

ORIGINAL ARTICLE

The clinical consequence of using less than four sensory perception examination methods in the Swedish surveillance system for Hand-Arm vibration syndrome

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Abstract

Objectives: The Swedish surveillance system aiming to reveal undetected Hand-Arm Vibration Syndrome (HAVS) in workers exposed for vibrations is regulated by the provision AFS 2019:3. The goal for the surveillance system is to diagnose HAVS, as well as to find workers at risk for developing HAVS due to other conditions. The national guidelines stipulate examination using at least two out of four hand sensory examination methods (SEM); monofilament (touch), two-point discrimination (discriminative), tuning fork (vibrotactile), and Rolltemp (thermotactile). The aim of this study was to examine the clinical consequence of using less than four of these SEMs.

Methods: We collected data on SEMs from the medical records of all individuals that went through the specific surveillance medical check-up in a large occupational health service for 1 year. We then calculated the number of workers found with HAVS when using one, two, or three SEMs, and compared with the result from using all available SEMs.

Results: Out of 677 examined individuals, 199 had positive findings in at least one SEM. The detection rate for these findings was on average 47% when using one SEM, 71% using two SEMs, and 88% using three SEMs (out of 100% detection when all four SEMs were used).

Conclusions: If fewer than four sensory examination methods are used for surveillance of HAVS, many workers with incipient injuries may stay undetected. This may lead to further exposure resulting in aggravation of injury.

KEYWORDS

hand-arm vibration syndrome, hazard surveillance system, neurologic examination, occupational health, sensory Function

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1 | INTRODUCTION

It has been known for over 100 years that exposure to vibrations can cause injuries in hands and arms. Today, this is referred to as Hand-Arm Vibration Syndrome (HAVS).¹ HAVS is a disorder of injuries to nerves and vessels that worsen with increased exposure time and amplitude of vibrations. As HAVS in the more advanced stages is considered a chronic condition, only reversible to a small extent in the case of vessel injuries, and virtually irreversible in the case of nerve injuries, prevention is mandated.^{2–5} In Sweden, it has been estimated that approximately 400 000 workers, whereof the majority is male, are exposed to vibrations to such an extent that they are at risk for developing HAVS.⁴ In 2016, HAVS was the most common occupational injury in Sweden,⁶ representing a fourth of all occupational injuries reported the same year.

In accordance with the directive 2002/44/EC of the European Union,⁷ the Swedish surveillance system aiming at revealing early symptoms of, or undetected, HAVS in workers exposed to mechanical vibrations is regulated by the provision AFS 2019:3 “Medical check-ups and health assessment in working life”. It concerns workers exposed to various occupational risk factors including vibrations. The current provision, AFS 2019:3, has been used since 2019, succeeding the provision AFS 2005:6.⁸ Both provisions state that employers are obliged to offer their workers a specific medical check-up aimed to detect vibration induced disorders (MCV) if any of the following conditions apply: (1) The daily action value of $2.5 \text{ m/s}^2 \text{ A(8)}$ for hand-arm vibrations is exceeded, (2) the worker is exposed in such a way that it could be presumed that the exposure could cause ill health, illness, or injury (for example, dentistry⁹ or work with percussive impact tools, such as riveting hammers¹⁰) even though the action value is not exceeded, or (3) the exposure has caused vibration injuries, or suspicion of vibration injuries, in another worker with similar exposure. The purpose of the MCVs is to prevent HAVS by finding workers with a high risk for disease as well as workers with disease in early stages. Notably, there is a large discrepancy between the estimated number of exposed workers and the number of workers actually participating in the MCVs (unpublished data from internal quality project at Feelgood). The workers do not have to pay anything for the MCV, however, fear of losing their job, macho culture, and workers not even receiving the offer to participate in the MCV by their employers have been proposed as possible reasons for this discrepancy,¹¹ although published scientific data is still scarce.

The law stipulates that a physician with good knowledge of vibrations and occupational health carries out the MCV. These physicians are employed in the occupational health service and are generally specialists in Family

medicine, sometimes with an additional specialization in occupational health medicine. The MCV should be offered before work with exposure to hand and arm vibrations commences, as stipulated in the AFS 2019:3, and thereafter at least every third year. The MCV comprises work history, medical conditions predisposing for developing HAVS or similar symptoms, medications, tobacco use, and occurrence of vibration related symptoms. If findings are present, the debut, frequency, gravity, spread, and relation to vibration exposure for the symptoms is further examined. A physical examination is performed, particularly addressing musculoskeletal disorders in the hands, arms, shoulders, and neck, as well as disorders related to vessels, nerves, and skin.¹² Since the diagnosis of HAVS is based largely on exclusion,¹³ the MCV is not only aimed at screening for typical symptoms of HAVS, but also at rejecting other possible causes of the findings.

To comply with the provisions AFS 2005:6 and 2019:3, national guidelines, including a standardized manual on both the clinical history and the physical examination, have been issued consecutively. These guidelines were provided by a national Swedish expert group on HAVS consisting of researchers and clinicians from several medical faculties in Sweden, and (chief-) physicians from the largest occupational health companies.¹⁴

According to the guidelines, the clinical neural examination should include hand sensory perception in the hands on digit II and V at a hand temperature of at least 28°C . The previous version of the guidelines stipulated that the examination should consist of the use of the four following sensory examination methods (SEM) but was, in the latest edition, changed by the national Swedish expert group to consist of at least two of the four SEMs¹⁴: *vibrotactile*—128 Hz tuning fork or similar, *discriminative*—static two-point discrimination (2PD), *thermotactile*—Rolltemps at 25 and 40°C , and *touch*—Semmes–Weinstein monofilaments. A staging of gravity of HAVS is recommended according to the gold standard Stockholm Workshop Scale (SWS)^{4,5,13} in both vascular (SWS V, grade 0–4) and sensorineural (SWS SN, grade 0–3). Further, grip strength (dynamometer, e.g., Jamar[®]) should be tested and, to exclude polyneuropathy, Achilles tendon reflex and vibrotactile sense in the feet (128 Hz tuning fork) should be examined. The change in the guidelines was, to our knowledge, not preceded by any scientific evaluation. It was suggested in order to simplify the MCV and decrease its duration with the hope that this would increase the number of conducted MCVs (personal e-mail).

The SEMs described above have long been used for examining signs of HAVS as well as other neurological disorders. According to McGeoch et al, sensitivity and specificity for HAVS cannot be assessed since there is no

independent method of defining the disorder.¹⁵ Hence, we compare the sensitivity and specificity for the SEMs in other neurological disorders. Static 2PD has been shown to provide an adequate reliability and repeatability. In affected index fingers in patients with Carpal Tunnel Syndrome (CTS), the inter-rater reliability was 0.96 and the intra-rater variability was 0.97 for a single measurement.¹⁶ A study on polyneuropathic individuals found a sensitivity of 28%¹⁷ and significant correlations between 2PD values and function scores (overall disability sum score ($r = 0.33$) and Weinstein enhanced sensory test ($r = 0.58$). The diagnostic accuracy in the 128 Hz tuning fork has been evaluated for prediction of axonal neuropathy and had a low sensitivity of 21% and a high specificity of 88% when compared with the corresponding healthy joint of the examiner.¹⁸ The Semmes–Weinstein monofilaments have been shown to have a sensibility of 57%–86% and a sensitivity of 81%–82% in detecting known CTS.¹⁹ No validated sensitivity or sensibility data on the Rolltemp could be found, but apart from being one of the stipulated tests in the guidelines, it is reported to be a “practical and effective method of readily testing temperature perception and is among the best available clinical tools for delineating the anatomical boundaries of a sensory abnormality”.²⁰

As for comparing the different SEMs to each other in terms of importance for diagnosis, a study on HAVS by McGeoch et al gave a coefficient of 1.30 for 2PD compared to 1.13 for a temperature neutral zone test, which is very similar to the Rolltemp, indicating that 2PD is of greater importance than Rolltemp.¹⁵ The use of 2PD has been questioned^{5,21} but has also been reported to provide valuable information.²² A recent study by Tekavec et al concludes that diminished perception of touch and vibrotactile perception are the most common clinical findings in vibration exposed carpenters and painters.²² In this study, all four SEMs are used in conjunction, as described in the National guidelines, with the alternation that vibrotactile perception was examined with the more advanced Vibrosense equipment instead of tuning fork. Rolke et al found that a 64 Hz tuning fork was the most sensitive instrument to detect sensory loss in HAVS in comparison with monofilament and cold and warm detection thresholds in a population of mainly lumberjacks.²³ In terms of predictive value for finding early HAVS, one could thus presume that vibrotactile perception and touch should be the SEMs best suited.

In Sweden, Ekenvall et al,³ as well as the prior Swedish guidelines that accompanied the provision AFS 2005:6,⁸ recommend that a worker with a SWS SN stage of 2 or higher should abstain from further work with vibrations. Similar recommendations are found in other industrialized nations.¹⁵ In order for HAVS to be classified as SWS SN stage 2 (or higher), objective findings of diminished

hand sensory perception, as measured e.g, with the different SEMs mentioned above, must be present.²⁴

The national guidelines recommendation to use (at least) two out of four SEMs has been questioned, as it could be interpreted that performing only two out of four SEMs is sufficient for detecting individuals at risk for developing or with manifest HAVS. Individuals with pathology in only one type of sensory perception, but not in the others, could easily be missed in the surveillance system if that SEM is not included. If so, the time until the exposed worker could be incorporated into rehabilitation would be prolonged, increasing the risk of developing chronic HAVS. However, the magnitude of this possible clinical consequence of using fewer SEMs has, to the best of our knowledge, not been examined.

1.1 | Aim

The aim of this study was to examine the clinical consequence of using less than four of the SEMs when evaluating hand sensory perception in MCV. In more specific terms, our primary goal was to examine how many individuals with positive findings would go undetected if using less than four SEMs in different combinations (i.e., an assessment of sensitivity). Our secondary goal was to put the number of missed individuals into perspective of the degree of shortened time duration of performing the MCV.

Our hypothesis was that using fewer than four SEMs significantly increases the risk of individuals with positive findings (indicating incipient, or diagnosis, of HAVS) going undetected.

2 | PARTICIPANTS AND METHODS

We conducted a retrospective study where we examined the medical records of all MCVs that were carried out at any clinic at Feelgood during the period between the 6 March 2019 and the 6 March 2020. Feelgood is one of the three largest occupational health companies in Sweden and has customer companies of all sizes throughout Sweden, including the construction and manufacturing industries. Data on age, sex, and outcome of SEMs (thermotactile, vibrotactile, touch sensibility, and 2PD) in all performed MCVs were collected from the medical record computer system CGM J4 (Compugroup Medical Sweden AB). The ethical permission from the National Ethics Committee in Sweden allowed an opt-out methodology, a method that has been recommended as a gold standard for studies with low-risk for the participants.²⁵

Thermotactile sensibility was examined with Rolltemp (Somedic SenseLab Ltd, Sösdala, Sweden). According to the National guidelines, Rolltemp can be substituted for a room tempered metal object if the equipment is missing or malfunctioning, in which case only thermotactile sensibility to cold can be reported. In this study, only thermotactile sensibility to cold was used in a total of seven cases, three with positive and four with negative findings. Vibrotactile sensibility was examined with a tuning fork (128 Hz), touch sensibility with Semmes Weinstein monofilament test, and 2PD with a static two-point discriminator. The National guidelines stipulate how to perform the different SEMs, albeit without any instructions for the tuning fork.¹⁴ For detection levels, see [Table 1](#).

A total of 677 MCVs were found in the medical records. Of the individuals examined, 636 (94%) were men and 41 (6%) were women. The age span was 20–67 years, mean age was 45 and median age was 48 years at the date of examination. No participant chose to opt out of the study. Reduced sensibility, as measured by any of the SEMs above, was found in 212 individuals. In 13 of these cases, information was missing regarding which specific SEM (or SEMs) in which reduced sensitivity was found. In 199 individuals, there was at least one finding of reduced sensitivity in a specified SEM, and these were included in the analyses. Among these, three were examined with only one SEM, 23 with 2 SEMs, 118 with three SEMs, and 52 with all four SEMs. [Figure 1](#) shows the number of SEMs used in relation to percentage of the population.

We evaluated the detection rate from all possible combinations of the four SEMs. There were 15 possible combinations of the four SEMs; one of any of the four SEMs, two SEMs (six combinations), three SEMs (four combinations), or all four SEMs ([Table 2](#)).

In order to evaluate the time consumption for the different SEMs, all physicians at Feelgood in the Scania region were asked to record the time required to perform each SEM for 1 month (December 2021). In total, time consumption for SEMs from 14 MCVs were reported during this time. All physicians that provided data had at least 4 years of work experience after attending the course “Medical check-ups and health assessment in working life” provided by the Swedish Work Environment Agency.

2.1 | Statistical Methods

We used STATA MP 17.0 (Stata Corp) for statistical calculation.

Since the data were categorical, we performed the Cochran-Armitage test for trend in statistical hypothesis testing concerning the use of various numbers of SEMs. This is a non-parametric test for linear trends in proportions across groups.²⁶ We performed a Monte Carlo permutation test²⁷ with 10 000 repetitions for an exact *p*-value.

3 | RESULTS

The risk of missing true pathological findings increased as fewer of the four sensory examination methods (SEM) were used ([Table 2](#)). If only one SEM was included in the screening, on average 47% of the workers that had objective findings in the MCV would have been detected. Rolltemp was found to be the most sensitive method, finding 66% of the individuals with a positive finding in the MCV. The detection rate ([Table 2](#)) is the sensitivity for the test in finding an individual with impaired sensibility that could be signs of incipient or manifest HAVS. Only applying 2PD missed 65%, monofilament 46%, Tuning fork 83%, and Rolltemp 34% of those with impaired sensibility. When increasing the number of SEM to two, on average 71% of the individuals were detected, and the most sensitive combination was monofilament and Rolltemp with an 85% detection rate. When using three SEMs, on average 88% of the individuals with known objective findings were detected, and combining 2PD, monofilament, and Rolltemp gave the highest detection rate, 94%. This increase in detection rate of reduced sensibility was significant with a *p*-value of less than 0.001.

The time consumption to perform all four SEMs in a clinical setting was approximately 5 min (median) [Table 3](#).

4 | DISCUSSION

The main finding of this study was that many workers with signs of HAVS, would go undetected if using less

Hand sensory modality	Sensory examination method	Detection level
Touch	Semmes–Weinstein monofilament test	>no 3.61 (0.271 g)
Discriminative	Two-point discriminator	>5 mm
Vibrotactile	Tuning fork (128 Hz)	Diminished
Thermotactile	Rolltemp (25–40°C)	Diminished

TABLE 1 Detection levels for positive findings with the four sensory examination methods

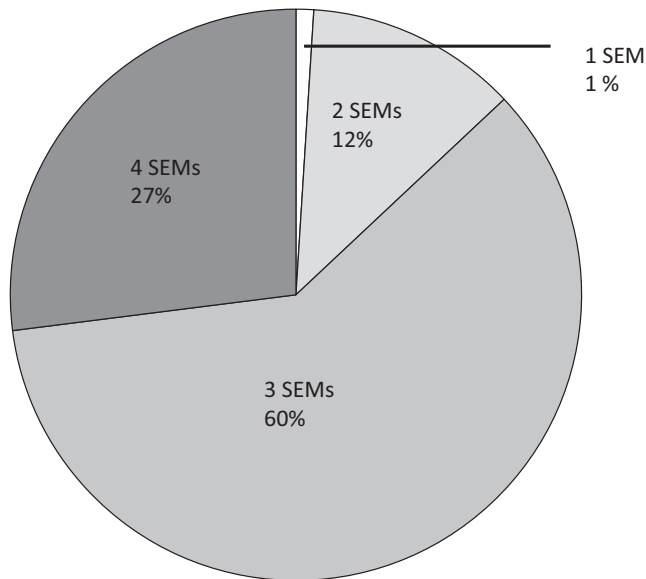


FIGURE 1 Number of used Sensory Examination Methods in relation to percentage of individuals in the population ($n = 199$).

than four SEMs when performing the MCV. As neurological injuries due to vibrations have been shown to affect both unmyelinated and myelinated nerves as well as different mechanoreceptive units and thermoreceptors,¹⁵ it is not very surprising that a combination of SEMs is needed to detect as many affected workers as possible. A reduction in detection rate from 100% to 94% when using three instead of four SEMs might seem harmless, but considering the large numbers of workers exposed to vibrations, this lost 6% represents considerable numbers of individuals at risk of developing permanent nerve damage. The extra time needed to perform four instead of two SEMs in a MCV was approximately 3 min in this study. Considering the possible consequences, this appears to be a very reasonable investment, particularly as it barely affects the marginal cost of the MCV.

Approximately 400 000 workers, representing 14% of all working Swedish men, and 3% of the women, are exposed to vibrations for at least 25% of the workday.⁴ Already at the action value ($2.5 \text{ m/s}^2 \text{ A}(8)$)⁷ for hand and arm vibrations, one tenth of the exposed population is estimated to develop neurological injuries within 5 years and at the far lower A (8) value of 1 m/s^2 the corresponding time until injury would be approximately 8 years.²⁸ Fisk et al reports that virtually all Swedish carpenters exceed the action value.²⁹ Furthermore, some tasks, e.g. demolition, even exceed the limit value ($5 \text{ m/s}^2 \text{ A}(8)$),⁷ indicating that many of the carpenters risk ending up with HAVS. Almost a third of the examined carpenters already had signs of nerve injury examined in accordance with the National guidelines also used in this study. In the same study, even painters, chosen to be a control group with lower exposure

to vibrations, were shown to have signs of injury in one fifth of the cases.²⁹

To our best knowledge, there are currently no quantitative data on vibration exposure in terms of A(8) of the Swedish 400 000 workers available. Considering the daily vibration exposure of 2 h, and that many different worker categories are likely (or shown) to be exposed to at least the action value, a worryingly large number of workers are at great risk of ending up with nerve injury. In Sweden, as many as 40 000 workers would thus end up with early signs of nerve injuries after 5 years at action value, or 8 years with the far lower exposure level of $1 \text{ m/s}^2 \text{ A}(8)$.²⁸ With our finding of a detection rate of 71%, the average when using two SEMs, about 10 000 of those workers with early nerve injuries would go undetected, letting this chronic and untreatable injury persist and aggravate. By a mere 3-min increase in face time with the physician, those injured workers could readily be detected.

Fewer SEMs, and variable use of the different SEMs, also hinder evaluation of progression or regression over time, which has been reported to be a problem.³⁰ Qualitative data, hitherto unpublished, also point out that trust in the physician's ability to make an adequate test that will find HAVS is an important factor for whether a worker attends to their MCV. Fewer SEMs, and an inconsistent use of them, is thus likely to make the examination less trustworthy, further adding to the problem of avoidance of MCVs in vibration exposed workers.

Diagnosing HAVS is known to be difficult.³¹ The natural progress of the disease is very variable, and even after a complete stop of exposure to vibrations in a worker with objective findings, the disease could both stay unchanged, improve or deteriorate. In a 15 year follow up study, 43% with white fingers improved, and 12% deteriorated.³² A Finnish study showed that approximately a third of the workers with neurological symptoms improved neurologically after 8.5 years. This study, which was based on questionnaires, reported a lack of clinical investigations as a serious limitation of their work.³⁰ The use of more SEMs would give additional possibility to follow the improvement or deterioration of the disease, without the limitation reported in the Finnish study, and would make the diagnostics and staging more accurate.¹⁵

No previous studies on the detection rate of pathological findings in a surveillance system for vibration exposed workers could be found, so no comparisons with previous studies could be made. However, some studies in experimental populations have been made. One study recommended the use of 2PD, the Temperature Neutral Zone test, and grip strength as examination methods. The authors furthermore stated that no single test can show damage to the various end organs, nor reliably stage the sensorineural element.¹⁵ Their conclusion about using several SEMs

Sensory examination methods	Examinations (N)	At least one with reduced sensitivity (N)	Detection rate (%)
One SEM			
Two-point discriminator (2PD)	185	64	35
Monofilament (Mono)	192	103	54
Tuning fork (TF)	71	12	17
Rolltemp (Temp)	170	112	66
N of one SEM examinations	618	291	47***
Two SEMs			
2PD and Mono	180	120	67
Mono and Temp	165	141	85
2PD and TF	69	28	41
TF and Temp	56	43	77
2PD and Temp	157	121	77
Mono and TF	69	40	58
N of two SEM combinations	696	493	71***
Three SEMs			
2PD, Mono, and Temp	154	144	94
2PD, TF, and Temp	68	48	71
2PD, Mono, and TF	54	47	87
Mono, TF, and Temp	54	50	93
N of three SEM combinations	330	289	88***
All four SEMs			
2PD, Mono, TF, and Temp	52	52	100***

*** $P < .001$.

SEM	n	Mean	Median	IQR
Two-point discrimination	13	148	136	132–162
Monofilament	14	66	51	40–76
Tuning fork	14	52	42	23–74
Rolltemp	14	80	76	63–88
Total duration of four SEMs		346	305	

TABLE 2 Sensory examination methods (SEM) and outcomes after number of SEMs used and findings of reduced sensitivity, stratified by combination of SEM(–s), among 199 individuals with at least one positive finding. Not all individuals had four SEMs performed. *p*-value from the Cochran-Armitage test for trend

TABLE 3 Time duration in seconds for the Sensory Examination Methods (SEM) with interquartile range (IQR)

in a research setting is also applicable in a clinical surveillance system. In a study of sensitivity and specificity of hand functions the authors recommend the use of several tests and state that the SEMs may also help to detect functional disturbances before they manifest with subjective clinical symptoms.³¹ In a surveillance system aiming to

find high risk individuals before the onset of fulminant disease, this is of the uttermost importance.

A significant number of workers with SWS SN2 or SN3 would not be detected if using less than four SEMs in the MCV. Workers where no objective findings are found are likely to be recommended the maximum

allowed time frame stipulated in the provision (AFS 2019:3) of 3 years before the next MCV. During this time, it is likely that they would continue to be exposed to an undiminished quantity of vibrations, further aggravating their situation. Ideally, these workers would instead be detected in MCVs, allowing the worker to minimize or completely abstain from further hand-arm vibrations, thus maximizing their chances of preventing permanent nerve damage. Swedish law stipulates that the employer is responsible for rehabilitating the worker back to working capacity, in accordance with the needs of the individual. This process is far less complicated before chronic damage has occurred and also minimizes the risk of permanently losing skilled workers.

5 | STRENGTHS AND LIMITATIONS

This is the first study conducted to analyze the consequence of using various numbers of SEMs in a surveillance system for detecting vibration injuries. A core strength is the breadth of the included patients from all kinds of companies and all over Sweden including various climate zones: from the arctic north of the polar circle to the temperate continental northern European in the south of Sweden. Furthermore, all workers of the companies that are exposed to a hazardous amount of vibration (over $2.5 \text{ m/s}^2 \text{ A}(8)$), or with a colleague having acquired symptoms of HAVS, should have been offered to participate. This makes for a population that is diverse and thus also generalisable to other countries and surveillance systems.

It is likely that inclusion of all individuals with as little as one objective finding in any finger is somewhat too liberal, and some of them might not be deemed as caused by vibration exposure after a full clinical examination and exposure investigation. The objective findings of sensorineural deficiencies are however, albeit not deemed caused by vibrations, a likely liability when it comes to risk of injuries due to further exposure. Affected workers should therefore be regarded as risk patients when it comes to exposure for hand-arm vibrations. Sensible risk management when it comes to interactions with other co-morbidities and other modifying factors, e.g. pharmaceuticals, has been advised.³³ One way of doing this is by applying the recommendation in the provision AFS 2019:3 with much shorter intervals between the MCVs for exposed workers with objective findings.

In seven cases Rolltemp was substituted with room-tempered metal (such as reflex hammer). This is a use supported by the national guidelines. However, this methodology only examines thermotactile sensibility for cold

and is likely to diverge more from the stipulated 25°C than the Rolltemp, thus providing data with lower quality. In order to evaluate whether including the data from these individuals would affect our findings we performed a sensitivity analysis where we removed the seven individuals examined for only cold thermotactile sensibility. This analysis showed no significant difference and thus did not influence the conclusions of our findings. The difference between 25 and 40°C degrees in the Rolltemp test is supported by a study using a more finely tuned methodology, suitable for research, where a temperature neutral zone threshold test was used and 15°C was deemed quasi normal and a 10°C difference as fully normal.¹⁵ This indicates that the Temproll test with a temperature neutral zone of 15°C is adequate for finding reduced sensibility in a surveillance system, as it will detect early pathology. The test is sensible to error due to low temperature in the hands. Consequently, the hand temperature should be assessed, and the hands warmed before testing if they are colder than 28°C , as recommended by the national guidelines.

There was rarely any data on the tuning fork methodology for vibrotactile sensibility examination. We assume that this method (in its most basic form consisting of noting whether a vibrating tuning fork can be sensed at all), is included as it is traditionally used in standard neurological examinations (such as screening for diabetes). However, it is a fairly crude method as an injury needs to be rather severe in order for the test to be positive. A standardization of this SEM in the national guidelines would be useful.

The reasons why the physicians used fewer than four SEMs, in spite of the previous National guidelines (under which most of the MCVs were performed) as well as the company guidelines, are unclear. The reason for diverging from the guidelines could not be deducted from the medical records. One possible explanation for why fewer than four SEMs were used was that one Health occupational company that was incorporated into Feelgood corporation at the end of the period seemed to not follow the guidelines in a cohesive way resulting in the use of fewer SEMs. A possible reason for the relatively few examinations with tuning fork, about 40% in comparison with the other SEMs, is the fact that there was no keyword in the medical record template for the MCV. All the other SEMs had their specific keywords in the template, but for vibrational sensitivity this had to be recorded under the keyword "Evaluation", risking that it was often overlooked. When no data on SEMs could be found in the medical record, we also searched for the data in the National guideline protocol if present. However, this protocol was often not included in the medical records.

Furthermore, the study is based on a large sample of many experienced physicians' decisions and thorough physical examinations in accordance with a standardized

manual provided by the national Swedish expert group on HAVS which makes for sound ecological validity in clinical settings.

In conclusion, many workers with symptoms of HAVS would go undetected if using less than four sensory examination methods in a surveillance system. The extra time needed in a clinical setting is barely noticeable, and with the increased risk of workers developing permanent nerve damage as a potential consequence, this appears to be a very reasonable investment.

AUTHOR CONTRIBUTIONS

CA drafted the manuscript. CA, FT, and CN developed the manuscript. CA collected the data. CA did the statistical analyses with the aid of a statistician. CA, FT, and CN interpreted the data. CA, FT, and CN designed the study. The final version was approved by all authors.

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CONFLICT OF INTEREST

One author was employed at Feelgood, a company that co-funded the study. However, none of the funding organizations had any influence over any part of the scientific process or analysis of data. All authors could also access the original data. We have followed the guidelines of the International Committee of Medical Journal Editors³⁴ and we believe that the study has no biases on basis of conflict of interest.

DATA AVAILABILITY STATEMENT

Anonymized data that supports the findings of this study is available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

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