

## EFFECTS OF FLUORIDE ON PSYCHOMOTOR PERFORMANCE AND MEMORY OF ALUMINUM POTROOM WORKERS

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**SUMMARY:** In this cross-sectional study, the psychomotor performance and memory skills of a fluoride-exposed group (FEG) of 64 male workers in an aluminum potroom were compared with those of 60 male workers in a nonfluoride-exposed group (NFEG). The FEG had a mean age of  $37.59 \pm 4.82$  yr and had been employed for  $13.06 \pm 4.29$  yr, which compared closely with the NFEG. Both groups were selected randomly and had no previous history of neuropsychological, hepatic, renal, or immune disorders. The neurobehavioural functions were measured using the World Health Organization neurobehavioural core test battery (NCTB), a computer based test, for reaction time, and a Purdue pegboard test for manual dexterity and hand-eye coordination. The FEG had significant impairments compared to the NFEG for mean reaction time, Purdue pegboard for the preferred hand and both hands, pursuit aiming, digit span, Benton Visual Retention ( $p < 0.001$ ), and digit symbol memory ( $p < 0.01$ ). The digit symbol performance scores, but not those for the other parameters, decreased with increased work duration ( $p < 0.05$ ). Overall, the mechanism for the impairments did not appear to be the result of impaired thyroid function. We conclude that neurobehavioural testing is useful for detecting impairment of psychomotor performance and memory that associated with occupational F exposure.

Keywords: Aluminum production; Arak, Iran; Industrial fluoride exposure; Memory ability; Neurobehavioural core test battery; Potroom workers; Psychomotor performance.

### INTRODUCTION

Gaseous and particulate fluoride (F) emissions are released from the cryolite ( $\text{Na}_3\text{AlF}_6$ ) and fluorspar ( $\text{CaF}_2$ ) used to lower the temperature required for the electrolytic reduction of alumina ( $\text{Al}_2\text{O}_3$ ) in potrooms for the production of aluminum metal. Adverse health effects of F on skeletal, dental, and soft tissues resulting from biochemical changes, as reviewed in the 2006 US National Research Council (NRC) report, include lethargy and weakness as well as effects on memory, cognition, and IQ, which can affect persons of all ages.<sup>1-4</sup> Altered behaviour has also been recorded in rats following exposure to NaF in drinking water or by prenatal injection.<sup>5</sup> A study in China found neurobehavioural and mood changes in aluminum potroom workers with both short ( $\leq 5$  yr) and long-term ( $> 5$  yr) occupational exposure to F emissions.<sup>6</sup>

The present investigation, the first such neurobehavioural study related to exposure to F to be done in Iran, follows our two previous studies done on calcium, parathyroid hormone, and thyroid hormone levels on workers at this plant and was undertaken because of the importance of using screening methods for the

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early detection of such changes following occupational exposure to hazardous neurotoxins.<sup>7,8</sup>

### MATERIALS AND METHODS

In this cross-sectional study, several neurobehavioural assessments were made on a F-exposed group (FEG) consisting of 64 male aluminum potroom workers, in Arak, Iran, randomly chosen from those referred to the factory clinic for an annual health evaluation. This group was compared with a non-F-exposed group (NFEG) of 60 men as controls selected randomly from workers at a factory producing truck-mounted cranes with no history of exposure to F or other neurotoxins. Data on health status were obtained by a self-administered questionnaire. None in the FEG or NFEG had a history of neuropsychological, hepatic, renal, or immune disorders, head trauma, prolonged sedative use, or of working on a night shift immediately prior to the examination. The two groups were also approximately matched for tobacco and alcohol use.

Apart from reaction time (RT) and manual dexterity, psychomotor performance and memory were measured using the World Health Organization (WHO) recommended neurobehavioural core test battery (NCTB) for such assessment in both the FEG and NFEG. Simple visual reaction time (RT) testing was measured with software designed on the basis of the WHO-NCTB guidelines. This test consisted of 64 trials over a period of six min with random interstimulus intervals of one to ten sec. Manual dexterity and hand-eye coordination were assessed by the Purdue pegboard test, which involved three trials with: a) the preferred hand, b) the non-preferred hand, and c) both hands.

Preshift urine samples were taken from the FEG, and urinary F was measured with an ion selective electrode and urinary creatinine by a Jaffe kit supplied by Pars Azmon, Iran. The psychomotor and memory test results were normalized, and SPSS 13.0 was used for statistical analysis. The intercorrelation coefficient matrices, ranging from 0.26 to 0.64 for the FEG and from 0.33 to 0.92 for the NFEG, indicated a high degree of validity for the tests.

### RESULTS

Means for age, work duration, body mass index (BMI), and urine F/creatinine of the FEG and NFEG are shown in Table 1.

**Table 1.** Age, work duration, BMI, and urine F/creatinine of the FEG and NFEG (values are mean±SD)

| Group | Age (yr)   | Work duration (yr) | BMI (kg/m <sup>2</sup> ) | Urine F/creatinine (mg/g) |
|-------|------------|--------------------|--------------------------|---------------------------|
| FEG   | 37.59±4.82 | 13.06±4.29         | 26.28±4.44               | 4.27±2.42 <sup>*</sup>    |
| NFEG  | 37.71±5.22 | 12.65±5.49         | 25.35±3.05               | 1.2±0.53                  |

<sup>\*</sup>p<0.001 compared with NFEG.

As seen in Table 2, the means of the psychomotor and memory scores of the two groups were significantly different. In all the tests, the performance of the FEG was clearly diminished compared to the NFEG.

**Table 2.** Comparison of psychomotor and memory results between the FEG and NFEG (mean  $\pm$ SD)

| Test                             | FEG<br>(n=64)                   | NFEG<br>(n=60)     |
|----------------------------------|---------------------------------|--------------------|
| Digit symbol                     | 38.04 $\pm$ 10.35 <sup>†</sup>  | 43.79 $\pm$ 12.35  |
| Mean RT (reaction time)          | 313.82 $\pm$ 58.64 <sup>†</sup> | 270.89 $\pm$ 34.52 |
| Purdue Peg board, preferred hand | 10.45 $\pm$ 1.36 <sup>†</sup>   | 11.56 $\pm$ 1.53   |
| Purdue Peg board, both hands     | 8.96 $\pm$ 1.29 <sup>†</sup>    | 10.06 $\pm$ 1.17   |
| Pursuit Aiming                   | 107.37 $\pm$ 16.92 <sup>†</sup> | 121.74 $\pm$ 21.66 |
| Digit span                       | 9.03 $\pm$ 2.64 <sup>†</sup>    | 10.53 $\pm$ 2.38   |
| Benton Visual Retention          | 6.68 $\pm$ 1.50 <sup>†</sup>    | 8.45 $\pm$ 1.11    |

<sup>†</sup>p< 0.01; <sup>††</sup>p< 0.001 compared with NFEG.

As seen in Table 3, psychomotor and memory scores were not significantly correlated with age and urinary F/g creatinine. Work duration in the FEG was significantly associated with the digit symbol test but not with any other psychomotor and memory scores.

**Table 3.** Correlation coefficients of psychomotor and memory scores in the FEG with age, duration of work, and urinary F/g creatinine

| Test                            | Age<br>(yr) | Duration of work<br>(yr) | Urinary F/g<br>creatinine<br>(mg/g) |
|---------------------------------|-------------|--------------------------|-------------------------------------|
| Digit symbol                    | -0.21       | -0.25 <sup>*</sup>       | 0.03                                |
| Reaction time (RT)              | -0.01       | -0.01                    | -0.02                               |
| Purdue Pegboard, preferred hand | -0.2        | -0.23                    | -0.15                               |
| Purdue Pegboard, both hands     | -0.05       | -0.15                    | -0.16                               |
| Pursuit Aiming                  | -0.02       | -0.1                     | -0.07                               |
| Digit span                      | -0.07       | -0.07                    | -0.01                               |
| Benton Visual Retention         | -0.11       | -0.14                    | -0.22                               |

\*p<0.05.

## DISCUSSION

In recent years the toxicity of F on the nervous system has received increased attention. Persons living in areas of endemic F poisoning have been found to have central nervous system deficits including poor memory, fatigue, headaches, insomnia, polyuria, and polydipsia.<sup>1,9</sup> In the present study, significant differences were found between the FEG and the NFEG in the results from psychomotor and memory testing, particularly for attention, auditory, and visual retention, and for physical dexterity. These findings suggest that occupational exposure to F has harmful effects on the functions of the central nervous system and can negatively affect both cognitive and psychomotor functions.

Whereas in a previous study of aluminum potroom workers in China by Guo et al., the FEG was compared to a NFEG of employees from service departments of the plant,<sup>6</sup> in the present study the FEG comprised workers from a potroom, and the NFEG was employed at a truck-mounted crane factory. In the Guo et al. study there was diminished performance in the FEG for all the NCTB tests apart from the Benton Visual Retention Measurement. In the present study, the results for the FEG showed impairment for all the NCTB parameters including the Benton Visual Retention Measurement.

In our study the score for the Digit Symbol test, a subtest of the Wechsler Adult Intelligence Scale (WAIS), was found to be sensitive to global brain damage and decreased significantly as work duration increased. This negative relationship between work duration for the FEG and cognitive performance is consistent with the findings of Guo et al. that prolonged F exposure for more than five years was associated with increased neurobehavioural impairments.<sup>6</sup> The level of significance for the Digit Symbol test, when comparing the FEG and NFEG groups ( $p < 0.01$ ) was less than that found ( $p < 0.001$ ) for the other variables (Mean RT, Purdue Peg Board preferred hand and both hands, Pursuit Aiming, Digit Span, and Benton Visual Retention). Guo et al. also noted that the Digit Symbol test differed from the other parameters in the NCTB, apart from the Benton Visual Retention, in not being negatively correlated with the serum F.

As found here, psychomotor performance and memory were impaired in the FEG, but in one of our previous studies at this plant, only a minority, 5.2% of the 116 workers who were studied, exhibited evidence of thyroid dysfunction with the presence of subclinical hypothyroidism as indicated by thyroid stimulating hormone (TSH) levels above the new normal range of 0.3–3.0 mIU/L.<sup>8</sup> Thus, although F is known to produce thyroid dysfunction, the impairments of psychomotor performance and memory found in the present study were, for the most part, apparently not related to impaired thyroid function.

In summary, this study found that neurobehavioural testing can detect impairments in psychomotor performance that result from occupational F exposure.

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