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Diagnosing soft tissue rheumatic disorders of the upper limb in epidemiological studies of vibration-exposed populations

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Abstract

Objectives—To investigate approaches adopted to diagnose soft tissue rheumatic disorders of the upper limb (ULDs) in vibration-exposed populations and in other settings, and to compare their methodological qualities.

Methods—Systematic searches were made of the Medline, Embase, and CINAHL electronic bibliographic databases, and of various supplementary sources (textbooks, reviews, conference and workshop proceedings, personal files). For vibration-exposed populations, qualifying papers were scored in terms of the provenance of their measuring instruments (adequacy of documentation, standardisation, reliability, criterion-related and content validity). Similar criteria were applied to general proposals for whole diagnostic schemes, and evidence was collated on the test-retest reliability of symptom histories and clinical signs.

Results—In total, 23 relevant reports were identified concerning vibration-exposed populations - 21 involving symptoms and 9 involving examination/diagnosis. Most of the instruments employed scored poorly in terms of methodological quality. The search also identified, from the wider literature, more than a dozen schemes directed at classifying ULDs, and 18 studies of test-retest reliability of symptoms and physical signs in the upper limb. Findings support the use of the standardised Nordic questionnaire for symptom inquiry and suggest that a range of physical signs can be elicited with reasonable between-observer agreement. Four classification schemes rated well in terms of content validity. One of these had excellent documentation, and one had been tested for repeatability, agreement with an external reference standard, and utility in distinguishing groups that differed in disability, prognosis and associated risk factors.

Conclusions—Hitherto, most studies of ULDs in vibration-exposed populations have used custom-specified diagnostic methods, poorly documented, and non-stringent in terms of standardisation and supporting evidence of reliability and/or validity. The broader literature contains several question sets and procedures that improve upon this, and offer scope in vibration-exposed populations to diagnose ULDs more systematically.

Keywords

diagnosis; upper limb disorders; reliability; validity

Introduction

Human exposure to hand-transmitted vibration (HTV) has been linked with a number of health effects in the upper limb, including Raynaud's phenomenon secondary to vibratory tool use (vibration-induced white finger), sensorineural impairment in the digits, carpal

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tunnel syndrome (CTS), hand and arm pain, weakness of grip strength, and certain specific musculoskeletal disorders of the upper limb (ULDs) [66].

The research literature on human health effects of HTV is large. However, the topic of ULDs appears relatively to have been neglected. In early historical accounts emphasis was given to vascular effects [1,32,41]. The possibility of musculoskeletal and osteoarticular injury was recognised by some researchers [42], but when Agate et al. reported a classic case series from British manufacturing industry they stated that 'pain was an unusual symptom' and only one man among 278 had 'symptoms and signs to suggest osteoarthritis of the shoulder-joints'; a detailed appendix listing the occupational and leisure time disability of cases focused solely on the effects of blanching [1]. More recently, in Griffin's comprehensive *Handbook of Human Vibration* [29], some 287 pages were given over to HTV but just eight of these concerned bones, joints and disorders of muscle; and in a 206 page evidence-based review by Mason and Poole of clinical testing for individuals exposed to HTV, none of over 600 references concerned the diagnosis of ULDs [46]. Finally, and perhaps most telling is the omission of direct reference to musculoskeletal injury in the two Stockholm scales, used widely to grade the severity of Hand-arm Vibration Syndrome.

Hagberg, in preparing an article of similar title for the previous international workshop on diagnosis of disorders caused by HTV, found surprisingly limited empirical evidence for an effect of vibration on the upper limb musculoskeletal system [31]. But absence of good evidence cannot be taken as good evidence against important risks. On the contrary, the existence of several potential risk factors in vibration-exposed workers (e.g. forceful gripping, repetitive movements, manual material handling, work in non-neutral postures, repeated impacts, shocks, and the possibility of a tonic-vibration reflex, with higher muscle loading) underpins the need for more targeted research.

A matter of concern in the context of a workshop on diagnosis of vibration-related health effects is whether a lack of sufficient assessment tools is acting as a discouragement to research of ULDs. Proper classification is a pre-requisite to meaningful inquiry, but the diagnosis of rheumatic disorders of the upper limb is notoriously challenging. In particular, problems arise for want of an adequate reference standard and because in its absence researchers have employed a multiplicity of approaches to address the problem [15,18,78].

Objectives

In the hope of offering better tools of inquiry, the author has undertaken a systematic literature review to investigate (1) which approaches to diagnosis of ULDs have been used hitherto in relation to vibration research; and (2) which approaches have been developed more generally, and in other populations, to aid rheumatological and epidemiological investigation. In each case an evaluation was made to identify approaches that were evidence-based with empirical support in terms of constructs which researchers seek (for example, repeatability, face and construct validity and predictive validity).

Methods

Attention was restricted to painful disorders of the musculature and soft tissues, excluding osteoarthritis. Weakness of grip, clumsiness, and lack of dexterity (all important but non-specific markers of dysfunction) were not considered as part of this review; nor were the various schemes aimed at determining functional limitations, rather than diagnosis.

First search – strategy, data abstraction and assessment

To determine which approaches to diagnosis of ULDs have been used previously in vibration-exposed populations, a systematic search was conducted of the Medline, Embase

and CINAHL electronic bibliographic databases from inception to April 1st 2006. Key words and medical subject headings for the exposure (HTV) and the outcome(s) (upper limb disorders) were combined using Boolean strings. The terms for exposure included a list of powered vibratory tools and machines that had previously been compiled following review of published literature, standards testing documents, and textbooks, and a field consultation with vibration experts, trades unions and trade associations in the UK. Those for outcome were adapted for purpose but based on terms chosen in several earlier systematic reviews of ULDs [15,73,75,78,84]. The full strategy is reproduced in an appendix (as search 1). References and abstracts were imported into a reference manager software package (Refman 10.0), where duplicates were removed. The remaining material was inspected for relevance.

The search was supplemented using several other sources: (i) the textbook, Handbook of Human Vibration [29]; (ii) the comprehensive Critical Review of Epidemiologic Evidence for Work-related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back, compiled by the National Institute for Occupational Health and Safety [6]; (iii) the textbook Work-related Musculoskeletal Disorders: A Reference Book for Prevention [37]; (iv) the conference proceedings from the last six International Conferences on Hand-arm Vibration (1989-2004); and (v) the author's personal files on HTV. The references of retrieved papers were checked for further relevant primary research.

To be eligible for inclusion, papers had to describe an epidemiological investigation of upper limb symptoms or ULDs in vibration-exposed workers, and had at least to include musculoskeletal symptoms, clinical examination of the musculoskeletal system, or a musculoskeletal diagnosis within the reported findings. Non-English language publications were excluded.

A standard set of information was abstracted from all qualifying papers, detailing the authors, study population and setting, the content of any symptom inquiry and/or physical examination, and the source and provenance of the instruments used. In particular, note was made whether the questions or examination were documented, standardised, and fulfilled basic measurement criteria of reliability and of criterion-related and content validity according to the scheme set out in Table 1. Where particulars were missing or unclear, the default assumption was that the criteria were 'poorly met'.

Second search – strategy, data abstraction and assessment

To investigate which approaches have been developed more generally to classify rheumatic disorders of the upper limb, a second search was conducted using the same databases and covering the same time period. Similar outcome terms were used as in the first search, but these were combined with key words and medical subject headings relevant to the assessment of classification, diagnosis, diagnostic criteria, and the repeatability, validity and other measurement properties of ULD diagnostic schemes (appendix, search 2).

As before, references and abstracts were imported into a reference manager package and assessed for relevance. And the search was supplemented, where not otherwise covered, with several authoritative reviews [6,15,20,44,47,78,84], a reference list of standard textbooks [21,30,37], the records of diagnostic workshops in which the author had participated [33,73], and his own personal library and research output.

The second search strategy identified a large literature. Thus, following the model of Buchbinder et al. and van Erp et al. [15,78], attention was confined to studies whose aim was to define a diagnostic criterion, method, or system of classification for at least one soft tissue rheumatic ULD and which did so by means of clinical history or examination. Studies

that relied on secondary care investigation (radiographs, ultrasonography, imaging, neurophysiology etc) were excluded.

Two broad categories of report were summarised:

- i. papers that focused on the measurement properties of symptom questionnaires or commonly used physical signs;
- ii. papers that reported whole schemes of classification. (Note was also taken of reviews about diagnostic schemes, and papers that later used and evaluated candidate systems.)

For qualifying papers in the first category a note was made of the authors, the elements of history or examination assessment, the assessment protocol, and the observed within- or between-observer or within-subject agreement. For papers in the second category similar information was collected, where available, and diagnostic schemes were scored according to the criteria in Table 1.

Results

Surveys in vibration-exposed populations (search 1)

The first database search retrieved 102 titles of which 21 were considered potentially relevant following an assessment of abstracts. In addition 19 papers and research abstracts were identified from the other bibliographic sources. These 40 accounts were read.

Table 2 summarises the main observations, which related to 23 finally relevant reports (21 studies).

Symptom inquiries—Twenty-one of the 23 reports included symptom inquiry within the ambit of investigation. Around a half of these were classed as poor (or unclear) in terms of their documentation (10 reports), standardisation (7), and/or choice of instruments with established measurement properties (11). Only two reports [40,49] fully met all of the symptom criteria in Table 1.

Examination and/or diagnosis—Nine reports included elements of examination and/or proposed specific rheumatological diagnoses relevant to this review. None of these fully met all of the criteria proposed in Table 1, although several partially met them – typically by specifying the elements of examination and/or case definition without explicit details of method or cut-points; and by making choices that, although not empirically evaluated, were reasonable in terms of face validity and supported by expert consensus. The schemes proposed by Waris et al. [85] and Viikari-Juntura [80], which are assessed in further detail below, have been taken up in several investigations of vibration-exposed workforces, and recently incorporated into the consensus criteria proposed by the European research consortium VINET [<http://www.vibrisks.soton.ac.uk/>].

On balance, Table 2 suggests that only limited effort has been expended thus far in bringing well-documented, standardised and evidence-based approaches to bear in the diagnosis of ULDs in vibration-exposed populations.

Tools and schemes in more general use (search 2)

The second search identified 1,043 unique titles, including 55 with relevant abstracts that were examined in greater detail. Additionally, 16 papers from other sources were screened. The final relevant material comprised 50 accounts, including 12 reviews. Among the papers retrieved, were more than a dozen schemes directed at the classification of one or more

ULDs, 14 concerned with the measurement properties of specific physical signs in the upper limb, and four concerned with the test-retest reliability of symptom histories. Findings are summarised separately in relation to each of these elements.

Reliability of symptom histories—Many researchers base musculoskeletal symptom enquiries on the Standardised Nordic Questionnaire, which is well documented and has acceptable face validity. The search identified four papers [23,25,38,59] which had assessed within-subject repeatability when this questionnaire or close variants of it, were self-completed on two occasions, typically spaced by a one-week interval (Table 3). Observed agreement mostly exceeded 80%. Some investigators also calculated chance adjusted kappa coefficients (κ), and these proved to be acceptable by Fleiss's criteria ($\kappa > 0.75$ denotes excellent agreement while that of 0.4 - 0.75 denotes good agreement) [24].

Although the evidence base is not extensive, it seems that this agreement - at least in the short-term - encompasses (i) recent symptoms, (ii) symptoms in the past 12 months, (iii) symptoms of interfering with daily activities, (iv) symptoms for which treatment is sought, (v) frequency of symptomatic episodes, and (vi) certain doctor-named diagnoses [25].

Less is known about the repeatability of questions on sensory symptoms of the upper limbs, but in one survey of rheumatological outpatients, levels of observed and chance-adjusted agreement were scarcely different to items on upper limb pain [59].

Reliability of physical signs—Most effort has been expended on assessing the measurement properties of signs used to diagnose CTS, and the search identified two comprehensive reviews by Marx et al. and Massy-Westropp et al. which, by themselves, summarised 27 other reports, mostly on Phalen's test and Tinel's test [44,47]. Table 3 lists the studies in which repeatability of these signs were assessed. They appear to have good to excellent inter-observer and intra-observer reliability in the secondary care setting (with κ ranging from 0.53 - 1.0), but in one community survey where the case mix is likely to have been less severe, the inter-rater reliability of Tinel's test was poorer ($\kappa = 0.38$), and Salerno et al. reported κ that ranged from 0.20 to 0.43 in an occupational survey of keyboard operators [71]. The review by Marx et al. also explored the reliability of five other clinical tests (moving and static two-point discrimination, Semmes-Weinstein monofilament testing, vibration sense, and motor power) and found that in general they were unsatisfactory [44].

A second principal area for research focus concerns measurement of active and passive shoulder movement through goniometry, pleurimetry or visual estimation (Table 3). Nine relevant papers were identified which used various protocols and numerical measures of agreement. In general, most schemes showed adequate repeatability. Thus, observed agreement in one study ranged from 54% to 80% (higher within and between-observers) for a crude categorical classification of functional capability, in raising the hand, placing the hand behind the back, and raising the hand to the neck, or to the opposite shoulder in front of the body [9]; in several studies the intra-class correlation coefficient (ICC) exceeded 0.8, overall [8,28] and for specific shoulder cut points, such as the first experience of pain in a painful arc of abduction [19]; and one study found small mean differences in measured active and passive movements with 70% of paired between-observer measurements within 20° of one another [60]. Two studies reported generally favourable κ for other shoulder signs including tenderness, painful arc and pain on resisted shoulder movements [60,81].

Findings at the neck have been similar (Table 3) although less extensively documented, while one solitary investigation has documented 'fair' agreement between pre-trained observers over tenderness, muscle wasting and muscle strength in the neck-shoulder region [79].

Other observations on the repeatability of upper limb physical signs seem sparse, but in two studies that assessed elbow tenderness and pain on resisted wrist movement, κ range from 0.5 to 0.79, being higher in the hospital outpatient setting than in a community sample [60,81]. Finally, Palmer et al. found the between-observer repeatability of radial wrist tenderness and the Finklestein's test to range from 0.66 to 0.79 in a panel of 88 rheumatological subjects, including seven with tenosynovitis or De Quervain's disease [60], and Salerno reported κ for Finklestein's test that ranged from 0.15 (right side) to 0.49 (left side), with 94-97% observed agreement [71]. (These authors commented on the instability of their reliability statistics, owing to the low prevalence of pathology among those tested.)

In general, therefore, reasonable evidence was found to suggest that a range of physical signs could be elicited with a reasonable measure of agreement between observers. Pre-training of examiners to ensure consistent application of an agreed methodology is a pre-requisite, but the documentation of this and the methods for use by other investigators varied from exemplary to lacking.

Diagnostic schemes—Table 4 summarises the diagnostic elements of four classification schemes in use beyond the paper in which they were originally proposed. Van Eerd et al. [78] have noted that these and several other classification schemes [2,3,7,26,39,48,63,65,67,69,72] have tended to differ in the conditions that they cover and the criteria they propose. However, some commonality is also in evidence - for example the criteria for epicondylitis, tenosynovitis and supraspinatus tendinitis appear similar under the schemes in Table 4.

Although developed in different settings, all rate well in terms of face validity. The scheme proposed by Waris et al. [85] and modified by Viikari-Juntura [80] was developed following a systematic literature review; that of Harrington et al. [33], as modified by Palmer et al. (Southampton Examination Schedule) [60], was based on the Delphi consensus criteria of a multi-disciplinary expert workshop; and the criteria of Sluiter et al. (the SALTSA criteria) [73] derive from a similar consensual process, shared several participants in the steering group, and considered the Harrington criteria in preliminary drafting.

In terms of documentation, each of these schemes provides the elements of examination and case definition; and the SALTSA criteria go further, being supported by an excellently illustrated and publicly available procedures protocol, with photographs demonstrating the examination methodology [73]. However no single account was found to be complete in all particulars of documentation. Thus, only the Southampton Examination Schedule defines explicit cut points of abnormality in relation to criteria based on measured joint movements, but the precise methods of eliciting signs and performing manoeuvres (although existing, as perhaps for other schemes, in a research procedures manual) have been available hitherto only on request.

The biggest difference between the schemes, however, lies in their completeness of assessment. At the time of searching, only the Southampton Examination Schedule had been evaluated in terms of repeatability of diagnosis and concurrent validity of diagnosis with respect to an independent reference standard. In the first of two linked studies, consecutive cases from rheumatology and orthopaedic outpatients were examined by a research nurse blinded to diagnosis and then independently examined according to the same scheme by a rheumatologist [60]. The between-observer reliability of physical signs, as illustrated in Table 3, was generally found to be good to excellent ($\kappa = 0.66 - 1.0$) for most categorical observations and in this setting the schedule was found to have a good specificity (84% - 100%) and reasonable sensitivity (58% - 100%), assuming the clinic's diagnosis to be a reference standard (Table 5). In a follow-up investigation of 1,960 recently symptomatic

subjects from the general population, 97 consecutive participants were examined twice, blinded and in random order, by a pre-trained research nurse and a rheumatologist, the latter independently ascribing diagnosis according to usual care criteria [81]. The median κ for diagnosis was 0.66 (range 0.21 to 0.93), with good to excellent agreement by Fleiss's criteria for most of the diagnoses (Table 5). In a separate investigation, de Winter et al. found assessed agreement over shoulder diagnosis among two physiotherapists to be 'moderate' ($\kappa = 0.45$ (95% CI 0.37-0.54) in 201 referrals with varying severity and duration of complaint: disagreement tended to be greater where complaints were bilateral, chronic or severe [22]. Better agreement over shoulder diagnosis was found in another study when two physiotherapists applied classical textbook (Cyriax) criteria to assess 21 patients among whom 19 were placed in the same diagnostic category ($\kappa = 0.88$) [62].

Further infill work on the Southampton Schedule has seen the criteria for CTS reviewed and refined [68]. Among the 1,960 subjects of the community survey, associations with putative risk factors were explored according to different definitions of sensory involvement in the hand. The strongest association with physical risk factors such as flexing and extending the wrist was found for symptoms in a strictly classical median nerve distribution, whereas for non-median patterns (including the involvement of all digits) stronger associations were found with painfully restricted neck movement and low mood and vitality. Differential association with risk factors was thus proposed as a basis for underpinning a more restrictive case definition of CTS [17,68]. And, in similar vein, the schedule was tested for its capacity to distinguish groups receiving different treatments and with differing levels of disability. Subjects classified as having a specific disorder of the shoulder, elbow or wrist/hand were most likely to report disability for activities of daily living, more likely to have had an injection, and more likely to be taking prescription medication than those classed as having only non-specific pain [82]. Employed subjects who worked with their hands above shoulder height were also more likely to have non-specific shoulder pain than a specific shoulder disorder, and those who typed at work were more likely to have a specific rather than a non-specific complaint at the hand-wrist [83]. Such differential associations imply the potential, using the schedule, to identify subgroups that require different preventive or management actions – that is, a practical utility or added value to case classification. The predictive validity of the Southampton Examination Schedule is also currently being assessed (personal communication).

Discussion

As judged by this review, there have been rather few attempts, of limited scope, to assess the impact of explicitly defined ULDs in vibration-exposed populations. In general the approaches adopted have been custom-specified, poorly documented, and non-stringent in terms of the steps taken to ensure standardisation and to evaluate repeatability and/or validity. In the broader rheumatological literature there is more evidence that symptom histories and signs can be elicited in a reasonably reproducible manner, more is known or proposed concerning diagnostic criteria, the completeness of documentation is of a higher order, and for at least one diagnostic scheme some concerted attempt at evaluation has been undertaken.

In considering whether vibration specialists should make more use of the Southampton Examination Schedule or the SALTSA criteria a number of issues need to be aired. Firstly, there is no absolute consensus on the range of ULDs that exist or how they should be diagnosed [15,58,78]. Of fundamental importance, diagnosis remains a subjective process, reliant on patients' accounts (of pain, tenderness, or pain on resisted movement) and clinical judgement, with few objective investigations to underpin the process. Differences of opinion exist commonly between specialists and specialisms. Although the consensus criteria of

Delphi expert workshops paper over some of the cracks, they may still be considered only to represent the agreement of a limited selection of experts. Differences between schemes reflect such tensions. For example, the Harrington workshop considered the thoracic outlet syndrome such a rare disorder in UK experience to preclude further discussion, whereas looser criteria have led to the disorder being diagnosed frequently in workers from other countries. No absolute gold standard can be said to exist.

In the absence of an agreed and wholly satisfactory reference standard researchers have turned, in general, to expert consensus as a source for criteria that can be used in surveillance and research inquiries. This approach has the benefit of face and content validity, but also has some limitations. In particular, it requires an empirical as well as a pragmatic underpinning, given the disagreements among experts. In addition to being sensible in clinical terms, clearly specified, unambiguous, feasible to implement, and comprehensive in coverage, a satisfactory classification scheme should fulfil basic measurement properties that researchers value (eg demonstrable repeatability); it should be documented in sufficient detail that others could follow it and reach the same conclusion; and it should agree with other imperfect but plausible surrogates of the same end-point (eg independent specialist's opinion).

Coggon et al. have also emphasised utility and added value as a way of choosing between alternative candidates [17]. According to their logic, a 'diagnosis' should be considered a means to an end, the end being usually the management or prevention of cases. A diagnostic scheme that 'adds value' would distinguish subgroups among whom different useful actions might ensue; thus, for example, differences in response to treatment, or differences of prognosis or association with putative risk factors could be used to assess whether the pre-condition of adding value is satisfied.

When judged against the criteria of the previous two paragraphs, no scheme among those described can be considered perfectly complete. The criteria proposed by Waris et al., Viikari-Juntura and Sluiter et al. cover a wider range of disorders than the Harrington criteria, as modified by the Southampton Examination Schedule; those by Sluiter et al. are best illustrated in a publicly available document; while the Southampton Examination Schedule is unique so far in the extent of empirical evaluation. As a matter of future policy, the proponents of diagnostic schemes should be encouraged to document their methodology in as much detail as possible, thereby encouraging a more uniform approach to diagnosis in an area that badly requires a convergence of methods. In addition, they should be encouraged to assess the minimum level of training needed to assure repeatability (clearly a convenient scheme would be reproducible without the need for an extensive and time-consuming programme of training).

Having stated these limitations, it may be helpful to highlight the potential for improvement. In terms of symptom histories in research there is a strong case for adopting the Nordic questionnaire as the normal standard - the case being founded on face validity, repeatability, documentation and wide research use in other settings. In terms of clinical signs there is sufficient evidence that some procedures are reliable enough to encourage their use in field research. And in terms of diagnosis, several schemes now exist with face validity, some of which are built upon consensus, and many of which look similar in their components of overlap. At least one is well documented, while the Southampton Examination Schedule provides a model for a scheme of sufficient repeatability and concurrent validity to be adopted more widely as a tool of investigation in vibration-exposed populations. Approaches used to diagnose ULDs in vibration-exposed populations seem to have been less than systematic hitherto; but the broader literature contains several question sets and procedures of promise, with immediate scope to improve upon the historic position.

Acknowledgments

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Appendix

Search strategy 1: Hand-transmitted vibration and upper limb disorders

- 1 ((hand-transmitted or hand-arm) adj2 vibrat\$.tw
- 2 (hand-powered adj3 tool\$.tw
- 3 (forest\$ or grinder\$ or plater\$ or chainsaw\$ or (hammer adj1 drill\$) or ((jig or circular) adj1 saw\$) or (impact adj1 (wrench\$ or screwdriver\$)) or mower\$ or (chipping adj1 hammer\$) or ((road or concrete) adj1 breaker\$) or roadbreaker\$ or ((nailing or stapling) adj1 gun\$) or (metal adj1 drill\$) or sander\$ or polisher\$ or vibrotamper\$ or tamper\$ or grinding or riveting or riveter\$ or caulking or (bucking adj1 bar\$) or pneumatic or fettling or fettler\$ or clinching or flanging or swager or swaging or scaler or scaling or descaler or descaling or (vibratory adj1 compactor\$) or wacker\$ or (elephant adj1 foot) or (kango adj1 hammer\$) or breaker\$ or scabbl\$ or rammer\$ or stoneworking or (jack adj1 leg) or rotary or polishing or polisher\$ or stihl or pedestal or buffer\$ or buffing or (engraving adj1 pen\$) or poker\$ or dolly or linisher\$ or (brush adj1 (saw\$ or cutter\$)) or (hedge adj1 trimmer\$) or linish\$ or reamer\$ or barking or router\$ or routing or (pounding adj1 machine\$) or (vibratory adj1 (plate\$ or roller\$)) or nibbling or (water adj1 jetting) or handlebar\$ or snowmobile\$ or (snow adj1 mobile\$) or vibrothickener\$ or (metal adj1 shear\$)).tw
- 4 1 or 2 or 3
- 5 (upper limb pain or upper extremity pain or ((arm or shoulder or elbow or wrist or hand or forearm) adj1 pain\$) or shoulder tendonitis or ((shoulder or adhesive) adj1 capsulitis) or epicondylitis or tenosynovitis or tendinitis or de quervains or olecranon bursitis or carpal tunnel syndrome or ulnar nerve compression or ulnar nerve neuropathy).tw
- 7 5 and 4
- 8 Remove duplicates from 7

Search strategy 2: Diagnosis of upper limb disorders

2A. Schemes and systems

1. exp Carpal Tunnel Syndrome/[Classification, Diagnosis]
2. exp Tenosynovitis/[Classification, Diagnosis]
3. exp Tendinopathy/[Classification, Diagnosis]
4. capsulitis.mp
5. exp Bursitis/[Classification, Diagnosis]
6. exp Tennis Elbow/[Classification, Diagnosis]
7. epicondylitis.mp
8. de Quervains.mp
9. exp Ulnar Nerve Compression Syndromes/[Classification, Diagnosis]

10. exp Ulnar Neuropathies/[Classification, Diagnosis]
11. exp Cumulative Trauma Disorders/[Classification, Diagnosis]
12. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13. Upper Extremity/or upper limb.mp
14. 12 and 13
15. exp Musculoskeletal Diseases/[Classification]
16. exp Occupational Diseases/[Classification, Diagnosis]
17. 15 or 16
18. 14 and 17
19. (between-observer or within-observer or inter-observer or intra-observer or inter-rater or intra-rater or reliability or repeatability or reproducibility or reliable or repeatable or reproducible or kappa or coefficient or consistency or sensitivity or specificity or validity or ((predictive or prognostic) adj1 value) or standardised or standardized or standardisation or standardization or (classification adj1 (scheme\$ or system\$ or criterion or criteria)) or (case adj1 definition) or (diagnostic adj1 (criteria or criterion)) or (consensus adj1 (criteria or criterion)) or (evidence-based adj1 (criteria or criterion))).tw
20. 18 and 19
21. remove duplicates from 20

2B. Diagnostic properties of individual tests and procedures

- 22 ((upper adj1 (limb\$ adj1 pain)) or ((arm or shoulder or elbow or wrist or hand or forearm) adj pain\$) or (shoulder adj1 (tendonitis or capsulitis)) or epicondylitis or tenosynovitis or tendonitis or tendinitis).tw.
- 23 carpal tunnel syndrome.mp.
- 24 22 or 23
- 25 19 and 24
- 26 diagnosis.mp. [mp=ti, hw, ab, it, sh, tn, ot, dm, mf, nm]
- 27 classification.mp. [mp=ti, hw, ab, it, sh, tn, ot, dm, mf, nm]
- 28 26 or 27
- 29 25 and 28
- 30 remove duplicates from 29

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Table 1
Criteria used to assess the adequacy of documentation, standardisation and assessment of symptom questionnaires and diagnostic schemes

	Documentation	Standardisation	Properties
Symptoms			
Fully met	Exact question given or referenced	Self-completed questionnaire, or administered questionnaire with training aimed at standardisation	(i) Agreed by expert panel; and/or good face validity; (ii) documented properties of test-retest reliability
Partially met	Question paraphrased, leaving some doubt as to exact wording and qualifiers	Administered questionnaire with no pre-training (or no mention of this)	Agreed by expert panel and/or good face validity, but not tested empirically
Poorly met or unclear	Content only indicated in outline	Questions at discretion of interviewer, or not clearly based on a prescribed list	Poor or uncertain face validity; user specified without peer input or empirical evaluation
Examination and diagnosis			
Fully met	(i) Exact method of eliciting physical signs/performing a manoeuvre or measuring given or referenced; (ii) cut-points of abnormality defined; (iii) criteria for caseness explicit and unambiguous	Examiners pre-trained to ensure consistent application of an agreed method	(i) Documented properties of test-retest reliability; (ii) concurrent validity (eg sensitivity, specificity) relative to another independent reference standard
Partially met	Ingredients of examination and case definition specified, but methods and cut-points left open to interpretation		Agreed by an expert panel, but not tested empirically
Poorly met or unclear	Less explicit than above	Examiners not pre-trained to ensure consistent approach (or no mention of this)	User specified without peer input or empirical evaluation

Table 2
Evaluation of the symptom inquiries and diagnostic methods used to assess disorders of the neck and upper limb in research investigations of vibration-exposed populations

	Documentation	Standardisation	Properties
Symptoms			
Fully met	[10,11], [16], [40], [49], [52], [75]	[10,11], [12], [14], [16], [40], [49], [52], [61]	[40], [49], [61]
Partially met	[13], [36], [55], [61]	[13], [36], [55], [74], [75]	[10,11], [13], [14], [16], [36], [52]
Poorly met or unclear	[4], [12], [14], [27], [45], [50,51], [53], [64], [74]	[4], [27], [45], [50,51], [53], [64]	[4], [12], [27], [45], [50,51], [53], [55], [64], [74], [75]
Examination and diagnosis			
Fully met		[55], [77]	
Partially met	[10,11], [13], [36], [54], [55], [74], [77]		[10,11], [13], [55], [77]
Poorly met or unclear	[27]	[10,11], [13], [27], [36], [54], [74]	[27], [36], [54], [74]

The figures in the body of the text represent the reference numbers of particular studies identified by search 1

Table 3
Repeatability of symptoms and physical signs used in the assessment of upper limb disorders

Ref(s)	Setting/protocol	Items	Agreement	
Symptoms			Observed (%)	κ /weighted κ
[23]	44 cashier workers; self-completed Nordic-style questionnaire; test-retest at 1 week interval	Trouble (aches, pain, discomfort, numbness): In past 7 days In past 12 months In past 12 months interfering with normal activity	74 - 100	
[25]	148 industrial workers; self-completed Nordic-style questionnaire; test-retest at 1 week interval	At least 3 episodes or 1 lasting >7 days in past 12 months: Any episode Current episode Sought treatment Frequency of episodes Doctor diagnosed: Carpal tunnel syndrome Ulnar neuropathy Tendinitis Thoracic outlet syndrome Rotator cuff injury	89 - 93 86 - 88 89 - 92 91 - 93 98 99 88 99 98	0.76 - 0.82 0.46 - 0.61 0.62 - 0.72 0.73 - 0.74 0.92 0.85 0.64 0.60 0.56
[38]	27 clerical workers and 82 women in the electronics industry; self-completed Nordic questionnaire, test-retest at 3 week interval	Trouble (aches, pain, discomfort, numbness): In past 7 days In past 12 months In past 12 months interfering with normal activity	70 - 100%	-
[59]	105 rheumatology outpatients; self-completed Nordic-style questionnaire; test-retest at 1 week interval	Pain in past 7 days Pain in past 12 months Pain in past 12 months interfering with work or leisure Numbness/tingling in past 7 days Numbness/tingling in past 12 months	83 - 86 89 - 91 80 - 89 82 - 87 86 - 87	0.66 - 0.71 0.73 - 0.82 0.59 - 0.75 0.63 - 0.73 0.70 - 0.75
Physical signs			Measure of agreement	Estimate
Elbow				
[60]	88 rheumatological outpatients examined independently by two pre-trained observers	Tenderness over lateral epicondyle Pain on resisted wrist	κ κ	0.75 0.75 - 0.79

Ref(s)	Setting/protocol	Items	Agreement	
flexion/extension				
[81]	97 working age adults with neck or upper limb pain, identified from the general community; examined independently by two pre-trained observers	Tenderness over lateral epicondyle	κ	0.64
		Pain on resisted wrist flexion/extension	κ	0.52 - 0.56
Neck				
[5]	21 healthy volunteers: 6 neck movements measured by 3 physical therapists using a goniometer; intra- and inter-rater comparisons		Inter-rater reliability coefficient	0.26 - 0.84 (10/18 0.6)
			Intra-rater reliability coefficient	0.31 - 0.86 (10/18 0.6)
[60]	88 rheumatological outpatients examined independently by two pre-trained observers	Range of active movement (various)	Between-observer mean differences	−4.9 to 6.2° (88% of pairs within 20°) *
[79]	52 neurosurgical outpatients referred for cervical myelopathy; examined independently by two pre-trained observers	Tenderness at various pre-specified neck-shoulder sites	κ	0.43 - 0.67
		Muscle atrophy (deltoid, triceps, hypothenar eminence)	κ	0.32 - 0.81
		Muscle strength (deltoid, triceps, biceps, dorsal interossei)	κ	0.40 - 0.64
		Limitation of neck movements (various)	κ	0.40 - 0.56
[86]	60 patients with orthopaedic disorders of the neck; 6 active neck movements measured by goniometry, visual inspection and custom-designed device by 11 physical therapists; intra- and inter-rater comparisons	Intra-rater:		
		Goniometer	ICC	0.78 - 0.90
		Custom device	ICC	0.84 - 0.95
		Intra-rater:	ICC	
		Goniometer	ICC	0.54 - 0.79
		Custom device	ICC	0.73 - 0.92
		Visual inspection	ICC	0.42 - 0.70
Shoulder				
[8]	Once weekly replicate measurements of shoulder movement over 4 weeks by 4 testers with varying experience of goniometry; intra- and inter-rater comparison		Inter-rater reliability	0.97
			Inter-tester reliability	0.96
[9]	8 patients with rheumatoid arthritis; shoulder movements assessed in terms of functional achievements (categorical descriptors)		Inter-rater/intra-rater:	
		Hand raising	% agreement	81/85
		Hand behind back		65/75
		Hand to neck		54/87
		Hand to opposite shoulder		81/85

Ref(s)	Setting/protocol	Items	Agreement	
[19]	6 patients with shoulder problems from primary care, observed in random order by 6 physicians; inter-rater comparison of joint movements (observed, recorded by diagram and measured by protractor)	Passive arm abduction:		
		To start of pain	ICC	0.84
		To maximum elevation	ICC	0.95
		Passive external rotation	ICC	0.43
[28]	54 patients with shoulder pain; 6 movements measured by 6 physiotherapists using a pleurimeter; intra- and inter-rater comparisons		Intra-rater ICC	0.38 - 0.85 (4/8 >0.8)
			Inter-rater ICC	0.45 - 0.90 (6/8 0.66)
[60]	88 rheumatological outpatients examined independently by two pre-trained observers	Tenderness	κ	0.80
		Pain on various resisted movements	κ	0.54 - 0.93
		Painful arc	κ	0.93
		Range of active movement	Between-observer mean differences	-1.4 to 11.9° (70% of pairs within 20°)*
		Range of passive movement	Between-observer mean differences	-1.4 to 11.0° (71% of pairs within 20°)*
[70]	50 patients referred to a physical therapy department; 7 shoulder movements measured by random pairs of 16 therapists using 2 sizes of goniometer; intra- and inter-rater comparisons		Intra-rater ICC	0.87 - 0.99
			Inter-rater ICC	0.32 - 0.90 (6/14 0.8)
[34]	6 patients with shoulder pain and stiffness; 8 movements measured by 6 rheumatologists in random order, Latin square design	Total shoulder flexion	Inter-rater ICC	0.72
		Total shoulder abduction	Inter-rater ICC	0.49
		Glenohumeral abduction	Inter-rater ICC	0.51
		External rotation in neutral	Inter-rater ICC	0.29
		Hand behind back	Inter-rater ICC	0.80
[81]	97 working age adults with neck or upper limb pain, identified from the general community; examined independently by two pre-trained observers	Tenderness	κ	0.94
		Pain on various resisted movements	κ	0.29 - 0.66
		Painful arc	κ	0.47
[57]	136 rheumatology patients assessed in random order by a specialist, trainee and research nurse	Tenderness	κ	0.32 [‡]
		Painful arc (start of pain)	κ	0.48 [‡]
		Painful arc (end of pain)	κ	0.64 [‡]
		External rotation <45°	κ	0.68 [‡]

Wrist

Ref(s)	Setting/protocol	Items	Agreement	
[60]	88 rheumatological outpatients examined independently by two pre-trained observers	Radial wrist tenderness	κ	0.66
		+ve Finkelstein's test	κ	0.79
[71]	160 keyboard operators examined independently by two experienced observers	+ve Finkelstein's test	κ	0.15 - 0.49
[43, 60,71,81]	Various	Phalen's test	Intra-rater κ	0.53
			Inter-rater κ	0.41 - 1.0
		Tinel's test	Intra-rater κ	0.80
			Inter-rater κ	0.20 - 0.79
[81]	97 working age adults with neck or upper limb pain, identified from the general community; examined independently by two pre-trained observers	Radial wrist tenderness	κ	0.16
		+ve Finkelstein's test	κ	0.35

* Mean difference.

Agreement within one category.

[†] Specialist vs. doctor in postgraduate specialist training

Table 4
Classification schemes in common use to diagnose soft tissue and rheumatic disorders of the upper limb

Disorder	Waris et al (1979) [85] Viikari-Juntura (1983) [80]	Ohlsson et al (1994) [56]	Harrington et al (1998) [33] Palmer et al (2000) [60]	Sluiter et al 2001 [73]*
Rating [†]				
Documentation	++	++	++	+++
Content validity	+++	+++	++	++
Test-retest reliability:				
- within-observer	+/-	+/-	+++	+/-
-between-observers	+/-	+/-	+++	+/-
Agreement with external reference standard	+/-	+/-	+++	+/-
Content				
Tension neck syndrome	Feeling of fatigue or stiffness in the neck, neck pain or headache radiating from the neck; at least two tender spots or palpable hardenings; muscle pain or tightness upon neck movement			
Cervical syndrome	Pain radiating from the neck to upper extremity +limited neck movement + radiating pain provoked by test movements			
Thoracic outlet syndrome	Pain radiating to arm, positive Morley's sign, positive Adson's test, or drooping shoulder	Pain radiating to arm in ulnar nerve distribution; paresthesia in ulnar nerve distribution; positive Roos' test (increase of the subjective symptoms, not only fatigue); intense tenderness over the brachial plexus		
Supraspinous tendinitis	Shoulder pain + local tenderness + pain during abduction, or painful arc + limited active abduction	Shoulder pain + local tenderness over the tendon insertion + pain at resisted isometric abduction	Pain in deltoid region + pain on resisted active abduction	Pain in shoulder without parasthesiae that is worsened by active elevation of the upper arm + one of more of (1) pain on resisted shoulder abduction, external rotation or internal rotation; or (2) resisted elbow flexion; or (3) painful arc

Disorder	Waris et al (1979) [85] Viikari-Juntura (1983) [80]	Ohlsson et al (1994) [56]	Harrington et al (1998) [33] Palmer et al (2000) [60]	Sluiter et al 2001 [73]*
Bicipital tendinitis	Pain shoulder region + local tenderness	Shoulder pain + local tenderness over the tendon(s) + pain at resisted isometric elevation of the arm (straight and elevated 90°) and/or resisted isometric flexion of the elbow (flexed 90° and hand supinated)	Anterior shoulder pain + pain on resisted active flexion or supination of forearm	
Frozen shoulder syndrome	Progressive pain and shoulder stiffness during the last 3-4 months + active and passive outward rotation limited	Shoulder pain + progressive stiffness of the shoulder during the last 3-4 months + limited outward rotation, and abduction	Pain in deltoid area + equal restriction of active and passive glenohumeral movement with capsular pattern (external rotation > abduction > internal rotation)	
Acromioclavicular syndrome	Pain in shoulder region + local tenderness during palpation or percussion of the joint	Shoulder (epaulet) pain + palpable tenderness of joint + pain provoked by horizontal adduction and/or by outward rotation of the arm (90° abducted, with flexed elbow)	Pain + tenderness over the acromioclavicular joint + a positive acromioclavicular joint stress test	
Epicondylitis	Local pain during rest and/or movement + local tenderness at the lateral/medial epicondyle + pain on resisted extension/flexion of the wrist and fingers	Elbow pain + palpable tenderness of epicondyle + pain at resisted isometric wrist extension/flexion; for the diagnosis lateral epicondylitis, pain and/or weakness in gripping	Epicondylar pain + epicondylar tenderness + pain on resisted wrist flexion/extension	Activity-dependent pain localised around epicondyle + local pain on resisted wrist extension or flexion
Tenosynovitis of the wrist/forearm	Local ache, pain during movement, tenderness along the course of the tendon or muscle-tendon junction, swelling, weakness in gripping	Wrist pain + palpable tenderness of the tendon(s) + local swelling, redness, or heat	Pain on movement localised to the tendon sheaths in the wrist + reproduction of pain by resisted active movement	Intermittent pain/ache in ventral or dorsal forearm or wrist + provocation of symptoms during resisted movement of the muscles + reproduction of pain during palpation of the affected tendons or palpable crepitus under symptom area or visible swelling of dorsum wrist/forearm
Infraspinous tendinitis	Pain in shoulder region + local tenderness + pain on resisted isometric outward rotation of the humerus; painful arc possible	Shoulder pain + local tenderness over tendon insertion + pain on resisted isometric outward rotation	Pain in deltoid region + pain on resisted active external rotation	
De Quervain's disease			Pain over the radial styloid + tender swelling of first extensor compartment	Pain or tenderness localised over the radial wrist, which may radiate

Disorder	Waris et al (1979) [85] Viikari-Juntura (1983) [80]	Ohlsson et al (1994) [56]	Harrington et al (1998) [33] Palmer et al (2000) [60]	Sluiter et al 2001 [73]*
			+ either pain reproduced by resisted thumb extension or positive Finkelstein's test	proximally to the forearm or distally to the thumb, and at least one of the following tests positive: 1) Finkelstein's test, 2) resisted thumb extension, 3) resisted thumb abduction
Olecranon bursitis	Palpable painful olecranon bursa		Pain + tenderness + fluid-filled swelling over the posterior elbow	
Carpal tunnel syndrome	Pain or paresthesia in the median distribution of hand + positive Tinel's sign at the carpal tunnel or positive Phalen's wrist flexion test; diminished sensitivity to touch or pain in 3½ fingers on radial side of the hand and diminished strength of the short abductor of the thumb possible	Nocturnal numbness of the hand; paresthesia in the distribution of the median nerve; positive Tinel's sign over the carpal tunnel; positive Phalen's test; decreased sensibility in the distribution of median nerve; decreased strength in opposition of the thumb	Pain or paraesthesia or sensory loss in the median nerve distribution and one of: Tinel's test positive, Phalen's test positive, nocturnal exacerbation of symptoms, motor loss with wasting of abductor pollicis brevis, abnormal nerve conduction	Parasthesiae or pain in at least two of digits 1, 2 or 3, which may be present at night as well (allowing pain in the palm, wrist, or radiation proximal to the wrist) and at least one of the following tests positive: 1) flexion compression test, 2) carpal compression test, 3) Tinel's sign, 4) Phalen's sign, 5) 2-point discrimination test, 6) resisted thumb abduction or motor loss with wasting of abductor pollicis brevis
Pronator syndrome	Pain in proximal volar forearm or paresthesia or numbness on volar side of the forearm; paresthesia in 3½ fingers on radial side of the hand possible; symptoms increased by resistance to pronation of the forearm and flexion of wrist, forearm supination and elbow flexion or flexion of the middle finger at the proximal interphalangeal joint; diminished sensation in 3½ fingers on the radial side of the hand, the thenar eminence and weakness of the short abductor of the thumb possible	Pain of the medial/proximal part of the forearm; local tenderness over the edge of <i>m. pronator teres</i> ; pain and decreased strength in pronation; decreased flexion strength in pronation; decreased flexion strength of the wrist and/or of the distal phalanges of the fingers 1 and 2.		
Ulnar nerve entrapment	Pain, paresthesia or numbness in 4th and 5th fingers, tenderness to palpation at the cubital tunnel, Tinel's sign at the cubital	Pain and paresthesia or numbness in the distribution of the ulnar nerve; decreased		At least intermittent parasthesiae in the 4 th and/or 5 th digit or the ulnar border of the forearm, wrist, or hand and a

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	tunnel possibly present; diminished sensation in 4th and 5th fingers and weakness of interossei and the 3rd and 4th lumbricales possible	sensibility of the 4 th and 5 th fingers and of the ulnar part of the back of the hand; positive Tinel's sign over the cubital tunnel; decreased strength in spreading the fingers and in flexion of the distal phalanx of finger 5		positive combined pressure and flexion test
Ulnar nerve entrapment at Guyon's tunnel	Pain, paresthesia, numbness and/or weakness of the 5th finger, tenderness to palpation at the Guyon's tunnel possible; diminished sensation in 4th and 5th fingers or weak abduction of 5th finger	Pain and paresthesia or numbness in the distribution of the ulnar nerve; decreased sensibility of the fingers IV-V; positive Tinel's sign over Guyon's tunnel (volar/ulnar at the wrist); decreased strength in spreading the fingers		Intermittent parasthesiae in the palmar ulnar nerve distribution of the hand, distal to wrist or pain in the ulnar innervated area of the hand, which may radiate to the forearm and at least one of the following tests positive: 1) weakness or atrophy in the ulnar-innervated intrinsic hand muscles, 2) Tinel sign, 3) reversed Phalen test, 4) pressure test over the Guyon's canal
Painful first carpometacarpal joint/Osteoarthritis of finger joints	Painful joint at palpation, pain in the joint when moved Heberden's nodes noticed		Pain in joint + pain in joint movement	
Posterious interosseus nerve entrapment (Frohse's syndrome)	Elbow pain at rest, radiating pain downward or upward and tenderness at the edge of the superficial portion of the supinator muscle (the arcade of Frohse); extension force of the middle finger possibly diminished	Elbow pain at rest; tenderness about 2-3 inches distally of the lateral epicondyle; pain of the proximal, lateral part of the forearm and pain and decreased strength in supination; decreased strength in ulnar deviation		
Radial tunnel syndrome				Pain in the lateral elbow region or forearm muscle mass of wrist extensors/supinator or weakness on extending the wrist and fingers and tenderness in supinator region on palpation over the radial nerve 4-7 cm distal to the lateral epicondyle and at least 1 of the following tests positive: 1) resisted forearm supination, 2) resisted middle finger extension

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Non-specific diffuse forearm pain			Pain in forearm in the absence of a specific diagnosis or pathology (sometimes includes: loss of function, weakness, cramp, muscle tenderness, allodynia, slowing of fine movements)	Diagnosis of exclusion

* for >4 days of last 7 days

† +/- = poorly met/not tested; ++ = partially met; +++ = fully met

Table 5
Between-observer agreement on diagnosis using the Southampton Examination Schedule for upper limb disorders

Disorder	Hospital outpatient study [60]		Community Study [82]
	Nurse vs clinic		Nurse vs rheumatologist
	Sensitivity (%)	Specificity (%)	Kappa
Adhesive capsulitis	87	90	0.66
Bicipital tendinitis	100	98	0.49
Rotator cuff tendinitis	58	84	0.46
Lateral epicondylitis	73	97	0.75
Carpal tunnel syndrome	67	100	0.93
De Quervain's disease	71	100	0.66
Tenosynovitis	100	97	0.21