ORIGINAL ARTICLE

Health and neuropsychological functioning of dentists exposed to mercury

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Objectives: A cross sectional survey of dentists in the west of Scotland and unmatched controls was conducted to find the effect of chronic exposure to mercury on health and cognitive functioning.
Methods: 180 dentists were asked to complete a questionnaire that included items on handling of amalgam, symptoms experienced, possible influences on psychomotor function, and the 12 item general health questionnaire. Dentists were asked to complete a dental chart of their own mouths and to give samples of urine, hair, and nails for mercury analysis. Environmental measurements of mercury in dentists' surgeries were made and participants undertook a package of computerised psychomotor tests. 180 control subjects underwent a similar procedure, completing a questionnaire, having their amalgam surfaces counted, giving urine, hair, and nail samples and undergoing the psychomotor test package.
Results: Dentists had, on average, urinary mercury concentrations over four times that of control subjects, but all but one dentist had urinary mercury below the Health and Safety Executive health guidance value. Dentists were significantly more likely than control subjects to have had disorders of the kidney and memory disturbance. These symptoms were not significantly associated with urinary mercury concentration. Differences were found between the psychomotor performance of dentists and controls after adjusting for age and sex, but there was no significant association between changes in psychomotor response and mercury concentrations in urine, hair, or nails.
Conclusions: Several differences in health and cognitive functioning between dentists and controls were found. These differences could not be directly attributed to their exposure to mercury. However, as similar health effects are known to be associated with mercury exposure, it would be appropriate to consider a system of health surveillance of dental staff with particular emphasis on symptoms associated with mercury toxicity where there is evidence of high levels of exposure to environmental mercury.

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The debate concerning the safety of dental amalgam as a dental filling material continues both in the United Kingdom and internationally. Mercury is known to have effects on the kidney and nervous system[1 2] and has been implicated in adverse effects on other systems including the immune system[3] and the female reproductive system.[4] Although many reports assert that the health risk from amalgam restorations is negligible for most dental personnel and patients,[5–7] other authors have maintained that the use of amalgam results in considerable adverse health effects.[8–11]

There have been considerable reductions in exposure to mercury among the dental profession in recent years.[12] These reductions are likely to have been the result of mercury screening programmes, the use of automated methods of amalgam preparation and improvements in mercury hygiene in dental surgeries.[13–16] However, several studies have shown that chronic exposure to low concentrations of mercury—such as those experienced by dentists—may have an effect on psychological performance.[9 10 17–19]

In a pilot study we established the suitability of a computerised package of psychomotor tests to determine possible low level effects of mercury on an exposed population.[20] The test system used has been developed by Cognitive Drug Research (CDR)[21 22] and has been widely used to measure the effect of drugs and illness on cognitive performance. This package of tests takes about 20 minutes to administer and is therefore appropriate for use in occupational settings.

The project reported here is a cross sectional study of 180 dentists and 180 control subjects who had biological samples taken for mercury analysis, undertook the CDR computerised package of tests, and in the case of the dentists had environmental mercury measurements taken at their place of work.

METHODS

Study population

Dentists

The list of registered dentists practising in four health boards areas in the West of Scotland was provided by the Dental Practice Division of the Common Services Agency. From this list an initial random sample of 20% of about 900 dentists in these health board areas was selected by means of the random sample facility within SPSS for Windows. Identified dentists were sent a letter of introduction including details of the research project and were subsequently contacted by telephone. Several dentists responded to an article in *Scottish Dentist* and volunteered to participate, and an additional group of other dentists who had heard of the project by word of mouth also volunteered to participate. In total 129 dentists (71.7%) were recruited by randomly sampling from the register and 51 dentists (28.3%) were self selected volunteers.

Controls

Control subjects, matched to dentists by academic ability were recruited from the staff of the University of Glasgow. Subjects

Abbreviations: CDR, cognitive drug research; OES, occupational exposure standard in the control group were invited to participate through an article published in the university newsletter and through email mailing lists of university employees and postgraduate students. Emails were targeted to those staff likely to meet the requirements of having a first degree and not to have been exposed to mercury on a regular basis.

Sample size
A sample of 180 dentists and 180 controls gives 90% power to detect a difference in mean reaction times between dentists and controls of about 20 ms for simple or choice reaction times, or a difference in mean number of words recalled of 0.7. For percentages reporting each symptom or condition, a difference of 5% versus 15% is detectable with 90% power. This sample size was the largest feasible, given the available resources.

Data collection
Dentists
On agreement to participate an appointment to visit the dentist at his or her surgery was made. Before the visit to the surgery, the dentist was sent a questionnaire for completion. The questionnaire requested information about amalgam preparation, mercury storage, and mercury spillages. Also, questions relating to other possible influences on psychomotor response—for example, alcohol intake, stress, and regularly taken medication—were included. The questionnaire also covered personal habits—such as the use of chewing gum and bruxism (non-functional tooth grinding). Dentists were asked to complete by self examination a dental chart for their own teeth to allow counting of the number of amalgam surfaces. The questionnaire also included the general health questionnaire version 12.

The level of exposure to mercury was assessed by three separate measures:

Urinary mercury analysis
Subjects were asked to provide a sample of urine on the day of the visit to the surgery for analysis of mercury concentration. Urinary mercury concentration gives an indication of the exposure to mercury over the previous 2–3 months. Samples were taken for analysis to the Biochemistry Department of Glasgow Royal Infirmary. Analysis was conducted by cold vapour atomic absorption spectroscopy and results expressed in relation to creatinine content to take into account the concentration of a person's urine.

Hair and nail mercury analysis
Subjects were asked for samples of head hair, pubic hair, finger nails, and toe nails. Hair and nail samples give an indication of long term exposure to mercury. Samples were sent for analysis at the Health and Safety Laboratory, Sheffield.

Environmental mercury concentration
The concentrations of mercury vapour in the dental surgeries were measured with a Jerome 431-X gold film mercury vapour analyzer and personal mercury dosimeter (worn as close as possible to the wearer's breathing zone, connected by tubing to a pump). During the visit to the dentist's surgery measurements were taken of airborne mercury concentrations present at eight areas within the surgery.

Psychomotor performance
Psychomotor performance was measured with a package of eight tests developed by CDR and described in our pilot study.[20] The test package took around 20 minutes to complete with results being recorded on floppy disks which were returned to CDR for analysis.

Controls
Control group volunteers were given an appointment to attend a centre on the university campus to undergo the psychomotor test battery. Before their visit, they were sent a questionnaire for completion similar to that of the dentists but excluding questions specifically relating to the use, storage, and spillage of amalgam. As well as undergoing the psychomotor test package subjects had the number of amalgam surfaces in their mouths counted by a dentist and were asked to provide samples of urine, hair, and nails for mercury analysis.

A database was created which comprised results of each of the biological and psychomotor tests and questionnaire responses together with environmental measurements of exposure to mercury where appropriate.

Statistical analyses
All of the biological mercury concentrations (for urine, hair, and nails) were highly positively skewed. However, a logarithmic transformation (base 10) resulted in an approximately normal distribution for each.

Two sample *t* tests were used to compare mean reaction times, mean word recall scores, and means of log transformed mercury concentrations between groups. The 95% confidence intervals (95% CIs) for the ratio of geometric mean mercury concentrations of dentists and controls were computed. χ^2 Tests were used to compare the percentages of dentists and controls who had various symptoms and disorders. Fisher's exact test was used when numbers were too small for χ^2 tests to be valid. Two tailed significance levels have been reported throughout.

Multiple logistic regression was used to examine the effect of job category (dentist or control) and urinary mercury concentration on the occurrence of various symptoms and disorders after adjusting for age and sex. Multiple linear regression was used to examine the effect of job category and urinary mercury concentration on reaction times and word recall scores after adjusting for age and sex.

The main outcome variables for comparison between dentists and controls as well as mercury concentrations were the reaction times, numbers of words recalled, and the prevalence of various conditions and symptoms. It is not possible to specify a primary outcome variable in each of these categories because although the pilot study indicated differences between groups for simple reaction time and immediate and delayed word recall, other studies have noted differences in other aspects of psychomotor functioning. Similarly, previous studies have found significant differences between exposed and unexposed groups in reporting of a range of conditions and symptoms. Because of this, a Bonferroni correction for multiple comparisons was applied separately to each of the groups of outcomes. Thus, p values in table 1 (conditions) were multiplied by 7, those in table 1 (symptoms) were multiplied by 8 and those in tables 4 and 5 (reaction times and word recall) were multiplied by 8. Both corrected and uncorrected p values are presented in the tables.[23]

RESULTS
Sample description
The total sample was made up of 180 dentists and 180 controls. Significantly more dentists than controls were men (60% and 47% respectively, $p=0.015$). The mean (SD, range) age of dentists was 39.3 (9.7, 23–62) years and of controls 32.1 (9.7, 21–63) years. The dentists were significantly older than the control subjects with the mean difference in age being 7.2 years ($p<0.001$, 95% CI 5.2 to 9.3). Where this difference in age has had an effect on a variable in the analyses this has been fully described.

Questionnaire results
Of the 180 in the sample 166 dentists completed and returned the questionnaire. Most completed all questions. Of the

Table 1 Number of dentists and controls indicating that they had had conditions and symptoms

	Dentists (n=170) n (%)	Controls (n=179) n (%)	p Value	Corrected p value
Conditions:				
Kidney disorders	11 (6.5)	1 (0.6)	0.004	0.028
Fertility problems	5 (3.0)	2 (1.1)	0.41	
Blood disorders	4 (2.4)	7 (3.9)	0.60	
Heart or lung disorders	10 (5.9)	14 (7.8)	0.62	
Liver disorders	4 (2.4)	3 (1.7)	0.94	
Immune system disorders	4 (2.4)	3 (1.7)	0.94	
Nervous system disorders	7 (4.1)	7 (3.9)	1.00	
Symptoms:				
Memory disturbance	44 (25.9)	17 (9.4)	<0.0001	<0.001
Loss of appetite	11 (6.5)	24 (13.3)	0.032	0.26
Tiredness	106 (62.4)	101 (56.1)	0.24	
Hand tremor	18 (10.6)	13 (7.2)	0.27	
Gastrointestinal disturbance	44 (25.9)	40 (22.2)	0.42	
Problems with sleeping	60 (35.3)	65 (36.1)	0.87	
Poor concentration	55 (32.4)	59 (32.8)	0.93	
Nervousness	38 (22.4)	40 (22.2)	0.98	

control subjects 179 completed and returned the questionnaire, again with most completing all questions.

The mean (SD, range) number of years of practice as a dentist was 15.6 (9.5, 0.5–39) years. The mean (SD, range) number of hours worked in the surgery was 32.8 (6.4, 6–43) hours/week. Dentists were asked to indicate how long the premises in which they worked had been used as a dental practice. Of the 167 dentists who provided this information, 47% stated that their premises had been used as a surgery for over 20 years.

Dentists and control subjects were asked to indicate if they had ever required medical treatment for several disorders. Responses are shown in table 1. Dentists were significantly more likely to have had kidney disorders than control subjects (6.5% *v* 0.6%). This difference remained significant after correction for multiple comparisons. This difference also remained significant ($p=0.01$) after using logistic regression to adjust for age and sex.

The effect of urinary mercury concentrations on reporting of kidney disorders was examined for dentists but not controls because of small numbers. In logistic regression urinary mercury concentration was not significantly associated with reporting of kidney problems ($p=0.47$) after adjusting for age and sex.

Both dentists and controls were asked several questions about specific symptoms that have been associated with exposure to mercury. Responses are shown in table 1. Controls were significantly more likely to report loss of appetite than dentists (13.3% *v* 6.5%). Dentists were significantly more likely to report memory disturbance than controls (25.9% *v* 9.4%). Only the effect on memory disturbance remained significant after correction for multiple comparisons. The effect of job on memory disturbance also remained significant ($p<0.001$) after adjusting for age and sex by logistic regression. There was an age effect on reported memory disturbance for dentists with older dentists reporting memory disturbance more often than younger dentists. This was not found among the control group. The effect of urinary mercury concentration on reporting of memory disturbance was examined for dentists and controls separately by logistic regression and was not significant after adjusting for age and sex for dentists ($p=0.36$) nor for controls ($p=0.09$).

There was no significant difference between the mean GHQ-12 scores of dentists and controls ($p=0.29$). Dentists had a mean (SD, range) score of 11 (4.0, 2–33) and controls 11.6 (5.1, 1–31).

Biological measurements

Urinary mercury analysis

Urine samples were obtained and tested for mercury concentration for 162 dentists and 163 controls. A summary of the results is shown in table 2.

There was a large and highly significant difference between urinary mercury concentrations of dentists and controls. The

Table 2 Mercury concentrations in urine, hair, and nails

	n	Mean	SD	Median	Minimum	Maximum
Urinary mercury (nmol Hg/mmol creatinine):						
Dentists	162	2.58	2.76	1.70	0.02	20.90
Controls	163	0.67	0.68	0.50	<0.01	4.20
Head hair (mass Hg/g):						
Dentists	161	1.00	0.77	0.80	0.10	5.67
Controls	161	0.57	0.48	0.47	0.04	3.86
Public hair (mass Hg/g):						
Dentists	167	0.88	1.00	0.69	0.09	11.71
Controls	168	0.46	0.36	0.37	0.03	2.54
Finger nail (mass Hg/g):						
Dentists	164	5.25	20.60	1.05	0.12	239.60
Controls	155	0.32	0.30	0.23	0.02	2.49
Toe nail (mass Hg/g):						
Dentists	163	0.71	1.38	0.38	0.20	14.74
Controls	155	0.24	0.19	0.18	0.02	1.22

Table 3 Environmental measurements of mercury in surgeries

Measurement area	Surgeries (n)	Time weighted average (µg/m³) Mean	SD	Median	Minimum	Maximum
Chair	180	28.9	32.0	16.3	0	236
Skirting	180	38.9	52.9	21.2	0	484
Mixing device	110	37.8	47.2	21.0	0	289
Capsule storage and preparation	43	15.2	19.0	10.3	0	122
Waste amalgam storage	163	10.7	8.2	8.3	0	47
Autoclave	66	11.7	9.0	8.7	0	56
Preparation area	179	10.4	9.6	8.0	0	89
Dosimeter	153	29.2	48.8	15.0	0	452
Air	112	6.5	3.8	5.7	1	24

geometric mean concentration of urinary mercury for dentists was 4.17 times that for the control group (95% CI 3.36 to 5.19). There was no significant difference in the mean urinary mercury concentration of randomly selected and self selected dental volunteers. The geometric mean urinary mercury of randomly selected dentists was 1.08 times that of volunteer dentists (95% CI 0.67 to 1.25).

Hair and nail mercury analysis

Hair and nail samples were obtained from both dentists and control subjects and analysed for mercury concentration. In some instances there was insufficient sample to allow analysis to be conducted. The number of samples for which results were obtainable together with the mass of mercury measured in µg/g are shown for each group in table 2.

For all measurements of hair and nails the dentist group had significantly higher mercury concentrations than the control group. The greatest difference was found in the finger-nail mercury concentrations. For dentists, when compared with the control group, the geometric mean of the mercury concentration in head hair was 1.82 times greater (95% CI 1.55 to 2.13); in pubic hair it was 1.95 times greater (95% CI 1.68 to 2.29); in finger nails it was 5.86 times greater (95% CI 4.65 to 7.37); and for toe nails it was 2.44 times greater (95% CI 2.02 to 2.93). For randomly selected dentists when compared with volunteer dentists, the geometric mean of the mercury concentration in head hair was 1.06 times greater (95% CI 0.84 to 1.36); in pubic hair it was 0.96 times greater (95% CI 0.78 to 1.22); in finger nails it was 1.33 times greater (95% CI 0.87 to 2.06); and in toe nails it was 1.10 times greater (95% CI 0.83 to 1.49). None of the differences between randomly selected and volunteer dentists were significant.

The relation between the number of hours worked a week by dentists in the surgery and mercury concentrations was examined by Spearman's rank correlation. There was a significant correlation between the number of hours worked in the surgery and urinary mercury (r=0.24, p=0.003) but no correlation with this and concentrations of mercury in head hair (r=–0.04, p=0.62), pubic hair (r=–0.12, p=0.14), finger nails (r=–0.02, p=0.77), or toe nails (r=0.08, p=0.30).

The relation between the number of amalgam fillings placed and removed by dentists and concentration of urinary mercury was examined with Spearman's rank correlation. There was a highly significant correlation, between the number of amalgam fillings they place and remove in a week and urinary mercury concentration (r=0.38, p<0.001, and r=0.29, p<0.001, respectively).

Environmental mercury measures

Measurements of environmental mercury were taken from eight surgery areas. Measurements in the region of the skirting and chair were made for all surgeries. The number of other areas in which measurements were taken varied depending on the type of equipment used and the time available to undertake this part of the study. In most instances two measurements were taken in each area; however, up to four measurements were taken dependent on variations in layout of individual surgeries, the levels of consistency between measurements, and the amount of time available to undertake the measurements. The exception was for the personal dosimetry measurements when, in general, only one measurement was taken. These multiple measurements were then averaged for each of the surgery areas. The results of these environmental mercury measurements are detailed in table 3. Note that those surgeries with only amalgamators will not have a measurement for capsule storage, and dentists with only preloaded capsules will not have a measurement for a mixing device.

The Health and Safety Executive has set the occupational exposure standard (OES) for mercury vapour at 25 µg/m³ for 8 hours a day, 40 hours a week. Results from 180 surgeries showed that in 68% (n=122) of dental surgeries the direct reading instrument showed concentrations of mercury above that of the occupational exposure standard in one or more separate areas. There were no significant differences in the mean environmental mercury measurements between the surgeries of randomly selected and self selected dentists.

Table 4 Results of psychomotor tests for dentists and controls

Job	Mean	SD	p Value	Corrected p value
Simple reaction time (ms):				
Dentist	284	41		
Control	284	46	0.94	
Number vigilance (ms):				
Dentist	459	66		
Control	419	45	<0.001	<0.01
Choice reaction time (ms):				
Dentist	423	44		
Control	437	61	0.016	0.13
Spatial memory (ms):				
Dentist	997	229		
Control	966	268	0.26	
Memory scanning (ms):				
Dentist	892	188		
Control	819	173	<0.001	<0.01
Word recognition (ms):				
Dentist	926	209		
Control	872	180	0.013	0.11
Word recall (number correct):				
Dentist	7.0	1.8		
Control	7.2	1.8	0.23	
Delayed word recall (number correct):				
Dentist	5.7	2.0		
Control	5.8	2.0	0.69	

Table 5 Linear regression analysis of effect of job on psychomotor test results after adjusting for age and sex

	Adjusted mean difference (dentists–controls)	p Value	Corrected p value
Simple reaction time (ms)	−1.87	0.71	
Number vigilance (ms)	28.25	<0.001	<0.01
Choice reaction time (ms)	−19.84	0.002	0.016
Spatial memory (ms)	−5.57	0.84	
Memory scanning (ms)	41.24	0.050	0.40
Word recognition (ms)	18.75	0.41	
Immediate word recall (number correct)	0.006	0.76	
Delayed word recall (number correct)	0.20	0.36	

Full details of analyses of environmental measures will be reported elsewhere.

Results of psychomotor testing

The distribution of data from the eight outcome variables considered are all approximately normal with the exception of a few outliers. The means (SDs) together with results of two sample *t* tests for dentist and control groups are shown in table 4. Although all dentists and controls underwent the computerised test system, technical problems with stored data resulted in missing results for 21 dentists and 13 controls. The immediate and delayed word recall scores were not stored electronically and therefore a complete set of results is available for these tests.

Correlations between age and results of psychomotor tests showed highly significant positive correlations ($p<0.001$) between age and all reaction times except for choice reaction time and simple reaction time where the correlation was just significant. There were significant differences in the results of male and female subjects for simple reaction time, choice reaction time, word recognition, immediate word recall, and delayed word recall with male participants having faster reaction times for simple reaction time and choice reaction time and female participants having faster reaction time for word recognition and having higher word recognition scores for immediate word recall and delayed word recall.

There were significantly more male dentists than male controls and the dentists were on average older than controls. As both age and sex were significantly associated with reaction times, comparison of mean reaction times (ms) and word recall scores of dentists and controls after adjusting for age and sex was carried out with linear regression. A summary of the age and sex adjusted mean differences between dentists and controls is shown in table 5.

For number vigilance there was a highly significant job effect with control subjects having the better mean score. For choice reaction time there is also a highly significant job effect with dentists having the better mean score. No significant effect of job was found for any of the other tests after correcting for multiple comparisons.

Table 6 Linear regression analysis of effect of urinary mercury concentration on psychomotor test results for dentists and controls after adjusting for age and sex

Job	Average change for each unit increase in log urinary mercury	p Value	Corrected p value
Simple reaction time (ms):			
Dentists	−8.19	0.36	
Controls	−16.79	0.036	0.29
Number vigilance (ms):			
Dentists	−33.00	0.021	0.17
Controls	−16.62	0.023	0.18
Choice reaction time (ms):			
Dentists	−4.61	0.63	
Controls	−9.70	0.37	
Spatial memory (ms):			
Dentists	13.65	0.80	
Controls	−43.97	0.34	
Memory scanning (ms):			
Dentists	−7.40	0.86	
Controls	−14.24	0.62	
Word recognition (ms):			
Dentists	42.00	0.37	
Controls	−60.69	0.046	0.37
Immediate word recall (number correct)			
Dentists	0.002	0.95	
Controls	0.67	0.029	0.23
Delayed word recall (number correct)			
Dentists	0.19	0.64	
Controls	1.12	0.001	0.01

Effect of exposure to mercury on psychomotor test results

The effect of age, sex, and urinary mercury concentration on psychomotor test results was considered for dentists and controls separately. The results of linear regression are summarised in table 6.

Table 6 shows that there is a significant effect among controls of urinary mercury on delayed word recall with those with higher mercury concentrations having a better average score, after correction for multiple comparisons. None of the other psychomotor tests performed were significantly affected by urinary mercury concentration.

The effects of age, sex, and other measures of biological uptake of mercury—that is, results of hair and nail analysis—were also examined by linear regression. There was no significant association between concentrations of mercury in head hair, pubic hair, finger nails, or toe nails and any of the CDR test results for dentists or controls after adjusting for age and sex and correction for multiple comparisons.

After adjusting for age and sex, there was no significant association between the number of amalgam surfaces in the mouths of the dentists or controls and their scores in any of the CDR tests.

DISCUSSION

Biological measurements

The concentrations of urinary mercury found in the dentists included in this study were similar to those reported in other studies in recent years and very close to those reported by Langworth *et al* in their study of dentists and dental nurses in 1997.[24] Biological uptake of mercury as measured by urinary mercury analysis among the dentists in our study was found to be related to the number of hours worked in the surgery, the number of amalgam fillings placed and removed and the number of amalgam surfaces they had in their own mouths. Among control subjects, concentrations of urinary mercury were highly correlated with the number of amalgam fillings they possessed.

Only one dentist and none of the controls in this study had a concentration of urinary mercury that exceeded the Health and Safety Executive's health guidance value of 20 μmol/mmol creatinine. There was, however, a large and highly significant difference between the concentrations of urinary mercury of dentists and controls with the dentists having a mean concentration of urinary mercury of 4.17 times that of the controls.

It is known that mercury accumulates in the kidneys of dental staff.[18] In our study dentists were significantly more likely than control subjects to report that they had had and received treatment for a kidney disorder, but there was no relation found between concentrations of urinary mercury and reporting of kidney disorders. Vershoor *et al*[13] similarly reported a relatively high percentage of dental staff with renal dysfunction but found no significant relation between concentrations of urinary mercury and kidney disorders. These authors suggested that other potential nephrotoxic agents used in dental practice including antibiotics, local anaesthetics, or composite resins might be responsible for the increase in protein excretion. The mean concentration of urinary mercury in our study was considerably lower than the threshold level of 50 μg/g creatinine below which there is no effect on kidney function as suggested by Roels *et al*.[26] It is therefore unclear what might be responsible for this incidence of renal symptoms reported by dentists.

As well as reporting a high incidence of kidney disorders, the dentists in our study also reported a significantly higher incidence of memory disturbance than did the control subjects. As with reported kidney problems the reporting of memory disturbance was not related to concentrations of urinary mercury. Langworth *et al*[26] similarly reported a significant difference in memory disturbance between a group of chloralkali workers exposed to mercury and a non-exposed control group, although they also found an increase in reported tiredness.

The increased levels of self reported kidney disorder and memory disturbance in our group of dentists suggests that there are aspects of practising dentistry which may have a detrimental effect on some aspects of health, although these cannot be attributed to exposure to mercury vapour. It is, however, acknowledged that analysis of the data generated in the course of this study has resulted in multiple tests for significance being performed. These associations remain significant after correction for multiple comparisons. Also, given that these findings are similar to the results of previous studies this may warrant research on the influences on the health of dentists.

Psychomotor performance

There were significant differences in the scores of dentists and controls for two of the eight tests used. For one of these—choice reaction time—control subjects had higher mean scores than dentists (slower reaction times). The strong correlation between performance in all the tests and age suggests that the tests, as used in this study, were sensitive for determining changes in cognitive functioning.

When the relation between psychomotor performance and concentrations of urinary mercury was explored after adjusting for age and sex and making a correction for multiple comparisons, there was a significant dose-response relation between urinary mercury and delayed word recall for control subjects. It should be noted that the size of this effect was very small and higher urinary mercury concentrations were associated with better scores, with a 10-fold increase in concentrations of urinary mercury resulting in an average of one additional word being recalled. No significant association was found between urinary mercury and any of the other psychomotor tests. The results therefore indicate that exposure to mercury, at levels experienced by the dentists in our study, does not have a detrimental effect on psychomotor performance.

These results oppose those of other authors who have explored the relation between exposure to mercury and cognitive functioning,[9 10 19 21] although the levels of exposure to mercury of the subjects in these studies were considerably higher than the exposures experienced by our dentists as measured by urine analysis. In their study, Langworth *et al*[25] found no significant differences in psychomotor performance between groups of exposed and non-exposed workers and suggested that reported symptoms are a more sensitive indicator than psychomotor tests of the effects of exposure to mercury on the central nervous system.

Overall findings

Several authors have proposed that uptake of mercury varies considerably between people exposed to similar environmental or other concentrations and that there are those who are particularly susceptible to mercury toxicity.[24] High variation within individual people may require an average to be taken of several urinary mercury measurements.[27] It is for this reason that biological monitoring of mercury has been considered less reliable than direct environmental exposure measurements.

Variations in individual people's biological response to mercury exposure may also explain why differences were found between reporting of symptoms and psychomotor test results between our group of dentists and the control group which could not be attributed to their concentration of urinary mercury. Alternatively, we may have selected a control group which was not comparable with our dentist group in respects which impacted on their reported symptoms and cognitive functioning. In our pilot study we used as controls general medical practitioners, which may be considered a more comparable group in terms of education, exposure to patient groups, levels of occupational stress, and so on. However, the difficulty in gaining the cooperation of such a large group of doctors to act as controls for this study was considered insurmountable.

We have found several differences in the health and cognitive functioning between our dentists and the control group. These differences could not be directly attributed to their exposure to mercury, but as mercury exposure at higher levels is known to cause similar health effects an association cannot be ruled out.

It is concluded that there is no evidence that exposure to mercury at the levels experienced by this group of dentists has an effect on psychomotor functioning. However, environmental monitoring of dental surgeries should be regularly conducted to ensure that staff are not exposed to mercury concentrations above the occupational exposure standard. The prevalence of self reported renal disease and memory disorders reflects other reports and suggests that these may be occupationally related. Therefore, further health surveillance of all members of dental teams, including dental nurses and dental hygienists, should be carried out to determine the nature of this association and the preventive health measures which may be required.

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