ORIGINAL ARTICLE

Hand-arm vibration syndrome in Swedish car mechanics

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Aims: To assess the occurrence of hand-arm vibration syndrome (HAVS) in Swedish car mechanics, and the relation between HAVS and duration of exposure.

Methods: A total of 806 mechanics answered a questionnaire on vascular and neurological symptoms, and exposure to vibrations. Mechanics with symptoms, and some mechanics without symptoms, were invited to a clinical examination, including also a timed Allen test. Vascular and neurological symptoms were classified using the Stockholm Workshop scales. The mean daily exposure (mainly using nut-runners) was 14 minutes and the mean exposure duration, 12 years. Published data have shown vibration levels in nut-runners of about 3.5 m/s^2.

Results: In the questionnaire, 24% reported cold induced white finger (WF), 25% persistent numbness, and 13%, reduced grip force. The clinical examination showed a prevalence of vibration induced white finger (VWF) of about 15%, mainly in stage 2, and after 20 years, of 25%. A survival analysis showed similar results. We found that the International Organisation for Standardisation (ISO) model underestimates the risk of VWF. The incidence after 1975 was 19 cases per 1000 person-years. Slow refill times in the timed Allen test were common (15% had a refill time of >20 seconds), and associated with the presence of VWF. The clinical examination revealed neurological symptoms in the hands in about 25% of subjects, mainly at stage 2. After 20 years, the prevalence was 40%. The questionnaire items on WF and numbness both showed likelihood ratios of 13.

Conclusion: HAVS is common among Swedish car mechanics in spite of short daily exposure times. This underlines the need for preventive measures.

Car mechanics constitute one of the largest occupational groups exposed to hand transmitted vibration, both in Sweden and in many other countries.[1] Today, their work involves the use of nut-runners, and to some extent also other vibrating tools. Few studies have examined the occurrence of vibration induced white fingers (VWF) and neurological symptoms in this occupational group.[2 3] Moreover, assessment of the risk of hand-arm vibration syndrome (HAVS) has generally been based on prevalence, while little is known about the incidence of this condition in vibration exposed groups.[4 5]

The present study reports estimates of the prevalence and incidence of VWF, and the prevalence of neurological symptoms in Swedish car mechanics, based on questionnaires and clinical examinations using the Stockholm Workshop scales[6 7] for classification.

SUBJECTS AND METHODS

Subjects and questionnaire

The study was performed in Göteborg, a Swedish city of 0.5 million inhabitants. The study base included all car mechanics and former car mechanics employed by the garages affiliated to a big occupational health service centre, specialising in this occupational sector. All authorised service garages for cars and trucks were affiliated, as were about half of the small or medium sized non-authorised garages in Göteborg. There were 900 mechanics in total. The former car mechanics (n = 130) were in most cases employed as supervisors or in customer service. Since the subjects were recruited from car garages, ex-mechanics who had left this occupational sector altogether were not included. Car body repairmen and car painters were not examined, although these groups are also exposed to hand-arm vibrations.

All 900 subjects were given a questionnaire on their occupational history with respect to use of vibratory tools, and symptoms of cold induced white fingers (WF) or numbness, pain, or decreased grip force in their hands. The screening question for WF was "With white finger we mean that one or several fingers become white with loss of sensitivity when it is cold. Do you suffer from white finger?" (Yes/No). After an explanation of the meaning of numbness, a first screening question asked whether the subject suffered from numbness in the hands or arms (Yes/No), and a second question whether the numbness occurred only when using vibratory tools (Yes/No).

After reminders, 806 mechanics (90%) answered the questionnaire. Eighteen mechanics among the non-respondents were randomly selected for a short telephone interview. Their mean age was the same as that of the respondents. Six could not be reached since they had moved from the city or were on long term sick leave. The other 12 mechanics reported that they had no symptoms and therefore had not answered the questionnaire.

The mean age of the respondents was 33 (range 18–63) years. Thirty two per cent were smokers. Some smokers (8% of the mechanics) also used moist snuff, which contains nicotine; another 18% were non-smokers, but used moist snuff. Thirteen per cent were ex-smokers or had previously used moist snuff.

Vibration exposure

The mean exposure time using hand held vibratory tools was 12 years, most of it owing to exposure as a car mechanic or at school during training. Only a few per cent of the mechanics had been exposed at other jobs.

A separate study was performed on the daily exposure time for hand-arm vibrations. The length of exposure was

Abbreviations: CTS, carpal tunnel syndrome; HAVS, hand-arm vibration syndrome; ISO, International Organisation for Standardisation; QST, quantitative sensorineural testing; WF, white finger; VWF, vibration induced white finger

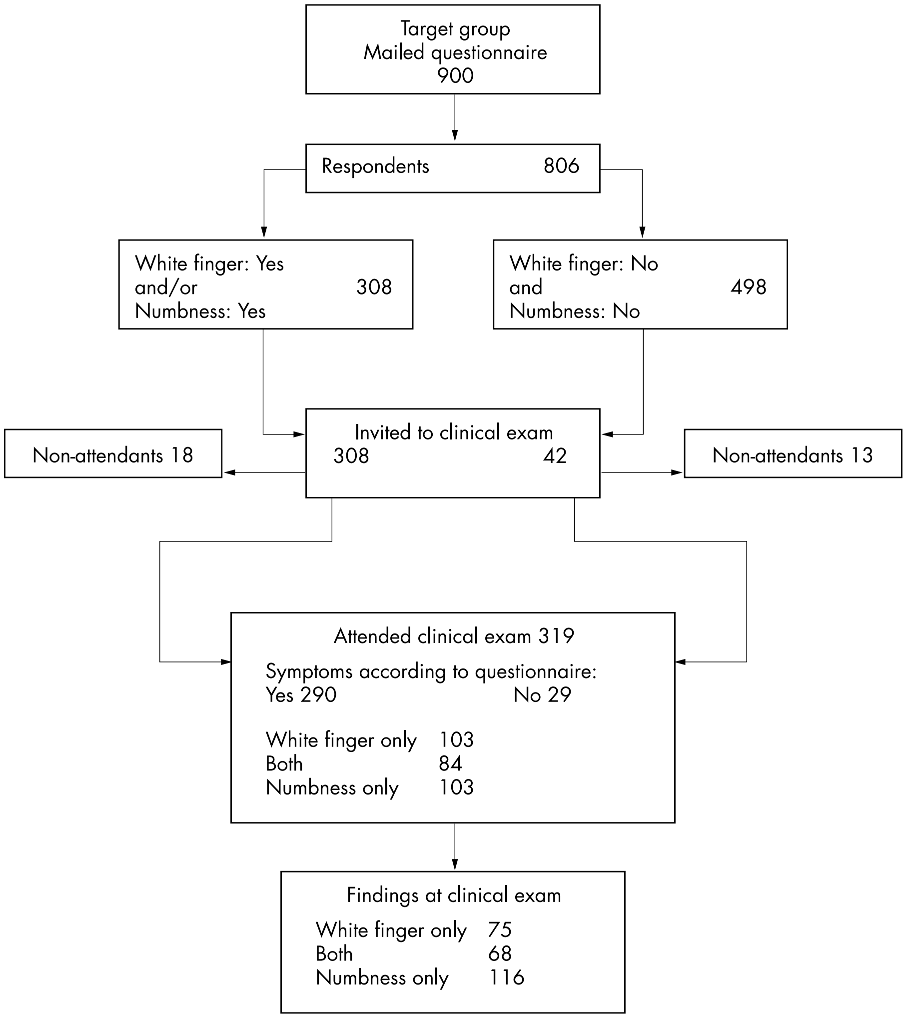

Figure 1 Participants and non-participants in the study. The numbers in the boxes refer to the number of persons.

measured in 51 randomly selected car mechanics on 95 randomly selected working days. The study was carried out in three large authorised service garages, one medium sized garage, and two large truck garages. The mean effective length of exposure, of holding any running vibrating tool in the hand, was 14 minutes per day. For nut-runners, it was 11 minutes. Tools used only rarely were electric grinding tools and drills and pneumatic chisel hammers. The results from that study are reported elsewhere.[8]

The intensity of the vibrations can be estimated from a large survey[9] on 286 nut-runners used at 26 garages in Sweden showing an average weighted acceleration level of 3.5 (SD 0.6) m/s^2. In that survey, the vibration levels were measured in three directions, according to ISO standard 5349,[10] on the handles of the nut-runners operating against a break device that provided realistic loading, and using the instruments Brüel & Kjaer 2513 and 2033. Since the tools evaluated in that study were nearly identical, in terms of brand, type, and age, with those used by the car mechanics in our study, we consider that 3.5 m/s^2 is a good estimate of the average vibration levels during the 1980s for the car mechanics we studied here.

Clinical examinations

All 308 mechanics who reported, in the questionnaire, that they suffered from WF or numbness (other than from immediate tools use), or both, were invited to come for a clinical examination. In addition, 42 randomly selected mechanics from the respondents who had, in the questionnaire, denied any symptoms, were invited. Thirty one mechanics did not show up for the examination, which therefore left a total of 319 subjects for clinical assessment (fig 1).

The clinical examination included a detailed history on symptoms and other diseases, medication, and use of alcohol, as well as a timed Allen test, and the Tinel's and Phalen's tests. The timed Allen test (examiner not blind to the history) measures the time lapse until blood flow in the ulnar and radial arteries is resumed, after release of compression (by the physician) of the two arteries.[11] From the history of present symptoms, a classification according to the Stockholm Workshop scales was made for WF[6] as well as for neurological symptoms.[7] The diagnosis of WF was based on a history of cold induced attacks of demarcated blanching of fingers or parts of fingers.[6] The history of neurological symptoms focused on the occurrence of numbness, or decreased sensory perception, tactile discrimination, or manual dexterity. Assessment was based on the clinical history alone. Positive cold provocation tests, or neurological signs, were not required for the diagnoses. Each hand was separately classified, and the stage of the "worst" hand was considered the subject's stage.

Statistics

The 95% confidence interval (CI) was calculated for the point estimates of prevalence of symptoms and HAVS using the standard normal approximation or the binomial distribution.[12] For sensitivity and specificity of the questionnaire, 95% CI were calculated using the standard bootstrap technique, with random resampling (n = 10 000) from binomial distributions (RANBIN function[13]). The association between exposure time, age, and use of nicotine, on the one

Table 1 Prevalence of self reported symptoms in a questionnaire in 806 Swedish car mechanics

Symptoms	%	(95% CI)
Cold induced white fingers	24	(21 to 27)
Cold fingers in general	45	(41 to 48)
Numbness in hands or arms*	25	(22 to 28)
Pain in hands, arms, and/or shoulders	42	(39 to 45)
Decreased hand grip force	13	(11 to 15)

*Not only during work with a vibratory tool.

hand, and prevalence of HAVS, on the other, was examined using the χ^2 test, analysis of variance, linear regression, or logistic regression.[13] Using the subjects' information on the first year of exposure to hand-arm vibrations and the first year of WF, the incidence of VWF was calculated using the person-years method. Subjects contributed person-years at risk from start of exposure until diagnosis of white finger or end of exposure. Owing to extensive loss to follow up, data were also assessed using survival analysis.[13] Life tables and survival curves were constructed from the start of the vibration exposure until occurrence of VWF, censoring subjects without VWF at end of exposure or follow up.

RESULTS

Table 1 shows the prevalence of self reported symptoms in the hands. Twenty four per cent of the mechanics (n = 195) reported cold induced WF, and nearly half of these also had problems with numbness in their hands or arms. In total, 198 mechanics (25%) reported numbness, even when they were not working with vibratory tools. Another 4% of the mechanics reported that they had problems with numbness, which disappeared shortly after vibration exposure.

White finger

After clinical examination of 187 of the 195 mechanics reporting cold induced WF in the questionnaire, such a diagnosis could be established in 138 cases. The history revealed that 49 of the 187 mechanics did not meet the criteria. Based on the interview, 5/103 mechanics reporting numbness, but not WF, were, however, considered suffering from the latter condition, giving a total of 143 mechanics with WF.

Of the 143 car mechanics with WF, eight were considered to have Raynaud's disease. Their symptoms started at ≤20 years of age, in six cases before vibration exposure, and in two cases after less than half a year of exposure. All had bilateral WF, mainly in stage 2–3 according to the Stockholm Workshop scale.[6] In two cases the causes of WF were frostbite (unilateral WF starting before vibration exposure), and in another five cases (three of them preceding the start of vibration exposure), the causes of WF were unclear (including, for example, possible Raynaud's disease or VWF). Thus there were 128 mechanics with a history of VWF. Forty four were classified to have stage 1 VWF, 66 stage 2, and 18 stage 3.[6] The minimum prevalence of VWF was therefore 14% (128/900). The true prevalence may, however, have been somewhat higher (see "Discussion"). Among mechanics with VWF, 94 had bilateral symptoms, 18 had WF in the right hand only, and 16 in the left hand only.

There was a clear increase in prevalence of VWF with the duration of vibration exposure as shown in fig 2. As could be expected, the covariance between age and exposure time was very marked. When age and length of exposure were included in a logistic regression model, the effects of both factors on VWF prevalence were statistically significant, but the model was not considered biologically plausible (see "Discussion").

The prevalence of VWF was slightly lower in subjects who had never used tobacco (fig 3), but analysis of variance showed no statistically significant differences between groups. This was true also if smokers, snuff takers and ex-tobacco users were aggregated into one group. The difference between never smokers and all others was 4.8% (95% confidence interval –0.2 to 9.8%). Nicotine use was seen to have no significant impact on the risk of VWF when it was added to the logistic regression model.

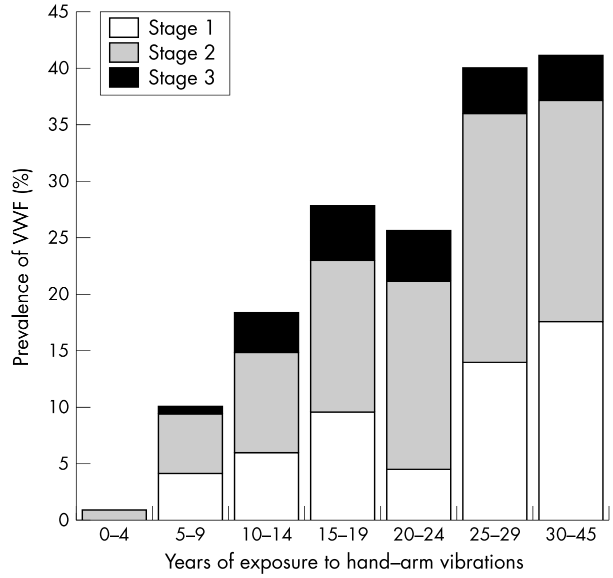

Figure 2 Prevalence of different stages of VWF, according to the Stockholm Workshop scale,[6] in 801 car mechanics, as function of exposure to hand-arm vibrations (in years, information lacking in five mechanics). The total number of workers diagnosed with VWF at the clinical examination was 128.

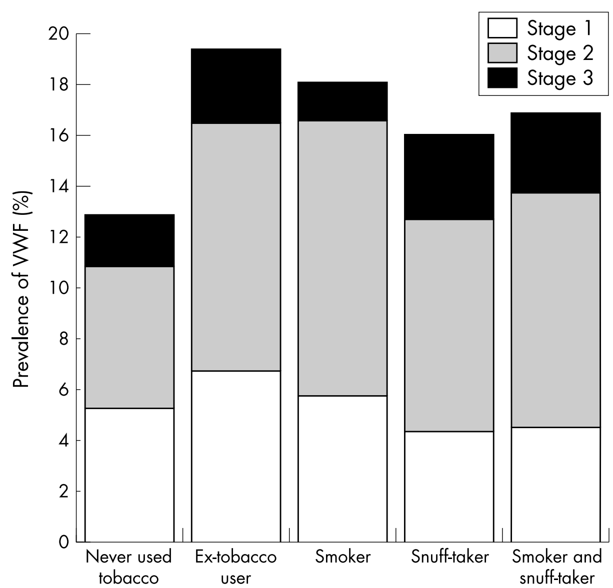

Figure 3 Prevalence of different stages of VWF, according to the Stockholm Workshop scale,[6] in 806 car mechanics in different categories of tobacco use. The total number of workers with VWF at the clinical examination was 128.

The average latency from vibration exposure to VWF was 15 years (median 13 years). Only four mechanics had a latency of less than three years.

The minimum incidence of VWF was 19 per 1000 person-years for the period 1976–90, based on 110 new cases. The period before 1976 was difficult to assess owing to few cases and exposed subjects.

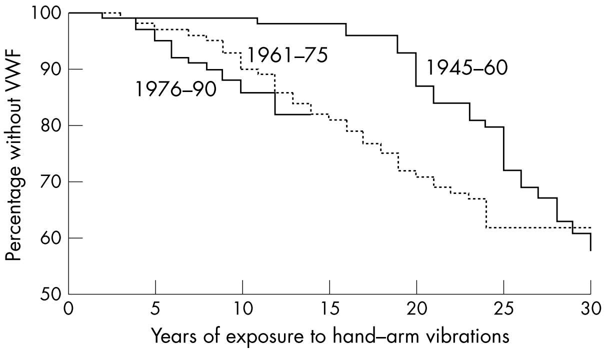

Figure 4 Occurrence of VWF in 755 car mechanics as function of exposure to hand-arm vibrations (in years) with start of exposure 1945–60, 1961–75, and 1976–90. Non-attendants at the clinical examination, cases with white finger of other origin, and mechanics with unknown year of start of exposure were excluded from the analysis. The graphs are based on survival analysis using life tables.

Table 2 Occurrence of VWF in 755 Swedish car mechanics, using a survival analysis with life tables

Duration of exposure (years)	VWF (%)
5	3.4
10	10
15	17
20	27
25	38
30	49

Non-attendants at the clinical examination, cases with white finger of other origin, and mechanics with unknown year of start of exposure were excluded from the analysis.

A survival analysis using life tables showed occurrence of VWF by exposure time according to table 2. A stratification according to start of exposure 1945–60, 1961–75, or 1976–90 showed a significant difference in occurrence between periods ($p = 0.01$, log rank test), mainly owing to a difference between the first and the last period (see fig 4).

Table 3 shows the sensitivity and specificity of the questionnaire item on WF, using the subject's history taken by the physician during the clinical examination as the basis for the true diagnosis. In the calculations, it was assumed that the findings in the small group of interviewed mechanics who denied both WF and numbness were representative of all such respondents. The sensitivity was 97%, the specificity 92%, and the positive predictive value 74%. The likelihood ratio was 12.7.

The timed Allen test showed that slow refill times were very common among the car mechanics examined. Among the mechanics (all of whom had reported WF or neurological symptoms in their hands) who took this test, about 50% had a refill time >6 seconds in their ulnar and radial arteries, and about 15% had a refill time of >20 seconds. There were also clear differences, in terms of the test, between mechanics with and mechanics without WF (table 4). The results in the Allen test were not associated with tobacco use.

Neurological symptoms

After clinical examination of 187 mechanics reporting numbness in their hands or arms in the questionnaire, symptoms of numbness, or decreased sensory perception, tactile discrimination, or manual dexterity were considered to be present in 158 subjects. In addition, such symptoms were found among 23/103 mechanics who reported WF but not numbness, and in 3/29 subjects who had denied both WF and numbness. Neurological symptoms were therefore found in 184 car mechanics. The history was used to classify stages of neurological symptoms, according to the Stockholm Workshop scale,[7] which is based on such symptoms rather than on objective signs. Out of the 184, 83 were classified as stage 1, according to the Stockholm Workshop scale, 76 as stage 2, and 25 as stage 3 sufferers.

In 20/184 mechanics with neurological symptoms, causes other than exposure to hand-arm vibrations were considered to have contributed to the condition. In most cases, this assessment was based on signs in the feet as well, and in a few cases, on presence of other diseases (diabetes, hypothyreosis, and cervical rhizopathia).

The minimum prevalence of neurological symptoms was therefore 20% (184/900), or 18% (164/900) if cases with other contributing causes are excluded. The true prevalence may, however, be somewhat higher (see "Discussion").

Figure 5 shows the prevalence of neurological symptoms stages 1–3 according to the Stockholm Workshop scale, as function of vibration exposure. In a logistic regression model with presence of neurological symptoms (yes/no) as function of age and duration of exposure, there was no statistically significant impact of age.

Table 5 shows the sensitivity and specificity of the questionnaire item on neurological symptoms, using the subjects' history take by the physician during the clinical examination as the true diagnosis. In the calculations, it was assumed that the findings in the small group of interviewed mechanics who denied both WF and numbness were representative for all such responders. The sensitivity was 68%, the specificity 95%, and the positive predictive value, 84%. The likelihood ratio was 13.0.

At the clinical examination, 17% and 18%, respectively, had a positive Tinel's test in the right and left hand (8% in both hands). For a positive Phalen's test, the figures were likewise 17% and 18% (9% in both hands). The association between the results from the Tinel's and Phalen's tests and the staging of

Table 3 Estimates of sensitivity and specificity for a questionnaire item on cold induced WF

Diagnosis of WF at the clinical examination	WF according to the questionnaire Yes	No	Total		95% CI
Yes	138	5	143	Sensitivity 97%	82 to 99
No	49	596	645	Specificity 92%	90 to 94
Total	187	601	788		

The assessment after clinical examination, including a careful history, was used as the gold standard.
In total 806 mechanics had answered the questionnaire (see fig 1). A clinical examination was performed in 187 subjects (of 195) who answered "yes" to the question of whether they had white finger, 103 subjects (of 113) who answered "no", but who reported numbness (5/103 were diagnosed with white fingers at clinical examination), and in a random sample (n=29) of those 498 subjects (see fig 1) who denied white finger as well as numbness (none had the diagnosis at clinical examination). The figure 596 in the table is derived from 498 + (103 − 5). The total number in the table is 788 instead of 806 owing to the 18 non-attendants.

Table 4 Results (in per cent) of the timed Allen test in 122 car mechanics with a diagnosis of VWF and 171 car mechanics without white finger

	Refill time (seconds)		
	≤6	6.5–20	>20
Subjects with VWF			
Right radial	39	39	22
Right ulnar	25	49	26
Subjects without VWF			
Right radial	67	25	8
Right ulnar	61	30	9

Mechanics with white finger with cause other than vibrations were excluded. Note that the latter group were exposed to hand-arm vibrations too, and had neurological symptoms. The results for the left hands were similar. All differences between groups with and without VWF were highly significant (p<0.001).

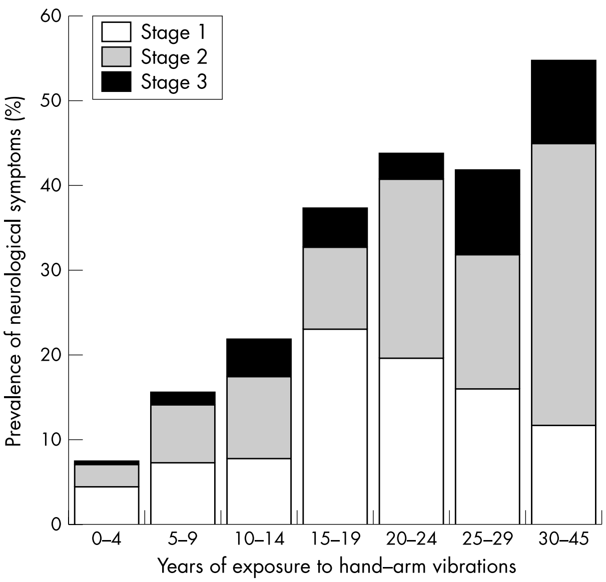

Figure 5 Prevalence of neurological symptoms in different stages according to the Stockholm Workshop scale,[7] in 801 car mechanics, as function of exposure time (in years, information lacking in five mechanics) to hand-arm vibrations. The total number of workers with symptoms and/or signs at the clinical examination was 184, including 20 workers with other conditions that could have contributed to the symptoms (see "Results").

neurological symptoms was absent or weak, and statistically significant only for positive Phalen's test in the right hand and staging for that hand.

DISCUSSION

Validity

In our opinion, merits of the present study are the relatively large sample of car mechanics and a high rate of response to the questionnaire and attendance of the clinical examination. Various types of garages, such as large authorised service garages, medium sized and small garages, and also truck garages, were represented. We therefore think that the external validity is good with respect to Swedish car mechanics in general. It should be noted, however, that in small garages with only one or two workers, mechanics may combine mechanical work with car body repair and car painting, which would increase exposure to vibration.[14] The mechanics in the present study did not do any car body repair or spray painting of cars.

The standardised clinical assessment, using the Stockholm Workshop scale, facilitated comparisons with other studies performed using this scale. In our study, the daily exposure was measured in a sample of mechanics, while the estimate of typical vibration levels was based on results from another study,[9] performed when the mechanics of the present study were examined. A study with the tools used by our mechanics would have been preferable. However, another study on nut-runners, performed by Hansson and colleagues,[14] with subjects tightening and loosening car wheel nuts showed very similar results. The median vibration level in that study was 4 m/s^2, while the most common tool used by our mechanics (CP 734), had a level of 3.5 m/s^2, identical to the result for this tool in the larger study by Ekholm and Falk.[9] We therefore consider the estimate of the vibration levels for the mechanics in the present study to be relatively accurate.

A mechanic's history on start of vibration exposure should be correct, while we believe that the year when symptoms started may be uncertain. This was illustrated by a tendency towards clustering of the years of reported start of WF to multiples of five years—that is,there were more mechanics stating that white finger symptoms started in 1975 or 1980 than in the years 1976–79. The stratification of the survival graphs by start of exposure (fig 4) shows that the graphs tend to be different in the beginning but meet again after a couple of decades. Therefore we think that the differences should be interpreted with caution. It is possible that mechanics with VWF whose exposure started long ago found it difficult to remember when symptoms started, and erroneously reported start of symptoms at later points in time than the true ones.

In the calculations of the sensitivity and specificity of the questionnaire items on WF and neurological symptoms, using the subject's history taken by the physician during the clinical examination as the basis for the true diagnosis, it was assumed that the findings in the small group (n = 29) of interviewed mechanics who denied both WF and numbness were representative of all such respondents. This results in the point estimates as presented in tables 3 and 5. If the true

Table 5 Estimates of sensitivity and specificity for a questionnaire item on neurological symptoms, such as numbness in the fingers or hands

Neurological symptoms at the clinical examination	Neurological symptoms according to the questionnaire				
	Yes	No	Total		95% CI
Yes	158	75	233	Sensitivity 68%	54 to 92
No	29	526	555	Specificity 95%	92 to 97
Total	187	601	788		

The assessment after clinical examination, including a careful history, was used as the gold standard.
A clinical examination was performed in 187 subjects (of 198) who responded with "yes" to the question on numbness, in 103 subjects (of 110) who answered "no", but who reported white fingers (23/103 were found to suffer from numbness at clinical examination), and in a random sample (n=29) of those 498 subjects who denied white fingers as well as numbness (three reported numbness at clinical examination). The figure 75 in the table is derived from 23 + (3/29 × 498) and the figure 526 is derived from the calculation (103 − 23) + 26/29 × 498. The total number in the table is 788 instead of 806 owing to the 18 non-attendants.

prevalence of VWF in all 498 mechanics denying WF and numbness is 2.5% (half the prevalence of VWF found in 5/103 mechanics who denied WF but reported numbness), there will be 10 more cases of VWF. The sensitivity in table 3 will then decrease to 90%, while the specificity will remain unchanged. As shown in table 3, the 95% CI for the sensitivity was 82–99%, while the estimate of the specificity was more precise (95% CI 90–94%).

White finger

We found 128 car mechanics with VWF, 16% of the 806 who answered the questionnaire, or 14% of the whole study base of 900 mechanics. Assuming that the prevalence with VWF was lower among the non-respondents, 15% is a reasonable estimate of the true prevalence of VWF.

There was a strong association between the duration of exposure and the prevalence of VWF (fig 2). This is in agreement with many previous studies.[15] Bovenzi[16] found the association between VWF and duration of exposure to be nearly as strong as it was for duration combined with weighted or unweighted acceleration. There was a strong covariance between age and duration of exposure. A logistic regression model including also age, predicted an unrealistic increase of VWF prevalence with age in absence of vibrations. We think that the simple model with VWF as function of duration of exposure is appropriate, since in northern Europe WF from causes other than vibration is expected to be rare in men of this age.[17 18]

It is noteworthy that about 15% of car mechanics had VWF, although their effective daily length of exposure was only 14 minutes a day. After 20 years of such exposure, the prevalence of VWF was about 25% (fig 2), and a similar result was found in the survival analysis (table 2)—that is, 27% VWF, censoring subjects without VWF at end of exposure or end of follow up. Both hands were affected, which is reasonable considering that both hands are exposed to a similar extent.

In the annex of the ISO 5349 guidelines, a prediction model is presented for prevalence and latency time of VWF.[10] If we use the arithmetic mean of the daily exposure time—that is, 14 minutes, and a vibration level of 3.5 m/s^2, the model would predict that only about 3% of the car mechanics should suffer from VWF after 20 years of exposure. Using the recent revision of the ISO model yields approximately the same results. Although the prediction is outside the range of the ISO standard, it suggests that the model of the ISO 5349 standard is insufficient, at least for the impact vibrations created by nut-runners. The validity of the ISO model has previously been questioned.[16 19–23] The frequency weighting may not be justified, and the effect of impact tools may be underestimated.[20 21 23] Burstrom and colleagues[24] showed that the unweighted vibration level of a nut-runner is higher than that of grinding tools, although the latter display higher ISO 5349 weighted vibration levels. We examined whether previous work with other tools or long daily exposure could explain the lack of agreement between our findings and the ISO 5349 model, but found that this was not the case. Nor is it likely that previously, vibration levels were much higher, since the survival analysis rather indicated a higher occurrence of VWF in the past couple of decades. In workers who started their exposure after 1975, 14% had VWF after 10 years of exposure (fig 4).

Cross sectional studies may cause a selection bias, since workers with occupational disease may have left the occupation (the "healthy worker effect").[25] We do not think, however, that such selection bias had any strong influence on our findings. Among the former car mechanics studied (n = 130), the prevalence of VWF was about the same as in those still active as mechanics, taking the duration of exposure into account. In our experience, VWF rarely causes car mechanics to change their career.

We found only one previous study on VWF in car mechanics. In a Norwegian questionnaire study, 14% of 172 mechanics reported WF. No clinical examination was performed.[2] In a study on truck assemblers, using impact wrenches, 12% of subjects reported WF in a questionnaire, but no clinical examination was performed. The daily exposure time was as short as it was in the present study, 10–15 minutes.[26] In a British national survey (questionnaires only), 18% of an aggregated occupational group, including motor mechanics and auto engineers, reported cold induced finger blanching.[3]

The minimum incidence of VWF for the period 1976–90 was 19 per 1000 person-years, indicating that about 2% of mechanics acquired the disease every year. We found only one previous study reporting the incidence rate of VWF.[3] In Japanese forest workers, the incidence rose to 5% per year when chain saws were introduced, and fell to <1% after preventive measures.[4] In another study of forest workers,[5] the cumulative incidence over a seven year period was reported, and the incidence can be estimated to have been about 20 per 1000 person-years. Kihlberg and Hagberg[27] reported a cumulative incidence of about 16% over five years in a mixed group of vibration exposed workers, based on about 40 new cases, indicating an incidence of about 40 per 1000 person-years. In a report by Bovenzi and colleagues,[28] the cumulative incidence was 50% during a six year follow up, which would correspond with an incidence of about 110 per 1000 person-years. However, these figures are based on only eight new cases.

The survival analysis indicated that the occurrence of VWF is higher in mechanics that started their vibration exposure in the 1970s and 1980s than in those whose career started earlier (fig 4). This may be caused by an increased use of nut-runners over the years instead of non-vibrating wrenches. Or, alternatively, it is an artefact owing to difficulties in remembering which year symptoms actually started, as discussed above. Certainly the results do not show any improvement with declining occurrence of VWF.

Ekenvall and Lindblad[29] found the proportion of tobacco users (smokers and snuff takers) to increase with the severity of VWF. In the present study, too, stages 2 and 3 were slightly more common among tobacco users than among subjects who had never smoked, or taken snuff. This is plausible, since nicotine induces vasoconstriction in cutaneous vessels and also affects endothelial function.[29] Whether tobacco use also increases, the risk of developing VWF is difficult to assess in a cross sectional study. In our study, former users of tobacco had the highest prevalence of VWF. They were, however, somewhat older and on average had had longer exposure. Moreover, mechanics with VWF had been advised more often to quit tobacco use than had other mechanics. Although we found no statistically significant effect of tobacco use in the present study, there may well be a small difference, as indicated by the 95% CI.

The diagnosis of "primary" Raynaud's disease was established in only about 1% of mechanics. Possibly the true prevalence was somewhat higher if some cases were atypical—that is, not symmetrical, and had started after many years of vibration exposure. Nilsson and colleagues[17] found a prevalence of 2% of Raynaud's disease in unexposed office workers, based, however on only one case in 45 subjects. In a large British questionnaire study, about 3% of respondents never exposed to hand transmitted vibration reported cold induced blanching with a sharp edge.[18] Our own data from questionnaires and clinical examinations showed, however, that an affirmative answer in a questionnaire was not always verified during the interview with a physician. In the latter case it is possible to ask follow up questions, explain the meaning of "blanching", etc. Sometimes the mechanics had simply misunderstood the questions in the questionnaire. Others have observed similar findings. In a study by Riera and colleagues,[30] only 61% of affirmative answers to a questionnaire on Raynaud's phenomenon were confirmed at a subsequent interview.

The high occurrence of pathological results for the timed Allen test is in agreement with the finding by Nilsson and colleagues[17] in platers. In a group of platers with or without symptoms of HAVS the prevalence of pathological Allen tests was 18–37%, while in the present study, it was about 50% in mechanics with symptoms of HAVS. A pathological result in the Allen test was also clearly related to the presence of VWF in the car mechanics. This too is in agreement with the study on platers, where an odds ratio of about 4 for a pathological timed Allen test was found among platers with VWF. This test is therefore of value in the examination of patients with suspected VWF, as suggested by Nilsson and colleagues.[17]

Neurological symptoms

Neurological symptoms were found in 184 car mechanics at the clinical examination. This is 23% of the 806 respondents, or 20% of all 900 mechanics. However, only 29 subjects were interviewed among those 498 who denied neurological symptoms in the questionnaire, and three of them were found to suffer from such symptoms. If these 29 are representative of all the 498 mechanics who denied symptoms (see fig 1), the true prevalence will be 29%. This estimate is not very reliable, however, due to small numbers. A reasonable estimate is that about 25% of the car mechanics have neurological symptoms, in most cases stage 1–2 symptoms, according to the Stockholm Workshop scale (fig 5), with abnormal numbness in their hands and reduced sensory perception. This is about four times the prevalence of numbness only, reported in a Swedish population based questionnaire study of adult men,[31] or in safety engineers, without hand-arm vibrations or other manual work.[32] After 20 years of exposure, 40% of the car mechanics had neurological symptoms. Since there was a strong covariance between age and duration of exposure, there may be an impact of age, although it was not statistically significant in our analysis.

In a study on shipyard workers,[33] using the Stockholm Workshop scale for classification of questionnaire answers, neurological symptoms were more common than in the present study. The duration of exposure was similar (mean 10 years), but the vibration exposure more extensive. Fifty three per cent of workers with a self reported daily exposure of three hours reported neurological symptoms.[33] In Italian stone workers, about 40% reported such symptoms.[34]

Few previous studies have examined the exposure-response relation between vibration and neurological symptoms, as classified according to the Stockholm Workshop scale.[16] Several studies have, however, shown an association between results at quantitative sensorineural testing (QST) and vibration exposure.[16 35–37] Since we used subjective symptoms (the basis for the Stockholm Workshop scale[7]), their results are difficult to compare with ours. There seems to be a clear association, however, between staging using the Stockholm Workshop scale and QST.[37 38] For stage 1 (only intermittent numbness or tingling), however, there are less clear associations between symptoms and QST.[39]

In a separate study (unpublished data), we performed more detailed clinical examinations in 20 of the 25 mechanics classified in stage 3, according to the Stockholm Workshop scale. Many of them also had objective signs of decreased sensory perception or tactile discrimination, as well as abnormal neurophysiological findings. The mechanisms behind the neurological, or possibly neuromuscular, disturbances in HAVS are not fully understood. While we found some cases of suspected carpal tunnel syndrome (CTS) in the above mentioned 20 mechanics, most of the cases could be characterised as diffusely distributed neuropathy affecting terminal nerve fibres in the fingers or damage at the receptor level.[40 41] The symptoms or signs do not follow the distribution of the median, ulnar, or radial nerves. For the CTS cases, vibration exposure could be involved, but other ergonomic factors such as repetitive wrist movements and forceful gripping, may be at least as important.[40 42–46]

Subjectively reduced grip force was reported in the questionnaire by 13% of the car mechanics in our study. Reduced grip force in vibration exposed subjects has been reported for chain saw operators,[47–49] in quarry drillers and stone carvers,[34] as well as in mixed groups of vibration exposed workers.[38] In the report by McGeoch and colleagues,[38] there was a clear association between grip strength and the sensorineural stages described in the Stockholm Workshop scale. We do not fully understand what causes reduced grip force. One explanation could be the disturbed neurological function; however, direct effects on muscle fibres have also been suggested.[50 51]

Main messages

- The prevalence of vibration white finger was about 15% in Swedish car mechanics, and the incidence about 20 per 1000 person-years.
- Neurological symptoms were present in 25% of the mechanics.
- Most cases were in stage 2 according to the Stockholm workshop scales.
- Hand-arm vibration syndrome was common in spite of short daily exposure times, mainly to nut-runners.

Policy implications

- The ISO 5349 model underestimates the risk of vibration induced white finger.
- Preventive measure should be taken to reduce the use of nut-runners.

Conclusions

The present study shows that HAVS is common among Swedish car mechanics, in spite of short daily exposure to vibrations through vibratory tools. After 20 years of exposure, about 25% of the mechanics had VWF and 40% had neurological symptoms. Preventive measures should be taken to reduce the use of nut-runners, and when they are used, choose those with the lowest vibration levels.[52]

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