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Hand-arm vibration syndrome Clinical and Neuro-physiological studies

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Abstract: Hand-arm vibration syndrome (HAVS) is a group of symptoms caused by the use of vibrating hand-held tools. It appears to cause damage to both small blood vessels and small, un-myelinated nerve fibers, resulting in two specific diseases: vibration-induced white finger (VWF) and vibratory neuropathy. **Aims:** to assess VWF and carpal tunnel syndrome (CTS) in vibration exposed workers in three factories in Helwan, to investigate neural conduction in the upper limbs [somato sensory evoked potentials (SSEPs) and distal sensory latency (DSL) of the median nerve] in those patients- A further aim was to assess the efficacy of engineering control by application foundation and concrete for vibratory machines and protective measures for vibratory workers, as reassessment of VWF and SSEPs were done after one year. **Methods:** A total of 210 male workers were evaluated using Stages of Vibration White Finger (Taylor-Pelmear System). The upper limb SSEPs were done to 39 subjects with manifestation of VWF. Distal sensory latency (DSL) of the median nerve was done to 18 workers with clinical manifestation of CTS. After one year, from application protective measures, reassessment of stages of Vibration White Finger and upper limb SSEPs were done. **Results:** The study shows that 39 subjects had manifestations of VWF then reduced to 25 subjects after application protective measures. Upper limb SSEPs showed significant reduction at Erb's points, cervical and cortical points after implementation of protective measures. CTS is common in vibration exposed workers with manifestations of VWF (46%) and most of them showed increased DSL of the median nerve. **Conclusions:** VWF is common in workers exposed to vibration from metal grinding in some of Helwan factories and CTS is common among those workers with VWF. Assessments of upper limb SSEPs and DSL of the median nerve are important to detect early neural damage. Protective measures are important for those subjects.

Key words: Hand-arm vibration syndrome,Clinical and Neuro-physiological studies

INTRODUCTION

Vibration Syndrome (VS) is a group of symptoms related to use of vibrating tools e.g. chain saws, grinders, jack-hammers and drills. These tools produce a rapid back and forth movement, which is transmitted to the worker. The syndrome includes some or all of the following: muscle weakness, muscle fatigue, pain in the arms and shoulders and vibration-induced white finger (VWF). Many researchers believe that other symptoms e.g. headaches, irritability, depression, forgetful ness, and sleeping problems should also be included in descriptions of Vibration Syndrome. Sauni R, Virtema P, Paakkonen R, *et al* (2009).

For whole body vibration (vibration transmitted through the lower extremities and/ or the back) the vibrating machine appear to affect whole body. It is mainly implicated in low back disorders and a host of less well- understood symptoms (Schneider, S *et al*., 1995), while segmental vibration (vibration transmitted through the hands) appears to be more localized stress and causes damage to both the small blood vessels and small, unmyelinated nerve fibers in the fingers, resulting in two specific diseases: vibration-induced white finger (VWF) and vibratory neuropathy. Together, these are called the hand-arm vibration syndrome (HAVS) (Occupational 2007).

Vibration induced white finger (VWF) also known as white-finger disease, occupations Raynaud's phenomenon or dead hand is the result of impaired circulation (poor blood supply in the fingers) caused by the prolonged use of vibrating tools. Its symptoms include: numbness, tingling, blanching of the fingers, loss of finger dexterity, discomfort and pain in upper limbs. In whites the fingers actually have a blanched appearance and in blacks (or people of color) the fingers turn lighter in color. Working in cold climate temperatures precipitates the condition more rapidly than in working in warmer climates. Flodmark, B-T; lundborg, G. (2001) In later stages, the attacks become severe and painful, leading to blue, cold finger where the skin become atrophic, later ulcerated and finally gangrenous. Bovenzi, M (2002) These changes leads to difficulty in undertaking fine manual dexterity, difficulty in feeling and picking up small coins, difficulty in doing and undoing items of clothing (buttons) and clumsiness of fingers with increasing stiffness of finger joints. Wasserman, D (1994)

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Segmental vibration has also been implicated, in carpal tunnel syndrome (CTS). It is a group of symptoms in the hand which arise from pressure on the median nerve which passes through the palm side of the wrist. The early symptoms are similar to the early symptoms of VWF and consist of tingling in the fingers. Later, symptoms can progress to numbness. Pain in the wrist and fingers may also develop. The symptoms of CTS are frequently worse at night and a person may be awakened from sleep by pain or the feeling of pins and needles in fingers, hand or wrist. In very severe cases the symptoms are irreversible and may include weakness of the hand due to loss of muscle function. (Kouyoumdjian JA, *et al*., 2002).

Aim of the work:

This study was done to assess the occurrence VWF and CTS in vibration exposed workers in some of Helwan factories and to investigate neural conduction in the upper limbs [somatosensory evoked potentials (SSEPs) and distal sensory latency (DSL) of the median nerve]. A further aim was to assess the efficacy of engineering control by application foundation and concrete for vibratory machines and protective measure for vibratory workers, as reassessment of VWF and SSEPs were done after one year after application of these protective measures.

Subjects And Methods:

Workers exposed to vibrations generated from metal grinding in some of Helwan factories were assessed for VWF. They were 210 workers. Those are the workers in three of the finishing departments. The first department consisted of one medial covered working area (measuring 15 meters length, 10 meters width and 6 meter height). Five workstations were present and on each workstation we have 3 workers. The second department in another factory consisted of small covered area (l0meter length, 10 meter width and 7 meter height) 3 workstations were present and on each workstation we have 5 workers. The third department consisted of large covered area (40 meter length, 20 meter width and 10 meter height) 10 workstation were present and on each workstation we have 4 workers. Vibration was found to be continuous and uniform throughout the entire work-shift.

Workers with secondary Raynaud's phenomenon e.g. due to connective tissue disease, trauma, occlusive vascular disease, Dys-globulinemia, intoxication and neurogenic disorders were excluded from the study.

Clinical Assessment of vibration white finger (VWF):

All the workers (210 males) were evaluated using a self-administered questionnaire, to assess the common symptoms among the workers and to exclude the presence of systemic disease that may affect the workers. Raynaud's phenomenon grading system for Vibration-induced White Finger (Taylor-Pelmear System) (Palmer. K-T *et al*., 2002) was done for all the workers. Thirty-nine of them (18.6%) had manifestations of VWF. Clinical reassessment of those 39 subjects was done after one year of application of insulating concrete and foundation to the machine to minimize vibration and protective measure for vibratory workers before starting the job: worm the hands, keep them worm during the job and reduce smoking while using vibratory hand tools.

Somatosensory evoked potential Assessment:

Short latency somatosenosry evoked potentials (SSEPs) can be recorded following stimulation of peripheral sensory nerves. The evoked responses could be picked up at many levels in sensory pathway, starting from nerve trunks till the parietal sensory cortex.

In upper limb stimulation at wrist, the following waves could be picked up at certain recording electrodes. Chiappa, K., Martin, J. and Young.R (1987)

I) A positive negative wave at Erb's point appearing at about 9mesc after application of the stimulus. It represents the electrical activity passing through the brachial plexus.

II) N_{11}: is recorded at the second cervical spine (C2), 11-12 mesc after the stimulus. It may be generated in the entry zone of the cervical roots or nearby the posterior column.

Ill) N_{13}/P_{13}: is recorded at (C2) electrode 13mesc after the stimulus. It is generated from the dorsal column nucleus and medial lemniscus.

IV) N_{19}/P_{22} is recorded at scalp electrode over cortical sensory area contralateral to the stimulated limb.

Somatosensory evoked potential (SSEPs) was done to the 39 subjects with manifestation of VWF before and after 1 year of application foundation and concrete for vibratory machines and protective measure for vibratory workers. SSEPs was done by using *MK* 15-3 channel apparatus. The Surface disc electrodes were used for recording and they were placed to the following sites:

Erb's point: in the supraclavicular fossa ipsilateral to the nerve stimulated (about 2cms above the mid point of the clavicle).

Cervical electrode: on the nape of the neck in the midline at the level of the second cervical vertebrae.

Electrode referring to the central scalp area overlying the primary sensory cortex in the parietal lobe contralateral to the limb stimulated.

The stimulator: The stimulus is electrical in nature it is minimal that is does not produce movement on stimulation of the median nerve at the wrist. The rate was 4/second number of sweeps was 500. Chiappa, K., Martin, J. and Young.R (1987).

Clinical Assessment of carpal tunnel syndrome (CTS):

Out of the 39 subjects with manifestations of VWF 18 subjects (46%) were clinically suspected cases of carpal tunnel syndrome. The diagnosis of carpal tunnel was made based on the presence of two or more symptoms of the primary symptom complex, which included numbness, tingling clumsiness, sleepiness of the hand and nocturnal increase in symptoms was reported it needed to be supported by two or more of the secondary symptoms which included burning/cold, tightness, ache discomfort and puffiness. In 15 cases, the diagnosis was supported by the presence of appositive phalen test.

Assessment of the Distal sensory latency (DSL) of the median nerve:

All the subjects with clinically suspected cases -of CTS were referred for assessment of the distal sensory latency (DSL) of the median nerve with recording at thumb, index and middle fingers.

The nerve conduction velocity apparatus used was the Nihon-Kohden model with an average model DAT-3201. The action potentials recorded were amplified and displayed on the screen of a cathode ray-oscilloscope. Silver paper of 70mm width and 60m length was used for recording and printing data.

Ring electrodes were used to record sensory potentials and were formed of thin strips of silver with lint and soaked in saline before use. They were wrapped around the distal phalanx and the base of the proximal phalanx.

Disc electrodes were used to record sensory potentials and were formed of active and reference electrodes. Bipolar stimulating surface electrodes were used.

Distal sensory latency (DSL) of the median nerve was measured as the time of the first negative peak (conduction velocity was calculated using the distance between stimulating cathode and active electrode).

Statistical methods:

The data were collected analyzed using statistical software package (EP1-5).

Results:

Out of 210 workers 39 subjects (18.6%) had manifestations of VWF. Their age vary between 30-55 years with a mean of 36.2±10.6 years. The mean duration of exposure was 22±3.2 years.

Table (1) shows: Raynaud's phenomenon grading system for workers exposed to vibration. Six cases (15%) were complaining of intermittent tingling (OT), 5 cases (13%) were complaining of intermittent numbness (ON), 9 cases (24%) complaining from blanching of fingertip with or without tingling or numbness (stage 1), 7 workers (18%) with blanching of one or more fingers (stage 2). 6 (15%) with extensive blanching of all fingers in winter (stage 3), and 6 (15%) with extensive blanching of both summer and winter (stage 4).

Table (2) shows: Raynaud's phenomenon grading system after one years of application foundation and concrete and protective measure for workers that about 13 (33%) with intermittent numbness, 6 (15%) with extensive blanching of all fingers in winter (stage 3) and 6 (15%) with extensive blanching of all fingers both summer and winter (stage 4).

Table 1: Stages of vibration-induced white finger before application foundation, concrete and recommendation

No *of patients (%)*	*Stage*	*Condition of digits*	*Work and social interferenc*
	00	No tingling, numbness or blanching of fingers	No complaints
6(15%)	OT	Intermittent tingling	No interference with activities
5(13%)	ON	Intermittent numbness	No inteiference with activities
11(28%)	TN	Intermittent tingling and numbness	No interference with activities
9 (23%)	I	Blanching of a finger tip with or without tingling and/or numbness	No interference with activities
7(18%)	2	Blanching of one or more fingers beyond tips, usually during winter.	Possible interference with activities outside work, no interference at work
6(15%)	3	Extensive blanching of all fingers; frequent episodes in both summer and winter	Definite interference at work, at home and with social activities and restriction of hobbies
6(15%)	4	Extensive blanching of most fingers, frequent episodes in both summer and winter	Occupation usually changed because of severity of signs and symptoms

Table 2: Stages of vibration-induced white finger after one years of application foundation, concrete and recommendation among the examined group:

No of patients (%)	Stage	Condition of digits	Work and social interference
14(36%)	00	No tingling, numbness or blanching of fingers	No complaints
	OT	Intermittent tingling	No interference with activities
13(13%)	ON	Intermittent numbness	No interference with activities

	TN	Intermittent tingling and numbness	No interference with activities
	1	Blanching of a finger tip with or without tingling and/or numbness.	No interference with activities
	2	Blanching of one or more fingers beyond tips, usually during winter.	Possible interference with activities outside work, no interference at work
6(15%)	3	Extensive blanching of all fingers; frequent episodes in both summer and winter	Definite interference at work, at home and with social activities and restriction of hobbies
6(15%)	4	Extensive blanching of most fingers, frequent episodes in both summer and winter	Occupation usually changed because of severity of signs and symptoms

Table 3: the screening history and examination for 18 workers only • used to ensure that the referring diagnosis of C.T.S

Neurological abnormalities	* Number of patients	percentage
• Primary symptoms complex : - bilateral complain - unilateral complain	 15 3	 83% 16%
• Phalen's Maneuver	15	83%
• X-ray cervical	0	0%

** the age of this patients ranged from 30 to 55 with a mean age of36.6±10.0 years. 15 were affected bilaterally and 3 had unilateral complains*

Table 4: The latency for conduction of both median sensory nerves, impulses over standard distances between wrist and fingers in 18 workers with carpal tunnel syndrome.

No	14 cm index (RT)	Wrist finger (Left)	14 cm middle (RT)	Wrist finger (LF)	14 cm thumb (RT)	Wrist finger (LT)
1	22.0	7.0	27.8	7.9	18.6	5.5
2	5.2	5.3	5.0	5.0	' 4.0	4.3
3 J	4.1	5.1	4.7	5.5	4.0	4.3
4	5.4	3.5	6.4	3.7	7.1	2.9
5	6.U	4.8	6.6	5.6	5.6	4.9
6	4.1	4.1	3.8	4.2	3.7	4.1
7	5.0	3.2	3.4	3.4	5.5	3.2
8	16.5	10.3	7.4	8.3	16.3	14.1
9	5.0	. 7.2	5.3	16.1	4.9	18.5
10	5.0	7.4	4.8	5.5	4.4	4.9
11	5.9	6.8	6.3	8.1	5.5	6.7
1^{n}	4.8	4.7	5.7	7.0	5.1	4.6
13	4.9	4.4	6.9	4.7	5.6	4.1
14	5.3	5.8	5.2	8.3	5.1	5.7
15	7.6	6.4	7.4	7.5	6.3	6.3
16	7.5	6.3	6.8	6.2	5.9	5.1
17	9.3	4.6	10.1	4.8	8.2	4.2
18	9.2	4.5	6.7	5.4	8.2	4.3
No	18	18	18	18	18	18
Range	4.1-22.0	3.2-10.3	3.4-27.8	3.4-16.1	3.7-18.6	2.9-18-5
Mean	7.40	6.1	7.1	6.31	6.21	5.55
S.D	4.397	2.30	5.1	2.66	3.40	3.34

Table (3) Shows:

The screening history and examination for 18 workers exposed to vibration only used to ensure that the referring diagnosis of carpal tunnel.

The age of the patients ranged from 30 to 55 with a mean age of 36.6±10.0 years, 15 were affected bilaterally and 3 had unilateral complains. Out of 18 workers exposed to vibration, fifteen 15 (38%) cases showed positive phalen's test and 18 (100%) cases had primary symptoms complex.

Table (4) shows: The mean and standard deviation of the distal sensory latency for the wrist-digit segments of both median nerves measuring to the peaks of evoked responses. The distal sensory latency to the middle finger was greater than 4.4 (upper limit of normal) in 18 patients of which 15 were affected bilaterally and 3 were affected unilaterally. The distal sensory latency to the middle finger was greater than 5.1 (upper limit of normal) in 18 patients of which had unilateral delayed. The distal sensory latency to thumb was greater than 3.40 (upper limit of normal) in 18 patients of which 5 had unilateral delayed.

Table (5,6 & 7) showed: the results of the somatosensory evoked potential in workers exposed to vibration. Erb's point of workers exposed to vibration is 18.3±4.1 compared to 11.3± 0.9 after application foundation, concrete and protective measures, the differences in Erb's points are statistically significant. Cervical point of the workers exposed to vibration is 24.2±6.3 compared to 17.5± 3.5 after application foundation, concrete and protective measures. The differences in cervical points are statistically significant. Cortical P points of workers exposed to vibration is 30.2± 10.1 compared to 24.4±6.2 after application foundation, concrete and protective measure. The differences in cortical P are statistically significant.

Table 5: Somatosensory evoked potential of the workers exposed to vibration before application foundation

Neurological abnormalities	Means	SD
• Erb's point	18.3	±4.1
• Cervical	24.2	±6.3
• Cortical N	28.1	±8.9
• Cortical P	30.2	±10.1

Table 6: Somatosensory evoked potential of the workers exposed to vibration after application foundation, concrete and recommendation among the examined group

Neurological abnormalities	Means	SD
• Erb's point	11.3	±0.9
• Cervical	17.5	±3.5
• Cortical N	21.1	±5.1
• Cortical P	24.4	±6.2

Table 7: Somatosensory evoked potential of the workers exposed to. vibration before, after application foundation, concrete and recommendation

Neurological abnormalities	Exposed to vibration before application	Exposed to vibration after application	P-Value
• Erb's point	18.3±4.1	1L3±0.9	.001*
• Cervical	24.2±6.3	17-5±3.3	.008*
• Cortical N	28.1±8.9	21.1±5.1	.045*
• Cortical P	30.2±10.1	24.4±6.2	.139

*P-Value <0.005 * Is considered significant*

Discussion:

Hand-arm vibration syndrome (HAVS) is one of the unrecognized hazards that has gained increased awareness today, as many workers discover their illness after many years of using vibrating tools. It's not apparent as other hazards e.g. toxic chemicals or fumes. (Occupational 2007) Every year in winter, many cases with manifestations of HAVS in vibration exposed workers are seen. So we did this study to assess the problem, evaluate the use of protective mechanisms and try to decrease the number of new cases.

Occupational vibration has existed since pneumatic tools were introduced in the 1900s. The link was made gradually, and in 1918 HAVS was discovered characterized by two specific diseases: vibration-induced white

finger (VWF) and vibratory neuropathy. This hazard exists in many industries from a power saw operator in the woodworking field to a riveter in an automotive or aerospace facility. Wasserman, D (1994).

Sympathetic hyperacrivity has long been postulated to account for VWF, but damage to vasoregulatory structures and functions in the finger skin now also seems to be involved. Ryoichi INABA, *et al* (1996) Cytokines and cell adhesion molecules both play an important role in this interaction and basal vascular tone and vasodilatation are regulated by nitric oxide which may contribute to the micro vascular damage seen in this disease. (Kennedy G; *et al*., 1999)

Vibratory neuropathy usually results from damage to the small, unmyelinated nerve fibers. Bovenzi M; Giannini F; Rossi S (2000) However, Hirata *et al*. (1999) postulated that vibration affects the peripheral nervous system function via mediation of circulatory disturbance as VWF.

In the present study the workers were exposed to vibration for 15-32 years with the mean duration22±3.2 years. Their mean age of 36.2±10.6 years. Manifestation of VWF was found in (18.6%) of vibration exposed workers. It was found that Ray-naud's phenomenon grading system for Vibration-induced White Finger for workers exposed to vibration with intermittent tingling and numbness (11) (28%) only nine (9) (23%) complaining from blanching with or without tingling (6) (15%) with extensive blanching of all finger in winter and (6) (15%) with extensive blanching of all fingers in both summer and winter. These results are similar to those reported by Barregard *et al*. (2003) who found the prevalence of vibration induced white finger (VWF) in Swedish car mechanics is 15% in workers exposed to vibration less than 20 years, mainly in stage 2. the prevalence of VWF increases up to 25% in workers exposed to vibration more than 20 years. These results were also in harmony with the work of Noel, (2001). Who studies Raynaud's phenomenon in workers exposed to vibration.

One of the aims of this study is to assess the efficacy of engineering control for prevention of vibration from machine. After implementation of foundation and concrete for 6 machine, the frequencies from the machine stopped. Workers were advised to wear gloves at all time when using vibrating hand tools before starting job, the hands keep them warm during the job, do not allow the hand to become wet chilled, stop smoking and decrease duration of exposure.

So after application of engineering control and recommendation for workers for one year, we found Raynaud's phenomenon grading system decreased for workers exposed to vibration (Table 2). These results proved the importance of preventive measures in reduction of VWF.

However, out of 39 workers exposed to vibration 5 (13%) had intermittent numbness and 6 (15%) had extensive blanching of all fingers bilaterally and 6 (15%) had extensive blanching of all fingers both summer and winter. These results are in agree with study of Palmer *et al*. (2002). Who concluded that extensive blanching (affecting nine or ten digits) not improved after application of adjustment for machine compared with one to two digit which improved.

The assessment of the impact of tobacco use, and by extension stopping smoking on the long-term course of disease decreased Raynaud's phenomenon grading in workers exposed to vibration. This finding agree with study of Chemiack *et al*, (2000). who concluded that the effects of smokin? and stooping smoking on symptoms of Raynoudis phenomenon will decreased. The workers wann the hand *and* keep them warm during the job and wear gloves at all time this is agree with study of Montrone *et al*, (2000) and Olsen (2001).

In our study the dose-response relation for vibration induced white finger the application of foundation and concrete for the machine the dose of vibration for the workers and the workers exposed to vibration improved. This finding agree with study of Saunir *et al*, (2009) How concluded that the dose-response relationship for workers with VWF in this study suggests a time dependency such that halving the years of exposure allows a doubling of the energy equivalent vibration.

In the present study the decrease in peripheral nerve conduction speed which is related to duration of exposure and the presence of Raynaud's phenomenon of workers exposed to vibration (Table 5). These results were in harmony with the work of Discaizi and Per-relli (2000).

The short latency somatosensory evoked potential (SLSEP) were significantly delayed compared with workers exposed to vibration after application foundation, concrete and protective measures for vibratory workers (Table 5). These results are in harmony with the work of Hirata *et al*, (1995), Kaji *et al*, (2001), Alaranta and seppalainen (2001) who found that short latency-somato sensory evoked potentials were delayed in workers exposed to vibration compared with those in the control.

In our results, the screening history and examination of eighteen workers (18) only used to ensure that the referring diagnosis of carpal tunnel syndrome (Table 3) revealed fifteen (15) workers with positive Phalen's test and eighteen workers (18) with primary symptoms complex.

The symptoms of peripheral neuropathy in the hands are common among workers using vibratory tools. The mechanism of this and its relation to carpal tunnel syndrome (CTS) was studied in workers exposed to vibration at their work place, and median nerve conduction velocities were measured to prove the diagnosis. This was in agree with study of Brismar and Ekenvall *et al*, (2001) with respect to the median nerve distal sensory latency (DSL) to the index finger, it was delayed in 98.2% of the cases of this study, of which the syndrome was

bilateral in 15 workers. These findings are in harmony also with those reported by Hirata *et al*. (2002) who reported Reduction of sensory nerve conduction velocity of the distal part of the radial nerve among patients with vibration syndrome.

The DSL to middle finger was prolonged in 97.9% of the cases of which, the findings were bilateral in 15 workers. Our study showed that a DSL of more than 4.3msec were considered abnormal (at 14cm distance between the stimulating and recording electrodes). This results is abit delayed more than what has been reported by Cassvan *et al*. (1986) who considered 3.7 and 3.8 msec to be the accepted normal upper limit respectively. From this study we may come to the conclusion that in cases diagnosed clinically as CTS, on electro-physiological basis.

With respect to the median nerve distal sensory latency in our study showed that delayed to index, middle fingers in more than 97% of workers exposed to vibration, this is in agreement with the results of Giannini *et al*, (2001) who found in 58% of group of workers exposed to vibration versus 62.5% of group not exposed.

It is recommended that engineering control should be the first order of protection of vibration by application of foundation and concrete for the machines. Awareness of the workers is also very important, early reported symptoms may mean early detection and prevention of the adverse effects. Workers advised to wear gloves at all time when using vibrating machines, before starting the job, warm the hands and keep them warm during winter. Smoking play definite role of developing sign as of tingling, numbness and white or blue finger occurs.

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