

Long-term exposure to jet fuel

An investigation on occupationally exposed workers with special reference to the nervous system

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KNAVE, B., PERSSON, H. E., GOLDBERG, J. M. and WESTERHOLM, P. Long-term exposure to jet fuel: An investigation on occupationally exposed workers with special reference to the nervous system. *Scand. j. work environ. & health* 3 (1976) 152—164. In the present study the results of a neurological and neurophysiological health examination of 29 aircraft factory workers chronically exposed to jet fuel vapors are presented. The exposed subjects were classified into a heavily exposed and a less heavily exposed group. The examination included a standardized clinical neurological examination, measurements of the conduction velocities in the peripheral nerves, and threshold determinations of vibratory sensations in the extremities. All 13 persons examined in the heavily exposed group and 7 of the 16 in the less heavily exposed group stated that they had repeatedly experienced acute effects (dizziness, respiratory tract symptoms, heart palpitations, a feeling of pressure on the chest, nausea, headache) of the jet fuel vapors in the inhaled air. A high rate of symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy was observed both in the heavily exposed group and in the two groups combined in comparison with reference groups. Considering the presented facts concerning (a) the acute effects on repeated occasions, (b) the high rates of symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy, and (c) the differences in the observations made between the two groups with varying degrees of exposure to jet fuel, the authors interpreted the results as indicative of a possible effect of long-term exposure to jet fuel on the nervous system.

Key words: jet fuel, organic solvents, motor nerve conduction velocities, vibration thresholds, neurological examination, neurasthenia, psychasthenia.

Long-term exposure to petroleum-distilled fuels can produce deleterious changes in the nervous system. In man symptoms of

neurasthenia and psychasthenia, as well as of polyneuropathy, are known to be predominant. Recently a number of employees working with jet fuel in an aircraft factory complained of such symptoms. This group constituted the basis of the present study in which the most heavily exposed workers were examined with neurological and neurophysiological methods and in which the results obtained

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were compared with those from studies of different reference groups of industrial workers. The actual jet fuels, commonly referred to as MC 75 and MC 77, have raw gasoline and kerosene as their principal components. For an evaluation of the health hazards which may arise from exposure to these jet fuels, consideration must be given to their contents of aliphatic hydrocarbons as well as aromatic hydrocarbons such as benzene, toluene, xylene, and trimethylbenzene.

Acute gasoline exposure is known to cause a depression of the central nervous system in man. Felix (14) tried to use gasoline as a general anesthetic. He found that the inhalation of 5—15 gm during a period of 7 to 12 min caused dizziness, nausea, vomiting, drowsiness, eye irritation, and a burning sensation in the chest. Anesthesia and sleep followed the administration of 20—40 gm given over a period of 8 to 12 min. Several cases of acute gasoline and kerosene poisoning by inhalation have since been reported. [For an early review the reader is referred to Potts (33) and also von Oettingen (32), Gerharde (16) and Jacobziner and Raybin (23).] Cases of slight intoxication may show inebriation with an atactic, staggering gait. With increasing intoxication symptoms such as nausea, vomiting, and headache may develop. These symptoms have also been described in a case of in-flight intoxication due to jet fuel fumes (9).

Serious neurological after-effects have been described in the early literature after recovery from acute heavy gasoline poisonings, e.g., epilepsy (15, 39), retrobulbar neuritis (5), encephalitis (15, 33), a condition similar to multiple sclerosis (11), and vertigo and nystagmus (34). In a recent long-term follow-up study on 35 industrial workers focal neurological symptoms were reported to develop after acute heavy poisonings from different industrial hydrocarbons (36).

In chronic occupational gasoline intoxications the following symptoms of neurasthenia and psychasthenia have been found to be early manifestations of disease: dizziness, headache, mental confusion, loss of memory, impaired mental faculties, depression, irritability, and nervousness (19, 30, 37, 38, 40, 42).

The peripheral nerves may also be affected in cases of chronic gasoline poisoning. According to Machle (30) and von Oettingen (32) one of the most common sequelae is a polyneuropathy. Several case reports have been published (4, 8, 13, 29, 40). Furthermore, an industrial solvent, the aliphatic hydrocarbon *n*-hexane, which is a significant component of petroleum distilled fuels, has been found to produce polyneuropathy in occupationally exposed workers (7, 20, 21, 22, 43, 44, 45) and experimentally exposed rats (28, 31, 41).

THE WORKPLACE

At the factory from which the subjects of the present study came, the personnel were exposed to jet fuels during the production and installation of fuel systems for planes in isolated test cells and in a specially constructed fuel rig and during work on the fuel system in the complete airplanes (adjustments, repairs, etc.) at several workshops within the factory.

In the fuel rig the fuel system was set up on a scaffold ("rig") where it was tested under conditions simulating actual flight. The tests usually resulted in jet fuel vapors throughout the testing area. In the test cells the fuel pumps and vents were subjected to careful checks as the jet fuel flowed through them.

With the fuel system installed in the planes another category of personnel, the mechanics, were exposed to fumes from the fuel. During inspections, repairs, etc., a worker often had to place his head in the narrow and semiclosed tanks containing residual jet fuel. During precision work of a technically difficult nature, the exposure time could amount to an hour or two.

THE EXPOSED PERSONNEL

With the aid of employer records and interviews of the personnel (the individual's own description of his earlier and present work conditions) 32 employees considerably exposed to fuel fumes from 1955 on were selected for the present investigation. During the evaluation of the results three of the examined persons were

excluded because of the existence of a disease which per se might give rise to symptoms of neurasthenia and polyneuropathy (organic nervous diseases and juvenile diabetes mellitus).

The exposed persons were divided into two groups with regard to degree of exposure, group A being heavily exposed and group B being less heavily exposed. These classifications took into consideration both the duration and the intensity of the exposure. All 29 of the persons examined had been exposed for at least 5 years of employment. For exposure intensity the following criteria were used: group A: continuous exposure for several hours daily to high concentrations of jet fuel fumes in the fuel rig or the test cells or intermittent exposure to high concentrations for at least 20—30 min each time with an average frequency of at least every second or third week; group B: less frequent intermittent exposure than group A. The majority of persons in group B stated a varying pattern of exposure with several days of heavy, intermittent exposure alter-

nating with weeks or months without exposure. Employees with intermittent, heavy exposure of less than 20—30 min each time were excluded from the investigation. After group allocation the heavily exposed and less heavily exposed groups consisted of 13 and 16 persons, respectively. The examined persons were grouped independently of the examination and prior to the evaluation of the results.

METHODS

Personal history

In the general part of the personal history information was recorded on heredity, previous health, occupational history, tobacco smoking, use of alcohol, etc, as well as current symptoms associated with acute exposure and symptoms which had developed successively during the period 1960—1974. In a specific part of the personal history the persons were asked about

Table 1. Evaluation and gradation of early neurological signs upon examination of the peripheral nerve function [from Lindblom (3)].

Subject of evaluation	Evaluation and gradation
Pain	Needle-prick on the foot and leg. Grade 1: reduced in the feet (if a prick is felt more on the knee than on the foot, a slight reduction in the response of the foot is considered to have occurred, i.e., grade 1).
Temperature	The metallic part of a percussion hammer was placed against the dorsum of the foot and the knee-cap; one percussion hammer had been cooled in water at room temperature (about 20°C) and another warmed up with warm tap-water (about 40°C). Grade 1: reduced in the feet.
Touch	Pathological signs designated when a significant number of touches with a cotton ball was unnoticed. Grade 1: reduced in the feet.
Discriminative sensitivity	Arabic numerals were written on the dorsum of the foot (with a blunt pencil; the subject with eyes closed). Grade 1: only numbers of 5—8 cm can be identified.
Joint kinesthesia	Normally, $\pm 5^\circ$ can be distinguished.
Tendon reflexes	Knee, ankle, biceps and triceps jerks. Grade 1: at least 2 symmetrical reflexes (out of 4) in the legs clearly reduced or entirely missing.
Grade of paresis	Grade 1: slight but certain paresis in the legs, usually only in the dorsal extensors of the feet.

the occurrence of symptoms considered indicative for neurasthenia and polyneuropathy. As to neurasthenia a standardized inquiry was used that was earlier applied in studies on industrial workers exposed to lead (26, 27). As to polyneuropathy a standardized inquiry was used which had been worked out by Lindblom and used in studies on the peripheral nerve function of uremic patients (3). This inquiry was used by the present authors in earlier investigations on industrial workers exposed to carbon disulfide (25) and lead (26, 27). The examined persons were thus questioned as to the occurrence of restless legs (6, 24), muscle cramps, pain in the extremities, distal paresthesia and numbness, and paresis. For the evaluation of neurasthenia and polyneuropathy symptoms the same standardized criteria were used as in our earlier investigations on industrial workers, i.e., a symptom was considered "positive" when the subject experienced it at a frequency exceeding once a month. It should be emphasized that "positive" symptoms according to these criteria do not necessarily indicate manifest disease in terms of a clinical evaluation.

Neurological examination

The clinical examination included a general neurological examination and a neurological examination especially designed to detect early aberrations indicative of polyneuropathy. A basis for such an evaluation was developed by Lindblom in studies on uremic patients with subclinical and manifest polyneuropathy (3) and was later used by the present authors in investigations on industrial workers (25, 26, 27). The method allows the examination signs to be graded between 0 and 3 (0 = normal, 1 = earliest and mildest changes, 2 and 3 = different grades of manifest polyneuropathy). The criteria used for grade-1 changes are given in table 1. This standardized neurological examination is sensitive in detecting slight aberrations from normal. Thus the grade-1 changes may be "normal" signs, especially in older persons (25, 26, 27).

Conduction velocities in peripheral motor nerves

In the present study measurements were made of the maximal conduction velocity in the median (MCV_{med}) and the ulnar nerve (MCV_{uln}), as well as the conduction velocity of the slow fibers in the ulnar nerve ($CVSF_{uln}$). The technique of measuring $CVSF_{uln}$ has previously been used by Seppäläinen and Hernberg (35). According to these authors this method is a more sensitive detector of nerve dysfunction due to lead exposure than conventional conduction velocity measurements.

Sensation thresholds of vibration in the extremities

The vibration threshold was determined from the application of a 100-Hz sine wave stimulus from an electromagnetic biotthesiometer (Bio-Medical Instruments Inc., Chagrin Falls, Ohio). The stimulator head consisted of a plastic probe 6 mm in diameter with a rounded edge. An accelerometer was mounted on the shaft of the stimulator, the movement of which was displayed after amplification on an oscilloscope and calibrated in μm peak to peak. The stimulator was applied with the pressure of its own weight (440 g) and with the moving shaft in a position as near to vertical as possible, and, at the same time, perpendicular to the skin surface. Care was taken to apply the stimulator to the underlying bone by placing it where the subcutaneous tissue was the thinnest. This application gave the least variation in threshold in repeated tests. The threshold was determined with the method of limits. A full description of the method, including normal threshold values for commonly used stimulus sites such as the metatarsal and metacarpal regions, is being prepared by Goldberg and Lindblom.

RESULTS

Personal history

Acute symptoms in connection with exposure to jet fuel vapors. All persons in the heavily exposed group stated that they

Table 2. Symptoms and examination signs in the jet fuel exposed groups.

Symptoms and examination signs	Group A (n = 13)	Group B (n = 16)
Acute effects	13	7
Dizziness	10	5
Headache	3	5
Nausea	4	2
Respiratory tract symptoms	6	3
Palpitations, pressure on the chest	3	2
Chronic symptoms		
Symptoms indicative of neurasthenia and psychasthenia	12	9
Dizziness	10	3
Respiratory tract symptoms (feelings on suffocation etc.)	6	1
Palpitations, pressure on the chest	8	4
Depressions, anxiety	8	4
Sleep disturbances	5	3
Headache	4	5
Memory impairment	2	2
Irritability	3	3
Symptoms indicative of polyneuropathy (listed in table 3)	11	6
Examination signs		
Signs indicative of polyneuropathy (listed in table 4)	11	8

Table 3. Symptoms indicative of polyneuropathy in the jet fuel exposed groups.

Symptom	Group A (n = 13)	Group B (n = 16)
"Restless legs"	8	3
Muscle cramps	3	3
Diffuse pain in the extremities	4	2
Distal paresthesia and numbness	10	4
Paresis	0	1

had repeatedly experienced acute symptoms on exposure to high concentrations of jet fuel vapors (table 2). The acute symptoms consisted of dizziness (10 out of 13 persons), headache (3 persons), nausea (4 persons), respiratory tract symptoms (6 persons), palpitations and a feeling of pressure on the chest (3 persons). The feeling

of dizziness was described in various ways, e.g., as "a feeling of whirling around," "swaying sensation," "felt his mind was not all there." The respiratory tract symptoms were described as "feeling of suffocation," "pain upon inhalation," "slight cough," "ache in the chest," etc. All of the examined persons who had experienced acute symptoms (including also the persons with acute symptoms in the less heavily exposed group) reported that on such occasions they repeatedly had to interrupt their work to "get a breath of fresh air" for relief of symptoms. Seven of the 16 less heavily exposed workers also reported acute symptoms in the form of dizziness (5 persons), headache (5 persons), nausea (2 persons), respiratory tract symptoms (3 persons), palpitations and pressure on the chest (2 persons).

Chronic symptoms: A. Symptoms indicative of neurasthenia and psychasthenia. From table 2 it is evident that the exposed persons successively developed a number of symptoms which could be referred to as symptoms of neurasthenia and psychasthenia, i.e., dizziness, respiratory tract symptoms (feeling of suffocation, pain upon inhalation), palpitations, pressure on the chest, depression, anxiety, sleep disturbances, headache, memory impairment, and irritability. The presence of these symptoms was found to be remarkably consistent in many of the cases. Twelve of the 13 heavily exposed and 9 of the 16 less heavily exposed reported one or more of these symptoms. Among the 12 persons in group A with neurasthenic and psychasthenic symptoms 10 had consulted a physician and had been treated for the symptoms long before the present study (in 8 cases since the middle and late 1960s and in the remaining 2 cases since 1971 and 1972, respectively). Five out of seven in group B had been treated by physicians for the same reasons (4 since the 1960s and 1 since 1972).

B. Symptoms indicative of polyneuropathy. The examined persons were questioned as to the occurrence of symptoms which might be indicative of polyneuropathy. The distribution of the var-

ious symptoms among the examined persons is presented in table 3. Subjects who experienced at least one of the symptoms listed in table 3 were classified as "positive" in table 2. According to these criteria, 11 out of the 13 heavily exposed and 6 out of the 16 less heavily exposed showed symptoms which might be indicative of polyneuropathy.

Other neurological diseases. Four of the 29 workers had been examined in the hospital for neurological disease, viz., epilepsy, mental confusion of unknown etiology, rhizopathy, and inactivation atrophy in the hands due to chronic joint disease.

Skin changes. Three of the examined persons had skin changes. Two had eczema; and one, suspected psoriasis.

Neurological examination

Signs indicative of polyneuropathy. All the signs noted as indicative of polyneuropathy in the present study were classified as grade-1 changes (table 4). Three of the subjects in group A had no positive polyneuropathy signs. Six persons had one positive sign and 4 persons had two positive signs. In the less heavily exposed group 9 persons had no positive signs, 5 persons had one positive sign, and 2 persons had two or more positive signs. One of the subjects in this group had four positive signs.

Other neurological signs. Two of the examined persons were found to have other pathological signs in the neurological examination. One subject showed a functional psychogenic disturbance upon performance of Romberg's test, and another had obvious muscular atrophies and pareses in his hands and fingers.

Frequency of symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy in the groups exposed to jet fuel in comparison with reference groups

In table 5 data from the present investigation are compared with data

on the occurrence of corresponding symptoms and examination signs in the reference group of an investigation of the effects of chronic carbon disulfide exposure in a viscose factory (25) and in the reference group of an investigation on the effects of lead exposure in a heavy metals industry (27). Although they are not reference groups, a group of persons moderately exposed to lead in a storage battery factory (26) and a group of persons moderately exposed to lead in a heavy metals industry (27) have been included in the table for comparison. These groups, named group C, D, E, and F, respectively, were investigated with the same standardized methods as were used in the present study.

Table 5 shows an increased rate of neurasthenic and psychasthenic symptoms, as well as symptoms and signs indicative of polyneuropathy, in the group heavily exposed to jet fuel (i.e., group A) in comparison to that of the other groups. The symptoms and signs are also more frequent in the group less heavily exposed to jet fuel (i.e., group B) than in the reference groups, but less frequent than in group A.

Age must be regarded as an important factor when the frequency of polyneuropathy signs is considered. Since groups A and B combined bear the most resemblance to group D as far as age composition is concerned, it is preferable to compare the present results with the observations made on group D. When groups A and D are compared for the frequency of polyneuropathy signs, the

Table 4. Signs indicative of polyneuropathy in the jet fuel exposed groups.

Sign	Group A (n = 13)	Group B (n = 16)
Cutaneous sensibility		
Pain	4	1
Temperature	9	7
Touch	1	0
Discriminative sensitivity	2	1
Depth sensibility		
Joint kinesthesia	0	0
Motor functions		
Tendon reflexes	0	3
Paresis	1	1

Table 5. Symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy in the jet fuel exposed groups and in reference groups.

Investigation	Number	Mean age (a)	Median age (a)	Symptoms of neurasthenia and psychasthenia	Symptoms of polyneuropathy	Signs of polyneuropathy in neurological examination
A. Group heavily exposed to jet fuel (Group A in the present investigation)	13	54.2	56.5	12 (92 %)	11 (85 %)	10 (77 %)
B. Group less heavily exposed to jet fuel (Group B in the present investigation)	16	46.3	45.0	9 (56 %)	6 (38 %)	7 (44 %)
C. Control group in a CS ₂ investigation in a viscose factory (25)	48	43.9	46.5	—	10 (21 %)	15 (31 %)
D. Control group in a lead investigation in a heavy metals industry (27)	58	51.8	53.0	6 (10 %)	10 (17 %)	20 (34 %)
E. Group moderately exposed to lead in a storage battery factory (26)	65	45.5	48.0	8 (12 %)	9 (14 %)	25 (38 %)
F. Group moderately exposed to lead in a heavy metals industry (27)	58	54.3	56.0	10 (17 %)	16 (28 %)	24 (41 %)

Table 6. Number of workers under and over 50 years of age with signs indicative of polyneuropathy in the jet fuel exposed and reference groups.

Age (a)	Group A	Group B	Group C + D
< 50	2 out of 2	4 out of 9	15 out of 52
> 50	8 out of 11	4 out of 7	19 out of 54

high rate in group A is obvious ($\chi^2 = 6.20$; $p < 0.02$). The same comparison made between group A + B on one hand and group D on the other shows the same trend ($\chi^2 = 3.67$; $p < 0.06$). The same procedure performed for group A + B versus group C + D also demonstrates an increased frequency of polyneuropathy signs ($\chi^2 = 5.33$; $p < 0.04$).

In table 6 the age factor is taken into consideration through the subdivision of the examined persons into two groups with 50 years of age as the dividing line. The trend of high rates of signs indicative of polyneuropathy in the jet fuel exposed groups can be seen below as well as above the age of 50 years. However, chi square testing becomes less meaningful in this situation because of the small numbers in the groups and the size differences in the samples compared.

Conduction velocities in peripheral motor nerves

Fig. 1 shows the MCV_{uln} as a function of age in the heavily exposed group (fig. 1 A) and in the less heavily exposed group (fig. 1 B); the continuous and broken lines

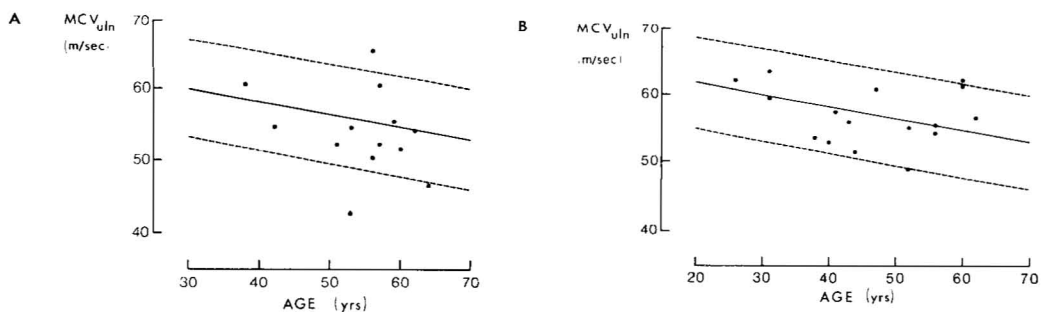


Fig. 1. Maximal motor conduction velocity of the ulnar nerve (MCV_{ulin}) as a function of age in the groups heavily (A) and less heavily (B) exposed to jet fuel. The continuous and broken lines represent the age regression and ± 2 SD, respectively, in the reference group from the heavy metals industry (27).

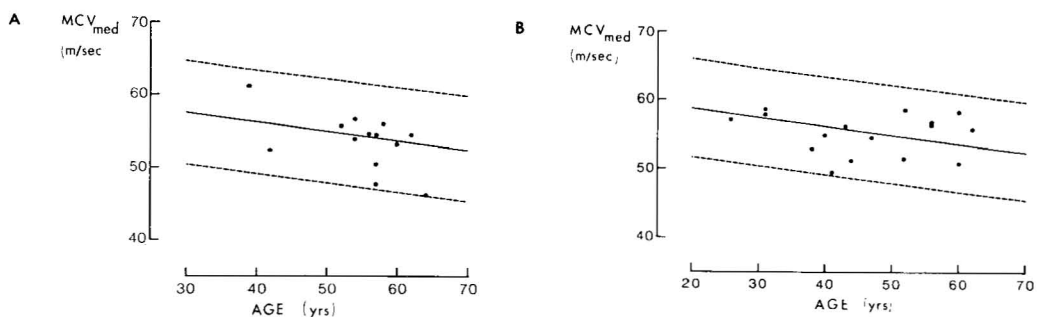


Fig. 2. Maximal motor conduction velocity of the median nerve (MCV_{med}) as a function of age in the groups heavily (A) and less heavily (B) exposed to jet fuel. The continuous and broken lines represent the age regression and ± 2 SD, respectively, in the reference group from the heavy metals industry (27).

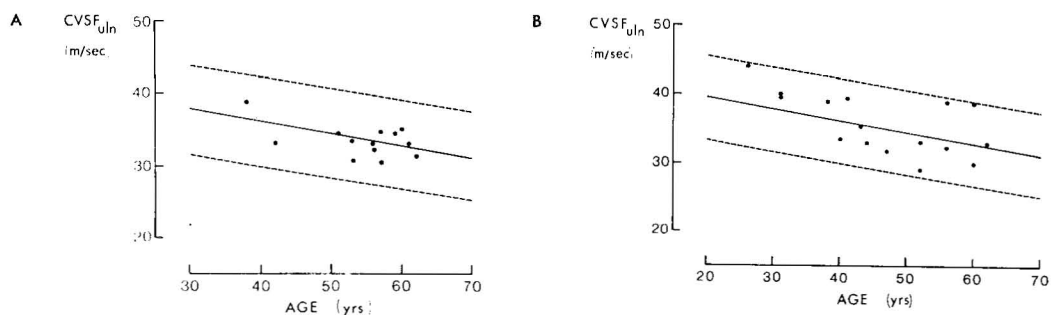


Fig. 3. Conduction velocity of the slow fibers of the ulnar nerve ($CVSF_{ulin}$) as a function of age in the groups heavily (A) and less heavily (B) exposed to jet fuel. The continuous and broken lines represent the age regression and ± 2 SD, respectively, in the reference group from the heavy metals industry (27).

represent the regression and the ± 2 SD, respectively, for the reference group (group D in table 5). In the diagram the values measured for each examined person have subsequently been plotted. In fig. 2 A and B the results from the measurements of the MCV_{med} are presented in the same manner. The $CVSF_{uln}$ has been plotted in the diagram in fig. 3 A and B for the heavily and the less heavily exposed groups, respectively.

An analysis of covariance in order to account for age-dependence gave no significant differences either between the heavily exposed group (group A) and the reference group (group D) or between the less heavily exposed group (group B) and the reference group for any of the three variables.

Threshold determinations of vibration sensation

In the present investigation vibration thresholds were compared with the results of the investigation on the reference group of workers in the heavy metals industry

(27), i.e., group D in table 5 (figs. 4 and 5). An analysis of covariance for the two measurements of vibration sensation showed a significant difference between the less heavily exposed group and the reference group for the measurements on the hand (carpal, fig. 5 B). Comparing the measurements of the heavily exposed and the reference group produced a p-value that was somewhat larger than 0.10. For the other vibration measurements there were no significant differences between the exposed groups and the reference group.

Evaluation of the neurophysiological recordings

For the assessment of the composite results of the neurophysiological recordings (the conduction velocities and the peripheral vibration thresholds, figs. 1–5), a multivariate analysis of covariance was made. This analysis showed no significant differences between either the heavily exposed group (group A) and reference group D or the less heavily exposed group (group B) and reference group D.

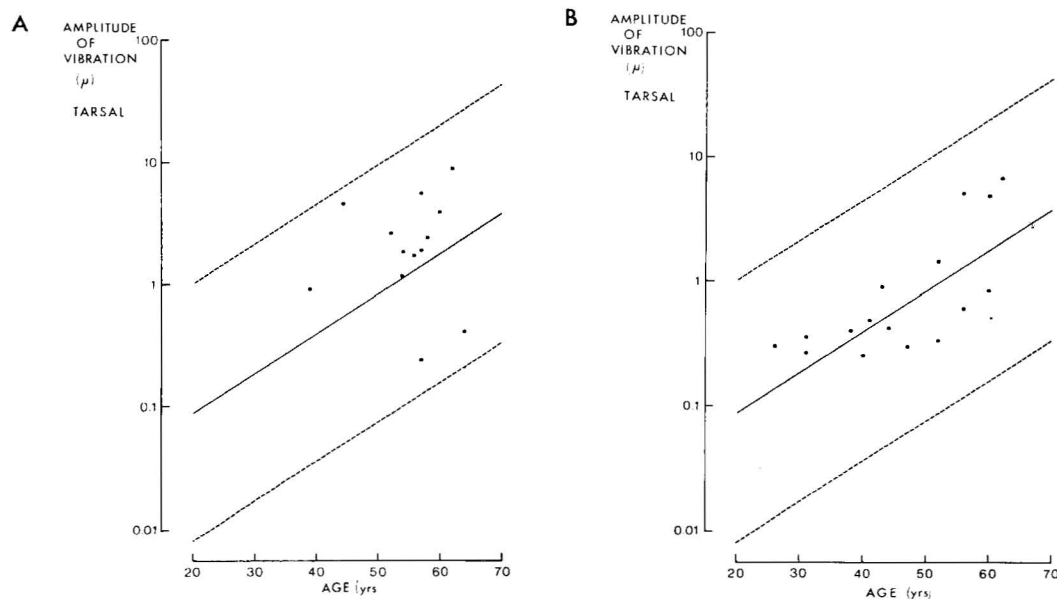


Fig. 4. Thresholds of vibration sensation (logarithmic scale) for the dorsum of the foot as a function of age in the groups heavily (A) and less heavily (B) exposed to jet fuel. The continuous and broken lines represent the age regression and ± 2 SD, respectively, in the reference group from the heavy metals industry (27).

DISCUSSION

Acute effects

All of the 13 persons in the heavily exposed group and 7 of the 16 persons in the less heavily exposed group had repeatedly experienced acute symptoms (dizziness, respiratory tract symptoms, palpitations, pressure on the chest, nausea, headache) on exposure to jet fuel vapors. The frequency and intensity of such repeated effects are, in analogy with the development of chronic gasoline poisonings (1, 30, 38) and alcoholism (17), probably relevant for the development of lesions in the nervous system.

Unfortunately, in the present investigation there is insufficient information available on the fuel concentration in the inhaled air when the acute effects described above occurred. On one occasion (in 1972) however, a piece of Dräger equipment (type CH 254) showed a concentration of 3,000 ppm at one workplace and about 500 ppm in two workrooms. These values are on the same order of magnitude as those measured in a Japanese workplace where polyneuropathy and neurasthenia developed in four workers engaged in cleaning brocade sashes with petroleum benzine (40). In studies on human volunteers at rest Drinker et al. (12) reported that exposure to 1,000 ppm of gasoline caused slight dizziness, nausea, and headache. When the concentration reached 2,600 ppm all subjects were drunk and somewhat anesthetized. In this respect attention must be paid to the increase in the uptake of solvents in blood and tissues as a function of physical exercise; according to Åstrand (2) even light work results in a significant increase in uptake. Drinker et al. (12) also found that in a group exposed to 160 and 270 ppm the most distinctive symptoms were irritation of the eyes and throat. Later Davis et al. (10) confirmed that eye irritation was the first symptom to appear during exposure to low concentrations of gasoline. Kerosene, however, has not been found to have such an eye irritating effect. The application of kerosene to the human eye causes no discomfort or injury (18), and this

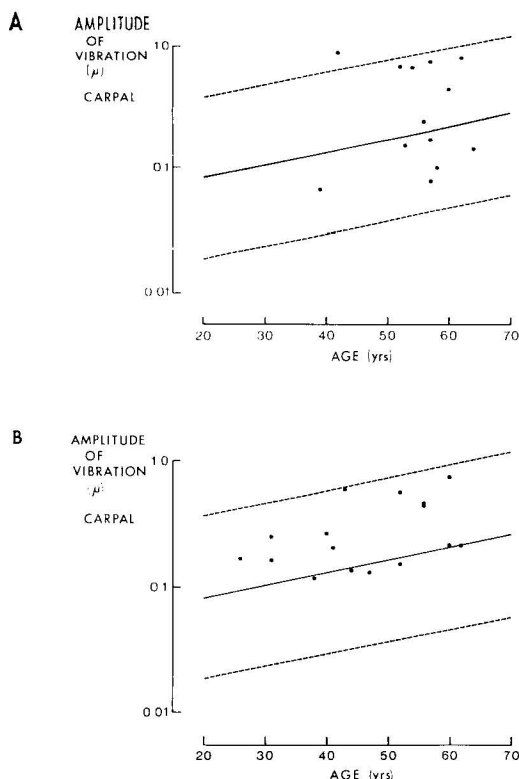


Fig. 5. Thresholds of vibration sensation (logarithmic scale) for the hand as a function of age in the groups heavily (A) and less heavily (B) exposed to jet fuel. The continuous and broken lines represent the age regression and ± 2 SD, respectively, in the reference group from the heavy metals industry (27).

phenomenon may offer an explanation to the absence of obvious eye irritation among the exposed persons in the present investigation.

Increased rates of symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy in the groups exposed to jet fuel in comparison with reference groups

The increased frequencies of symptoms indicative of neurasthenia and psychasthenia, as well as of symptoms and signs indicative of polyneuropathy, in the jet fuel exposed groups in comparison with reference groups of industrial workers are what could be expected from the

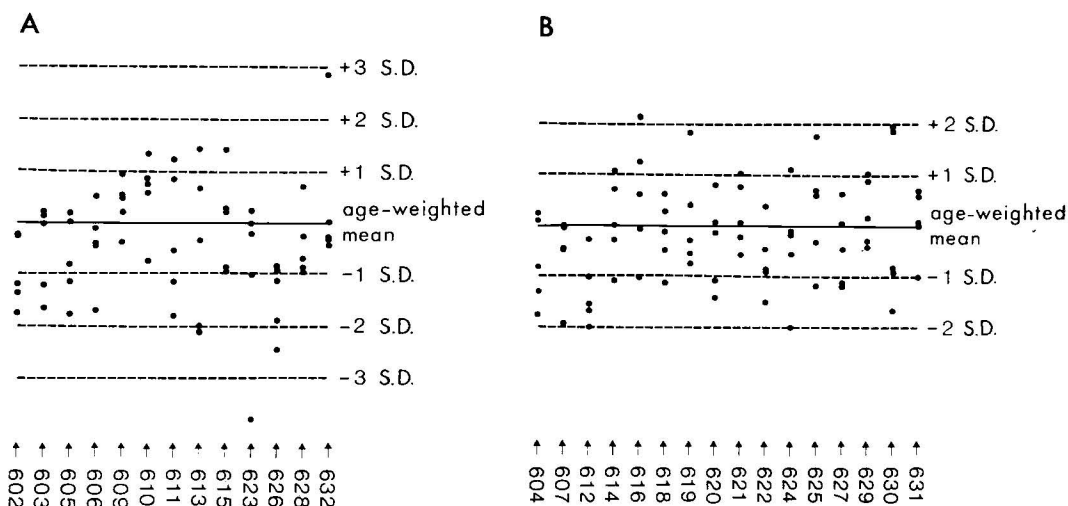


Fig. 6. Composite diagrams of the values of the maximal conduction velocity of the median and the ulnar nerve, the conduction velocity of the slow fibers in the ulnar nerve, and the thresholds of vibration sensation in the dorsum of the foot and in the hand of the examined groups expressed as standard deviations from the age-weighted mean value of the reference group (A = the heavily exposed group; B = the less heavily exposed group; the numbers at the bottom of the figure represent the examined subjects). Nerve conduction velocities lower than and thresholds of vibration sensation higher than the mean value are denoted with a negative sign. Nerve conduction velocities higher than and thresholds of vibratory sensation lower than the mean value are denoted with a positive sign.

descriptions of chronic fuel intoxications in the literature (4, 8, 13, 19, 29, 30, 37, 38, 40, 42). However, in an examination of a small number of persons limited to one place of work, the possibility of the psychological influence of individuals on one another cannot be excluded. Furthermore, the subjective complaints of the workers were generally discussed by the news media at the time of the investigation. However, the neurasthenic and psychasthenic symptoms had developed and were diagnosed and treated by physicians many years before the present investigation was undertaken.

Neurophysiological recordings

As already mentioned, analyses of covariance (including a multivariate analysis of covariance) gave no significant differences between exposed and reference groups with the exception of the carpal vibration thresholds of the less heavily exposed group and the reference group.

Based on these results, there are two principal alternatives as to whether long-term exposure to jet fuel causes any effect on the peripheral nerves, i.e., (a) in reality there is no such effect or (b) the sample is too small to show such an effect. However the results show a tendency towards slower conduction velocities (MCV_{uln} , MCV_{med} , $CVSF_{uln}$) and higher peripheral vibration thresholds (tarsal and carpal vibration thresholds). This tendency is illustrated in fig. 6 A and B, in which each test value of group A and B, respectively, is expressed as the deviation from the age-weighted mean of the reference group with the standard deviation as the unit of measure. Conduction velocities lower than the mean value and vibration thresholds higher than the mean have been denoted by a negative sign. Negative values, i.e., low conduction velocities and high peripheral vibration thresholds are results to be anticipated in the presence of an established nerve lesion. As can be seen in the figure, 41 of the 65 test values in group

A and 46 of the 80 in group B are negative in relation to the age-weighted mean of the reference group.

Comparisons between the two exposed groups

Since the investigation encompassed two groups of exposed persons, it was possible to observe the dependence of the findings upon the degree of the exposure. When such an internal grading is made, a higher rate is found in the heavily exposed group with regard to (a) acute symptoms, (b) symptoms indicative of neurasthenia and psychasthenia, as well as polyneuropathy, and (c) signs indicative of polyneuropathy.

Considering the facts presented concerning (a) the acute effects on repeated occasions, (b) the high rates of symptoms indicative of neurasthenia and psychasthenia and symptoms and signs indicative of polyneuropathy, and (c) the differences in the observations made between the two groups with varying degrees of exposure to jet fuel, the authors have interpreted the results as a possible indication of an effect of long-term exposure to jet fuel on the nervous system. However, further blind studies of other groups of workers exposed to jet fuel vapors and matched control groups of unexposed workers are needed before the validity of this interpretation can be established and any differences found between such exposed and nonexposed groups can be related to measurements or quantitative estimates of atmospheric fuel levels in the work areas concerned. Studies of this nature are already being carried out by the authors.

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