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A STUDY OF HAND-ARM VIBRATIONS FOR THE FORESTERS WORKERS

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ABSTRACT

The foresters workers are especially exposed to hand-arm transmitted vibrations. These vibrations can cause the complex of vascular, neurological and musculoskeletal disorders, collectively named hand-arm vibration syndrome. Among these, the most common disorder is the vibration-induced white finger. The group exposed to vibration included: 4 hand saws cutters, 5 electric saws cutters, 3 tractor drivers and 2 truck drivers. Each worker was interviewed within health and workplace assessment questionnaires. The vibration level on the handles was measured and analyzed. The frequency-weighted acceleration, given in m/s^2, was calculated and the obtained values are graphically presented. The measured vibration levels are then discussed with regard to the operator's daily exposure limits recommended by the ISO 5349. The greatest vibrations occurred at 24 Hz (fundamental frequency) and at 100 and 200 Hz. All these workers have quite an experience with vibrating tools (up to 14 years) given a daily vibration exposure $A(8) \in (10.8\text{-}13.2) (m/s^2)$. Lifetime vibration was estimated using a logarithmic scale as $\in (19.5\text{-}21.3)$ (m^2h^3/s^4). From the obtained data, a linear dependence was determined between the logarithm from the odds of occurrence of vibration induced white finger and the exposure time. According to the exposure data of this study, the estimated regression equation indicates that the expected percentage of foresters workers affected with VWF tends to increase roughly in proportion to the square root of A(8) or in proportion to the square root of the duration of exposure.

KEYWORDS: foresters workers, hand-arm vibration, vibration accelerations, equivalent daily acceleration, total exposure duration, lifetime dose

1. INTRODUCTION

The vibrations induced to the drivers by the tractor can cause occupational disease [4], [5], [10].

Overall professional diseases induced by physical agents (noise and vibrations)	34784
professional diseases caused by mechanical overstressing vibrations	23313
hypoacusis or deafness	8615
Raynaud syndrome (Fig. 1)	2515
osteoarticular professional diseases caused by mechanical vibrations	317

Between 2002 and 2010, in Romania, the professional diseases induced by osteomuscular overstrain are placed on the first places, followed by professional diseases induced by noise, cutaneous diseases, Raynaud syndrome, etc [14].

New professional diseases (PD) cases between 2002 and 2010

Year	Total number of cases	PD – noise	PD – vibrations
2002	2060	395	120
2003	1828	211	100
2004	1802	386	106
2005	1576	386	74
2006	2238	696	141
2007	2500	890	65
2008	1376	292	31
2009	990	258	51
2010	1002	213	56

It is estimated that 1.7-3% of the total number of workers in the European countries are

exposed to dangerous vibrations, transmitted through the hand-arm system. A research carried out in Great Britain shows that, in this country, are over 1 million people exposed to vibrations which exceeded 2.8m/s^2 [3], [8].

Fig. 1 Raynaud syndrome

The Dutch researchers showed that 4-8% employees are exposed to whole-body vibrations.

In Romania, in 2007, were declared 84895 cases of exposed workers, 24 cases of Raynaud syndrome and 11 cases of osteoarticular syndrome [14].

County apportionment of PD caused by vibrations		
County	**Raynaud syndrome**	**Osteoarticular syndrome**
Maramureş	12	4
Bistriţa	3	2
Cluj	1	1
Dolj	1	1
Bacău	1	-
Vaslui	1	-
Argeş	1	-
Bihor	1	-
Harghita	1	-
Mureş	1	-
Suceava	1	-
Alba	-	1
Gorj	-	1

Professional diseases caused by vibrations:

a) Neurological diseases because of vibrations (Upper limbs monoreupathia (Carpal tunnel syndrome, Guyon cubital tunnel syndrome, Epitrohleo-olecranon syndrome, Radial tunnel syndrome, Other upper limbs monoreupathia), Polyneuropathia, Neuropathia)

b) Cardiovascular diseases (Raynauld syndrome)

c) Skin and cutaneous tissue diseases (Rash, Angioedema (Quincke edema), Anaphylactic shock)

d) Muscle-bone system and conjunctive tissue diseases (Bursitis, Epicondylitis, Synovitis, Tendonitis, Tenosynovitis, Meniscus injuries, Osteoarthritis, Periarteritis, Spinal deformities, Spinal disc herniations)

2. MATERIALS AND METHODS

SUBJECTS: The study consisted of 14 foresters workers. The group exposed to vibration included:

1. Hand saws cutters – 4 workers (25%)
2. Electric saws cutters – 5 workers (43.75%)
3. Tractor drivers – 3 workers (18.75%)
4. Truck drivers – 2 workers (12.5%)

Each worker was interviewed within health and workplace assessment questionnaires.

The questionnaires contained items on the subject's personal, medical, and work history.

Sensorineural (SN) disturbances in the fingers and hands were staged according to the following symptom scale [1]:

stage SN0 = no SN symptoms;
stage SN1 = intermittent numbness with or without tingling;
stage SN2 = persistent numbness and reduced sensory perception;
stage SN3 = persistent numbness, reduced sensory perception, and impaired manipulative dexterity.

Vibration induced white finger (VWF) was graded according to the clinical stages [1]:

stage VWF0 = no finger blanching attacks;
stage VWF1 = occasional attacks affecting only the tips of one or more fingers;
stage VWF2 = occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers;
stage VWF3 = frequent attacks affecting all phalanges of most fingers.

The simultaneous presence of the following symptoms and signs was considered to be suggestive of carpal tunnel syndrome (CTS).

3. MEASUREMENT AND EVALUATION OF VIBRATION EXPOSURE

Acceleration values from one-third-octave band analysis can be used to obtain the frequency-weighted acceleration ahw. It shall be obtained using:

$$a_{hw} = \sqrt{\sum_{j=1}^{n} (W_{hj} \cdot a_{hj})^2} \qquad (1)$$

where a_{hj} is the acceleration (m/s^2) measured in the one-third octave band, and W_{hj} is the weighting factor for the one-third-octave band [6], [12], [13]..

In accordance with the mentioned ISO standards, the three directions of an orthogonal co-ordinate system, in which the vibration accelerations should be measured, were as follows: z-axis, x-axis and y-axis. The evaluation of vibration exposure in accordance with ISO 5349 is based on a quantity that combines all three axes. This is the vibration total value ahw or weighted acceleration sum and it is defined as the root-mean-square of the three component values:

$$a_{hv}=\sqrt{a_{hwx}^2+a_{hwy}^2+a_{hwz}^2} \quad (2)$$

where a_{hwx}, a_{hwy}, a_{hwz} are frequency-weighted acceleration values for the single axes.

The vibration exposure depends on the duration of the exposure and on the magnitude of the vibration total value. Daily exposure duration is the total time for which the hands are exposed to vibrations during the working day. The daily vibration exposure should be expressed in terms of the 8-hour energy-equivalent acceleration or frequency-weighted vibration total value:

$$A(8)= a_{hv}\sqrt{\frac{T}{T_0}} \quad (3)$$

where T is the total daily duration of the exposure [s], and T_0 is the reference duration of 8h.

The hand-arm vibrations were measured using a MAESTRO vibro-meter and a triaxial accelerometer, both produced by 01dB-Metravib, fixed with clips on the steering wheel, according to EN ISO 5349-2 [15]. The axes were oriented in the directions specified in EN 1032 [12].

On the basis of the estimated periods of tool use, a lifetime vibration dose for each worker was calculated by a method of summation suggested by Griffin:

Lifetime dose = $[\Sigma(a_{hw}^2 \cdot t_h)^{1/2} \cdot t_d \cdot t]^2$ (m^2h^3/s^4) (4)

where a_{hw} is the frequency weighted acceleration measured on the vibrating tools (m/s^2), t_h is the individually estimated daily exposure (h/day), t_d is the number of working days/year and t is the number of years during which the tool was used.

The measurement time for every test set was 15 minutes with 15 s integration period.

4. RESULTS

Fig.2 shows the magnitudes of the r.m.s. of the frequency weighted and unweighted accelerations measured in the dominant axis of vibration, and the vector sum of vibration accelerations from the power tools used.

As expected, small differences between the frequency weighted acceleration in the dominant axis and the acceleration vector sum were found for the saws cutters and for the drivers.

The mean value of the frequency weighted acceleration measured on the handles of the tools was:

- r.m.s. acceleration weighted (dominant axis): 12.08m/s^2; the nearest values are for the workers 5 and 12
- r.m.s. acceleration weighted (vector sum): 14.22m/s^2; the nearest value is for the worker12
- r.m.s. acceleration unweighted (dominant axis): 84.94m/s^2; the nearest values are for the workers 3 and 4
- r.m.s. acceleration unweighted (vector sum): 91.15m/s^2; the nearest value is for the worker 13

The greatest vibrations occurred at 24Hz (fundamental frequency) and at 100 and 200Hz.

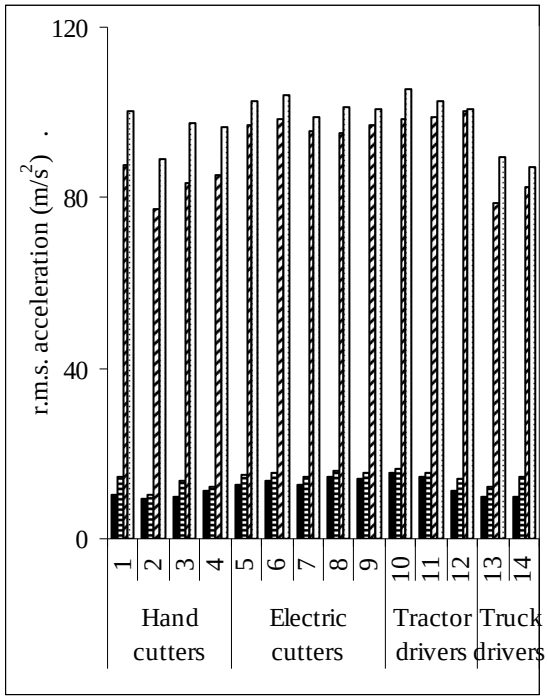

Fig. 2 Mean magnitude of root mean square of the frequency weighted and unweighted acceleration: (▉) weighted (Dominant axis); (≡) weighted (Vector sum); (▨) unweighted (Dominant axis); (▩) unweighted (Vector sum)

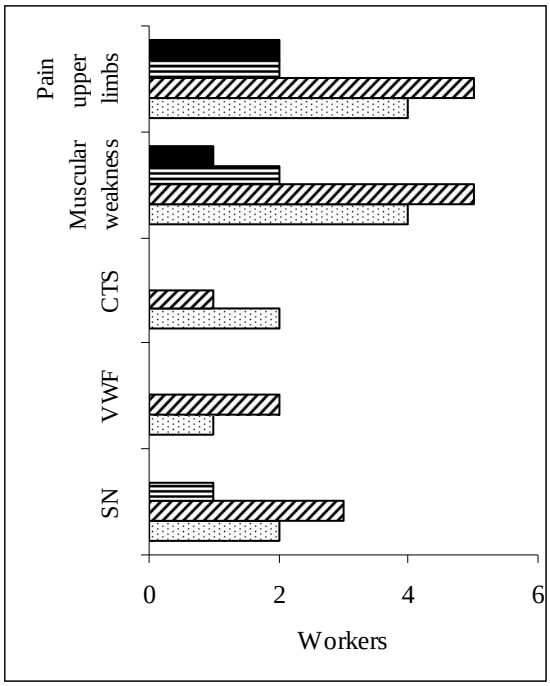

Fig. 3 Distribution of upper limb disorders among the controls workers exposed to hand transmitted vibration: (▉) Truck drivers; (≡) Tractor drivers; (▨) Electric cutters; (▩) Hand cutters

Fig.3 shows that most workers complained of sensorineural (SN) disturbances in the fingers and hands.

Also 3 cutters workers have VWF symptoms (Vibration induced white finger) and also 3 cutters workers were diagnosed with carpal tunnel syndrome (CTS).

Regarding the muscular weakness and pain upper limbs, these appeared – more or less severe – at all the questioned workers.

The characteristics of the workers exposed to hand transmitted vibration are shown in Table 1. Between the two groups no difference in other individual characteristics was found. Most workers have 30 to 45 years and most of them smoke more than a pack of cigarettes a day. Cutters workers drink more than 50g alcohol/day and the drivers drink less than 50g alcohol/day.

Table 1 Characteristics of the workers exposed to hand transmitted vibration

	Cutters n=9	Drivers n=5
Age (y)		
<30	1	-
30-45	5	4
>45	3	1
Cigarette smoking (pack/day)		
0	-	1
<1	1	-
>1	8	4
Alcohol (g/day)		
0	-	-
<50	2	5
>50	7	-

Between the 14 studied workers, 11 complained of upper limb injuries and only one declared that he takes cardiovascular drugs (Table 2).

Hand and electric saws cutters work on average 10h/day with vibrating tools and the drivers an average of 6 to 8h/day. All these workers have quite an experience working with vibrating tools (up to 14 years) given a daily vibration exposure $A(8) \in (10.8\text{-}13.2)$ (m/s^2).

Lifetime vibration was estimated using a logarithmic scale as $\in$ (19.5-21.3) (m^2h^3/s^4).

Table 2 Mean exposures to hand transmitted vibration

	Cutters n=9		Drivers n=5	
	Hand saws	Electric saws	Tractor	Truck
Cardiovascular drugs	-	-	1	-
Upper limb injuries	3	5	3	
Previous jobs with vibrating tools	2	1	3	-
Daily exposure (h)	10	10	6	8
Duration of exposure (year)	8	5	12	14
A(8)* (m/s^2)	11.5	13.2	12.1	10.8
Lifetime vibration ** (ln (m^2h^3/s^4))	20.8	21.3	19.5	20.4

* A(8) is the frequency weighted energy equivalent acceleration for a period of 8 h.

** Lifetime vibration is expressed on a logarithmic scale.

The log odds of risk of VWF associated with vibration exposure was also estimated with A(8) and duration of exposure as quantitative predictor variables (Fig. 4). From here a linear dependence is determined between the logarithm from the odds of occurrence of vibration induced white finger and the exposure time:

$$\text{Log(VWF)}=0{,}06t+1{,}6 \text{ (t-exposure time)} \quad (5)$$

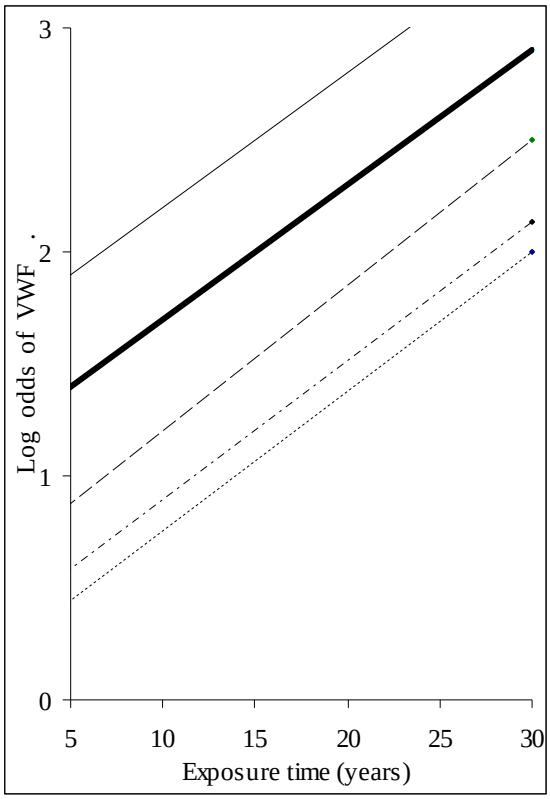

Fig. 4 Log odds of occurrence of vibration induced white finger according to the 8h frequency weighted energy equivalent acceleration and duration of vibration exposure (—): A(8) – 1m/s^2; (▬): A(8) – 2.5m/s^2; (— —): A(8) – 5m/s^2; (— ▪ —): A(8) – 10m/s^2; (- - -): A(8) – 15m/s^2;

Tests for data transformations suggested a linear model in which the ln transformed prevalence of VWF was regressed on lnA(8) and in duration of exposure (Fig. 5).

Fig. 5 shows that the regression equation was approximated to:

$$\ln[\text{Expected(VWF)}]=0{,}495\cdot\ln[\text{Exposure time}]+10{,}50$$

Fig. 6 shows that the regression equation was approximated to:

$$\ln[\text{Prelevance (VWF)}]= 0{,}355\cdot\ln[\text{Lifetime dose}]+2{,}44$$

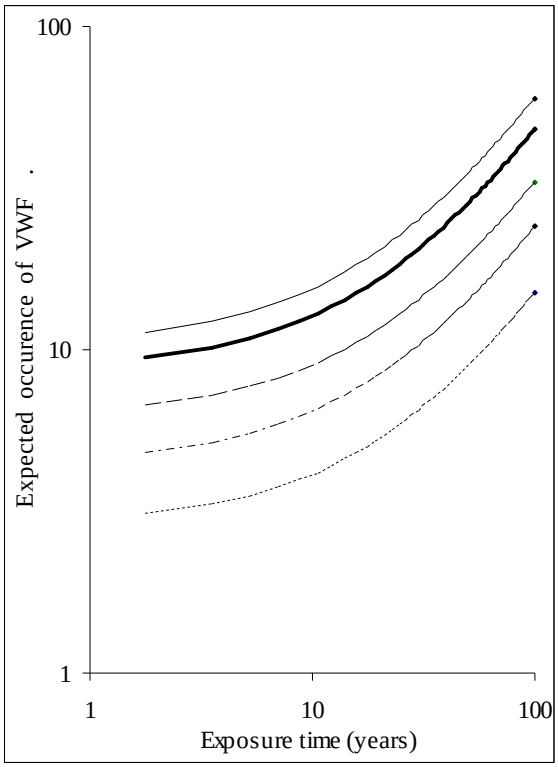

Fig. 5 Expected occurrence of vibration induced white finger among the workers operating vibrating tools: (—): A(8) – 1m/s^2; (▬): A(8) – 2.5m/s^2; (— —): A(8) – 5m/s^2; (—▪—): A(8) – 10m/s^2; (- - -): A(8) – 15m/s^2

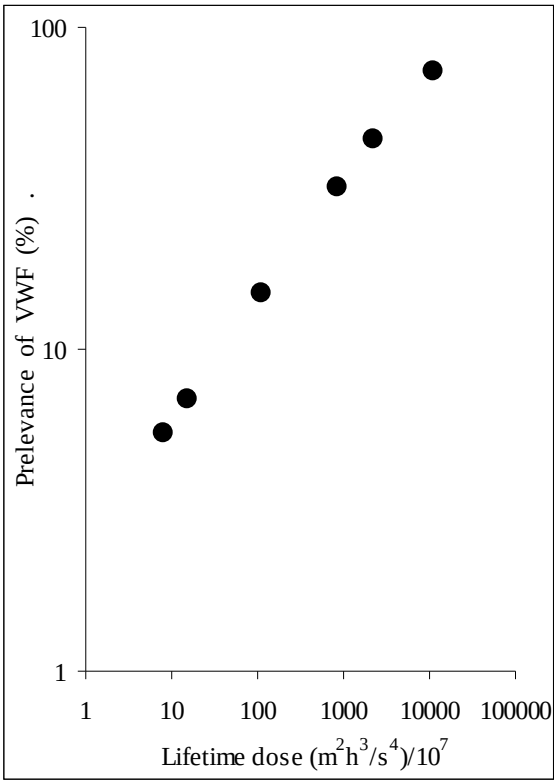

Fig. 6 Relation between the prevalence of vibration induced white finger and the estimated lifetime vibration dose

According to the exposure data of this study, the estimated regression equation indicates that the expected percentage of foresters workers affected by VWF tends to increase roughly in proportion to the square root of A(8) (for a particular exposure period) or in proportion to the square root of the duration of exposure (for a vibration of constant magnitude). This relation was confirmed by the one found between VWF and lifetime vibration dose (Fig. 7).

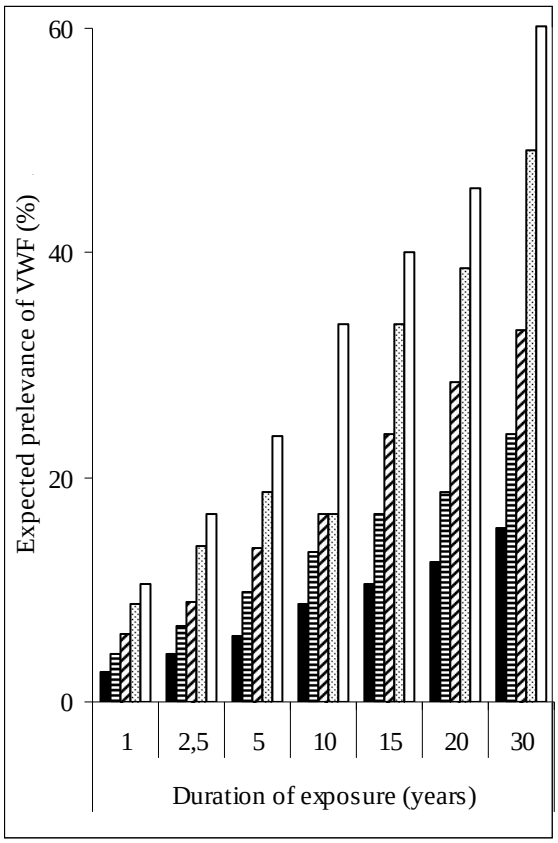

Fig. 7 Expected prevalence of vibration induced white finger (%) among workers according to the estimated 8 h frequency weighted energy equivalent acceleration and the duration of exposure
(▉) A(8)=1m/s^2; (≡) A(8)=2.5m/s^2;
(▨) A(8)=5m/s^2; (▩) A(8)=10m/s^2;
(∏) A(8)=1m/s^2;

5. DISCUSSION AND CONCLUSIONS

It is well known the relation between the professional exposure to hand transmitted vibrations by vibrating tools and the occurrence of VWF (Vibration induced white finger), yet this phenomenon is not completely understood.

During this study, we took into account many more factors: equivalent daily acceleration, total exposure duration, and lifetime dose, characteristics of vibration exposure (magnitude, frequency and duration), also the medical and social background of every worker.

For this study group, a monotonic dose-response relation was discovered.

Because different quantities are used to express exposure duration (latency or total exposure period), discrepancies can be seen between the different studies [2], [9], [11] regarding the analyses for VWF risk assessments.

Our analyses indicate that acceleration vibrations levels currently under discussion are over the reasonable exposure limits for the workers protection against the harmful effects of hand transmitted vibrations.

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