J Occup Rehabil (2007) 17:227–245
DOI 10.1007/s10926-007-9083-2

Accuracy of a Disability Instrument to Identify Workers Likely to Develop Upper Extremity Musculoskeletal Disorders

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Received: 9 October 2006 / Accepted: 5 March 2007 / Published online: 9 May 2007

Abstract

Background Work related upper extremity musculoskeletal disorders (MSD) result in substantial disability, and expense. Identifying workers or jobs with high risk can trigger intervention before workers are injured or the condition worsens.

Methods We investigated a disability instrument, the QuickDASH, as a workplace screening tool to identify workers at high risk of developing upper extremity MSDs. Subjects included workers reporting recurring upper extremity MSD symptoms in the past 7 days (n = 559).

Results The QuickDASH was reasonably accurate at baseline with sensitivity of 73% for MSD diagnosis, and 96% for symptom severity. Specificity was 56% for diagnosis, and 53% for symptom severity. At 1-year follow-up sensitivity and specificity for MSD diagnosis was 72% and 54%, respectively, as predicted by the baseline QuickDASH score. For symptom severity, sensitivity and specificity were 86% and 52%. An a priori target sensitivity of 70% and specificity of 50% was met by symptom severity, work pace and quality, and MSD diagnosis.

Conclusion The QuickDASH may be useful for identifying jobs or workers with increased risk for upper extremity MSDs. It may provide an efficient health surveillance

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screening tool useful for targeting early workplace intervention for prevention of upper extremity MSD problems.

Keywords Cumulative trauma disorders · Musculoskeletal diseases · Occupational diseases · Workplace surveillance

Introduction

The loss of workers from the workforce and the economic costs resulting from upper extremity musculoskeletal disorders (MSD) warrant preventive intervention. Early workplace detection can facilitate successful interventions that reduce the incidence and severity of these disorders. A few questionnaires have been developed for the early detection of MSDs in the workplace [1, 2]. However, little research has been published that describes their validity and accuracy. This study evaluates the accuracy of a disability instrument for classifying workers for upper extremity MSDs.

MSD burden

Work related disability associated with upper extremity MSD is a burden for society, employers, and families. For example, Cheadle reported an average disability duration of 160 days for workers who were on disability in Washington State with carpal tunnel syndrome (CTS) [3]. Furthermore, the burden of injury does not end when the person returns to work. Foley and Silverstein reported significantly greater loss in earnings for CTS claimants than those with upper extremity fractures even 6 years after claim filing [4]. Among Maryland workers' compensation claimants with upper extremity MSDs, 53% continued to have persistent symptoms that interfered with work, sleep, and recreation during a 4-year post-injury period [5]. The economic cost for employers is also high. Employers paid 15–20 billion dollars in 1995 in workers' compensation indemnity benefits (wage replacement) for work related musculoskeletal injuries, and 45–60 billion dollars more in indirect costs [6]. These cost estimates are conservative because less than half of work-related MSDs are reported [7, 8]. For example, a survey in Michigan found that 25% of workers diagnosed with work related MSDs filed workers' compensation claims [9].

Detection of MSDs

Researchers and federal agencies have cited the need to improve detection and evaluation of work-related MSDs. The NIOSH research agenda calls for improved definitions of stages of MSD disease process, including discomfort, pain, injury, disability, and recovery [10]. The National Research Council and the Institute of Medicine recommend research for the early detection and prevention of work-related MSDs, and improved outcome measures for epidemiologic and intervention studies [6]. Further, the detection of upper extremity MSD and early intervention has been successful in reducing disability and cost [11–14]. However, there is no gold standard for identifying workers with upper extremity MSDs [15]. Some tools for detection and evaluation of MSDs exist but need to be validated in working populations to assess their accuracy and improve interpretation [15, 16].

Workplace screening

One approach to early detection of MSDs is the use of workplace screening instruments as one component in the larger process of workplace health and hazard surveillance programs. Surveillance is the ongoing systematic collection, analysis, interpretation, and dissemination of health and hazard information in order to identify trends, develop prevention strategies, and evaluate the effectiveness of those strategies [10, 17].

Passive surveillance uses existing administrative data, like injury rates, absentee records, or job title, and requires no additional resources for data collection. Job specific incidence and prevalence rates can be calculated to help identify departments or jobs in which workers are experiencing disability or discomfort and to establish priorities in addressing these problems [18]. Passive surveillance measures, like lost workdays, may be insensitive to upper extremity MSD incidence because many workers continue to work despite experiencing symptoms and pain. For example, among Canadian newspaper workers with some musculoskeletal symptoms, 15% experienced work disability while 58% experienced disability in other roles [19].

Surveillance screening aims to detect injury early, before workers would normally feel compelled to report it [18, 20]. Active surveillance tools, including disability instruments, are not routinely used in administrative data systems and thus require more initial investment. Additionally, many workers are exposed to hazards associated with MSDs so screening tests need to be easy to administer and interpret to be practical in the workplace. Disability questionnaires may provide a method to identify groups of workers or jobs that warrant more in-depth follow-up with physical examinations or nerve conduction studies or job analysis.

Checklists and postural discomfort measures

Checklists for identifying musculoskeletal hazards in the workplace are useful for identifying problems with jobs, tasks, or equipment that may be the cause of musculoskeletal problems. If resources are very limited, risk factor identification should have priority in surveillance programs [18]. These instruments are completed by occupational health and safety practitioners thus they do not rely on the accuracy of worker responses. These checklists can identify situations where risk factors like force, repetitiveness, awkward posture, vibration, or poor task design might be present. If problem areas are identified, follow-up evaluation with more detailed job task analysis is appropriate to identify contributors to the risk factors being present.

Studies assessing the performance of ergonomic interventions often use postural discomfort measures like the Body Part Discomfort Scale to identify potential areas for exposure assessment [21]. Postural discomfort scores have been shown to be associated with biomechanical load, the time a subject could hold a posture, and frequency of postural loading at the joints [22]. The relationship between postural discomfort measures and development of upper extremity MSDs has not been reported. However, MSD symptoms have been found to be associated with discomfort scores [23]. Both health (symptom or functional disability surveys) and musculoskeletal risk factor surveillance (checklists or job analyses) should be conducted before workplace interventions are initiated to provide a baseline for evaluating the intervention performance [18].

Disability screening tool

There is a theoretical basis that suggests disability measures may be appropriate for detecting MSDs. Upper extremity MSDs affect many life domains that influence work performance, family responsibilities, self-esteem, sleep, social and recreational activities, and others [1]. Functional status includes factors not represented in symptom status, like personality, motivation, social and economic supports, effects of the physical environment, and cognitive adaptation [1, 24]. Measures of disability may detect problems earlier, and relate them more clearly to workers experience of MSDs than clinical measures [25]. Functional and health status measures are more reproducible [26] and can better discriminate levels of severity and predict subsequent disability and lost hours of work than physical examination or laboratory measures [25, 27–29]. In CTS patients in Maine, baseline functional status of the hands was a significant predictor of work absence at 6, 18, and 30 months, and should be a primary target for intervention [30].

The instrument evaluated in this study, the 11-item QuickDASH was derived from the 30-item Disabilities of the Arm, Shoulder and Hand (DASH) [31]. The QuickDASH was developed to provide a measure of disability that has low administrative burden, and is quick to score and interpret. The QuickDASH quantifies physical disability and symptoms for the entire upper extremity region. QuickDASH items include difficulty with everyday activities, work, household chores, washing back, recreational and social activities, sleeping, pain severity, and tingling, among others.

The 30-item DASH has been validated on patient populations to assess treatment and in epidemiologic studies and found to be valid, and reliable [32, 33]. Validity of the QuickDASH has been examined in this study population. Briefly, validity of the QuickDASH to assess upper extremity MSD disability in working populations was supported by increasing QuickDASH scores with increasing levels of upper extremity symptom severity, and higher QuickDASH scores for workers with a diagnosis versus workers without a MSD diagnosis (unpublished observations).

We also examined the optional ‘‘high performance’’ Work Module. The four question Work Module includes questions like ‘‘Do you have difficulty using your usual techniques at work?’’ and completing work in the usual time with the usual quality. The Work Module was created to identify difficulties in jobs that require a high degree of physical performance that may not be reflected in items in the QuickDASH that addresses activities of daily living [31]. Responses to the Work Module provides information concerning the worker’s perception of the extent upper extremity MSD problems interfere with work. More information about the QuickDASH and the Work Module is available at www.iwh.on.ca.

We investigated the accuracy of a new disability instrument, the QuickDASH and the optional Work Module for workplace upper extremity MSD screening. In this study, screening accuracy is the ability of a test, the QuickDASH, to classify those with or likely to develop a MSD problem and clinical case status from those who are not.

Methods

Workers with recurring upper extremity symptoms in the prior 7 days at baseline were given the QuickDASH and the optional Work Module. We evaluated the accuracy of the baseline QuickDASH and Work Module scores to identify workers with or likely to develop upper extremity MSD problems at baseline, 4-month, and 1-year. We tested these instruments against several measures suggested as important markers for successful MSD screening programs.

The QuickDASH and Work Module items have responses 1 through 5 and are transformed into a score of 0 through 100, with 0 indicating no disability. The Work Module is scored separately from the QuickDASH. This study was approved by the Washington State Institutional Review Board.

Data

Data are from an ongoing prospective study conducted by the Safety and Health Assessment and Research for Prevention (SHARP) program at the Washington State Department of Labor and Industries. The purpose of the SHARP study was to evaluate the relationship between work-related risk factors and the development of non-traumatic upper extremity MSDs. Participating workplaces include hospitals, a sawmill, manufacturing firms, a plywood mill, and a medical research organization from 12 workplaces in Western Washington. Characteristics of the study population are presented in Table 1. To participate in the SHARP study, a firm needed to have a minimum of 200 full time equivalent workers at the site. Voluntary participation without additional compensation was sought from full-time permanent workers who were in one of six different job types based on the estimated hand force and frequency characteristics of the job. Informed consent was completed by each participant following an explanation of the study. Health assessment and data collection was conducted during normal work hours with no loss in pay. Data collected for this study is confidential and workers with medical problems were advised to seek medical attention from their usual source of health care. Data include an extensive set of health indicators for upper extremity MSD, psychosocial factors, workplace organizational factors, and detailed physical demands exposure assessment. Interviewers administered questionnaires regarding health history, symptoms frequency, duration and severity that were used in establishing a symptoms-based case definition. The QuickDASH was interviewer administered along with other forms to facilitate the timely return of workers to their jobs.

Table 1 Characteristics of the study population

Worker characteristic		Workers completing QuickDASH, *n* = 559		Overall baseline population, *n* = 759	
		N	%	*N*	%
Age	18–29	111	20	170	22
	30–39	147	26	205	27
	40–49	166	30	229	30
	50–64	135	24	155	20
Male		246	44	377	50
Race	White, non-Hispanic Origin	358	64	460	61
	Asian or Pacific Islander	102	18	135	18
	Hispanic	56	10	94	12
	American Indian, Alaskan Native	20	4	27	4
	Black not Hispanic Origin	17	3	30	4
	Other, Unknown	6	1	13	2
BMI kg/m^2	16–23	130	24	180	24
	>23–26	125	23	175	23
	>26–30	136	25	186	25
	>30	149	28	192	25
Current smoker		161	29	211	28
Length of symptoms[a], median, IQR		2.71	0–30.71	2.58	0.82–6.61
Years in job, median, IQR		3.74	0.14–29.81	3.51	1.53–8.05
Concurrent condition		191	34	229	30
Previous upper extremity MSD diagnosis					
Ruptured disk in their neck		7	1	9	1
Carpal tunnel syndrome		51	9	55	7
Thoracic outlet syndrome		3	0.5	4	0.5
Hand or wrist tendonitis		65	12	73	10
Epicondylitis		35	6	41	5
Rotator cuff syndrome		30	5	32	4
Trigger finger		8	1	10	1

[a] Years of upper extremity MSD symptoms at baseline for the longest duration problem across neck, shoulder, elbow/forearm, and wrist/hand

Physical examinations were conducted by health care professionals blinded to work and health history status. Baseline and follow-up data for this study were collected between January 2002 and July 2003.

Outcome measures

Outcome measures of lost work days, job change, light or restricted work, obtaining medical care, and pace and quality of work data were gathered at baseline and 1-year follow-up. Upper extremity MSD diagnosis and symptom severity, data were collected at baseline, 4-month, and 1-year follow-up, Table 2. Diagnosis was determined for specific upper extremity MSD based on physical examination, health history, nerve conduction studies, self-reported symptoms, and other information following criteria previously described [34, 35].

Based on the screening question ''In the past year, have you had pain or discomfort in your neck, shoulder, elbow or hand/wrist at least three times or lasting more than one week?'' those indicating yes had a number of follow-up questions for the affected body areas. Symptom severity at baseline and at 1-year follow-up was measured with questions such as ''In the past week, how would you rate the symptoms in your neck at its worst?'' The symptom questions have a 5-point scale (1 = none, mild, moderate, severe, 5 = very severe). A similar question was asked about each body part, shoulder, neck, elbow, and wrist or hand. At 4-month follow-up, workers reported how their symptoms were in the last week for each of the four body parts.

Statistics

We evaluated the accuracy of the QuickDASH and the optional Work Module with sensitivity, specificity, and receiver operator characteristic (ROC) curves with

Table 2 Outcome measures for assessing the screening accuracy of the QuickDASH

Variables	Description	Collection period		
		Baseline	4-month	1-year
Diagnosis	Specific upper extremity musculoskeletal disorders based on physical examination, health history, nerve conduction studies, grip and pinch force, and self-reported symptoms	X	X	X
Symptom severity	Maximum across four body parts; neck, shoulder, elbow or forearm, wrist or hand. Individual item response are, none (0), mild (1), moderate (2), severe (3), and very severe (4). We also used a dichotomous variable 0 through 2 = 0, 3 and 4 = 1.	X	X	X
Lost work days	In the past 12 months, how many days have you missed work because of your neck[a] problem?	X		X
Change in job	Did you change from another job to your current job to avoid more neck problems?	X		X
Light or restricted work	In the past 12 months, how many days have you done light or restricted work because of your neck problem?	X		X
Pace and quality	Have you had difficulty maintaining your normal work pace or quality of work because of your neck problem?	X		X
Obtaining medical care	In the past 12 months, how many times have you seen a health care provider (doctor, nurse, physical therapist) for this neck problem?	X		X

[a] The same question is asked for neck, shoulder, elbow or forearm, and hand or wrist

respect to the outcome measures described above. All measures were assessed at baseline, 4-month, and 1-year where data were available (Table 4).

A cut point or 'threshold score', that indicates the 'test' is normal, or abnormal, is needed to perform sensitivity and specificity analysis. We used sensitivity ($P(T+|Dx+)$) 70% and specificity ($P(\text{T}-|Dx-)$) of 50% as the target accuracy criteria. See the discussion section for details of cut point score selection.

The predictive value of a positive test (PPV = $P(Dx+|T+)$) is the probability that a worker with a positive test actually has the disorder. The predictive value of a negative test (NPV = $P(Dx-|T-)$) is the probability that a worker testing negative actually does not have the disorder. These predictive values are based on the sensitivity, specificity, and the prevalence of the disorder in the population studied.

We used ROC curves to plot the sensitivity by 1-specificity of the QuickDASH for assessing its performance. The ROC curves provide a graphical representation of the test performance across all possible QuickDASH scores. The greater the area under the curve the better the global performance of the test (Fig. 1) [36].

We assessed the cross-sectional precision of the baseline QuickDASH score. The cross-sectional precision is a range of QuickDASH scores within which the true score falls. The cross-sectional precision is based upon the standard error of measurement (SEM). The SEM is the variation around the observed score and is computed as $\text{SEM} = \text{SD} \times \sqrt{1-R}$, where R is the reliability coefficient Cronbach's alpha [31, 37, 38]. Cronbach's alpha is the internal consistency in terms of the degree of inter-correlation among items in the QuickDASH [39]. The SEM is multiplied by ±1.96 to obtain the 95% confidence interval when added to or subtracted from the worker QuickDASH score. A QuickDASH score larger than the cross-sectional precision value was selected for the threshold score so that we can be confident that the workers true score differs from 0.

Results

Participant description

A total of 759 workers provided baseline information for the SHARP study. Of these workers, 584 (77%) had some upper extremity problem in the previous week and 559 (74%) completed the QuickDASH. Among the workers who provided information for the QuickDASH, 388 completed a 4-month follow-up survey, and 294 completed a 1-year follow-up survey. The 559 workers who completed the QuickDASH were, on average, 40 (SD 11) years old, 246 (44%) were male, and 358 (64%) were White. Upper extremity symptoms with a median of 2.7 (IQR 0–31) years were reported by 537 workers at baseline. A concurrent health condition that could contribute to MSD risk was confirmed by a medical doctor for 191 (34%) workers at baseline. More details about the study population are provided elsewhere [40]. At baseline, 37% of the workers had an upper extremity MSD diagnosis, and in the previous year 36% had received medical treatment, and 8% changed jobs due to upper extremity MSD (Table 3).

Table 3 Prevalence of outcome measures by follow-up period

	Baseline		4-month		1-year	
	n	%	*n*	%	*n*	%
Diagnosis	207	37.0	104	26.8	90	30.6
Symptoms	85	15.2	109	28.1	49	16.7
Lost work days	71	12.7	–	–	29	9.9
Med. treatment	204	36.5	–	–	90	30.6
Change job	46	8.2			18	6.1
Light work	77	13.8	–	–	30	10.2
Total	559	–	388	–	294	–

Symptoms, are positive for severe or very severe upper extremity problems in the last 7 days, Med. treatment, has the worker obtained medical treatment in the last year for upper extremity MSD problem

QuickDASH

The mean QuickDASH score at baseline was 16.7 (SD 0.7, median 11.4, IQR 4.5–25.0). The QuickDASH score was skewed, 11% of workers had a score of 0, no disability, and an additional 11% had a score of 2.3. QuickDASH accuracy for classifying workers by symptom severity meet the target criteria (70% sensitivity and 50% specificity) at baseline, 4-month, and 1-year. Accuracy criteria for pace and quality of work, and diagnosis were meet at baseline and 1-year follow-up. At baseline, accuracy for upper extremity MSD diagnosis was 73% sensitivity and 56% specificity, symptom severity was 96% sensitivity, and 53% specificity (Table 4). Baseline accuracy for classifying workers by lost work days, light or restricted work, and job change exceeded 70% sensitivity, but had specificities below the target at 48%. Baseline QuickDASH accuracy for obtaining medical treatment was 67%, with specificity of 52%. At 4-month follow-up the QuickDASH classified workers for symptom severity, sensitivity 77% and specificity 54%, and for diagnosis, sensitivity 65% and specificity 49%. One-year follow-up accuracy for upper extremity MSD diagnosis, and symptom severity was sensitivity 72% and 86%, specificity was 54% and 52%, respectively. Although the QuickDASH did not meet the accuracy criteria for some outcomes at some time periods, accuracy was not far from the criteria. The lowest sensitivity observed was 65% for diagnosis at 4-month follow-up, and the lowest specificity was 47% for lost work and change of job at 1-year follow-up.

The QuickDASH ROC area of 0.87, for classifying workers by symptom severity at baseline, indicates that 87% of the time a randomly selected individual from the severe symptom group has a higher QuickDASH score than a randomly selected individual from the low severity symptom group. The ROC areas for the baseline performance of the QuickDASH for diagnosis and job change was 0.70, and lost work days 0.64 (Fig. 1). At 4-month follow-up, ROC areas for symptom severity was 0.74, and diagnosis 0.63. At 1-year follow-up the ROC area was 0.75 for symptom severity, and pace and quality was 0.71. Other ROC areas at 1-year were between 0.63 and 0.67 (Table 4). These results will be useful for comparing the

Table 4 Measures of QuickDASH performance for each time period

	Sensitivity	Specificity	PPV	NPV	ROC area
Baseline					
Symptoms	96.5	52.7	26.8	98.8	87
Lost work days	73.2	47.9	17.0	92.5	67
Med. treatment	66.7	52.1	44.4	73.1	64
Change job	84.8	47.9	12.7	97.2	70
Light duty	72.7	48.1	18.3	91.7	64
Pace or quality	81.5	58.4	49.0	86.6	76
Diagnosis	73.4	56.2	49.7	78.3	70
4-Month follow-up					
Symptoms	77.1	54.1	39.6	85.8	74
Diagnosis	65.4	49.3	32.1	79.5	63
1-Year follow-up					
Symptoms	85.7	52.2	26.4	94.8	75
Lost work	69.0	47.5	12.6	93.3	63
Med. treatment	65.6	51.0	37.1	77.0	64
Change job	77.8	47.5	8.8	97.0	64
Light duty	73.3	48.1	13.8	94.1	65
Pace quality	75.3	54.0	38.4	85.2	71
Diagnosis	72.2	54.4	41.1	81.6	67

performance of the QuickDASH to other instruments when that information becomes available.

For all outcome measures positive predictive values were greater at baseline than at 4-month or 1-year follow-up. This may show the episodic nature of upper extremity MSD particularly in a working population that was still able to work. At baseline, positive predictive value for upper extremity MSD diagnosis was 50% indicating that half of workers predicted to have diagnosis based on the QuickDASH actually had a MSD diagnosis. The negative predictive value was 78% indicating that 78% of those predicted by the QuickDASH not to have a diagnosis actually did not. Baseline positive and negative predictive value for severe or very severe symptoms was 27% and 99%, respectively. Positive and negative predictive value at 1-year follow-up for MSD diagnosis was 41% and 82%, respectively. For severe or very severe symptoms, positive and negative predictive value was 26% and 95%, respectively (Table 4).

The cross-sectional precision, as measured by the standard error of the measurement, was 5.7, with a 95% confidence interval of ±11.3. The closer the SEM is to zero the closer the observed score is to the true score. For example, if a worker's score was 20, 95% of the time the true score lies between 8.7 and 31.3. A QuickDASH score of 11.4 was used as the cut point score for sensitivity and specificity analysis. We can be confident that a workers score of 11.4 is truly above 0. Cronbach's alpha was 0.87 indicating good internal consistency among the 11 items in the instrument.

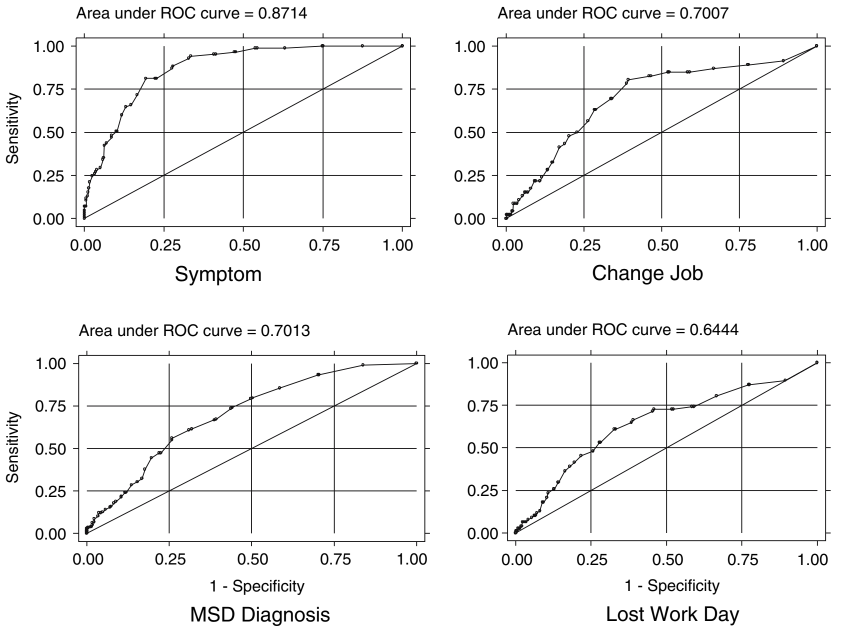

Fig. 1 Receiver operating characteristic curves of QuickDASH performance in classifying workers for the best four outcome measures at baseline

Work Module

The Work Module was completed by 553 workers at baseline. The mean baseline Work Module score was 11.6 (SD 17.0, median 0, IQR 0–19). Scores ranged from 0 to 100, with 258 (51%) workers having a score of 0. Internal consistency was good with a Cronbach's alpha of 0.89. The Work Module had a standard deviation of 17.0, and alpha of 0.89, resulting in a standard error of the measurement of 11.1. The same cut point score of 11.4 was used for the Work Module and the QuickDASH. Sensitivity for baseline upper extremity MSD diagnosis was higher for the QuickDASH, 73%, than for the Work Module, 50%, while specificity was 56% for the QuickDASH and 70% for the Work Module. Similarly, sensitivity and specificity for MSD diagnosis was 72% and 54%, respectively, for QuickDASH, and 39% and 69% for the Work Module (Table 5). There was high correlation between the Work Module score and the QuickDASH scores of 0.69 ($P < .001$). On average, across all outcomes and follow-up periods, the ROC curve area was 7.4 points larger for the QuickDASH than the Work Module.

Discussion

We have examined the accuracy of the QuickDASH as a screening tool to identify upper extremity MSDs in an actively working population not necessarily seeking

Table 5 Measures of Work Module performance for each time period

	Sensitivity	Specificity	PPV	NPV	ROC area
Baseline					
Symptoms	73.2	68.8	29.0	93.6	76
Lost work days	59.4	65.7	19.8	91.9	65
Med. treatment	47.3	68.3	46.4	69.1	58
Change job	48.9	63.6	10.6	93.3	58
Light duty	55.8	65.5	20.8	90.2	61
Pace or quality	67.0	77.1	58.9	82.7	75
Diagnosis	49.8	69.9	49.3	70.2	61
4-Month follow-up					
Symptoms	50.0	68.9	38.6	78.0	60
Diagnosis	40.8	65.2	30.0	75.1	55
1-Year follow-up					
Symptoms	53.1	70.5	26.3	88.2	60
Lost work	51.7	68.6	15.3	92.8	62
Med. treatment	46.7	72.4	42.9	75.4	61
Change job	38.9	66.9	7.14	94.4	51
Light duty	50.0	68.4	15.3	92.3	61
Pace quality	56.8	75.5	46.9	82.8	67
Diagnosis	38.9	69.5	36.1	71.9	54

treatment. The study's findings suggest the QuickDASH may be useful as a screening tool to identify workers with symptoms who may have or be likely to develop disability due to upper extremity MSDs. The QuickDASH was not sensitive in detecting differences among the 22% of workers that scored near the least disabled with scores of 2.3 and below. This indicates a floor effect for the QuickDASH in this population of symptomatic workers. The floor effect suggests that QuickDASH has a weak ability to distinguish between disability levels at the low end of the scale, low disability.

A direct comparison of the QuickDASH scores to other instruments is not possible because other measures do not have composite scores or were not collected in this study. However, components of the NMQ can be compared with QuickDASH scores for specific outcomes. The QuickDASH classified workers at baseline for severity of symptoms with sensitivity of 96% and specificity of 53%. In comparison, components of the NMQ, pain frequency, duration, and intensity were used to classify 287 workers reporting hand discomfort in the past 7 days [41]. Pain levels above the median for frequency, duration or intensity were considered a positive test. These test results were compared with abnormal findings from physical examination of the hands, with resulting sensitivity of 71% and specificity of 72%. Given these definitions for classification, the QuickDASH does a better job at identifying most cases compared to the NMQ but would result in a greater number of follow-ups for workers with less severe symptoms.

The NMQ was also used to classify workers by clinical diagnosis among 165 female workers, accuracy was measured for each upper extremity body part [16]. Sensitivity and specificity were 92% and 39%, respectively, for the shoulder, 79% and 20% for the elbow, 67% and 27% for the hand, and 66% and 33% for the neck. Across the neck, shoulders, elbows, and hands positive diagnosis was determined for 75 women. Additionally, at least one positive item concerning aches, pains, or discomfort of the upper extremity in the past 7 days was found for 94 women. Using any musculoskeletal complaint (pain, ache, discomfort) of the neck or upper limb in the past 7 days as a positive test to predict diagnosis of an upper extremity MSD, sensitivity was 83% and specificity was 64%. Comparatively, for classifying workers by diagnosis at baseline the QuickDASH had a sensitivity of 73% and specificity of 56%.

Two other measures appear to have good performance in patient populations. The Neck and Upper Limb Index (NULI) has been demonstrated to have good internal consistency (Cronbach's alpha 0.90) and test–retest reliability (intraclass correlation coefficient 0.88) among 99 workers with neck or upper extremity disorders from Ontario [42]. The Upper Extremity Function Scale score (UEFS) was associated with symptom severity (Pearson r 0.36, $P < 0.001$) among Massachusetts patients with CTS at baseline [28]. The UEFS had good internal consistency with alphas ranging from 0.83 to 0.93 across different groups of patients with CTS and other upper extremity MSDs. Comparatively, the baseline QuickDASH score in the present study had a stronger correlation with symptom severity (Pearson r 0.71, $P < 0.001$).

Caution should be exercised in using this instrument for individual level evaluation. In this study, the QuickDASH does not meet recommendations of precision for assessing individual level disability. Cronbach's alpha for the QuickDASH is 0.87, which is below the 0.90 minimum recommendation for individual-level application [43]. The accuracy of the QuickDASH does not provide confidence intervals narrow enough to provide a true measure of functional status for individual level decisions.

Predictive values

The predictive values established by this study may be underestimated. The positive predictive value of a QuickDASH score for symptom severity at baseline was 27% in the present study. Predictive values are influenced by the prevalence of disability in the study population. Biased results may have resulted because some workers may not have been available to participate in the study because they left work due to MSD related disability (survivor bias). The contribution of bias cannot be determined because the number of those not working due to MSD related disability is unknown. However, if the baseline prevalence of severe or very severe symptoms was 20% in this population, instead of 15%, the PPV would be 34% instead of 27%, holding sensitivity and specificity constant.

Work Module

The Work Module meets accuracy criteria for identifying workers with MSD problems only for baseline symptoms. This finding does not support the use of the

Work Module for classifying workers for MSD status in a working population. Sensitivity was higher, specificity was lower, and ROC curve areas were larger for the QuickDASH than for the Work Module for all outcomes and all follow-up periods (Table 5). Several factors may contribute to the Work Module not meeting expected accuracy criteria. Workers report disability in activities outside of work more readily than disability with work. For example, in the present study 51% of workers reported interference with activities outside of work because of MSD symptoms, although, only 33% reported that MSD symptoms interfered with the pace or quality of their work. Several factors encourage workers to remain on the job and not report injuries, including their perception that the injury is not serious, unwillingness to miss work [9], fear of reprisal, desire not to lose their usual job, performance evaluations may be partially based on recordable injury goals, or the belief that pain is a normal part of the job [8, 44]. This and other studies [45] have found that many workers with MSD symptoms continued to work. In this study 15% of workers had severe or very severe MSD symptoms in the last week, and 37% had moderate symptoms.

ROC and threshold score

The ROC curve area provides the probability of correctly classifying individuals across all possible pairs of sensitivity and specificity values across all QuickDASH scores [36]. ROC analysis can be used to help determine the most useful threshold score. A threshold score or, cut point, is the QuickDASH score above which we classify a worker as abnormal, test positive, and below as normal, test negative. Generally, the point at which the ROC curve is the closest to the top left corner of the graph is the test score that correctly classifies workers with the least error (Fig. 1) [37]. For epidemiological studies a threshold score which maximizes the precision of the estimate may be desired [46]. The sensitivity and specificity criteria used to evaluate the usefulness of a test is determined by the context in which it is used [47].

The internal reliability and the cross-sectional precision of the QuickDASH are good, with Cronbach's alpha of 0.87, SEM of 5.7 with a 95% CI of ±11.3. This performance is slightly below that of the 30-item DASH, alpha 0.96, SEM of 4.4, and CI of ±8.8 points [31].

Regional instruments

A strength of the QuickDASH is that it is a regional instrument. Instruments that cover multiple disorders and body parts are efficient tools for surveillance programs. Regional instruments assess several disorders in a population, as well as the combined effect of several disorders in one individual. Many items in musculoskeletal disorder and joint specific instruments of the upper extremity are applicable to the entire region. Thus they provide a means to collapse multiple assessments into a single instrument [48]. Furthermore, within a group of workers, with similar musculoskeletal hazards, several different MSDs occur in different individuals, perhaps making evaluation of a group of disorders preferable to a single disorder for surveillance triggering job assessments but not for treatment purposes [49]. Regional instruments can expand the range of information integrated for the assessment of disability by drawing from several disorders and body parts in combination.

Measures of specific disorders may be more sensitive for early detection, severity assessment, and responsiveness. For example, a measure of disease specific quality of life (Western Ontario Shoulder Instability Index) used in patients with shoulder instability was found to be more responsive to change than the DASH [50]. However, among patients with upper limb disorders, the DASH performed similarly to joint specific measures of the upper extremity [32]. Specific joint or disorder measures may also point to different causal factors than higher-level disability instruments [15, 48]. This may not be relevant in general surveillance programs, but should be considered for intervention evaluation.

Early identification of MSDs

Once identified through screening programs the severity and incidence of many work-related MSDs can be reduced through appropriate intervention [51–53]. For example, 126 independent Ohio companies implemented engineering controls designed to decrease worker exposure. This resulted in a reduction of lost work days of 42% [54]. Prevention is an effective management tool for medical, social, and economic loss [13, 55]. However, implementation of more global prevention intervention has been delayed partly due to governmental priorities [56], and business requirements for stronger evidence of causal relationships between exposure, disability, and the effectiveness of safety regulation and intervention programs [7]. Validation and demonstration of accurate instruments for early MSD detection may facilitate epidemiological studies, and workplace safety program evaluation, and strengthen prevention by improving the focus for ergonomic workplace design, referral for medical management, job modification or job reassignment.

The QuickDASH minimizes the administrative burden, which makes the instrument practical for screening, epidemiologic studies, program evaluation, and worker education. In this study the accuracy of the QuickDASH was adequate to detect upper extremity MSDs and classify symptomatic workers for follow-up.

QuickDASH scores were not collected from workers without some current recurring musculoskeletal complaint. Thus, the evaluation of floor effects cannot be fully assessed. Likewise, the accuracy of the screening test to identify those without MSD symptoms cannot be tested by this study. However, our estimates are likely to be conservative. By adding workers with no MSD complaints (no disease) and low QuickDASH scores (negative test), specificity would be increased without a reduction in sensitivity. Sensitivity would not be affected because workers without MSD problems in the previous week are unlikely to have positive values on outcome measures.

The ethical use of disability information is critical for successful surveillance programs. Employees' trust in the way management will use data and with whom the data will be shared is essential to ensure accurate data collection. Forms should not include the workers name, and participation should be voluntary in nature [57]. Surveillance may be effectively implemented through the sampling of jobs or departments without requiring information from every worker. Individual injury rarely occurs in isolation. Evaluation at the job or department level can facilitate the identification of organizational or ergonomic factors that often are the underlying causes of injury. Guidelines to support the ethical use of data include the use of qualified health professionals that are independent and impartial, assurance of confidentiality of individual health information, results relate to the program purposes, consequences for workers' health and livelihood need to be considered, and program purposes clearly communicated to all [58].

Conclusion

The QuickDASH may provide an efficient method for identifying workers likely to develop upper extremity MSDs, for use in targeting early workplace intervention for prevention of upper extremity MSD disability. The QuickDASH minimizes the administrative burden, which makes the instrument practical for screening, epidemiologic studies, program evaluation, and worker education. This study indicates the accuracy of the QuickDASH is adequate to detect upper extremity MSDs and classify symptomatic workers for follow-up. However, our findings do not support the use of the supplementary Work Module for classifying workers for MSD status in this working population.

Acknowledgments This research was supported in part by CDC/NIOSH OH-070316, Washington State Department of Labor & Industries, NIOSH health services research training grant T42 CCT010418, and the work of Caroline Smith and Joyce Fan for coding and extraction of data.

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