

# A systematic review of diagnostic performance of quantitative tests to assess musculoskeletal disorders in hand-arm vibration syndrome

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**Abstract:** The purpose was to systematically review the published reports for the clinical utility of quantitative objective tests commonly used for diagnosing musculoskeletal disorders in hand-arm vibration syndrome (HAVS). Two reviewers independently conducted a computerized literature search in PubMed and Scopus using predefined criteria, and relevant papers were identified. The articles were screened in several stages and considered for final inclusion. Quality of the selected papers was evaluated by a modified QUADAS tool. Relevant data were extracted as necessary. For this review, only 4 relevant studies could be identified for detailed examination. Grip strength, pinch strength, and Purdue pegboard tests were commonly used with their reported sensitivity and specificity ranging between 1.7 to 65.7% and 65.2 to 100%, 1.7 to 40% and 94 to 100%, and 44.8 to 85% and 78 to 95%, respectively. A considerable difference across the studies was observed with respect to patient and control populations, diagnostic performance and cut-off values of different tests. Overall, currently available English-language limited literature do not provide enough evidence in favour of the application of grip strength and pinch strength tests for diagnosing musculoskeletal injuries in HAVS; Purdue pegboard test seems to have some diagnostic value in evaluating impaired dexterity in HAVS.

**Key words:** Diagnostics, HAVS, Musculoskeletal disorder, Impaired dexterity, Systematic review

## Introduction

Prolonged exposure to Hand-arm vibration (HAV) may cause a complex and potentially disabling chronic disorder

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of the upper extremities, the hand-arm vibration syndrome (HAVS). Besides vascular and neurological injuries, such exposure to HAV may cause damage to bones, joints, muscles, tendons of the upper extremity<sup>1)</sup>. It can also damage the motor nerves innervating the hand muscles<sup>2)</sup>. Therefore, HAV has been recognized as a significant health hazard for the workers engaged in many occupations worldwide, especially in temperate climates.

The musculoskeletal component of HAVS is not as well defined as its vascular and neurological components. Symptoms for musculoskeletal disorders in HAVS usually manifest as ache, pain, stiffness and loss of strength in the fingers, hand, wrist or arm; upper limb tendinitis and osteoarthritis are common among vibration-exposed workers<sup>3-5)</sup>. In the later stages, impairments of hand functions like reduced strength and manipulative dexterity may be potentially disabling, and may interfere with work, social and domestic activities<sup>6)</sup>.

At present, there is no accepted gold standard test for the diagnosis of musculoskeletal component of HAVS. The diagnosis is mainly based on work history including current or past use of vibrating tools, and description of relevant symptoms. But, for a reliable diagnosis of this disorder, quantitative objective assessment is necessary. A number of quantitative tests are being employed to diagnose and evaluate musculoskeletal disorders and impaired dexterity in HAVS. But, in recent years, the ability of various tests to diagnose HAVS has been called into question<sup>7)</sup>. As far as our knowledge goes, no study has systematically reviewed the efficacy of different quantitative tests to diagnose HAV-induced musculoskeletal disorders and reduced dexterity. Therefore, the purpose of this study was to systematically review the published reports to determine the quantitative objective tests commonly used in the diagnosis of musculoskeletal disorders and impaired dexterity

in HAVS, and to assess the clinical utility by quantifying the diagnostic accuracy of those tests.

## Subjects and Methods

### *Data sources and search strategy*

Two of the reviewers (MHM, YK) performed a computerized search independently using 2 online databases (PubMed and Scopus). The latest search was carried out in December 2013 in an attempt to identify all published relevant papers. No restrictions were applied due to the possibility of limited number of studies published on this topic. The key search terms were developed based on the acronym PICO: P, Patient/Population/Problem; I, Intervention; C, Comparison; O, Outcome<sup>8, 9)</sup>. The PICO framework was originally developed for therapy questions<sup>9)</sup>; we adopted the concept of PICO with modifications where P, I, C, and O denoted ‘Patient or problem’, ‘Intervention (diagnostic test)’, ‘Comparison (between groups with and without the disorders/injuries)’, and ‘Outcome (performance evaluation as a diagnostic test)’, respectively. The detailed search strategy is shown in Table 1. Search terms were used in combinations using Boolean operators. PubMed was searched using ‘Title/Abstract’ and Scopus was searched using ‘Article Title, Abstract, Key words’.

### *Selection of studies*

The titles and/or abstracts of all retrieved articles were screened by the previous two reviewers independently for appropriateness. An important consideration during the review of the abstracts was the inclusion of diagnostic studies assessing HAVS patients and control subjects. The reference list of the retrieved potential studies and related review articles were also cross-searched manually to identify additional relevant studies. After completion of this,

**Table 1. Key search terms**

PICO	Key search terms
P	“hand arm vibration syndrome” OR “hand transmitted vibration” OR “hand arm vibration”
I	“grip strength” OR “grasping power” OR “grip force” OR “pinch strength” OR “pinching power” OR “radiograph” OR “X-ray” OR “MRI” OR “pegboard test” OR “finger tapping test” OR “bean transfer test”
C	“musculoskeletal disorders” OR “musculoskeletal injuries” OR “bone disorders” OR “bone injuries” OR “joint disorders” OR “joint injuries” OR “osteoarthritis” OR “dexterity”
O	“sensitivity” OR “specificity” OR “reliability” OR “discrimination” OR “positive test” OR “negative test” OR “diagnos*” OR “objective diagnosis” OR “objective verification” OR “assessment” OR “evaluation”
Combination	P AND (I OR C) AND O

P: Patient or problem; I: Intervention (diagnostic test); C: Comparison (between groups with and without the disorders/injuries); O: Outcome (performance evaluation as a diagnostic test).

the full text of the probable articles were retrieved, and read and assessed for final inclusion.

*Criteria for study selection*

In this systematic review, a study was considered for final inclusion if it met the following eligibility criteria: 1) full-text original article published in a peer reviewed journal; 2) enrolment of HAVS patients and control subjects; 3) use of at least one relevant quantitative objective test; and 4) reporting of sensitivity and specificity values, or sufficient data for the calculation of these numbers. The exclusion criteria adopted in this review were as follows: 1) duplicate publication; 2) ongoing/unpublished study; 3) diagnostic accuracy of tests not investigated or reported; 4) review articles, case reports and conference abstracts. Any disagreements among the two reviewers in the process of study identification and selection were resolved by discussion.

*Methodological quality assessment*

The quality of the studies included in this systematic review was evaluated by the two reviewers (HMM, YK) independently using a modified version of the validated quality assessment tool, QUADAS (Quality Assessment of Diagnostic Accuracy Studies)<sup>10, 11</sup>. The 14 items described in the QUADAS tool were discussed in details by all of the study reviewers prior to the commencement

of the review, and the modifications were made based on those items. For interpretation of results of the tests investigated in this study, no knowledge of the reference standard (medical interview) or any other clinical data were required. Therefore, 4 items in the original QUADAS tool (no. 3, 10, 11, and 12) of Whiting *et al.*<sup>10, 11</sup> were considered irrelevant for the current review by the authors, and hence, 10 out of the 14 original items were included in this study (Table 2). One additional item (no. 11) was included by the reviewers. The items were scored as “yes” (Y), “no” (N) or “unclear” (U) according to the instructions of Whiting *et al.*<sup>10, 11</sup>.

*Data extraction*

A data extraction form was created and finalized by the study authors. Relevant data were extracted independently by the same two reviewers using this form. Any disagreements among the reviewers were resolved by consensus.

*Data synthesis and analysis*

Sensitivity (the proportion of patients in whom the test result was positive) and specificity (the proportion of control subjects in whom the test result was negative) were used to assess the clinical usefulness of different tests identified in this review. Further, diagnostic accuracy was determined by calculating positive likelihood ratio (LR<sup>+</sup>) and negative likelihood ratio (LR<sup>-</sup>). For various

**Table 2. Items for quality assessment of included studies and corresponding methodologic quality assessment with the QUADAS tool<sup>10, 11</sup>**

1. Was the spectrum of patients representative of the patients who will receive the test in practice?
2. Were selection criteria clearly described?
3. Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests?
4. Did the whole sample or a random selection of the sample receive verification using a reference standard of diagnosis?
5. Did patients receive the same reference standard regardless of the index test result?
6. Was the reference standard independent of the index test (i.e. the index test did not form part of the reference standard)?
7. Was the execution of the index test described in sufficient detail to permit replication of the test?
8. Was the execution of the reference standard described in sufficient detail to permit its replication?
9. Were uninterpretable/intermediate test results reported?
10. Were withdrawals from the study explained?
11. Was clear description of the cut-off value/s used for establishing the diagnosis reported?

Author/s	Item										
	1	2	3	4	5	6	7	8	9	10	11
Cederlund <i>et al.</i> <sup>12)</sup>	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cederlund <i>et al.</i> <sup>13)</sup>	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Harada N <sup>15)</sup>	U	N	Y	Y	U	Y	N	U	Y	Y	Y
Poole & Mason <sup>14)</sup>	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y

The numbers 1 to 11 indicate the items for quality assessment. Y: Yes; N: No; U: Unclear

tests in each study,  $LR^+$  [=sensitivity/(1-specificity)] and  $LR^-$  [(1-sensitivity)/specificity] were calculated from the reported sensitivity and specificity values. However, we observed considerable differences between the studies regarding study populations, test hand/s, cut-off values etc. Therefore, we did not calculate the pooled estimates for the diagnostic accuracy of different tests and descriptive statistics of the extracted data have been presented in this systematic review.

## Results

### Selection of studies

Electronic search in PubMed resulted in a total of 38 articles and in Scopus, 91 articles. After screening the titles and/or abstracts of those, 18 potentially relevant articles could be identified (Fig. 1). Review of the full text of those studies yielded 3 articles<sup>12–14</sup> that met the selection criteria. The studies were excluded because diagnostic performance of the conducted tests was not addressed by the study authors. Examination of bibliographies and other review articles yielded 1 more article<sup>15</sup>. Finally, only 4 relevant studies in English could be included in this systematic review.

### Methodological quality of reviewed papers

Overall, the quality of the included studies was good except the study of Harada<sup>15</sup>, which did not report the test methodologies and criteria for subject selection (Table 2). The main limitation was found to be the selection of patient population, which varied widely across the studies. In the evaluation of tests by Poole and Mason<sup>14</sup>, HAVS individuals with abnormal Disability of the Arm, Shoulder and Hand (DASH) scores were treated as patients. In contrast, other studies, recruited patients with vascular and/or neurological HAVS.

### Description of included studies

All four included studies were cross-sectional and published between 1987 and 2007. In those studies, 20 to 71 patients with HAVS or VWF and 30 to 157 control subjects with or without exposure to vibration were evaluated; in the study of Poole & Mason<sup>14</sup>, the participants were HAVS patients with abnormal and normal DASH scores. The age of the participants (all male) in the studies ranged between 19 and 65 yr.

### Diagnostic tests included

The diagnostic tests for HAVS-related musculoskeletal disorders and dexterity varied between the studies. Howev-

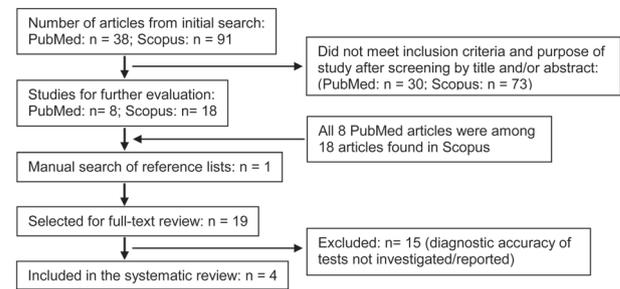


Fig. 1. Flow diagram of eligible studies.

er, the following three quantitative tests have been assessed and reported by multiple studies included in this review: grip strength, pinch strength, and Purdue pegboard tests. Characteristics of the included studies are shown in Table 3.

### Diagnostic performance of tests

Table 3 shows the diagnostic performance of various tests. Diagnostic ability of grip strength test was evaluated in all four studies. The sensitivity and specificity for the grip strength test ranged between 1.7 to 65.7% and 65.2 to 100%, respectively. Three studies<sup>12, 13, 15</sup> reported the diagnostic performance of pinch strength test. For this test, the sensitivity ranged from 1.7 to 40%; in contrast, the specificity was high (94 to 100%). In the three studies reporting the Purdue pegboard test<sup>12–14</sup>, the sensitivity ranged between 44.8 to 85% and the specificity, from 78 to 95% (Table 3). In terms of likelihood ratios for various tests, the studies produced conflicting results. However, in one study, the Purdue pegboard test achieved the values of 17.00 and 0.16 for  $LR^+$  and  $LR^-$ , respectively.

### Cut-off values

There was a wide variation between the studies with regard to cut-off values for the grip strength and pinch strength tests. The studies reporting the diagnostic performance of Purdue pegboard test used a cut-off value of 11–14 pegs (Table 3).

## Discussion

We have systematically reviewed the existing published literature to examine the diagnostic ability of commonly used quantitative objective tests for diagnosing musculoskeletal disorders in HAVS. However, we found a clear dearth of available literature evaluating the sensitivity and specificity or accuracy of those diagnostic tests which was unexpected to us. As observed in this systematic review, the quality of the included studies evaluating the diagnostic

**Table 3. Characteristics of the selected studies and diagnostic performance of different clinical tests to assess musculoskeletal injuries in HAVS**

Author/s	Included subjects <sup>a</sup>		Years of exposure to vibration		Test hand/s	Name of test	Cut-off value	Sensitivity (%)	Specificity (%)	LR <sup>+</sup> <sup>h</sup>	LR <sup>-h</sup>
	Number	Age in years Mean (Range) <sup>b</sup>	Mean (Range) <sup>b</sup>	Mean (Range) <sup>b</sup>							
Cederlund <i>et al.</i> <sup>12)</sup>	Pt (HAVS)	20	47 (28–65)	24 (8–45)	Worst	Grip strength	34.8–55.2 kg <sup>e</sup>	20	95	4.00	0.84
	Con (NEV)	20	46 (25–62)	–	affected	Pinch strength (palmar) Pinch strength (key) Purdue pegboard	9.6–11.9 kg <sup>e</sup> 10.1–12.1 kg <sup>e</sup> 14 pegs <sup>d</sup>	35 40 85	95 95 95	7.00 8.00 17.00	0.68 0.63 0.16
Cederlund <i>et al.</i> <sup>13)</sup>	Pt (HAVS)	30	47 (29–64)	26 (11–40)	Dominant/	Grip strength	c	17, 21	99, 96	17.00, 5.25	0.84, 0.82
	Con (EV)	81	40 (19–62)	15 (1–45)	affected	Pinch strength (palmar) Purdue pegboard	c	22, 24 57, 69	97, 94 80, 78	7.33, 4.00 2.85, 3.14	0.80, 0.81 0.54, 0.40
Harada N <sup>15)</sup>	Pt (VWF+)	34	43.2 (29–61)	13.6 (2–26)	Right	Grip strength	30 kg	3.4	97.5	1.36	0.99
	Con (NEV)	40	41.7 (31–56)	–	Left	Grip strength Pinch strength	30 kg 3 kg	1.7 1.7	100.0 95.0	g 0.34	0.98 1.03
Poole & Mason <sup>14)</sup>	Pt (ab DASH) <sup>e</sup>	71	49.7	25.7	Worst	Grip strength	44.3 kg	65.7 <sup>f</sup>	65.2 <sup>f</sup>	1.89	0.53
	Con (nor DASH) <sup>e</sup>	157	–	–	affected	Purdue pegboard	11 pegs	44.8 <sup>f</sup>	83.2 <sup>f</sup>	2.67	0.66

<sup>a</sup> Pt: Patients; Con: controls; EV: Exposed to vibration; NEV: Not-exposed to vibration. <sup>b</sup>Median (Range) values are shown for the study of Cederlund *et al.* (2003). <sup>c</sup>The authors did not mention the specific cut-off values; they used the age-specific normative data by Mathiowetz *et al.*<sup>21)</sup>. Here, the cut-off values are shown as the ranges for the corresponding age-specific normative data. <sup>d</sup>Control subject's data beyond the fifth percentile. <sup>e</sup>Among 228 individuals with HAVS [age 48.8 (27.3–66.7) yr; years of vibration exposure 23.9 (2–46)], 31% with abnormal and 69% with normal disability of the arm, shoulder and hand (DASH) scores were treated as patients and controls, respectively. <sup>f</sup>Sensitivity and specificity were calculated using ROC curve analysis giving best discrimination between normal and abnormal DASH scores. <sup>g</sup>Not calculated as denominator is 0. <sup>h</sup>LR<sup>+</sup>: positive likelihood ratio; LR<sup>-</sup>: negative likelihood ratio.

performance of different tests was good except one study.

The grip strength and Purdue pegboard tests have been recommended for the assessment of HAV-induced impairments of musculoskeletal functions of the upper extremity as these tests are quick with standardized procedures and readily available equipments<sup>16</sup>). The pinch strength test has also been frequently employed by various researchers in evaluating musculoskeletal impairments in HAVS. As revealed, the diagnostic performance of the tests and their cut-off values varied markedly between the studies.

Sensitivity and specificity are independent of disease prevalence in a study population, but may vary with the severity of the disease. The diagnostic ability of a test to discriminate patients from the healthy subjects is usually evaluated by sensitivity and specificity. Overall, the grip and pinch strength tests lacked sensitivity although these tests were found to be specific. Harada<sup>15</sup>) reported extremely low sensitivity for the grip and pinch strength tests. A possible explanation for the observed low sensitivity for grip and pinch strength tests found in different studies may be the selection of patient population, who were HAVS patients with vascular and/or neurological disorders (not necessarily with any musculoskeletal symptoms). It is well known that in HAVS, vascular, neurological, and musculoskeletal disorders can occur independent of each other. Therefore, considering all HAVS patients to have musculoskeletal disorders is likely to provide an underestimation of the test performance by estimating low sensitivity. On the other hand, Poole and Mason<sup>14</sup>) in their study treated HAVS patients (with normal DASH scores) as the control/comparison group subjects; it seems probable that some of those HAVS patients did have musculoskeletal disorders and/or reduced dexterity. Therefore, an underestimation of the specificity of the performed tests can not be excluded in that study.

The Purdue pegboard test is commonly employed in the assessment of manual dexterity. As observed, this test had a sensitivity ranging between 44.8–85% and a specificity ranging between 78–95%. This implies that the conducted test potentially fails to diagnose around 15–50% cases of such disorders; those people seeking supporting evidence for the disorder might fail to have it by this test. On the other hand, such a test would be falsely positive in about 5–20% of working people which might be a problem for them by affecting their ability to work.

Likelihood ratios are considered to be the best indices of diagnostic validity of a test<sup>17</sup>). Like sensitivity and specificity, likelihood ratios are independent of disease prevalence and thus useful for comparing diagnostic tests

between populations<sup>18</sup>). Tests with great sensitivity and small  $LR^-$  are useful clinically to rule out the presence of a disease; i.e. a negative result would virtually exclude the possibility that the subject has the disease of interest. In contrast, tests with high specificity and high  $LR^+$  are useful clinically to rule in the presence of a disease; i.e. a positive result would virtually include the possibility of the presence of the disease of interest<sup>19, 20</sup>). An  $LR^+$  value of 10 or above and an  $LR^-$  value of 0.1 or less is often perceived as an indication of a test with high diagnostic value<sup>21</sup>). Considering all these, none of the quantitative tests included in the current systematic review appeared to be reasonably accurate in diagnosing musculoskeletal disorders and dexterity in HAVS. However, the Purdue pegboard test performed better in discriminating HAVS patients with impaired manual dexterity from the controls.

There are several potential limitations to this systematic review, and hence, cautious interpretations are required for the current findings. The values of specificity shown in the included studies do imply cut-off values were probably set to make false positives as few as possible. The possibility of changes in the values of sensitivity and specificity (also the corresponding likelihood ratios) cannot be excluded if the cut-off values were set by the researchers to make the false negatives as few as possible. Also, with the available data, we were not able to calculate some other parameters like the Youden Index, for further evaluation of diagnostic values in this systematic review. There were considerable differences across the various studies included in the review with respect to patient and control populations, diagnostic performance and used cut-off values of different tests under study. Furthermore, methodological shortcomings, small number of available studies and small sample sizes in some studies hamper the generalizability of the study findings. Although we selected studies from only two electronic databases (PubMed and Scopus); however, these databases also include the references indexed in a wide range of commonly used databases like Medline, Embase, etc.

Despite the limitations of this study, the significance of the findings should be recognized as the diagnostic ability of grip strength, pinch strength, and Purdue pegboard tests in diagnosing musculoskeletal disorders in HAVS has been quantified in this systematic review. The findings of the present study emphasize the need for continued research works that will include appropriately selected representative populations, clearly describe the cut-off values and diagnostic values of different tests, and follow the relevant guidelines for reporting the studies of diagnostic accuracy of tests. This will help future systematic reviews with

meta-analysis to determine the role of the quantitative tests employed in the diagnosis of musculoskeletal disorders in HAVS.

### Conclusion

This systematic review has quantified the diagnostic accuracy of 3 widely-used clinical tests in diagnosing musculoskeletal disorders in HAVS: grip strength, pinch strength, and Purdue pegboard tests, respectively. However, the findings indicate that the published limited literature do not provide enough evidence in favour of the application of grip strength and pinch strength tests for the mentioned purpose. On the other hand, the Purdue pegboard test may have some diagnostic value in evaluating impaired dexterity in HAVS.

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