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X ray anomalies occurring in workers exposed to vibration caused by light tools

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ABSTRACT A high frequency of radiological anomalies (vacuoles, cysts, enostoses) was found in workers exposed to vibration caused by light tools (screw drivers, nutrunners) compared with a non-exposed group. The lesions were mostly localised in the spongy carpal bones (os capitatum, os lunatum, os scaphoideum). There was no significant difference between the sexes, nor between the "active" or "passive" hand, both hands being simultaneously exposed. These findings support the need to implement preventive measures.

The harmful effects of mechanical vibration on the human body are well known. Arthrosis and circulatory anomalies are well described.[1-5] In most cases, however, only the low frequency vibration caused by heavy tools is considered.[4 5] Little or no attention has been given to the possible damage caused by light tools (pneumatic screw-drivers and nutrunners) largely used in engine assembling factories. In our factory, where outboard motors (4HP to 140HP) are constructed, many workers handle these tools many times a day for short periods. During these activities, vibrations of very high frequency (up to 31 Khz) and accelerations (up to $10^{-1}-10^{2}$ m/sec^2) have been measured. We describe the results of our findings by comparison with a non-exposed group.

Materials and methods

There are two types of pneumatic tools: the first can be used as a screw driver and as a nutrunner, the second only as a screw driver. The double stroke nutrunner causes more perceptible and higher vibration frequencies than the single stroke nutrunner, partially due to the heavier material on which the nuts are to be fixed. Both are available in the press valve and in the pistol grip model. Table 1 summarises the characteristics of these tools. The exposure time varies widely in the course of a day, depending on the individual, the type of construction of the motor, and so on.

All measurements of vibration were performed with a Bruël & Kjaer apparatus (noise level meter T 2203—Oct band filter 1613—integrator ZR 0020—pick up 4332—filter UA0553) placed on the tool or the hand of the operator in vertical, horizontal, and tangential positions. Table 1 summarises the vibration exposure measures; for each type the maximum and minimum accelerations are given, at low and high frequency level.[6 7]

The job does not require a heavy physical effort, although at the end of each action some force is used to press on the screw driver in order to obtain a perfect fixation. The work is done inside the factory in good atmospheric conditions. The workers use one or two hands, without wearing gloves. Female workers sit while working.

The test group was composed of 282 men and 60 women; the characteristics of the group are shown in table 2.

Each worker had a clinical examination, an x-ray examination of the wrist, and a tonal audiometry test (noise risk of 92 to 114 dB A). A blood sample was taken on which the following biological examinations were performed: haemoglobin, red cell and white cell counts, haematocrit, sedimentation rate, blood sugar, total proteins, total lipids, SGOT, SGPT, uric acid, alkaline phosphatase, sodium, potassium calcium, phosphorus, CRP, RA, Rose Waaler, and ASLO. The radiographic examinations were carried out by the same radiologist and orthopaedist.

A control group of 401 workers (336 men and 65 women) with the same age and sex distribution was picked from different types of factories where no exposure to vibration was present (henchmen, pain-

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Table 1 *Description of some types of the "light type" pneumatic tools*

Type	*Weight (kg)*	*Rotation velocity (cycles/min)*	*Mean exposure time per action (s)*	*Mean exposure time per day (min)*	*Acceleration (m/sec²) min freq*	*max fr*
Atlas Copco LMS 06 HR 10 press-valve 6 screws G'case	0·9	12500	7	36	$\frac{2·3 \times 10}{31\ Hz}$	$\frac{3·7 \times 10}{16·10^3\ Hz}$
Atlas Copco LMV 22/S008 Press-valve 2 screws cover	0·93	800	12	79	$\frac{1 \times 10^{-1}}{31·5\ Hz}$	$\frac{2·1 \times 10}{16·10^3\ Hz}$
Atlas Copco LUF 22/SR008 Press-valve 2 screws G'case	1·2	800	6	13	$\frac{3·7 \times 10^{-1}}{31·5\ Hz}$	$\frac{6·5 \times 10}{250\ Hz}$
Atlas Copco LUF 33/HR016 Pistol-grip 8 screws G'case	1·6	1600	14	48	$\frac{4·5 \times 10^{-1}}{31·5\ Hz}$	$\frac{3·5 \times 10}{10^3\ Hz}$
Atlas Copco LUF 33/HR008 7 stuts cyl	1·6	800	39	80	$\frac{5·3 \times 10^{-1}}{31·5\ Hz}$	$\frac{4·6 \times 10}{8·10^3\ Hz}$

Measurements are performed in way described by CD Keight screening test.[6]

Table 2 *Survey of the examined population sample. Distribution by age and exposure time*

Age (years)	*Exposure time (years)*									
	<5		*5–10*		*11–15*		*16–20*		*Total*	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*
<20	27	—	—	—	—	—	—	—	27	—
20–30	89	5	25	3	5	—	—	—	119	8
31–40	33	8	21	6	13	5	7	6	74	25
41–50	14	6	10	2	8	12	12	2	44	22
51–60	—	—	4	2	4	2	10	1	18	5
Total	163	19	60	13	30	19	29	9	282	60

Table 3 *Comparison of the number of positive and negative x ray examinations in exposed and unexposed workers, by sex*

	No with radiological evidence			*No without radiological evidence*			*Totals*		
	Men	*Women*	*Total*	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*
Exposed group	228	49	277	54	11	65	282	60	342
Unexposed group	85	19	104	251	46	297	336	65	401
Total	313	68	381	305	57	362	618	125	743

ters, carpenters, bricklayers, bakers, plumbers, technicians). All were submitted to the examinations described above.

Results

FREQUENCY OF X RAY ANOMALIES

There was a striking difference in the frequency of x ray anomalies between the exposed and non-exposed workers. Table 3 summarises the results. The difference in the occurrence of these alterations is statistically significant for both sexes: (men: $\chi^2 = 190·6$; $p < 0·005$) (women: $\chi^2 = 34·6$; $p < 0·005$) and for the total population ($\chi^2 = 228·6$; $p < 0·005$).

DIFFERENT TYPES OF LESION

Two groups of lesions often appeared simultaneously (fig 1):

(1) Decalcifications: vacuoles (up to 1·5 mm) and cysts (>1·5 mm in diameter) or range zone of decalcification.

(2) Calcifications: enostoses (3 mm and more) (fig 2), marmoration.

The results are summarised in table 4. Because some workers had multiple lesions, the number of the lesions has been related to the number of workers' hands, thus giving the frequency of lesions per hand. Both sexes are equally affected ($\chi^2 = 0·02$; $p > 0·05$). The right hand shows slightly more anomalies, but the difference is not statistically significant ($\chi^2 = 0·46$; $p > 0·05$). Both hands are simultaneously affected in 179 workers (52·3%) and 31 controls (7·7%). This fact is not surprising, since in most cases the tools are handled with both hands, the non-preferred one doing some guiding. Large

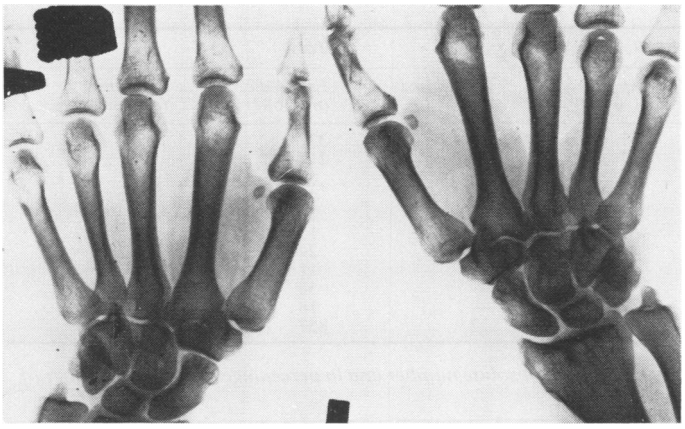

Fig 1 *L: cyst in os capitatum, vacuole in os scaphoideum; R: cyst in os capitatum.*

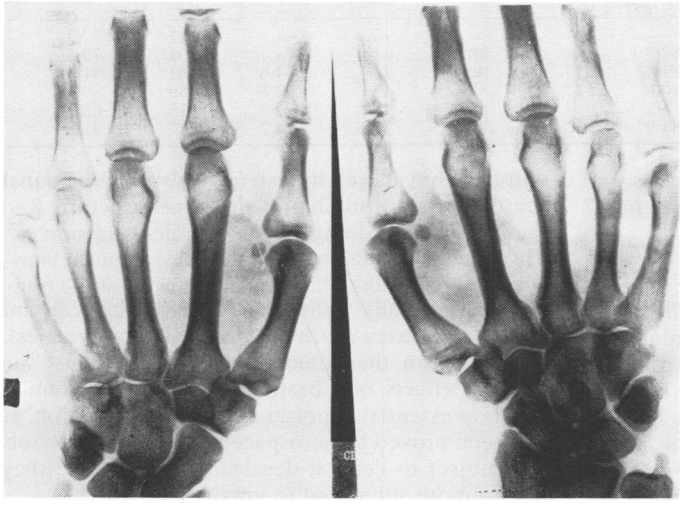

Fig 2 *Enostosis in os capitatum R and os scaphoideum R. Vacuoles in os lunatum R.*

Table 4 *Number of lesions expressed in absolute number and per workers' hand (p/h). For the exposed group, the x ray anomalies exceed the total number of hands affected*

	Men		*Women*		*Total*	
	Exposed (n = 564)	*Unexposed* (n = 672)	*Exposed* (n = 120)	*Unexposed* (n = 130)	*Exposed* (n = 684)	*Unexposed* (n = 802)
Vacuoles	407	91	81	8	488	100
	p/h 0·72	0·14	0·68	0·06	0·71	0·12
Cysts	133	59	44	8	177	67
	p/h 0·24	0·09	0·37	0·06	0·26	0·08
Enostoses	169	28	23	6	192	34
	p/h 0·30	0·04	0·19	0·05	0·28	0·04
All lesions	709	179	148	22	857	201
	p/h 1·26	0·27	1·23	0·17	1·25	0·25

Table 5 *Localisation of the lesions*

	Men		*Women*		*Total*	
	Exposed (n = 564)	*Unexposed (n = 672)*	*Exposed (n = 120)*	*Unexposed (n = 130)*	*Exposed (n = 684)*	*Unexposed (n = 802)*
Os capitatum	305	92	67	10	372	102
Os lunatum	170	46	47	7	217	53
Os scaphoideum	58	15	9	3	67	18
Os hamatum	43	4	5	1	48	5
Os triquetium	25	—	4	—	29	—
Os trapezoideum	13	—	—	—	13	—
Radius	15	4	9	1	24	5
Ulna	11	1	—	—	11	1
Metacarpal II	51	12	7	—	58	12
Metacarpal III	18	5	—	—	18	5
Total	709	179	148	22	857	201

Table 6 *Number of workers with positive x ray examinations in absolute number and in percentage of the total number of examined cases by age class and exposure time*

Age (years)	*Years of exposure*									
	<5		*5–10*		*11–15*		*16–20*		*Total*	
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
<20	21	77·7	—	—	—	—	—	—	21	77·7
21–30	72	76·7	25	89·2	4	90	—	—	101	79·5
31–40	31	75·6	22	81·4	17	90·4	11	84·6	81	81·8
41–50	17	85·0	12	100	17	85	13	92·8	59	89·4
>50	—	—	3	50	4	66·6	8	72·7	15	65·2
Total	141	77·4	62	84·9	42	85·7	32	84·2	277	81·0

zones of calcification are present in 27 cases and three controls and marmoration is present in 47 cases and four controls.

LOCALISATION OF THE LESIONS

Most injuries were seen in os capitatum, os lunatum, and os scaphoideum (table 5). The radius, ulna, and metacarpals remain mostly unaffected except for metacarpals II and III (calcification). In workers handling heavy vibrating tools, metacarpals I and V were most often affected.[3] The control group showed the same distribution. One has to keep in mind that this group is also composed of hand workers and therefore submitted to all types of pressure forces in the hand region. Exposure time and age do not seem to be important factors (table 6). The fall in positive cases among the oldest group may be due to autoselection factors: only a restricted number of workers stay at work until age 65. The lesions appear during the first five years of exposure.

All clinical examination results were negative and only three workers complained of pain in the wrist. All biological examinations gave negative results, but in four cases the serum uric acid was increased (>6 mg%).

Discussion

The harmful effects of vibration depend not only on mechanical factors such as frequency, energy, way of entrance, but also on human factors such as personal sensitivity, susceptibility of the bone structure, and the physical condition of the muscles and nerves.[4] The smaller the damping by the tension in the muscles the greater the effect.[5 8] The tension of the muscles is normally reflectary ordered by existant exposure reflexes which are decreasing by tiredness, putting down the defence mechanism against the noxious effects of vibrations. Mechanical stimulation is of essential importance for bone formation, as has been proved by aerospace medicine. Astronauts are subject to general decalcification because they are no more submitted to gravity.[9 10]

During the handling of a tool, two forces come into effect, the action of the forearm and the action due to strike back of the handled part. The action may be seen as a vector line going from the middle of the radius right to the hand. The reaction vector goes from the middle of metacarpal III to the arm. Both vectors cross in the os capitatum which is the shock absorber and the pressure centre of the carpus and this is why most of the lesions are localised in his bone in both the control and test groups.

The formation of cysts may be explained by the way of use, and the direct action of the tool. The back stroke especially may cause an overpressure in the wrist joint, resulting in a disturbance in the blood circulation[11] followed by the rupture of some fibres (collagen or elastic) of the osseus system, and finally leading to "microfractures." A regular reiter-

ation of these microtraumas might be the cause of a radiologically visible zone of decalcification.

The presence of these lesions is a sensitive indicator of exposure to light tool vibrations. The lesions appear before clinical symptoms become manifest. This is of great importance for the implementation of preventive measures. The question whether the lesions disappear after withdrawal from the risk cannot yet be answered. We need therefore a longitudinal study that is not yet finished.

There is some evidence that protection of the hand with gloves, covered with special absorbing materials of different thicknesses, provokes a clear diminution of the vibrations: from $4 \cdot 10^{-1}$ m/sec^2 to 10·1 m/sec^2 by 125 Hz (a damping factor 0·18 to 0·72). Further research on this means of protection is necessary.

References

[1] Brailsford J. Pathological changes in bones and joints induced by injuries. *Br J Med* 1936;ii:657.

[2] Heidenhoffer J. Zur ursächlichen Stellung der Lunatum malacie in Rahmen der örtlichen Malazien. *Fortschr Rontgenstr* 1949;**71**:472–5.

[3] Hunter D. *The diseases of occupations*. London: English Universities Press, 1964.

[4] Iowata H. Effects of rockdrillers on operator. *Ind Health* 1968;**6**:37–46.

[5] Linder GS. Mechanical vibration effects on human beings. *Aerospace Medicine* 1962;**33**:939–50.

[6] Hempstock TI, O'Conner DE. The measurement of hand-arm vibration. In: Taylor W, Pelmear PL, eds. *Vibration white finger in industry*. London; Academic Press, 1975.

[7] Agate JH. Druett HA. A study of vibrating tools in relation to the clinical effects which they produce. *Br J Ind Med* 1947;**4**:141–63.

[8] Stewart MA, Goda D. Vibration syndrome. *Br J Ind Med* 1970;**27**:19–27.

[9] Hattner RA, McMillan DE. Influence of weightlessness upon the skeleton: a review. *Aerospace Medicine* 1968;**39**:849–55.

[10] Pace N. Weightlessness: A matter of gravity. *N Engl J Med* 1977;**7**:32–6.

[11] Teissinger J, Louda L. Vascular disorders resulting from vibrating tools. *JOM* 1972;**14**:129–33.

Notice

Course in occupational neurotoxicology 17–21 September 1984

A course in occupational neurotoxicology will be held at the Institute of Neurology, Queen Square. Topics to be covered will include clinical and neuropathological aspects of peripheral neuropathy, the epidemiology of occupational neuropathy and psychopathy, clinical and psychological aspects of toxic organic psychoses, neurological examination, psychological testing in the field, and neurophysiological methods. In addition, a whole day will be spent at the MRC Toxicology Unit at Carshalton. The fee for the course will be £150 including registration. Participants will be responsible for their own travel and accommodation. Further details of the course may be obtained from Dr H A Waldron, TUC Centenary Institute of Occupational Health, London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London WC1E 7HT.

Correction

Reversibility of skeletal fluorosis (November 1983)

We regret that figure 3 (p. 458) was printed upside down. This was due to incorrect positioning by the printers.