Neurosensory component of hand–arm vibration syndrome: a 22-year follow-up study

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Background Knowledge about the long-term course of the neurologic component of hand–arm vibration syndrome (HAVS) is scarce.

Aims To study the course and prognostic factors of the neurosensory component of HAVS over a period of 22 years.

Methods Forty male sheet metal workers, with a mean age of 60 (range 45–78) years at follow-up, were examined with a test battery in 1994 and 2017. At baseline, the sample comprised 27 workers with HAVS symptoms and 13 workers without HAVS symptoms. Among the 27 workers, 25 workers reported work-related hand–arm vibration during follow-up (mean 3639 h). In 2017, the mean time since vibration stopped was 8.4 years.

Results Among the 27 workers with HAVS in 1994, no overall statistically significant change was observed in hand numbness (Stockholm Workshop Scale), shoulder/arm pain (pain scale) or finger pain from 1994 to 2017. However, vibration exposure during follow-up was associated with increased finger pain. Cotinine, carbohydrate-deficient transferrin, glycosylated haemoglobin and folate were not associated with changes in neurosensory symptoms or manual dexterity (Grooved Pegboard) from 1994 to 2017. A diagnosis of HAVS in 1994 did not predict poor hand strength 22 years later. Isolated hand numbness (without white finger attacks) was more common at baseline than at follow-up.

Conclusions This 22-year follow-up study indicates a tendency towards irreversibility of hand numbness and finger pain in workers with HAVS. Continued vibration exposure seems to predict increased finger pain. Our findings highlight the importance of HAVS prevention.

Key words Hand–arm vibration syndrome; musculoskeletal; neurosensory; pain; Stockholm scale.

Introduction

Hand–arm vibration syndrome (HAVS) is associated with peripheral sensorineural, vascular and musculoskeletal symptoms. Knowledge about the long-term course of the neurological component is scarce [1]. A recent systematic review identified three cohort studies of neurosensory HAVS [2], including a study reporting a tendency towards irreversible hand numbness [3], whereas hand pain improved to some extent [3]. To our knowledge, there are no studies of possible prognostic factors, such as comorbidity and lifestyle factors. Previously, we examined the vascular component of HAVS [4]. This study aims to assess the course and prognostic factors of the neurosensory component.

Methods

In 1994, all employees (n = 211) in two workshop units (sheet metal workers performing grinding/welding and machinists) of an engineering and construction company participated in a HAVS examination [4]. We used the 1994 questionnaire to select workers for the 2017 study. Workers who reported previous work-related exposure to hand–arm vibration (HAV), symptoms of hand numbness and/or white finger attacks were classified as the ‘HAVS group’. Those who answered ‘no’ to these three items were classified as the ‘non-HAVS’ group. Participation was voluntary. Written informed consent was obtained. The Regional Ethics Committee, South-East-B approved the study.
We interviewed the workers about work and leisure exposure to hand-transmitted vibration (tool, hours per day, days per year, number of years). Exposure was calculated as hours of occupational vibration exposure during follow-up. Neurosensory symptoms were assessed by the Stockholm Workshop Scale (SWS) [5,6]: 0 = no problems; 1 = periodically recurring numbness/paraesthesia; 2 = commonly recurring numbness/paraesthesia; 3 = constant numbness marked by reduced sensitivity, clumsiness and reduced dexterity. Scores for shoulder/arm pain and finger pain were assessed by the questions ‘Over the past five days, have you felt pain in your shoulder or arm?’ and ‘Over the past five days, have you felt pain in your fingers?’ Response alternatives were no pain/a bit of pain/some pain/quite a lot of pain (score range: 0–3). The carpal tunnel syndrome diagnosis was based on a prior known diagnosis of the condition.

The Grooved Pegboard test (manual dexterity) was used in 1994 and 2017. Other quantitative tests were used in 2017: the finger tapping test (fine motor speed), a hand dynamometer (strength) (all Lafayette Instrument Company) and a hydraulic pinch gauge (strength) (Saehan Corporation). The vibration measurements are described in the ISO 1309-1/2 standard. Blood samples (cotinine, carbohydrate-deficient transferrin (CDT), glycosylated haemoglobin (HbA1c) and folate) were collected during the examination in 2017, as described previously [4].

Wilcoxon signed rank test was used to estimate overall changes from 1994 to 2017 in hand numbness (SWS score), shoulder/arm pain (pain scale), finger pain and manual dexterity. Linear regression was used to assess associations between each prognostic factor (HAV during follow-up, cotinine, CDT, HbA1c and folate) and changes in the outcome variables (the 1994 value subtracted from the 2017 value), with and without age adjustment (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.).

Results

Of 110 workers who met the inclusion criteria (68/42 with/without HAVS in 1994), two were confirmed dead, and 47 could not be located. Of the 61 invited participants, 21 declined: 11 of 38 (71%) in the HAVS group and 10 of 23 (57%) without HAVS in 1994. Reasons included long travel time or lack of time. Therefore, 40 of 61 (66%) subjects participated in 2017: 27 with HAVS and 13 without HAVS at baseline. Table 1 presents background data and test results for the total sample (n = 40). Table 2 presents longitudinal results for the HAVS group (n = 27).

The 27 workers exhibited an overall reduced performance in Pegboard scores from 1994 to 2017: 5 s for the dominant hand (Z = −2.4, P < 0.05); 8 s for the non-dominant hand (Z = −2.5, P < 0.05). No statistically significant changes in hand numbness, arm pain or finger pain scores were found.

Age-adjusted regression analyses showed that 1000 h of HAV exposure during follow-up predicted an increase of 0.12 (95% confidence interval (CI) 0.06–0.17)
in finger pain score (pain scale score 0–3) from 1994 to 2017. Cotinine predicted a larger deterioration in Pegboard scores from 1994 to 2017: dominant/non-dominant hand: unstandardized $B = 0.016$ (95% CI 0.002–0.030)/0.030 (0.002–0.058).

**Discussion**

Workers diagnosed with HAVS in 1994 showed no statistically significant change in arm or finger pain over 22 years. However, vibration exposure during follow-up predicted
increased pain at follow-up. A previous follow-up study of travertine workers showed that hand pain was partially reversible [3]. Workers with HAVS often report pain in the upper extremity [7], hands and fingers [8]. Pain seems to be an important aspect of HAVS and should probably be given increased attention in the symptom-driven diagnosis and staging of neurosensory HAVS.

Our finding of no significant changes in hand numbness over 22 years is consistent with the above-mentioned study [3]. Another study of workers in whom exposure to chainsaw vibration was reduced during follow-up showed some improvement in hand numbness and complaints of hand muscle weakness [9]. Regarding manual dexterity, the present Pegboard score declined during 22 years of follow-up in agreement with published reference values when allowing for aging [10].

To our knowledge, no study has examined the effect of lifestyle factors and comorbidities on the course of neurosensory HAVS; in this study, the effect of smoking (cotinine), alcohol consumption (CDT), glucose metabolism (HbA1c) and folate deficiency (folate) (all established risk factors of polyneuropathy) showed no influence.

One weakness of this study is that the negative findings may be due to the small number of subjects (type 2 error). The longitudinal design, however, has more statistical power than a cross-sectional design due to the longer observation time; it uses repeated observations at individual levels. It also reduces selection bias and unmeasured confounding, so negative findings are easier to interpret. Intra-observer bias was reduced by using the same interviewers and standardized questions, and following a structured protocol. HAV exposure however was based on self-reports, which may introduce recall bias.

Finally, our descriptive data showed that isolated hand numbness without white finger attacks was more common in 1994 than in 2017, consistent with Nilsson et al.’s report that neurosensory injury occurs with a shorter latency than Raynaud’s phenomenon [2].

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**Competing interests**

None declared.

**References**

1. Mason SHAH. *A Critical Review of Evidence Related to Hand-Arm Vibration and the Extent of Exposure to Vibration*. Buxton Health and Safety Laboratory, 2015. [http://www.hse.gov.uk/research/rp/pdf/rr1060.pdf](http://www.hse.gov.uk/research/rp/pdf/rr1060.pdf) (3 April 2018, date last accessed).

2. Nilsson T, Wahlström J, Burström L. Hand–arm vibration and the risk of vascular and neurological diseases—a systematic review and meta-analysis. *PLoS One* 2017;12:e0180795.

3. Bovenzi M, Franzinelli A, Scattoni L, Vannuccini L. Hand–arm vibration syndrome among travertine workers: a follow-up study. *Occup Environ Med* 1994;51:361–365.

4. Aarhus L, Stranden E, Nordby KC et al. Vascular component of hand-arm vibration syndrome: a 22-year follow-up study. *Occup Med (Lond)* 2018;68:384–390.

5. Gemne G, Pyykkö I, Taylor W, Pelme PL. The Stockholm Workshop Scale for the classification of cold-induced Raynaud’s phenomenon in the hand–arm vibration syndrome (revision of the Taylor-Pelmear scale). *Scand J Work Environ Health* 1987;13:275–278.

6. Lawson JI. The Stockholm Workshop Scale 30 years on—is it still fit for purpose? *Occup Med (Lond)* 2016;66:595–597.

7. Griffin MJ, Bovenzi M. The diagnosis of disorders caused by hand-transmitted vibration: Southampton Workshop 2000. *Int Arch Occup Environ Health* 2002;75:1–5.

8. House R, Krajnak K, Jiang D. Factors affecting finger and hand pain in workers with HAVS. *Occup Med (Lond)* 2016;66:292–295.

9. Koskimies K, Pyykkö I, Starck J, Inaba R. Vibration syndrome among Finnish forest workers between 1972 and 1990. *Int Arch Occup Environ Health* 1992;64:251–256.

10. Heaton RK, Miller SW, Taylor M, Grant I. *Revised Comprehensive Norms for an Expanded Halstead-Reitan Battery: Demographically Adjusted Neuropsychological Norms for African American and Caucasian Adults*. Lutz, FL: PAR, 2004.