91.29 (18.0)	14.38	<0.001	7.57	0.001
Not afraid	90.46 (17.9)	90.75 (16.2)	92.22 (18.6)	0.28	0.753	0.13	0.876
Not tense	84.99 (26.7)	85.07 (23.3)	86.09 (26.4)	0.06	0.944	2.47	0.087
Draw-a-Person Test							
Man	84.82 (17.8)[a]	94.41 (15.7)	94.50 (15.3)	11.38	<0.001	1.79	0.168
Woman	85.01 (16.8)[a]	93.22 (15.9)	92.82 (14.5)	8.47	<0.001	2.07	0.128
Self	87.24 (18.2)[a]	95.94 (15.8)	96.86 (15.2)	10.24	<0.001	1.19	0.305
Total	82.60 (19.6)[a]	92.54 (16.8)	93.33 (16.7)	11.17	<0.001	1.68	0.189

[a]Bonferroni post-hoc test concludes statistically significant difference between mean of working exposed group and working nonexposed and between working exposed group and school children at $p<0.003$ value.

[b]Bonferroni post-hoc test concludes statistically significant difference between mean of school children and working children (exposed and nonexposed) at $p<0.003$ value.

[c]Using ANOVA

[d]Controlling for child's age, education, parental education, smoking, coffee drinking, substance sniffing, and head injury using ANCOVA

SD = standard deviation

WISC-R = Wechsler Intelligence Scale for Children—Revised

drinking, substance sniffing, and head injury as covariates. Significant differences were found in performance on the DAP, grooved pegboard, and Digit Span tests in the crude unadjusted analysis, indicating lower overall complex cognitive function or intelligence, slower motor coordination, and less attention and/or poorer memory. Controlling for age, educational level, parental education, smoking, coffee drinking, substance sniffing, and head injury as covariates, differences remained significant in all tests except for the WISC-R Digit Span backward and DAP tests. As for the POMS test, exposed working children showed adverse effects compared with nonworking school children and compared with nonexposed working children for some mood states. The exposed working children reported being angrier and more confused than nonexposed working and nonworking school children, suggesting a role for solvent exposure in this effect. Interestingly, both working groups reported being less happy, less energetic, and more tired than nonworking school children, indicating that working itself had an adverse effect on children. The findings did not change after controlling for covariates, except that the significant effect of feeling less happy and more tired, found for the working children, disappeared.

DISCUSSION

The results of this study strongly suggest that children who were working in occupations where they were exposed to solvents had significantly poorer neurobehavioral functions compared with nonworking children and, most importantly, also compared with nonexposed working children. Analysis of the non-computerized neurobehavioral tests has confirmed that there is an association between exposure to solvents and poorer neurobehavioral performance. Memory and motor-dexterity appear to be particularly affected in solvent-exposed working children even when differences in age, educational level of the child and parents, and other potential confounders of performance functions (smoking, coffee drinking, substance sniffing, and head injury) were accounted for statistically.

The exposed working group reported around six times the number of neurotoxic symptoms compared with both the nonexposed working and nonworking school children. Previous studies of the effects of solvent exposure have also shown higher reporting of subjective neurotoxic symptoms.[26,27] The previous report on the results of this study examined which of the individual neurotoxic symptoms were experienced by exposed working children and showed that not all symptoms were effected, but higher reports of feeling lightheaded, difficulty concentrating, higher irritability, and headaches differentiated working exposed children from the other nonexposed groups.[19] This specific pattern of effects also is consistent with the previous studies of neurotoxic symptoms and solvent exposure. Furthermore, the findings of this study on mood effects further suggest a role for solvent exposure in this effect, particularly when more reports of anger and confusion in working exposed children are consistent with other studies on mood states and solvent exposure.[28]

Although there are few studies of solvent toxicity in children assessed by neurobehavioral tests, previous studies have reported and assessed occupational solvent exposure in adults that have shown effects on memory, attention, and motor dexterity.[18,29–30] These functions also were clearly affected in this study. Furthermore, the nature and magnitude of the effects on performance in the exposed working children are of statistical and practical significance. Solvent-exposed children showed roughly a 20% slowing in hand-eye coordination (grooved pegboard) and in the capacity to remember new information (WISC-R Digit Span forward and total) compared with nonexposed children, whether they were working or not. These effects are likely to have implications for the capacity of the exposed children to respond to new demands and to learn new information. For the DAP test, exposed working children showed significantly poorer performance, although the effect disappeared when the analysis was adjusted for potential confounders. This indicates that the lower performance of exposed working children on this test was due to factors other than exposure.

The consistency of these results with patterns found in previous studies of solvent exposure and the fact that they persist after controlling for some of the common potential confounders of performance on neurobehavioral tests also strongly suggest that these neurobehavioral deficits may be due to solvent exposure. A causal link between solvent exposure and neurobehavioral deficits is plausible, considering the findings of this study and those of others who have reported similar effects on the nervous system.[31,32] Longitudinal research with careful assessment of solvent exposure and neurobehavioral function is necessary to clarify the nature of the relationship between solvent exposure and neurobehavioral deficits.

Certainly, the results are clearer than those found in many studies of solvent exposure in adult working populations, where no association has been found between solvent exposure and neurobehavioral deficits. A study in Australia found no significant changes in neurobehavioral function in the first two years of exposure to solvents in apprentice car spray painters.[33] Likewise, another study found no solvent-associated effects on the nervous system in currently employed painters.[34] This may be due to the higher vulnerability to solvent exposure in these very young workers compared with older adolescence and adults, or perhaps the level of exposure in this study is much higher than that seen in other studies.

CONCLUSIONS

Overall, the results of this study indicate that, in Lebanon, children working in areas exposed to solvents are at greater risk for serious health problems than those children who work in nonexposed areas. The findings in this study suggest that urgent action needs to be taken to address the effect of exposure in this group to prevent further deterioration in performance.

The authors would like to express their gratitude to the International Labour Organization–Beirut office, and the American University of Beirut Research Board for funding of this project. We would also like to acknowledge the assistance and invaluable contributions made by all the people involved in the data collection phase of this study. Our deepest appreciation and gratitude is extended to the children who participated in this study, their families, and employers.

REFERENCES

1. Issa N, Houry M. Characteristics of child labor in Lebanon. Report. Lebanon: Ministry of Social Affairs and UNICEF; 1998.
2. Nuwayhid I, Saddik B, Quba'a R. Working children in small industrial establishments in Tripoli and Akkar—Lebanon: their work environment and work activities. Proceedings of the International Programme for the Elimination of Child Labour (IPEC) at the International Labour Organization; 2001 Nov; Geneva, Switzerland.
3. CAS (Central Administration for Statistics, UNICEF). State of the children in Lebanon, 2000. Beirut: CAS and UNICEF; 2002.
4. Hamdan H. National report on child labour in Lebanon. Beirut: International Programme for the Elimination of Child Labour (IPEC) and Ministry of Labour (MOL); 1997.
5. Counter SA, Buchanan LH, Rosas HD, Ortega F. Neurocognitive effects of chronic lead intoxication in Andean children. J Neurol Sci 1998;160:47-53.
6. Dietrich KN, Berger OG, Succop P. Lead exposure and the motor developmental status of urban six-year-old children in the Cincinnati Prospective Study. Pediatrics 1993;91:301-7.
7. Walkowiak J, Altmann L, Kramer U, Sveinsson K, Turfeld M, Weishoff-Houben M, Winneke G. Cognitive and sensorimotor functions in 6-year-old children in relation to lead and mercury levels: adjustment for intelligence and contrast sensitivity in computerized testing. Neurotoxicol Teratol 1998;20:511-21.
8. Grandjean P, Weihe P, White RF, Debes F, Araki S, Yokoyama K, et al. Cognitive deficit in 7-year-old children with prenatal exposure to methlymercury. Neurotoxicol Teratol 1997;19:417-28.
9. Grandjean P, Weihe P, White RF, Debes F. Cognitive performance of children prenatally exposed to "safe" levels of methylmercury. Environ Res 1998;77:165-72.
10. Cordier S, Garel M, Mandereau L, Morcel H, Doineau P, Gosme-Seguret S, et al. Neurodevelopmental investigations among methylmercury-exposed children in French Guiana. Environ Res 2002; 89:1-11.
11. Zeitz P, Kakolewski K, Imtiaz R, Kaye W. Methods of assessing neurobehavioral development in children exposed to methyl parathion in Mississippi and Ohio. Environ Health Perspect 2002;110 Suppl 6:1079-83.
12. Stokes L, Stark A, Marshall E, Narang A. Neurotoxicity among pesticide applicators exposed to organophosphates. Occup Environ Med 1995;52:648-53.
13. Dittmer DK, Jhamandas JH, Johnson ES. Glue-sniffing neuropathies. Can Fam Physician 1993;39:1965-71.
14. Xiao JQ, Levin SM. The diagnosis and management of solvent-related disorders. Am J Ind Med 2000;37:44-61.
15. Tsai SY, Chen JD, Chao WY, Wang JD. Neurobehavioural effects of occupational exposure to low-level organic solvents among Taiwanese workers in paint factories. Environ Res 1997;73:146-55.
16. White RF, Proctor SP. Solvents and neurotoxicity. Lancet 1997;349: 1239-43.
17. Bleeker ML, Bolla KI, Agnew J, Shwartz BS, Ford DP. Dose-related subclinical neurobehavioural effects of chronic exposure to low levels of organic solvents. Am J Ind Med 1991;19:715-28.
18. Lee SH, Lee SH. A study on the neurobehavioural effects of occupational exposure to organic solvents in Korean workers. Environ Res 1993;60:227-32.
19. Saddik B, Nuwayhid I, Williamson A, Black D. Evidence of neurotoxicity in working children in Lebanon. Neurotoxicology 2003;24: 733-9.
20. Office of Occupational Health, World Health Organization. Operational guide for the WHO NCTB. Geneva: WHO; 1986.
21. Högstedt C, Andersson K, Hane M. A questionnaire approach to the monitoring of early disturbances in central nervous function. In: Aitio A, Riihimäki A, Vainio H, editors. Biological monitoring and surveillance of workers exposed to chemicals. Washington: Hemisphere Publishing; 1984. p. 275-87.
22. Lundberg I, Högberg M, Michelsen H, Nise G, Högstedt C. Evaluation of the Q16 questionnaire on neurotoxic symptoms and a review of its use. Occup Environ Med 1997;54:343-50.
23. Naglieri JA. Draw-a-person: a quantitative scoring system. San Antonia: The Psychological Corporation; 1988.
24. Dykens E. The draw-a-person task in persons with mental retardation: what does it measure? Res Dev Disabil 1996;17:1-13.
25. SPSS, Inc. SPSS: Version 11.0. Chicago: SPSS, Inc.; 2001.
26. Wang JD, Chen JD. Acute and chronic neurological symptoms among paint workers exposed to mixtures of organic solvents. Environ Res 1993;61:107-16.
27. Bockelmann I., Darius S, McGauran N, Robra BP, Peter B, Pfister EA. The psychological effects of exposure to mixed organic solvents on car painters. Disabil Rehabil 2002;24:455-61.
28. Escalona E, Yanes L, Feo O, Maizlish N. Neurobehavioural evaluation of Venezuelan workers exposed to organic solvent mixtures. Am J Ind Med 1995;27:15-27.
29. White RF, Proctor SP, Escheverria D, Schweikert J, Feldman RG. Neurobehavioral effects of acute and chronic mixed solvent exposure in the screen printing industry. Am J Ind Med 1995;28:221-31.
30. Zhou W, Liang Y, Christiani DC. Utility of the WHO Neurobehavioral Core Test Battery in Chinese workers—a meta-analysis. Environ Res 2002;88:94-102.
31. Bolla KI, Schwartz BS, Stewart W, Rignani J, Agnew J, Ford DP. Comparison of neurobehavioral function in workers exposed to a mixture of organic and inorganic lead and in workers exposed to solvents. Am J Ind Med 1995;27:231-46.
32. Grosch JW, Neale AV, Demers RY. Neurobehavioral and health-related deficits in solvent-exposed painters. Am J Ind Med 1996;30: 623-32.
33. Williamson AM, Winder C. A prospective cohort study of the chronic effects of solvent exposure. Environ Res 1993;62:256-71.
34. Nasterlack M, Dietz MC, Frank KH, Hacke W, Scherg H, Schmittner H, et al. A multidisciplinary cross-sectional study on solvent-related health effects in painters compared with construction workers. Int Arch Occup Environ Health 1999;72:205-14.