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Solvent exposure and cognitive function in automotive technicians

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ABSTRACT

Automotive technicians are commonly exposed to organic and chlorinated solvents, particularly through use of cleaning products. Occupational solvent exposures have been associated with deficits in cognitive function but, to our knowledge, no previous studies have investigated automotive technicians. The purpose of the present study was to investigate whether previous exposures to n-hexane, in particular, or general solvents posed a persistent neurotoxic hazard to automotive workers.

Enrolled in the study were 830 San Francisco Bay Area automotive repair workers. Each participant underwent a battery of cognitive function tests to investigate central nervous system impairment, with a primary focus on the domains of psychomotor speed, fine motor function, memory and mood. Cognitive test results regressed against estimated hexane and total solvent exposures showed little evidence of associations. Exposures to both solvents and hexane were well below the occupational exposure limits.

Our results provide some reassurance about persistent neuropsychological effects in automotive workers who use solvent-based products and those who previously used hexane-containing automotive cleaning products, since this solvent is believed no longer to be used in automotive cleaning products. The lack of observed effect in this study may be attributable to low exposures, or it may reflect improved cognitive function since hexane use in automotive cleaning products was discontinued. However, impacts on results of exposure misclassification and/or the healthy worker survivor effect cannot be discounted. Irrespective of the outcome of this study, the main known neurologic effect of n-hexane is peripheral neuropathy, and such an association in automotive technicians is not excluded by these results.

1. Introduction

Automotive technicians, who service and repair motor vehicles, are commonly exposed to organic and chlorinated solvents, particularly through use of spray cans to clean brakes and engine parts, but also from solvent tanks into which engines and parts are cleaned by dipping. Since the 1970s, evidence has accumulated that occupational solvent exposure is associated with deficits in cognitive function (Berr et al., 2010; Meyer-Baron et al., 2008; Sabbath et al., 2012). Most studies have involved exposure to solvent mixtures and most have been of painters of houses, cars and ships, but, to our knowledge, none have involved automotive technicians.

The present study was prompted by the finding in 1998 of 3 San Francisco Bay Area automotive technicians from one car repair facility with evidence of mild sensory or motor nerve conduction abnormalities (MMWR, 2001). Ages of these mechanics were 24, 45 and 52 years. Since 1989, automotive spray cans containing up to 85% hexane, often with acetone, had been used in California and other states. The technical grade of mixed hexanes used in industry typically contains 20–80% n-hexane. N-hexane is well-established as a peripheral neurotoxin. Its neurotoxic effects are enhanced in animal models by concurrent exposure to acetone, although to our knowledge the combined effects of the two solvents have not been studied in humans (Noraberg and Arlien-Soborg, 2000). The levels of hexane exposure associated with automotive spray can use have been shown to be below the current occupational exposure limits for exposure to n-hexane (Wilson et al., 2007).

The peripheral neuropathy findings (and color vision deficits in the same persons) prompted the California Department of Health Services in 2001 to issue a Health Hazard Advisory through HESIS, its Hazard Evaluation System and Information Service. Because the California market is large, manufacturers saw it as in their interest

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to remove hexane from all automotive spray cleaning products used across the U.S. (Wilson, 2003) However, hexane remains a widely used industrial solvent, for extraction of vegetable oils from crops, as a solvent for glues, varnishes and inks, and as a cleaning agent in the printing industry (http://www3.epa.gov/airtoxics/hlthef/hexane.html) (last accessed July 22, 2016).

Our primary purpose in conducting this study was to investigate whether previous exposures to hexane, previously shown to be below the ACGIH Threshold Limit Value (TLV®) (Wilson et al., 2007) posed a persistent neurotoxic hazard. Results for color vision testing have already been published (Beckman et al., 2016). Data on peripheral nerve function are being prepared for separate publication. We also collected urine samples for biomarker analysis.

Although the study focus was hexane, data were obtained on all solvents used in the automotive repair facilities at which our participants worked. As well as measures of peripheral nerve function, a battery of cognitive function tests was used to investigate central nervous system impairment. The results from the cognitive test battery are the focus of this paper. We hypothesized that we would find solvent exposure in general, and hexane exposure in particular, to be associated with deficits in cognitive function.

2. Methods

Institutional Review Board approvals for study procedures were obtained at the University of California, Berkeley, and at the University of California, Davis, under a University of California multi-campus agreement. Written informed consent was obtained from all participants before their participation. Participants were each paid $75 to cover transport to and from the study clinic and as some compensation for their time.

2.1. Participants

Participants were recruited from male members of 3 Northern California locals of District 19 of the International Association of Machinists and Aerospace Workers (IAMAW). Eligibility required that participants be males ≤60 years old at time of participation, have worked as an automotive technician for at least one year in the period 1990–2000 (when hexane was in use), and currently living in or near the San Francisco Bay Area. Women were not included as there were few female members of the IAMAW during the period of hexane use, and another part of the study investigated possible testicular effects of hexane, manifesting in infertility. Current work as an automotive technician was not a requirement.

We began recruitment with members of the Oakland-San Leandro local, moving to locals in San Mateo and Sacramento when we were unable to further recruit eligible and willing members of the first local. The first step in recruitment was obtaining the Local 1546 membership database, which contained records of former and current members. From this database we identified all members who fit the eligibility criteria, including their most up-to-date contact details. Current addresses were confirmed using other means, including Experian, California Department of Motor Vehicles, and California voter registration records. Recruitment was initiated by sending a letter to the current address, including a brochure describing the study and a stamped and addressed response envelope with a form to be returned indicating willingness to participate. If necessary, a further letter was sent, followed by telephone calls to the last recorded telephone number. Where necessary, efforts were made to find new or alternative telephone numbers. Recruitment efforts proceeded until we had received participation acceptance or refusal, the invitee was found to have moved out of the area, was found to be deceased, or we had made no contact after multiple (up to 30) attempts to do so.

2.2. Data collection

Participants from Locals 1546 and 1414 attended a dedicated clinic in San Leandro, California. A mobile clinical van was used for participants from Local 2182 in Sacramento. At the clinic they responded to questions in a questionnaire and underwent a series of clinical tests, including the cognitive function test battery.

2.2.1. Questionnaire

The questionnaire was programmed using Casic Builder™ (West Portal Software Corporation), for direct data entry. Data were downloaded as they were entered to a dedicated study server. In addition to collecting data on demographics, medical history, tobacco smoking, lifetime alcohol consumption, education and income, the questionnaire obtained detailed automotive technician work histories, including names of employers, solvent-using tasks and their frequency at each workplace, and names of solvent products. We did not collect information on other possible neurotoxic post-automotive work exposures, on the assumption that they would be unlikely to be correlated with automotive solvent exposures and, therefore, could not confound our results.

As a memory aid, a booklet containing 121 color pictures of spray-can products was provided. The booklet was not complete, as pictures of 17, mostly older, products could not be obtained.

The work history module of the questionnaire was developed using a focus group of 14 experienced automotive technicians to identify tasks with potential solvent exposures, work practices and historical changes in those that would have affected solvent exposure. A draft questionnaire was pilot-tested and revised, repeating this procedure until no change was necessary, before the final version was produced.

2.2.2. Cognitive testing

Tests assessed psychomotor speed, fine motor function, memory, and mood–important cognitive functions that are sensitive to adverse effects of a wide variety of injuries and diseases (Lezak et al., 2004). These neurobehavioral domains have been reported as affected by solvents or have been identified as relevant to neurotoxic assessment (Anger et al., 1994; Anger et al., 2000; Rohlman et al., 2003; White et al., 2003). Tests were administered in a fixed order in a quiet, light-controlled room and, for the Sacramento local, in a mobile clinic. Simple reaction time and finger tapping were measured by computer-driven tests administered using Presentation Software (http://www.neurobs.com; Neurobehavioral Systems, Inc., Albany, CA) and run on a personal computer with an LCD display and a high temporal resolution mouse (Copperhead 2000 DPI Gaming Mouse; Razer USA Ltd.).

Simple Reaction Time (SRT) Speed of simple motor response to a visual cue is a basic measure of psychomotor speed. Reaction time is sensitive to a wide variety of factors, including toxic exposures (Anger et al., 2000; Rohlman et al., 2003). The primary outcome variable was mean SRT across all trials after excluding times <100 ms and >1000 ms, resulting in exclusion of 3 participants.

Finger Tapping (Cousins et al., 1998; Jobbagy et al., 2005) speed for the index fingers, as a test of fine motor function, was measured over 30 s intervals using Presentation software, as described in Hubel et al. (Hubel et al., 2013a). The timing of each press and release was recorded using the Windows programmable clock, which has a temporal resolution of 0.1 ms, to provide a temporal uncertainty measure for each response. Outcome variables were taps per 30 s, separately for dominant and non-dominant hands.