Functioning of persons with distal upper extremity musculoskeletal disorders

Berduszek, Redmar Juliusz

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Assessment and evaluation of measurement instruments

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Colophon

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Contents

1

General introduction

The hand is very versatile, allowing a person to identify objects, grasp and manipulate items, operate devices, make gestures, and much more.[1] Proper hand function is crucial for performing daily activities, work, hobbies, and sports.[2] Distal upper extremity musculoskeletal disorders (UEMSD) are an important group of disorders directly affecting hand function. These disorders are located in the distal upper extremity (elbow, forearm, wrist, or hand). Distal UEMSD are part of the broader concept of complaints of the arm, neck, and/or shoulder (CANS), which encompasses upper extremity musculoskeletal disorders not caused by acute trauma or systemic disease, and classifies them into specific and non-specific disorders (figure 1).[3] Distal UEMSD occur commonly and often follow a recurring or chronic course.[4–7] Patients with distal UEMSD usually experience one or more impairments, such as pain, reduced joint mobility, or muscle weakness.[8] These impairments often contribute to activity limitations and participation restrictions, collectively resulting in disability.[5,6] Reducing disability and supporting functioning in patients with distal UEMSD is the main focus of hand therapy and rehabilitation.[9]

Complaints of the arm, neck, and/or shoulder (CANS)
Musculoskeletal complaints not caused by acute trauma or by any systemic disease
(e.g., rheumatic or malignant diseases)

↓

Specific CANS
Complaints classified as specific CANS

Bursitis of the elbow*	Lateral epicondylitis*
Carpal tunnel syndrome*	Local arthritis (not RA) in a joint of the upper extremities*
Cervical disc hernia	Medial epicondylitis*
Complex regional pain syndrome*	Oarsman's wrist*
Cubital tunnel syndrome*	Radial tunnel syndrome*
De Quervain's disease*	Raynaud's phenomenon*
Dupuytren disease*	Rotator cuff tears
Frozen shoulder	Subacromial impingement syndrome
Guyon canal syndrome*	Suprascapular nerve compression
Instability of the elbow*	Tendinitis of the biceps tendon
Instability of the shoulder	Trigger finger*
Labral lesion of the glenoid	

↓

Non-specific CANS
Complaints that are NOT one of the disorders classified as specific CANS

Figure 1 Classification of distal upper extremity musculoskeletal disorders within the complaints of the arm, neck, and/or shoulder (CANS) model.[3]

CANS: complaints of the arm, neck, and/or shoulder. *Distal upper extremity musculoskeletal disorders (UEMSD).

Assessment of functioning

Rehabilitation is aimed at achieving and maintaining optimal functioning in patients who experience disability. Within rehabilitation, the International Classification of Functioning, Disability and Health (ICF) is used as a framework to assess individual functioning and to describe the interaction between health conditions, body functions and structures, activities, participation, environmental factors, and personal factors.[10] Relevant components of the ICF for specific settings or disorders are described in ICF Core Sets: for patients with distal UEMSD in rehabilitation these are the Rehabilitation Set and the Hand Conditions Set (figure 2).[10,11]

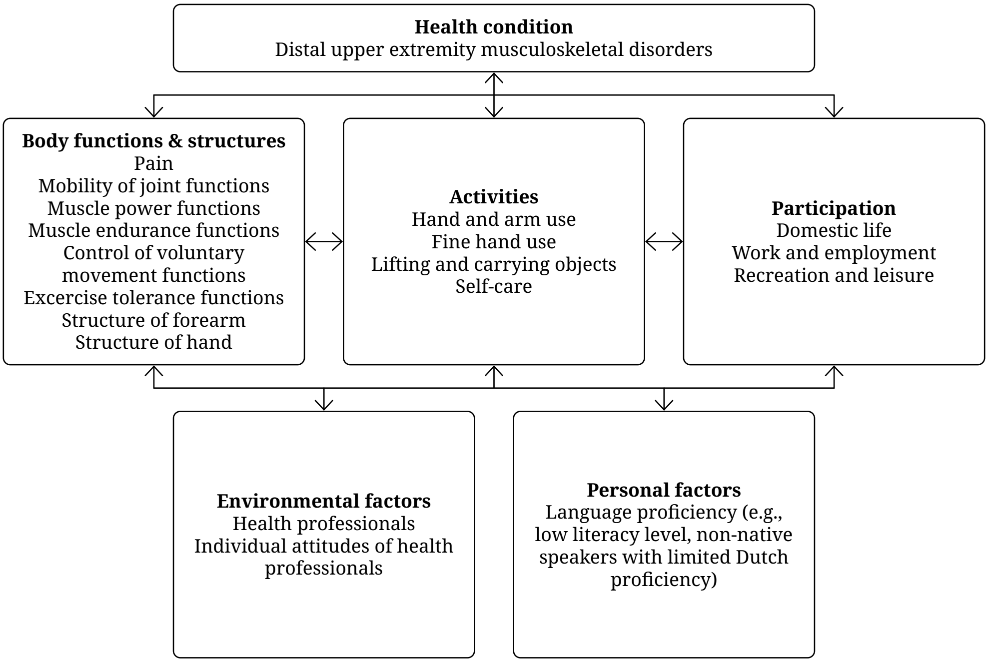

Figure 2 The ICF framework: selection of components from the Rehabilitation and Hand Conditions Core Sets.

Assessment of functioning and disability is essential in rehabilitation, for example, to make a rehabilitation diagnosis, guide treatment, and monitor the effect of interventions.[10,12] Measurement instruments can support this assessment, requiring that their measurement properties are adequate for the target population.[13] Various instruments are available to assess ICF domains in patients with impaired hand function.[11,14,15] However, questions remain about the assessment of functioning and disability of patients with distal UEMSD. These questions concern the diversity of available instruments (clinician-reported, patient-reported, and performance-based measurements), the adequacy of their measurement properties in this population (for example, construct validity, reliability, and responsiveness), and the limited assessment of certain ICF components (such as more physically demanding activities or exercise tolerance functions).

Aim of the thesis and research questions

The general aim of this thesis is to evaluate aspects of the assessment of functioning and disability of patients with distal UEMSD.

Health professionals routinely assess and interpret patients' conditions. This thoughtful process, known as clinical judgment, involves integrating clinical expertise, patient-specific information, and professional experience through critical reasoning. Given its central role in healthcare, understanding the accuracy of clinical judgment is essential. In several patient populations, discrepancies have been observed between clinician-reported and patient-reported levels of pain and disability.[16–19] However, the accuracy of clinician-reported measurements in patients with hand disorders remains unclear. Also, factors potentially influencing assessment accuracy, such as professional experience and education, are unknown in this population.

The first research question was: how do patient-reported and clinician-reported levels of pain and disability compare when measured during a consultation in patients with impaired hand function? Additionally, how do factors such as diagnosis, physician experience, and type of medical specialty influence the accuracy of these assessments?

The most used region-specific patient-reported outcome measures for patients with hand disorders are the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) and the Patient Rated Wrist/Hand Evaluation (PRWHE).[20] Both are brief questionnaires, available in many languages, with a similar content that covers relevant components of the ICF domains body functions and structures, activities, and participation.[21–24] Their measurement properties have been extensively studied; construct validity and reliability are generally strong, but less is known about responsiveness.[23,24] Most studies on measurement properties of the QuickDASH and PRWHE have been conducted in populations with traumatic hand injuries or other hand or wrist conditions requiring surgical treatment. However, their measurement properties have not yet been adequately assessed in patients with distal UEMSD, an important target population for the use of these questionnaires.[24,25]

The second research question was: what are the measurement properties of the Dutch language versions of the QuickDASH and PRWHE when used in patients with distal UEMSD?

The Hand Function Sort (HFS) is a patient-reported outcome measure of which the content focuses solely on activities, encompassing a broader range of body functions and physical effort needed to perform these activities than those represented in other questionnaires.[26] The QuickDASH and PRWHE include 4 to 6 activities respectively, of which the more strenuous are carrying a shopping bag, cutting food with a knife, and vacuuming. The HFS contains more specific activities (62 in total), many of which require more effort to perform, for example, cutting wood with a handsaw, digging a hole with a shovel, or pushing a full wheelbarrow. Therefore, the ability to perform not only usual daily activities but also more physically demanding tasks can be evaluated using this questionnaire. Another advantage of the HFS is the fact that it is an illustrated questionnaire. Each question is paired with an image that visually demonstrates how to complete the task. This is especially beneficial for individuals with limited language proficiency, as the visuals enhance understanding. The HFS was not available in a Dutch language version yet and its measurement properties in the target population of patients with distal UEMSD had not yet been studied.

The third research question was: can the HFS be translated into Dutch and what are the measurement properties of the Dutch language version of the HFS when used in patients with distal UEMSD?

Functional capacity evaluation (FCE) is a performance-based measurement to determine the current capacity to perform activities, while considering that person's body functions and structures, environmental factors, personal factors, and health condition.[27] A region-specific upper extremity FCE (UE-FCE) is relevant for use in patients with distal UEMSD.[11,15] A UE-FCE consists of tests covering activities (such as fine hand use and lifting objects) considering various aspects of body functions and structures (such as mobility of joint functions, muscle power functions, and muscle endurance functions).[28] Several UE-FCE tests consist of multiple repeated trials, where a mean value of these trials is calculated. A shorter UE-FCE (with one or two trials per test) agreed strongly with the original UE-FCE (with three or four trials per test) in healthy subjects, reducing test duration and burden on both patient and observer.[29] However, the application of a shortened UE-FCE (with fewer repetitions per test) and its measurement properties have not yet been assessed in patients.

The fourth research question was: what is the agreement between original and shortened UE-FCE tests and what are the measurement properties of these shortened tests when used in patients with distal UEMSD?

Patients with UEMSD often experience restrictions in performing their work and sports, leading to a less active lifestyle.[30] Physical inactivity and self-reported lower physical fitness were associated with the occurrence and more chronic course of UEMSD.[7,31] On the other hand, health-related physical fitness levels are relevant for the ability to perform and sustain activities.[32] Therefore, it is of interest to learn about objectively assessed health-related physical fitness in patients with distal UEMSD and if these levels are related to functioning and disability.

The fifth research question was: what is the health-related physical fitness of patients with distal UEMSD and how does it relate to symptom severity, upper limb function and physical activity?

Outline of this thesis

The research questions are addressed in five chapters and the findings are further discussed in the final chapter. In chapter 2, differences between patient-reported and physician-estimated pain and disability in hand and wrist disorders are analyzed. Furthermore, the effects of the type of diagnosis, physician experience (consultants versus trainees) and medical specialty (rehabilitation medicine versus plastic and reconstructive surgery) on these differences were assessed. In chapter 3, the measurement properties of the Dutch language versions of both the QuickDASH and the PRWHE in patients with distal UEMSD are assessed. In chapter 4, the translation and cross-cultural adaptation of the HFS into a Dutch language version is described, as well as the assessment of its measurement properties. In chapter 5, a shortened (less repeated trials per test) UE-FCE and its measurement properties are assessed in patients with distal UEMSD. In chapter 6, the health-related physical fitness of patients with distal UEMSD is assessed. The relationships between health-related physical fitness, self-reported functioning, and physical activity are also explored.

Chapter 7 provides a perspective on the findings from the previous chapters. Also, clinical implications and suggestions for further research are discussed.

2

Comparison between patient-reported and physician-estimated pain and disability in hand and wrist disorders

Redmar J. Berduszek
Heleen A. Reinders-Messelink
Pieter U. Dijkstra
Corry K. van der Sluis

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Abstract

Background
Pain and disability are important components of the assessment of hand problems, but it is unknown how physician estimates compare to patient self-reports.

Objective
To analyse differences between patient-reported and physician-estimated pain and disability in patients with hand or wrist disorders and to analyse factors influencing these differences.

Methods
Observational study of patients with hand or wrist disorders seen during multidisciplinary outpatient consultations. Patients, rehabilitation medicine (RM) consultants, RM trainees and plastic surgeons completed visual analogue scales (VASs) to rate the level of self-reported (patients) or estimated (physicians) pain and disability. Multilevel analyses were performed to evaluate differences in VAS-pain and VAS-disability scores between patients and physicians and to evaluate the influences of diagnosis, physician experience and medical specialty.

Results
Complete data were obtained for 250 patients. Levels of pain and disability estimated by physicians were lower compared to patient self-reports. Ratings differed among medical specialties. Pain was underestimated to a greater extent by plastic surgeons compared to RM consultants. Disability was underestimated to a greater extent by RM consultants compared to plastic surgeons. Estimates of pain and disability did not differ between consultants and trainees in RM. Type of diagnosis did not influence the degree of underestimation of pain and disability.

Conclusions
Physicians underestimate pain and disability compared to self-reports in patients with hand or wrist disorders. Ratings differ among medical specialties: plastic surgeons underestimate pain more, while RM consultants underestimate disability more. Physician experience and diagnosis do not influence the degree of underestimation of pain and disability.

Introduction

Pain is the most common symptom in patients with hand and wrist problems who visit their general practitioner.[33] The prevalence of wrist or hand pain in the general Dutch population is almost 18%.[34] Over 32% of people with pain in the elbow, wrist or hand report limitations in daily life and 4% are at least partially incapacitated for work.[34] Almost one-third of all unintentional injuries that were treated at an emergency department in the Netherlands were hand injuries.[35] The majority (52%) of patients with hand injuries are incapacitated for work for more than 10 weeks.[36] Hand and wrist injuries are more expensive than any other injury type when considering healthcare and productivity costs combined.[37] Therefore, both pain and disability are considered important components of the assessment of hand problems.[38] Several instruments are available to assess pain and disability in patients with hand or wrist disorders.[39,40] However, in clinical practice, physicians often do not systematically assess pain and disability using patient self-reports but usually rely on their 'clinical judgement'.[41,42]

Generally, physician estimates of pain and disability differ from patient self-reports in diverse patient groups, ranging from emergency department and burn unit patients to cancer patients and patients with chronic low back pain.[43–47] Physicians generally underestimate pain and disability compared to patients who self-report. Underestimation is thought to be larger in the absence of supportive medical evidence to explain the patient's complaints, for example in the case of non-specific complaints compared to specific complaints.[48] Experience and the physician's professional role and personal characteristics are also thought to influence the judgement of symptom severity.[49,50] As far as we know, it is unknown to what extent patient self-reports on pain and disability differs from physician estimates in patients with hand or wrist disorders.

The primary aim of this study was to analyse differences between patient self-reports and physician estimates of pain and disability in patients with hand or wrist disorders. Based on findings in patients with other disorders, we hypothesized that the levels of pain and disability that are reported by patients are higher than those estimated by physicians. The secondary aim was to analyse the effects of the type of diagnosis, physician experience and medical specialty on these differences.

Methods

Participants

Participants were recruited from newly referred patients with hand or wrist disorders who had an outpatient appointment for a consultation at the rehabilitation medicine (RM) department of the University Medical Center Groningen in Groningen, the Netherlands between 01 January 2011 and 31 December 2012.

All participants had to be 18 years old or over and be able to understand Dutch sufficiently to complete questionnaires. Patients were excluded if they had a hand or wrist disorder with a more variable course of complaints, where changes in severity could be expected over a relatively short period of time (e.g., inflammatory disorders such as rheumatoid arthritis, complaints after trauma that occurred less than 12 weeks ago) as judged by the treating physician during the consultation.

The treating physician recorded the (provisional) diagnosis, based on the patient's medical history, information gathered during the consultation and any optional additional examinations such as imaging studies. Patients were categorized into one of four different groups of diagnoses: a) specific complaints of the arm, neck and shoulder (CANS), b) non-specific CANS (according to the CANS model),[51] c) post-traumatic complaints (complaints after injuries such as fractures, tendon injury or joint dislocation, secondary osteoarthritis) or d) primary osteoarthritis.

The study proposal was evaluated by the Medical Ethics Committee of the University Medical Center Groningen. A formal ethics review was not required because usual care was evaluated and the research only posed a minor burden to participants (METc 2010.292).

Setting

Patients had an outpatient appointment for a multidisciplinary consultation with several physicians in one of two compositions (consultation type A or B). During a type A consultation, patients were seen concurrently by an RM consultant, an RM trainee and a plastic and reconstructive surgery consultant (plastic surgeon). During a type B consultation, patients were seen by the physicians described in consultation type A and also by an orthopaedic surgery consultant and a trauma surgery consultant.

Consultants had completed specialty training and were listed in the specialist register of their medical specialties. The consultants who were present during the consultations had a specific interest and expertise in hand and wrist disorders.

RM trainees were enrolled in a medical specialty training programme to become RM consultants. In the Netherlands, this training takes 4 years. RM trainees were present during the consultations as part of their specialty training.

Both multidisciplinary consultation types (A and B) were coordinated by the RM department. An RM consultant decided on the type of consultation, based on the referral letter. Generally, more patients with hand disorders were seen at consultation type A and more patients with wrist disorders were seen at consultation type B. The duration of either consultation was 20 min.

Patient characteristics

Age, sex, the affected side (unilateral or bilateral), handedness and involvement of the dominant hand were recorded. The presence of relevant comorbidity that possibly influenced functioning (such as other musculoskeletal disorders, neurological disorders and cardiopulmonary disease) was recorded if this was apparent from the medical history or the patient record. Socioeconomic variables that might influence pain and disability ratings were recorded, including marital status, level of education and employment status.

Patient self-reports

Pain and disability were assessed using visual analogue scales (VASs) and two questionnaires. Patients were asked to rate their level of pain ('How much pain do you have — on average — in your hand and/or wrist?') and disability ('To what extent do you experience disability due to complaints of your hand and/or wrist?') on two separate 0–100 mm horizontal VAS. The VASs were anchored at the symptom extremes of 'no pain' (score of 0) and 'pain as bad as it could be' (score of 100) for pain and 'no disability' (score 0) to 'most severe disability possible' (score 100) for disability. VASs are unidimensional, easy to administer and have good psychometric properties.[52] The severity of symptoms and disability was also recorded using Dutch language versions of the QuickDASH[53,54] and Patient Rated Wrist/Hand Evaluation (PRWHE),[55,56] both of which have been shown to be valid and reliable. The QuickDASH consists of 11 items to measure physical function and symptoms in people with musculoskeletal disorders of the upper limb. Its total score ranges from 0 to 100, a higher score indicates a higher level of disability. The PRWHE consists of five items that are related to pain and 10 items that are related to function. Both pain and function contribute equally to the total score, ranging from 0 to 100. A higher score indicates more pain and a higher level of disability. Reference values for both QuickDASH and PRWHE are generally low, yet they are higher in women than in men and higher with age.[57,58] Patients completed both VAS and questionnaires immediately after the consultation.

Physician estimates

The physicians saw the patient concurrently during the consultation, which means that all physicians made their estimates based on the same information. Physicians estimated the level of pain and disability based on the clinical presentation and other information available during the consultation. While pain and disability were, naturally, important topics to discuss during the consultation, physicians did not ask patients to report the level of pain or disability specifically, for example, using a numeric rating scale. Physicians rated the levels of pain ('According to your estimation, how much pain does the patient experience — on average — in their hand and/or wrist?') and disability ('According to your estimation, to what extent does the patient experience disability due to complaints of their hand and/or wrist?') on two separate 0–100 mm horizontal VAS. These VASs were anchored in the same way as patient self-reports. Patients were not told that the physicians were going to rate their pain and disability levels after the consultation to prevent patient ratings from being influenced by such knowledge. All rating forms were immediately put in an envelope to certify that physicians had no access to patient self-reports or to the ratings of the other physicians.

Data analysis

Descriptive statistics were used to calculate the mean and standard deviation for continuous data and frequencies and percentages for categorical data. Patients who attended different types of consultation were compared using independent t-tests or Chi-square tests where appropriate. Analysis of variance was used to compare QuickDASH and PRWHE scores between groups of diagnoses. Post-hoc testing (Bonferroni) was used to determine between which groups of diagnoses those scores differed significantly.

A multilevel analysis was performed to evaluate differences in VAS-pain and VAS-disability scores between patients and physicians. Two different models were analysed: model 1 analysed the VAS-pain scored by the patient, the RM consultant, the RM trainee and the plastic surgeon; model 2 analysed the VAS-disability scored by the patient, the RM consultant, the RM trainee and the plastic surgeon. The patient's VAS-pain and VAS-disability scores were set as the reference categories. Other factors that potentially influenced the VAS-pain and VAS-disability scores were also included in this analysis, such as patient characteristics and socioeconomic variables (all factors listed in table 1, as well as the consultation type, but excluding QuickDASH and PRWHE scores). Predictors were entered stepwise into the regression equation. If the model fit increased significantly (−log2 likelihood criterion), the predictor remained in the model. Interaction effects of factors were explored and remained in the model if the model fit increased significantly. Random intercepts and slopes were also explored. The values of $P < 0.05$ were considered statistically significant. Analyses were performed using IBM SPSS Statistics 19 and MLwiN 2.27.

Results

A total of 321 newly referred patients were potential participants. Of those, 18 patients were excluded due to the nature of their disorder and 9 patients because they did not understand Dutch sufficiently to complete the questionnaires. No self-reports were received from 37 patients and the self-reports of 7 patients missed essential values. Complete data were collected from 250 patients, whose characteristics are presented in table 1.

Table 1 Participant characteristics.

Factor	Total study population (n = 250)	Consulting hour A[a] (n = 152)	Consulting hour B[b] (n = 98)	*P*-value
Age (years)	45.5 SD 15.2	46.6 SD 14.2	43.8 SD 16.7	.15*
Sex (male), n (%)	105 (42)	63 (41)	42 (43)	.83
Diagnosis, n (%)				<.001
Specific CANS	54 (22)	44 (29)	10 (10)	
Non-specific CANS	60 (24)	33 (22)	27 (28)	
Post-traumatic complaints	108 (43)	52 (34)	56 (57)	
Primary osteoarthritis	28 (11)	23 (15)	5 (5)	
Relevant comorbidity, n (%)	111 (44)	75 (49)	36 (37)	.05
Handedness (right), n (%)	228 (91)	139 (91)	89 (91)	.86
Affected side, n (%)				<.001
Unilateral	206 (82)	112 (73)	94 (96)	
Bilateral	44 (17)	40 (26)	4 (4)	
Dominant hand affected, n (%)	153 (61)	99 (65)	54 (55)	.11
QuickDASH	46.8 SD 21.4	45.8 SD 21.9	48.5 SD 20.5	.33
PRWHE	60.2 SD 20.1	59.1 SD 21.0	62.0 SD 18.5	.28
Marital status, n (%)				.08
Single	61 (23)	30 (20)	30 (31)	
Living together/married	173 (65)	100 (66)	62 (63)	
Divorced/widow/widower	31 (12)	22 (15)	6 (6)	
Level of education, n (%)				.26
Vocational education or lower (lower education)	187 (71)	111 (73)	65 (66)	
Higher education/university (higher education)	78 (29)	41 (27)	33 (34)	
Employment status, n (%)				.40
Unemployed	61 (24)	41 (27)	20 (20)	
Employed (paid employment/self-employed)	161 (64)	93 (61)	68 (69)	
Retired	28 (11)	18 (12)	10 (10)	

CANS: complaints of the arm, neck and shoulder; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand. [a]Consultation type A: concurrent presence of a rehabilitation medicine consultant, a rehabilitation medicine trainee and a plastic surgeon; [b]Consultation type B: concurrent presence of a rehabilitation medicine consultant, a rehabilitation medicine trainee, a plastic surgeon, an orthopaedic surgeon and a trauma surgeon; *Result of an independent t-test, otherwise Chi-square tests.

The distribution of diagnoses differed between the two consultation types. Patients who had an appointment for a consultation where an orthopaedic surgeon and trauma surgeon were also present had post-traumatic complaints more often, had relevant comorbidity less often and were affected unilaterally instead of bilaterally more often. Mean QuickDASH and PRWHE scores did not differ significantly between the consultation types (P = 0.33 and P = 0.28, respectively) nor between the groups of diagnoses (P = 0.14 and P = 0.057, respectively). Therefore, post hoc testing was not performed.

Pain and disability were estimated by one of two RM consultants, one of six RM trainees and by one of five plastic surgeons. In some cases, one or more physicians were absent during the consultation. Pain and disability were estimated by at least one of the physicians. Out of all 250 patients, 197 were seen by an RM consultant, 183 were seen by an RM trainee and 205 were seen by a plastic surgeon.

Pain

Rater, sex, diagnosis, level of education, employment status and consultation type all contributed significantly to the regression equation predicting the level of pain reported (table 2). No interaction effects were significant. The mean VAS-pain score of the reference group (male patients with specific CANS, a lower-level education and in employment, who attended a type A consultation [where an RM consultant, an RM trainee and a plastic surgeon were present]) was 45.7 mm (SE: 3.5 mm).

Levels of pain reported by patients were higher than those estimated by RM consultants, RM trainees and plastic surgeons. There was no significant difference (mean difference: 2.7 mm [SE: 1.9 mm; P = 0.15]) between the level of pain estimated by RM consultants and RM trainees. Levels of pain that were estimated by RM consultants were significantly higher than those estimated by plastic surgeons (mean difference: 6.2 mm [SE: 1.8 mm; P < 0.001]).

Patients with primary osteoarthritis reported higher levels of pain than patients with specific CANS (mean difference: 15.2 mm [SE: 4.5 mm; P < 0.001]), non-specific CANS (mean difference: 11.2 mm [SE: 4.5 mm; P = 0.014]) and post-traumatic complaints (mean difference: 18.1 mm [SE: 4.2 mm; P < 0.001]). Levels of pain were higher in female patients, patients with a lower level of education and in unemployed patients compared to both employed patients and retired patients. Furthermore, reported levels of pain were higher in patients who attended a type B consultation (where not only an RM consultant, an RM trainee and a plastic surgeon were present, but also an orthopaedic surgeon and a trauma surgeon).

Table 2 Model 1: Differences in VAS-pain scores (multilevel analysis).

Variable	Mean VAS score (beta)	SE	Lower border 95% CI	Upper border 95% CI
Rater (reference: Patient)				
RM consultant	−6.8	1.7	−10.1	−3.5
RM trainee	−9.5	1.7	−12.8	−6.2
Plastic surgeon	−13.0	1.7	−16.3	−9.7
Sex (reference: Male)				
Female	6.3	2.5	1.4	11.2
Diagnosis (reference: Specific CANS)				
Non-specific CANS	4.0	3.7	−3.3	11.3
Post-traumatic complaints	−2.9	3.5	−9.8	4.0
Primary osteoarthritis	15.2	4.5	6.4	24.0
Level of education (reference: Lower education)				
Higher education	−8.5	2.7	−13.8	−3.2
Employment status (reference: Employed)				
Unemployed	7.0	2.9	1.3	12.7
Retired	−2.1	4.1	−10.1	5.9
Consultation type (reference: Consultation type A[a])				
Consultation type B[b]	8.3	2.6	3.2	13.4
Constant	45.7	3.5	38.8	52.6

CANS: complaints of the arm, neck and shoulder; RM: rehabilitation medicine; VAS: visual analogue scale. [a]Consultation type A: concurrent presence of a rehabilitation medicine consultant, a rehabilitation medicine trainee and a plastic surgeon; [b]Consultation type B: concurrent presence of a rehabilitation medicine consultant, a rehabilitation medicine trainee, a plastic surgeon, an orthopeadic surgeon and a trauma surgeon.

Disability

Rater, level of education and employment status contributed significantly to the regression equation predicting the level of disability reported (table 3). No interaction effects were significant. The mean VAS-disability score of the reference group (male patients with a lower-level education and in employment) was 57.4 mm (SE: 1.9 mm).

Levels of disability reported by patients were higher than those estimated by RM consultants, RM trainees and plastic surgeons. There was no significant difference (mean difference: 2.3 mm [SE: 2.0 mm; $P = 0.25$]) between the level of disability that was

Table 3 Model 2: Differences in VAS-disability scores (multilevel analysis).

Variable	Mean VAS score (beta)	SE	Lower border 95% CI	Upper border 95% CI
Rater (reference: Patient)				
RM consultant	−17.2	1.8	−20.7	−13.7
RM trainee	−14.9	1.9	−18.6	−11.2
Plastic surgeon	−9.3	1.8	−12.8	−5.8
Level of education (reference: Lower education)				
Higher education	−7.6	2.6	−12.7	−2.5
Employment status (reference: Employed)				
Unemployed	14.1	2.8	8.6	19.6
Retired	−3.0	3.8	−10.4	4.4
Constant	57.4	1.9	53.7	61.1

RM: rehabilitation medicine; VAS: visual analogue scale.

estimated by RM consultants and RM trainees. Levels of disability that were estimated by plastic surgeons were significantly higher than those estimated by RM consultants (mean difference: 7.9 mm [SE: 1.9 mm; $P < 0.001$]).

Levels of disability were higher in patients with a lower level of education and in unemployed patients compared to both employed patients and retired patients.

Discussion

The aim of this study was to analyse differences between patient self-reports and physician ratings of pain and disability in patients with hand or wrist disorders and to analyse the effect of the type of diagnosis, physician experience and medical specialty on these differences. Patients with hand or wrist disorders reported higher levels of pain and disability than estimated by their physicians. Estimates of pain and disability did not differ between RM consultants and RM trainees. Plastic surgeons estimated lower pain levels compared to RM consultants. On the other hand, levels of disability that were estimated by RM consultants were lower compared to those estimated by plastic surgeons. Even though the level of pain differed between diagnosis groups, there was no interaction effect between diagnosis group and rater, which means that the difference between the levels of pain estimated by physicians and those self-reported by patients did not differ between groups of diagnoses. Pain and disability ratings were higher in lower educated and in unemployed patients, pain ratings were also higher in female patients and in patients who attended a type B consultation (where an orthopaedic surgeon and a trauma surgeon were also present). None of these factors influenced the difference between the levels of pain or disability that were estimated by physicians and those that were reported by patients.

To our knowledge, this is the first study that assesses the relationship between patient self-reports and physician estimates regarding pain and disability in patients with hand or wrist disorders. The finding that physicians underestimate pain is consistent with numerous previous studies in patients with a diversity of disorders and in a range of healthcare settings.[59] Reports about the accuracy of disability assessments in the literature are very scarce but estimates of functional limitations made by healthcare providers are lower compared to self-reports by patients with low back pain.[60,61]

In this study, estimates of pain and disability did not differ between RM consultants and RM trainees. This is contrary to previous studies that have shown that an increase in professional experience is related to the extent of underestimation of pain. Nurses who worked on a burn unit for longer underestimated pain more often than more inexperienced colleagues.[62,63] Also, certified emergency medicine physicians underestimated pain in patients attending the emergency department to a greater extent compared to emergency medicine trainees and medical students.[64] We do not know why we did not find such an effect but comparable clinical judgement methods that are used by RM consultants and RM trainees, due to apprenticeship learning, may play a role. Another explanation might be that plenty of attention is being paid to chronic pain in courses for both RM consultants and RM trainees and such education is believed to diminish underestimation of pain.[44]

We did, however, find that estimates of pain and disability differed between RM consultants and plastic surgeons. Differences in ratings between consultants from different specialties have been found before in a vignette study, where neurosurgeons rated pain and disability at a lower level compared to internists.[65] Due to the nature of the medical specialties in our study, plastic surgeons may be more exposed to patients with severe pain, whereas RM consultants are more exposed to patients with severe disabilities. It has been stated that frequent exposure may desensitize physicians.[44] Another explanation for the extensive underestimation of disability by RM physicians might be that these physicians tend to consider possibilities as opposed to limitations. These explanations correspond with theories stated before about the rating of disability by RM consultants in patients with low back pain.[66]

We did not find differences in the extent of underestimation of pain by physicians between groups of diagnoses. In several vignette studies that described patients with chronic low back pain, both pain and disability were rated at a lower level by laypeople, medical students and internists in the absence of medical evidence.[67–70] In a similar vignette study that described patients with shoulder pain, laypeople assigned lower pain ratings in the absence of medical evidence.[48] Therefore, we expected to find that physicians underestimated pain and disability to a greater extent in the group of patients with non-specific CANS, where medical evidence to explain the patient's complaints is often lacking. It is unclear why we did not find such an effect. It is possible that the concept of medical evidence differs between experimental and practical settings. Another explanation might be that, given the frequency with which non-specific CANS was diagnosed during the consultations in this study, physicians did not rely substantially on medical evidence when estimating the levels of pain and disability experienced by patients.

Several factors predicted levels of pain and disability, most of which are consistent with previous literature. Higher levels of pain in females, higher levels of pain and disability in patients with a lower level of education and in unemployed patients and higher levels of pain in patients with primary osteoarthritis compared to patients with other hand disorders have been described previously.[71–73] Furthermore, we found levels of pain to be higher in patients who attended the consultation where an orthopaedic surgeon and trauma surgeon were present, in addition to an RM consultant, an RM trainee and a plastic surgeon. Even though there are some differences in characteristics of patients who attended the two types of consultation, we did not find an interaction effect between one of those factors and the consultation type. We speculate that, due to the department referral policy, more severely affected patients were seen at a consultation where an orthopaedic surgeon and trauma surgeon were also present. This might be reflected by slightly higher, yet not statistically different, QuickDASH and PRWHE scores in those patients.

Strengths and weaknesses

This study describes the differences between self-reported pain and disability and estimates thereof by physicians in a population of patients with hand or wrist disorders. To our knowledge, it is the first study that analyses differences between patient self-reports and physician estimates in this specific population. It is also one of the largest clinical samples in which these differences have been analysed in general, with specific attention paid to clinical experience and medical specialization as potential moderators of pain assessment accuracy. QuickDASH and PRWHE scores of participants in this study are higher than in the general population[57,58] and similar to those described in other studies that reported on patients with hand or wrist problems.[73–75] Even though wide ranges of scores are reported in the literature, depending on diagnosis and treatment phase, this might aid generalization of our results to other settings and populations where similar patients are treated. Possible predictors of pain and disability were selected based on previous studies. However, data were collected on a limited number of predictors for practical reasons. It is conceivable that we missed predictors that might have contributed to one of the models, such as physician characteristics (sex, ethnicity and empathy).[44,59] Another limitation of our study might be that groups of physicians were small and inter-rater differences might have influenced the results.

Clinical implications and suggestions for further research

It is important to be aware that ratings of pain and disability differ between patients and physicians, and also between physicians from different medical specialties. This might be particularly relevant in multidisciplinary settings, where a patient is assessed and treated by physicians from different medical specialties. Misestimating pain and disability might negatively influence treatment decisions.[76] The discrepancy found between patient self-reports and physician estimates indicates that the use of patient-reported outcome measures should be considered more frequently.[77] Multiple patient-reported outcome measures are available for use in patients with hand problems. However, it is unknown which measurement instrument is best and whether this affects the diagnostics or treatment decisions.[78] Further research is needed to evaluate the benefits of using patient-rated outcome measures in this population and to determine which instrument is favoured.

Conclusions

Levels of pain and disability that are estimated by physicians are lower than those reported by patients with hand or wrist disorders. Estimates of pain and disability differ between RM consultants and plastic surgeons, but not between RM consultants and RM trainees. The type of diagnosis does not influence the difference between patient-reported and physician-estimated levels of pain and disability.

3

Measurement properties of the Dutch versions of QuickDASH and PRWHE in patients with complaints of hand, wrist, forearm and elbow

Redmar J. Berduszek
Michiel F. Reneman
Rienk Dekker
Corry K. van der Sluis

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Abstract

Background
The shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Patient Rated Wrist/Hand Evaluation (PRWHE) are commonly used questionnaires to assess patient-reported hand function. Information about the measurement properties of the Dutch versions is scarce.

Objective
To gain insight into the measurement properties of the Dutch language versions of the QuickDASH and the PRWHE in patients with (non-)specific complaints of the hand, wrist, forearm and elbow.

Methods
Internal consistency, construct validity, test-retest reliability, responsiveness, and floor and ceiling effects were assessed according to COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations.

Results
Questionnaires were filled out by 132 patients. Internal consistency of QuickDASH (Cronbach's $\alpha = 0.92$) and PRWHE (Cronbach's $\alpha = 0.97$) was high. Predefined hypotheses for construct validity were not confirmed for 75% for both QuickDASH and PRWHE (accordance with 62% of predefined hypotheses for both questionnaires). Test-retest reliability of QuickDASH (ICC = 0.90) and PRWHE (ICC = 0.87) was good. Both QuickDASH (AUC = 0.84) and PRWHE (AUC = 0.80) showed good responsiveness. No floor or ceiling effects were present.

Conclusions
Measurement properties of the Dutch language versions of the QuickDASH and the PRWHE, applied to patients with (non-)specific complaints of the hand, wrist, forearm and elbow, were very similar. Test-retest reliability and responsiveness were good for both QuickDASH and PRWHE. Construct validity could not be demonstrated sufficiently.

Introduction

Complaints of the arm, neck and shoulder (CANS) occur frequently in the Dutch population, with a point prevalence of over 25% and over half of the population reporting an episode of chronic complaints at least once during a 15-year course.[5,7] Both pain and disability are considered important components of the assessment of hand problems.[79] Patient reported outcome measures (PROMs) are available to measure arm and hand function. Among the most frequently used region-specific questionnaires are the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Patient Rated Wrist/Hand Evaluation (PRWHE).[20,80] Both are brief self-report questionnaires, each taking less than 5 minutes to complete.[80] Both questionnaires, which are available in many languages including Dutch, have been considered essential tools to assess the outcome domain 'patient-reported hand function/activities of daily living' in patients with hand or wrist conditions.[14]

Several measurement properties of QuickDASH and PRWHE have been studied widely, especially validity and reliability, while information on other measurement properties such as responsiveness is scarcer.[23,24] Most studies have been performed in samples consisting of patients suffering from traumatic hand injury or other disorders requiring surgical intervention, but much less in patients with nontraumatic musculoskeletal complaints.[24,25] Furthermore, the methodological quality of studies where measurement properties were assessed varies and is often low according to quality criteria for measurement properties.[23,24,81,82] Measurement properties of the Dutch language versions of QuickDASH and PRWHE have been studied less extensively in general.[83,84] To use and correctly interpret the results of these PROMs in a predominantly nontraumatic rehabilitation population, a better understanding of their measurement properties in such population is important.[85]

Therefore, the aim of this study was to gain insight into the measurement properties (internal consistency, construct validity, test-retest reliability, responsiveness (including the minimal important change (MIC) value) and floor or ceiling effects) of the Dutch language versions of QuickDASH and PRWHE in patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm and elbow.

Methods

Study design

The design of this prospective observational study was based on the recommendations of the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) initiative.[86,87] This study was approved by the Medical Ethical Committee of the University Medical Center Groningen (METc 2015/115) and has been registered with the Dutch Trial Register (NL5657). All participants gave written informed consent.

Study sample

Participants were recruited between November 2015 and March 2020. Participants were originally selected from patients visiting the outpatient clinic of the department of rehabilitation medicine of one university hospital and, to expedite inclusion, since January 2017 also from two primary care hand therapy clinics located in the same region as the university hospital. Participants were eligible if they were 18 years or older and had musculoskeletal complaints of their hand, wrist, forearm and/or elbow. These complaints were classified as specific or non-specific CANS, according to the CANS model.[3] CANS is defined as musculoskeletal complaints of arm, neck and/or shoulder not caused by acute trauma or by any systemic disease. While CANS covers disorders located as proximally as neck and shoulder, participants in this study were affected by more distally located complaints (elbow and more distal) directly influencing hand function. This also included lateral epicondylitis, which involves the muscles and tendons of the forearm that extend the wrist and fingers. Exclusion criteria were insufficient understanding of the Dutch language to fill out questionnaires, disorders excluded by the CANS model (e.g., osteoarthritis, rheumatoid arthritis) and the presence of concomitant medical conditions causing considerate disability, such as neurological disorders (e.g., stroke, traumatic peripheral nerve damage) or (partial) amputation of the hand. Participants were selected through convenience sampling.

Intended sample size was based on COSMIN recommendations: at least 50 subjects to assess construct validity, reliability, responsiveness and floor or ceiling effects, and at least 7 times the number of items of a questionnaire (with a minimum of 100) to assess internal consistency (in this case the questionnaire with the most items was the PRWHE (15 items), therefore 7 × 15 = 105).[86]

Procedure

Participants filled out questionnaires two or three times (at T1, T2 and/or T3), depending on inclusion location and whether they were treated by a certified hand therapist at the institution where they were included (figure 1). Questionnaires were paper-based and handed out during a consultation (T1 at hand therapy clinics) or distributed by post (T1 and T2 at the university hospital, T3 at the university hospital and hand therapy clinics). In any case, participants could fill out the questionnaires at a self-selected moment and return them by post. The interval between T1 and T2 was 1–3 weeks, which was supposed to be long enough to prevent recall and allow administration of questionnaires by post, yet short enough to assume no clinical change occurred.[87] University hospital participants with a site visit within 1 week of T1 (n = 45) also performed a hand grip strength measurement, which was used to assess construct validity.

		UH	HTC	Total
T1	**Internal consistency** **Floor or ceiling effects** QuickDASH and PRWHE (first completion)	63	69	132
T1	**Construct validity** QuickDASH, PRWHE, PDI, NRS pain, RAND-36, WAS and hand grip strength (first completion)	63	N/A	63
T2	**Test-retest reliability** QuickDASH and PRWHE (1–3 weeks after first completion)	59	N/A	59
T3	**Responsiveness** QuickDASH, PRWHE and GRC (4–8 weeks after start hand therapy)	4	54	58

Figure 1 Flowchart of study procedure and number of participants. Overview of the three study measurement moments (T1, T2 and T3), the measures taken per moment (depending on the measurement properties studied) and the number of participants for each measurement property and location.

GRC: global rating of change; HTC: primary care hand therapy clinics; N/A: not applicable; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRHWE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand; RAND-36: RAND 36-item Health Survey; UH: university hospital; WAS: Work Ability Score.

Measurements

All participants filled out general demographic information regarding marital status, level of education, current work situation and handedness. Diagnosis was recorded from the medical record.

Primary measures

The QuickDASH is a shortened version of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, which was developed to measure physical function and symptoms in persons with musculoskeletal disorders of the upper limb.[21,88] It consists of 11 items regarding function (7 items) and pain (4 items). The total score ranges from 0–100, where a higher score indicates more pain and disability. Internal consistency, construct validity, reliability and responsiveness have been rated to be adequate (mainly in patients with neck or shoulder disorders, patients with fractures or other injuries, or surgically treated patients).[23,81]

The PRWHE is a questionnaire which was developed to assess pain and disability of the wrist and hand.[22,89,90] It consists of 15 items divided over two subscales regarding pain (5 items) and function (10 items) of wrist and hand. Both pain and function contribute equally to the total score, which ranges from 0–100. A higher score indicates more pain and disability. Its measurement properties have been assessed in diverse countries and populations (mainly in patients with fractures or other injuries), generally demonstrating very good internal consistency, construct validity and reliability.[24]

Secondary measures

Secondary measures were collected depending on location and the time the questionnaires were filled out (figure 1), to assess either construct validity or responsiveness. The Pain Disability Index (PDI) is a generic instrument for measuring disability related to pain. It consists of 7 items concerning self-reported disability due to pain in different situations such as work, leisure time, activities of daily living, and sports. The total score ranges from 0–70. A higher score reflects a greater disability due to pain. It has been proven valid and reliable in patients with different types of musculoskeletal pain.[91]

The numeric pain rating scale (NRS pain) is a valid and reliable, unidimensional scale to assess pain intensity.[92] It consists of a single item asking about pain intensity during the past week. It is scored on an 11-point Likert scale ranging from 0 (no pain) to 10 (worst pain imaginable).

The RAND 36-item Health Survey (RAND-36) is a questionnaire about physical, mental and social health and is used worldwide to measure health-related quality of life, which has been shown to be reliable and valid.[93] The RAND-36 is a license free version of the SF-36 and includes the same items.[94] It consists of eight subscales measuring either physical or mental health. While the complete RAND-36 was filled out, only the subscales physical functioning, social functioning, vitality, and mental health were analyzed in this study for the purpose of construct validity assessment. Subscale scores are calculated using an algorithm, the output being a score between 0 and 100. Higher scores indicate a better health status.

The Work Ability Score (WAS) is a single-item questionnaire asking about the current work ability compared to the lifetime best work ability, ranging from 0 (completely unable to work) to 10 (lifetime best work ability). It has been shown to be a valid, reliable, and responsive instrument to assess current work ability.[95]

Hand grip strength was measured using a Jamar dynamometer, the patient sitting with the elbow flexed at 90 degrees and the forearm and wrist in a neutral position. Both hands were assessed three times each in alternating order and the mean for each hand was calculated.[96]

A question about the global rating of change (GRC) was used as an external criterion to assess clinically meaningful change, in order to assess responsiveness.[97] Participants who were treated by a certified hand therapist (at their inclusion location, either the university hospital or one of the two hand therapy clinics) were asked to rate the perceived change in complaints of their hand, wrist or forearm since the start of hand therapy on a 7-point Likert scale, ranging from 1 (much better) to 7 (much worse). In general, hand therapy treatments included exercises, ergonomic advice and relative rest (e.g., splinting).

Data analyses

Statistical analyses were performed using IBM SPSS Statistics 28. Descriptive statistics were used to describe patient characteristics. Parametric or nonparametric statistics were used where appropriate. Statistical significance was set at $P < 0.05$.

Internal consistency

Cronbach's α was calculated for each (sub)scale, a value between 0.70 and 0.95 was considered adequate.[86]

Construct validity

Construct validity of QuickDASH and PRWHE was evaluated through 13 predefined hypotheses (table 1). Because of their equivalent construct, these hypotheses were the same for both QuickDASH and PRWHE.

The hypotheses were based on a theoretical assessment of the concepts being measured. Both QuickDASH and PRWHE assess pain of the arm/hand, the ability to use the hand and to perform daily activities. As such, a very strong relationship between these two questionnaires was expected. Also, because of their similar construct, the assumed strength of the correlation with other variables was identical for both QuickDASH and PRWHE. The PDI measures the impact of pain on the ability of a person to participate in essential life activities but does not focus specifically on the upper extremities.

Similarly, the RAND-36 subscale physical functioning is composed of items assessing the influence of health problems on different physical activities, some involving the upper extremity. Therefore, a moderate to strong relationship between QuickDASH/PRWHE and PDI/RAND-36 subscale physical functioning was expected. A similar relationship was expected between QuickDASH/PRWHE and WAS, as it is perceivable that upper extremity pain and disabilities have some effect on work ability. Because pain contributes partially to the total scores of QuickDASH/PRHWE, a moderate to strong correlation with NRS pain was expected. The correlation between QuickDASH/PRWHE and RAND-36 subscales social functioning, vitality and mental health was expected to be weak to moderate, because these subscales test constructs not directly related to upper extremity function. A moderate to strong correlation between QuickDASH/PRWHE and hand grip strength was expected, since hand grip strength might be affected by the disorder or associated pain. Age and sex influence QuickDASH/PRWHE scores only slightly, therefore a weak correlation with age and no differences between males and females were expected.[98,99] It was assumed that better hand function was reported by those who were working, therefore lower QuickDASH/PRWHE scores were expected in participants who were employed opposed to unemployed. Because use of the dominant hand is not assumed for the activities listed in QuickDASH/PRWHE, no difference in QuickDASH/PRWHE scores was expected between participants of which the dominant side was affected or not.

Table 1 Construct validity: predefined hypotheses and results.

	Predefined hypothesis*	**Correlation with QuickDASH (ρ) (accepted yes/no)**	**Correlation with PRWHE (ρ) (accepted yes/no)**
QuickDASH/PRWHE	>0.75	0.87 (yes)	0.87 (yes)
PDI	0.26–0.75	0.88 (no)	0.87 (no)
NRS pain	0.26–0.75	0.75 (yes)	0.84 (no)
RAND-36 physical functioning	0.26–0.75	−0.70 (yes)	−0.64 (yes)
RAND-36 social functioning	0.00–0.50	−0.61 (no)	−0.54 (no)
RAND-36 vitality	0.00–0.50	−0.59 (no)	−0.45 (yes)
RAND-36 mental health	0.00–0.25	−0.47 (no)	−0.38 (no)
WAS	0.26–0.50	−0.67 (no)	−0.63 (no)
Age	0.00–0.25	0.03 (yes)	0.03 (yes)
Hand grip strength[†]	0.26–0.75	−0.43 (yes)	−0.43 (yes)
	Predefined hypothesis	**Group comparison (accepted yes/no)**	**Group comparison (accepted yes/no**
Score: lower if employed	Yes	Yes, $P = 0.009$ (yes)	Yes, $P = 0.002$ (yes)
Score: male = female	Yes	Yes, $P = 0.53$ (yes)	Yes, $P = 0.94$ (yes)
Score: higher if dominant side affected	No	No, $P = 0.47$ (yes)	No, $P = 0.14$ (yes)

NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRHWE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand; RAND-36: RAND 36-item Health Survey; WAS: Work Ability Score. *0.00–0.25 weak, 0.26–0.50 moderate, 0.51–0.75 strong, >0.75 very strong; [†]Grip strength of the affected hand, or dominant hand in case of bilateral involvement.

Spearman's rank correlation coefficients (ρ) were calculated to assess associations with other measurements. Correlation coefficients were interpreted as follows: 0.00–0.25 weak, 0.26–0.50 moderate, 0.51–0.75 strong, above 0.75 very strong.[100] Known-group differences were assessed using the Mann-Whitney U test. Construct validity was deemed good when at least 75% of the results were in accordance with the predefined hypotheses.[86]

Test-retest reliability

An intraclass correlation coefficient (ICC) for absolute agreement (two-way mixed effects model) was calculated, an ICC ≥0.70 was deemed good.[86] The 95% Limits of Agreement (LoA) were presented using a Bland-Altman plot. LoA are defined as the mean difference between repeated measurements ± 1.96 SD of the difference.[101]

Responsiveness

The GRC was used as an external criterion (anchor-based method).[97] A score of 1 or 2 ((much) improved) was considered as an improvement, a score of 3 (slightly improved), 4 (the same) or 5 (slightly worse) was considered unchanged, and a score of 6 or 7 ((much) worse) was considered as a deterioration of complaints. The area under the receiver operating characteristics (ROC) curve (AUC) was calculated to assess discrimination between participants whose complaints had improved versus remained unchanged.[102] An AUC of at least 0.70 was considered adequate to distinguish between patients who have improved versus remained unchanged.[86] The MIC (the smallest change in the score that patients perceive as important) was determined by the ROC cut-off point associated with optimal sensitivity and specificity, using the sum of squares approach.[103] This approach determines the ROC cut-off point by finding the smallest sum of squares of 1 − sensitivity and 1 − specificity, assuming sensitivity and specificity are valued equally. The standard error of measurement (SEM) was calculated by the square root of the error variance of an ANOVA analysis including systematic differences (SEM agreement). The smallest detectable change (SDC, the smallest change that can be detected beyond measurement error) was calculated using the formula $SDC = 1.96 \times \sqrt{2} \times SEM$. The SDC should be smaller than the MIC, to distinguish between clinically meaningful change and measurement error.[86]

Floor or ceiling effects

Floor or ceiling effects were considered to be present if more than 15% of participants achieved the lowest or highest possible score.[86]

Results

The QuickDASH and PRWHE were filled out by 132 patients, 63 at the university hospital and 69 at the hand therapy clinics (table 2). The number of participants included in the analysis of each measurement property ranged from 58 to 132 (figure 1). Specific CANS were relatively more prevalent in patients included from the hand therapy clinics compared to those included from the university hospital (X^2 (df = 1, n = 132) = 11.90, P = 0.001), where non-specific CANS were more prevalent. Other characteristics did not differ significantly between university hospital and hand therapy clinic populations.

Table 2 Participant characteristics.

	Total (n = 132)	UH (n = 63)	HTC (n = 69)
Sex (male) (n (%))	49 (37)	23 (37)	26 (38)
Age (years) (mean (SD))	47.4 (16.7)	45.1 (15.1)	49.5 (17.9)
Diagnosis (n (%))			
Specific CANS	73 (55)	25 (40)	48 (70)
Lateral epicondylitis	20 (28)	7 (28)	13 (27)
De Quervain's disease	19 (26)	7 (28)	12 (25)
Trigger finger	17 (23)	7 (28)	10 (21)
Carpal tunnel syndrome	9 (12)	0 (0)	9 (19)
Dupuytren disease	8 (11)	4 (16)	4 (8)
Non-specific CANS	59 (45)	38 (60)	21 (30)
Handedness (n (%))			
Right-handedness	108 (82)	51 (81)	57 (83)
Left-handedness	14 (11)	9 (14)	5 (7)
Mixed or ambidexterity	10 (7)	3 (5)	7 (10)
Affected side (n (%))			
Unilateral	79 (60)	35 (56)	44 (64)
Bilateral	53 (40)	28 (44)	25 (36)
Dominant hand affected (yes) (n (%))	107 (82)	51 (81)	56 (81)
QuickDASH (0–100, median (IQR))	31.8 (29.0)	31.8 (29.6)	34.1 (30.7)
PRWHE (0–100, median (IQR))	46.8 (43.0)	41.5 (42.0)	50.0 (42.5)
Employed (yes) (n (%))	92 (70)	48 (76)	44 (64)
WAS (0–10, mean (SD))	–	5.7 (2.8)	–
NRS pain (0–10, mean (SD))	–	4.5 (2.3)	–

CANS: complaints of the arm, neck and shoulder; HTC: primary care hand therapy clinics; NRS pain: numeric pain rating scale; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand; UH: university hospital; WAS: Work Ability Score.

Internal consistency

For QuickDASH, Cronbach's α was 0.92. For PRWHE, Cronbach's α of the complete questionnaire (15 items) was 0.97, for the pain subscale (5 items) and for the disability subscale (10 items) it was 0.93 and 0.96, respectively.

Construct validity

Accordance with predefined hypotheses was observed in 8 of 13 (62%) hypotheses tested for both QuickDASH and PRWHE (table 1), meaning that construct validity of both questionnaires could not be demonstrated.

Test-retest reliability

For QuickDASH, ICC was 0.90 (95% CI: 0.84–0.94). The mean difference between test and retest was −0.21 with LoA of −18.34 (lower) and 17.92 (upper) (figure 2). For PRWHE, ICC was 0.87 (95% CI: 0.78–0.92). The mean difference between test and retest was −0.71 with LoA of −25.50 (lower) and 24.08 (upper) (figure 2).

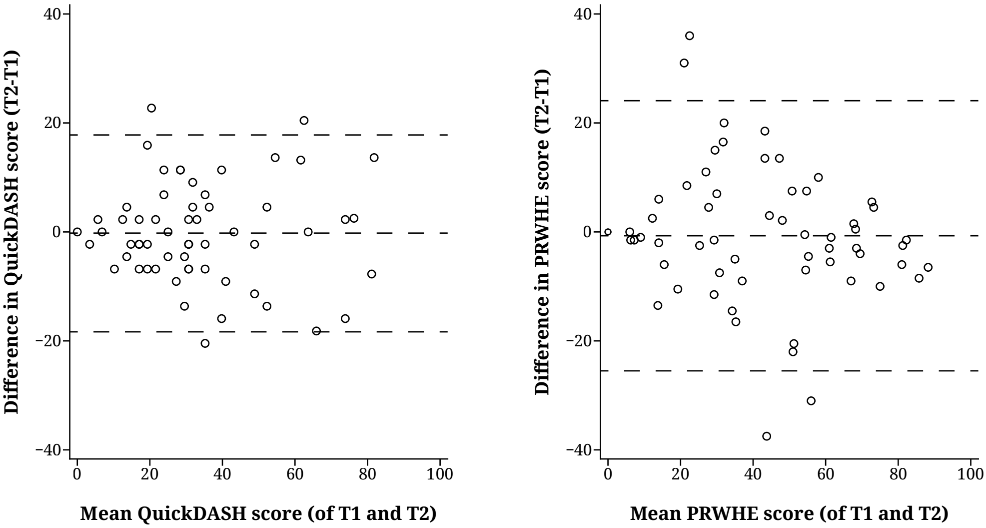

Figure 2 Bland-Altman plots for QuickDASH and PRWHE. Bland-Altman plots of differences between scores at the first measurement moment (T1) and second measurement moment (T2, 1–3 weeks after T1) versus the mean of these two measurements. For QuickDASH (left panel), the mean difference between T1 and T2 was −0.21 with LoA of −18.34 (lower) and 17.92 (upper). For PRWHE (right panel), the mean difference between T1 and T2 was −0.71 with LoA of −25.50 (lower) and 24.08 (upper).

LoA: 95% Limits of Agreement; PRHWE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand.

Responsiveness

Of the 58 participants who received hand therapy treatment, 21 (36%) indicated that their complaints had improved since the start of this treatment (GRC score 1 or 2), while 35 (60%) indicated that their complaints were unchanged (GRC score 3, 4 or 5). Participants whose complaints had improved after hand therapy had a greater reduction of both QuickDASH (mean difference 21.3, 95% CI: 12.2–30.4, $P < 0.001$) and PRWHE (mean difference 18.4, 95% CI: 9.3–27.6, $P < 0.001$) scores compared to participants whose complaints were unchanged.

The AUC was 0.84 (95% CI: 0.73–0.94) for QuickDASH and 0.80 (95% CI: 0.69–0.92) for PRWHE (figure 3). For QuickDASH, the ROC cut-off and MIC was 15.9 points (sensitivity 0.71, specificity 0.83), the SEM was 1.85 and the SDC was 5.13. For PRWHE, the ROC cut-off and MIC was 10.3 points (sensitivity 0.95, specificity 0.60), the SEM was 2.15 and the SDC was 5.96.

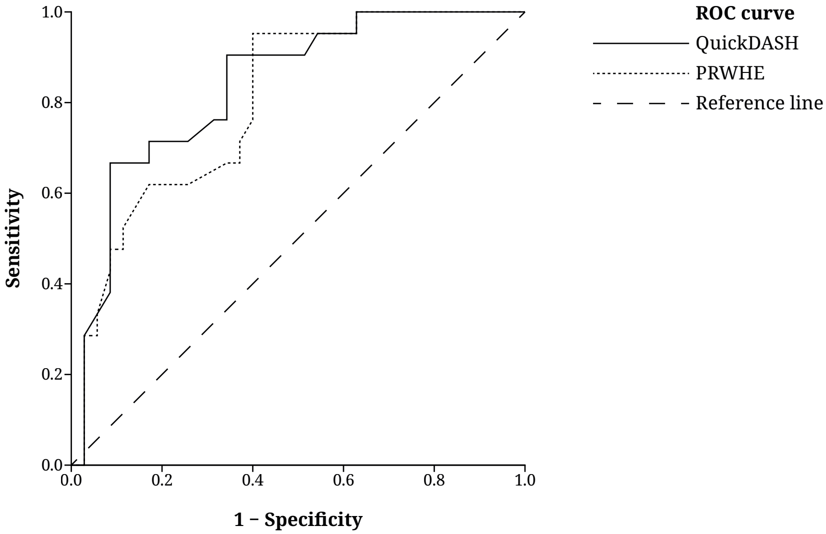

Figure 3 ROC curves for QuickDASH (solid line) and PRWHE (dotted line) represented in comparison to a reference line (dashed line). The AUC was calculated to assess discrimination between participants whose complaints had improved versus remained unchanged. The AUC was 0.84 (95% CI: 0.73–0.94) for QuickDASH and 0.80 (95% CI: 0.69–0.92) for PRWHE.

AUC: area under the ROC curve; PRHWE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand; ROC: receiver operating characteristics.

Floor or ceiling effects

For both QuickDASH and PRWHE, only one of 132 participants had the lowest possible score (less than 1%). None of the participants had the highest possible score on either of these questionnaires. This indicates that no floor or ceiling effects were present.

Discussion

This study assessed multiple measurement properties of QuickDASH and PRWHE in a Dutch rehabilitation population suffering from complaints of hand, wrist, forearm and/or elbow, classified as specific or non-specific CANS. Outcomes were compared to COSMIN quality criteria for measurement properties.[86] The quality of measurement properties of QuickDASH and PRWHE were similar in this study sample. Most measurement properties were sufficient: internal consistency, test-retest reliability, responsiveness and floor and ceiling effects for both QuickDASH and PRWHE. Construct validity was insufficiently demonstrated for both QuickDASH and PRHWE, because less than 75% of results were in accordance with predefined hypotheses.

Internal consistency of QuickDASH and PRWHE in previous studies was invariably high and similar to our findings.[23–25,82,104] The very high Cronbach's α of PRWHE disability subscale is indicative of item redundancy. Using factor analysis, multiple studies have demonstrated that PRWHE actually consists of three (pain, specific activities, usual activities) instead of two subscales (pain and function).[105–107]

Construct validity of QuickDASH and PRWHE in this study was insufficient, because less than 75% of observed correlations with other parameters were in accordance with predefined hypotheses. The correlations between QuickDASH/PRWHE and PDI, WAS and most RAND-36 subscales were stronger than hypothesized. While the strength of observed correlations matched with expected correlations for only 62% of the predefined hypotheses, the order of the observed correlation coefficients did correspond with those of the hypotheses. So, the RAND-36 subscale physical functioning was correlated more strongly with QuickDASH/PRWHE than the RAND-36 subscales social functioning and vitality. Also, as expected, the weakest correlation was observed for the RAND-36 subscale mental health. In two studies assessing the measurement properties of QuickDASH (Chinese version) and PRWHE (Turkish version) in patients with diverse upper extremity disorders, correlations with the subscales physical functioning, social functioning, vitality and mental health of 36-Item Short-Form Health Survey (SF-36, which resembles RAND-36 strongly) were assessed. The same order of correlation coefficients was described as in this study, yet the strength of these correlations was much weaker and within the ranges hypothesized in this study.[105,108] In a study assessing the measurement properties of the QuickDASH in patients with acute elbow trauma, a strong correlation was found between QuickDASH and SF-36 subscale physical functioning (similar to the correlation between QuickDASH and RAND-36 subscale physical functioning in this study), but a much weaker correlation between QuickDASH and SF-36 mental component scale (consisting of four SF-36 domains, amongst which social functioning, vitality and mental health) than between QuickDASH and RAND-36 subscales social functioning, vitality and mental health in this study.[84] While we carefully considered the synthesis of the predefined hypotheses, we argue that we could have been less strict in describing the precise strength of expected correlation coefficients. Even though alternative explanations might introduce bias, we were more confident about the relative than the absolute magnitude of the correlations. Therefore, we feel that both QuickDASH and PRWHE might be more valid than demonstrated in this study. In any case, the results provide more insight into the construct of both questionnaires in a sample of patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm and elbow.

Test-retest reliability of both QuickDASH and PRWHE was very good, which matches previous literature reporting similar reliability almost without exception.[23–25,82]

Responsiveness of both QuickDASH and PRWHE was good, with an AUC of over 0.70 and SDC smaller than MIC for both QuickDASH and PRWHE, indicating that clinically important change can be distinguished from measurement error. QuickDASH had a MIC of 16 points and PRHWE had a MIC of 10 points. Previously reported MIC differed amongst others between diagnoses and treatment type (generally lower for nonsurgical treatment compared to surgical treatment), but are similar to our findings for both QuickDASH (range 14–18) and PRWHE (range 13–14) in similar samples.[109–112] The cut-off point to determine MIC may be chosen differently, depending on the preferred balance between sensitivity and specificity (see supplementary tables S1–S2, at the end of the chapter, for cut-off values and associated sensitivity and specificity).[102]

Clinical implications and suggestions for further research

While construct validity and floor and ceiling effect results were on par between QuickDASH and PRWHE, internal consistency, test-retest reliability and responsiveness of QuickDASH seemed slightly favorable over those of PRWHE. Furthermore, QuickDASH consists of fewer items and can be used in a wider population experiencing problems anywhere in the upper extremity, while PRWHE focuses on wrist and hand problems. Therefore, we consider that use of the QuickDASH may be preferred over the PRWHE. Due to the instructions of the PRWHE (pain in hand/wrist) its use in patients with pain in the forearm or elbow may be limited (even when this pain is directly related to hand function). Small changes to these instructions might be considered to broaden its application.[113] Expansion of these insights may support decisions regarding the use of these questionnaires in clinical practice and contribute to the further development of a viable methodology for use in research on patients with upper limb disability.[114]

Suggestions for further research include further validation of the QuickDASH and PRWHE as well as the assessment of their measurement properties in different, but more homogenous populations (e.g., test-retest reliability should be evaluated additionally in a primary care population and responsiveness should be evaluated additionally in a tertiary care population). Also, because of possible item redundancy, further shortening or division in subscales of these questionnaires deserves attention.

Limitations

Despite adherence to COSMIN guidelines, COSMIN recommended sample sizes have been increased in recent design checklists and the sample size used in this study is currently considered as adequate instead of very good.[115] The sample size did not allow for a further division into groups of diagnoses. Stability on the construct measured during the interval for test-retest reliability was assumed but not assessed on an individual level. While all participants had similar disorders, there was a difference in distribution of specific versus non-specific CANS between university hospital and primary care hand therapy clinic populations. Not all upper extremity regions were represented in the population studied (e.g., no shoulder disorders). Also, even though participants originated from the same geographical area, the fact that some of them were seen in primary care and others in tertiary care might limit generalizability.

Conclusion

Measurement properties of the Dutch language versions of QuickDASH and PRWHE, applied to patients with (non-)specific complaints of the hand, wrist, forearm and elbow, were very similar. Internal consistency was slightly better for QuickDASH than PRWHE. Test-retest reliability and responsiveness were good for both QuickDASH and PRWHE. Construct validity could not be demonstrated sufficiently. No floor or ceiling effects were present.

Supplementary table S1 QuickDASH: ROC cut-off values for total score change after hand therapy treatment.

Positive if greater than or equal to*	Specificity	Sensitivity	1 − Specificity	1 − Sensitivity	Sum of squares (1 − Specificity and 1 − Sensitivity)
−30.546	0.000	1.000	1.000	0.000	1.000
−26.136	0.029	1.000	0.971	0.000	0.943
−19.318	0.057	1.000	0.943	0.000	0.889
−13.636	0.086	1.000	0.914	0.000	0.835
−9.091	0.114	1.000	0.886	0.000	0.785
−6.818	0.143	1.000	0.857	0.000	0.734
−5.682	0.171	1.000	0.829	0.000	0.687
−4.546	0.200	1.000	0.800	0.000	0.640
−3.409	0.229	1.000	0.771	0.000	0.594
−2.273	0.257	1.000	0.743	0.000	0.552
−2.273	0.314	1.000	0.686	0.000	0.471
−1.591	0.371	1.000	0.629	0.000	0.396
−0.455	0.371	0.952	0.629	0.048	0.398
1.136	0.457	0.952	0.543	0.048	0.297
3.409	0.486	0.905	0.514	0.095	0.273
4.546	0.514	0.905	0.486	0.095	0.245
5.682	0.571	0.905	0.429	0.095	0.193
6.818	0.600	0.905	0.400	0.095	0.169
6.818	0.629	0.905	0.371	0.095	0.147
7.955	0.657	0.905	0.343	0.095	0.127
9.091	0.657	0.905	0.343	0.095	0.127
9.091	0.657	0.762	0.343	0.238	0.174
10.227	0.686	0.762	0.314	0.238	0.155
11.364	0.686	0.762	0.314	0.238	0.155
12.500	0.743	0.714	0.257	0.286	0.148
14.773	0.800	0.714	0.200	0.286	0.122
15.909	0.829	0.714	0.171	0.286	0.111
17.046	0.829	0.667	0.171	0.333	0.140
18.182	0.857	0.667	0.143	0.333	0.131
18.182	0.857	0.667	0.143	0.333	0.131
18.523	0.914	0.667	0.086	0.333	0.118
20.796	0.914	0.619	0.086	0.381	0.153
22.727	0.914	0.619	0.086	0.381	0.153
23.864	0.914	0.524	0.086	0.476	0.234
26.136	0.914	0.476	0.086	0.524	0.282
27.273	0.914	0.476	0.086	0.524	0.282
30.682	0.914	0.381	0.086	0.619	0.391
34.091	0.914	0.381	0.086	0.619	0.391
35.227	0.943	0.333	0.057	0.667	0.448
36.364	0.943	0.333	0.057	0.667	0.448
37.500	0.971	0.286	0.029	0.714	0.511
39.773	0.971	0.238	0.029	0.762	0.581
42.046	0.971	0.190	0.029	0.810	0.657
48.182	0.971	0.143	0.029	0.857	0.735
53.864	0.971	0.095	0.029	0.905	0.820
55.682	0.971	0.000	0.029	1.000	1.001
57.818	1.000	0.000	0.000	1.000	1.000

QuickDASH: shortened version of the Disabilities of the Arm, Shoulder and Hand. *The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive ordered observed test values.

Supplementary table S2 PRWHE: ROC cut-off values for total score change after hand therapy treatment.

Positive if greater than or equal to*	Specificity	Sensitivity	1 – Specificity	1 – Sensitivity	Sum of squares (1 – Specificity and 1 – Sensitivity)
−29.000	0.000	1.000	1.000	0.000	1.000
−25.000	0.029	1.000	0.971	0.000	0.943
−18.500	0.057	1.000	0.943	0.000	0.889
−14.500	0.086	1.000	0.914	0.000	0.835
−10.750	0.114	1.000	0.886	0.000	0.785
−7.000	0.143	1.000	0.857	0.000	0.734
−6.000	0.200	1.000	0.800	0.000	0.640
−5.000	0.229	1.000	0.771	0.000	0.594
−3.750	0.257	1.000	0.743	0.000	0.552
−2.250	0.286	1.000	0.714	0.000	0.510
−0.750	0.343	1.000	0.657	0.000	0.432
0.500	0.371	1.000	0.629	0.000	0.396
1.500	0.371	0.952	0.629	0.048	0.398
3.500	0.400	0.952	0.600	0.048	0.362
6.250	0.429	0.952	0.571	0.048	0.328
7.750	0.486	0.952	0.514	0.048	0.267
8.750	0.514	0.952	0.486	0.048	0.239
9.750	0.543	0.952	0.457	0.048	0.211
10.250	0.600	0.952	0.400	0.048	0.162
11.250	0.600	0.905	0.400	0.095	0.169
12.250	0.600	0.810	0.400	0.190	0.196
13.250	0.600	0.762	0.400	0.238	0.217
14.250	0.629	0.714	0.371	0.286	0.219
15.250	0.629	0.667	0.371	0.333	0.249
16.250	0.657	0.667	0.343	0.333	0.229
17.250	0.743	0.619	0.257	0.381	0.211
19.250	0.771	0.619	0.229	0.381	0.198
20.750	0.800	0.619	0.200	0.381	0.185
21.250	0.829	0.619	0.171	0.381	0.174
22.500	0.857	0.571	0.143	0.429	0.204
23.750	0.886	0.524	0.114	0.476	0.240
25.750	0.886	0.476	0.114	0.524	0.288
27.750	0.914	0.476	0.086	0.524	0.282
28.250	0.914	0.429	0.086	0.571	0.333
28.750	0.943	0.333	0.057	0.667	0.448
32.250	0.943	0.286	0.057	0.714	0.513
35.750	0.971	0.286	0.029	0.714	0.511
41.500	0.971	0.190	0.029	0.810	0.657
48.500	0.971	0.143	0.029	0.857	0.735
51.250	0.971	0.095	0.029	0.905	0.820
55.000	0.971	0.048	0.029	0.952	0.907
58.875	0.971	0.000	0.029	1.000	1.001
61.250	1.000	0.000	0.000	1.000	1.000

PRWHE: Patient Rated Wrist/Hand Evaluation. *The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive ordered observed test values.

4

Cross-cultural adaptation and psychometric properties of the Dutch version of the Hand Function Sort in patients with complaints of hand and/or wrist

Annemiek Muskee
Redmar J. Berduszek
Rienk Dekker
Michiel F. Reneman
Corry K. van der Sluis

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Abstract

Background

Musculoskeletal complaints of arm, neck, and shoulder (CANS) can lead to loss of work productivity. To assess the functional consequences of impairments in work, patient-reported outcomes can be important. The Hand Function Sort (HFS) is a 62-item pictorial questionnaire that focuses on work task performance. The aims of this study were the cross-cultural adaptation of HFS into HFS-Dutch Language Version (HFS-DLV) (Part I) and determining construct validity, internal consistency, test-retest reliability, responsiveness and floor/ceiling effects of HFS-DLV (Part II).

Methods

I: Translation into Dutch using international guidelines. II: Construct validity was assessed with Spearman's correlation coefficients between the HFS-DLV and the Dutch version of the QuickDASH, PRWHE, PDI, RAND-36, NRS pain, and Work Ability Score. Internal consistency was assessed using Cronbach's α and reliability by a test-retest procedure. A global rating scale of change was used after 4–8 weeks of hand therapy to determine responsiveness.

Results

I: Forty patients were included, and no items were changed. II: 126 patients with hand, wrist, and/or forearm disorders classified as specific or non-specific CANS. Six predefined hypotheses (50%) were confirmed. Cronbach's α: 0.98. Test-retest reliability: ICC of 0.922. AUC of 0.752. There were no floor/ceiling effects.

Conclusions

I: Translation process into the HFS-DLV went according to plan. II: For construct validity, the presumed direction of correlations was correct, but less than 75% of hypotheses were confirmed. Internal consistency was high, suggesting redundancy. Reliability and responsiveness of the HFS-DLV were good. HFS-DLV can be used in research or clinical practice for Dutch patients with CANS, to evaluate self-reported functional work ability.

Background

Musculoskeletal complaints of arm, neck, and shoulder (CANS) not caused by acute trauma or systemic disease can lead to considerable disability and a substantial loss of productivity at work.[3,116–119] A broad range of 12-month prevalence of CANS can be found, from 2.3–41%.[4] In the working population, a 12-month prevalence of 22–40% was reported.[120]

To assess work abilities and to help interpret the functional consequences of impairments in work, patient-reported outcomes (PROs) can be important.[121] In rehabilitation medicine, PROs provide insights to guide decision-making in interventions and evaluate treatment effects.[26,122] Knowledge of a self-reported perception of ability can be an important indicator of functional status.[26]

PROs can be classified into different categories, including generic, disease-specific, or region-specific (i.e., focusing on a specific region, such as the upper extremity).[122,123] A region-specific measure can be used for patients with different disorders and is therefore more practical in daily use.[123] PROs are usually short questionnaires that can be administered before or after a clinical evaluation. Most PRO questionnaires are developed in English and should be translated and adapted to different languages and cultures because there can be relevant differences in disease terminology and general cultural differences.[124,125] Different PROs for complaints of the upper extremities are available, including the Patient-Rated Wrist/Hand Evaluation (PRWHE), the Disabilities of the Arm, Shoulder, and Hand outcome measure (DASH), and its shortened version, the QuickDASH.[21,22,126] These PROs focus on upper extremity function in daily life and symptoms, including pain. They include items that are related to the functional ability to work but do not address this directly.

The 62-item Hand Function Sort (HFS) was developed to quantify the physical ability to work and perform daily life activities.[26] The HFS is a self-reported, region-specific questionnaire that represents tasks across a range of physical demands and focuses on upper extremity performance in work tasks and other activities of daily living.[26] The HFS can be used for the quantification of work disability and for determining the ability to perform a particular job and its outcome can be used to guide functional capacity evaluation (FCE).[26] The HFS can be used for patients with CANS, as it has been shown that these complaints are frequently work-related.[116,118,119] The developers of the HFS found that the perception of functional ability can be a predictor of a return to work.[121] Since the HFS is pictorial, it can be used with a broad range of patients, including low literacy patients, an advantage most PROs do not have.

Before translated PROs can be used, a proper validation of the measurement instrument is necessary.[127] The HFS has been validated in English using construct validation in two approaches,[26] and recently the HFS was translated and validated into French.[128] The HFS has not yet been translated into Dutch. Therefore, the first aim of this study was the cross-cultural adaptation of the HFS into the HFS-Dutch Language Version (HFS-DLV). The second aim was to determine the psychometric properties of the HFS-DLV, including construct validity, internal consistency, test-retest reliability, responsiveness, and floor/ceiling effects.

Methods

Part 1: cross-cultural adaptation of the HFS-DLV

For the translation of the HFS, the guidelines of Beaton were followed.[125] Two native Dutch translators each wrote a translation from English into Dutch (T1 & T2). One of the translators was aware of the concepts being studied (informed), the other translator was not (uninformed). They both produced a written report, including comments and the rationale for their choices. These translations were synthesized into T-12 by the two translators and an observer, whereby consensus was reached on discrepancies. Two native English translators, who spoke Dutch fluently, made two back translations (BT1 & BT2) of the T-12 version into English. They were uninformed about the concepts of the study and had no medical background. An expert committee, consisting of two specialists in rehabilitation medicine (RJB & CKS), a methodologist, and the translators (forward and back translators), reviewed all the versions, and consensus was reached on discrepancies. This resulted in a prefinal version of the HFS-DLV. A total of 30–40 patients was recommended for testing this prefinal version.[125] Participants were included from the outpatient clinic of the department of rehabilitation medicine of a university hospital. All participants were receiving hand therapy and were asked to complete the prefinal version of the HFS-DLV after their therapy appointment. Inclusion criteria were: age 18 years or over and specific or non-specific complaints of the hand, wrist and/or forearm.[3] Patients with complaints caused by trauma were included, but only if the trauma was more than 3 months ago. Patients with complaints of stable osteoarthritis were also included. Patients with insufficient knowledge of the Dutch language or with other medical conditions causing considerable disability in functioning (e.g., neurological disorders or joint disease) were excluded. In the presence of a researcher (AM) the participants completed the prefinal version and gave comments on the comprehensibility of the items. These comments were reviewed by two specialists in rehabilitation medicine (RJB & CKS), a methodologist and a researcher (AM). In this consensus meeting the HFS-DLV was finalized. During the translation process contact with the original developers of the HFS was maintained.

Part 2: measurement properties of the HFS-DLV

Participants

Participants were included from the outpatient clinic of the department of rehabilitation medicine of a university hospital and from five locations of peripheral hand therapy practices in the northern part of the Netherlands. Inclusion criteria were: age 18 years or over and specific or non-specific complaints of the hand, wrist, and/or forearm.[3] CANS was defined as musculoskeletal complaints of arm, neck, and shoulder not caused by acute trauma or systemic disease.[3] We only included patients with complaints of the hand, wrist, and/or forearm, as we expected the most direct effects of these specific complaints on the hand function, as measured by the HFS. Exclusion criteria were identical to part 1.

Procedure

In this prospective observational study, participants completed the HFS-DLV and the Dutch version of the QuickDASH, PRWHE, Pain Disability Index (PDI), RAND-36, numeric pain rating scale (NRS pain), and Work Ability Score (WAS). Measurement properties were assessed using the definitions of the COSMIN group.[129]

If participants were included in the university hospital, the questionnaires were sent by mail. When included in a peripheral hand therapy practice, the participants had the option to complete the questionnaires directly after their therapy appointment or to complete the questionnaires at home and return to the researcher by mail. The second set of questionnaires was sent and returned by mail.

Questionnaires

We used the Dutch validated versions of all questionnaires, which were available for free. For the use of the Hand Function Sort, we had permission from the developer. The HFS-DLV is a 62-item pictorial questionnaire, wherein each item consists of a drawing of a task accompanied by a task description. Answers are given on a 5-point scale from able to unable (a "?" option is present for "I don't know"). An overall rating of perceived capacity (RPC) score can be calculated with ranges from 0 to 248, where a higher score indicates a better perceived capacity.

The HFS includes an internal reliability check: first, by checking three pairs of highly similar items for consistency (≥4 points difference between the similar items indicates an unreliable test) and second, by counting the total number of "?" answers (if ≥6 "?" answers are filled in, the test is marginally reliable). A questionnaire cannot be qualified as unreliable based on only too many "?", the difference between similar items should also be taken into account. Marginally reliable questionnaires will be included in the analysis; unreliable questionnaires will be excluded from the analysis.

All the items in the HFS are assigned to a five-level physical demand characteristics (PDC) system. This system can be used to categorize the demands of a given work position.[26,121] Items 1–16 of the HFS correspond to sedentary activities, items 17–34 to light activities, items 25–52 to medium activities and items 53–62 to heavy activities. An RPC score for each PDC level can be calculated. Minimum total RPC scores that would be necessary to function at a specific PDC level have been proposed: sedentary (100–136), light (154–190), medium (200–228), heavy (238–248), and very heavy. In this way, the HFS can be used to indicate a person's perception of capacity for different work demands.[121]

The QuickDASH is an 11-item questionnaire that measures symptoms and physical function involving disorders of the upper limb. It has a summative score on a 100-point scale, where a score of 100 indicates the most disability.[21] It has been shown to have good reliability, validity, and responsiveness in English.[21,130] Previous research shows that the QuickDASH performs comparably to the DASH,[21,130,131] but is preferable for conditions with functional limitations.[132] The DASH and QuickDASH have been translated into Dutch, and the DASH-Dutch Language Version has been validated.[133]

The Patient Rated Wrist Evaluation (PRWE),[22] was modified into the PRWHE (H: Hand).[89] It is a 15-item questionnaire designed to measure two modalities: wrist pain and disability (5 vs. 10 items). Both modalities are equally weighted, and the highest score is 100 (indicating the most pain and disability). The test-retest reliability is excellent, and validity and responsiveness are good.[22,89]

The PDI measures the extent to which chronic pain interferes with various life activities. An overall disability score is calculated by adding the scores of 7 items (categories of life activities), and ranges from 0 to 70 (a higher score indicates more disability).[134] The PDI is a valid measure for pain-related disability, with a modest to good test-retest reliability.[91,135]

The RAND-36 is a health-related quality of life survey that consists of 36 items that assess eight health concepts: physical functioning, social functioning, role limitations (physical problem), role limitations (emotional problem), mental health, vitality, pain, and general health perception.[136] The internal consistency of the RAND-36 is high and the construct validity satisfactory.[93] Most subscales appear to be strong, unidimensional, and reliable, except for the subscales general health perception and vitality. Therefore, the latter subscales have a lower reliability. Scores are calculated on a 100-point scale, where a higher score indicates a better quality of life.[93,137]

The NRS pain scale is a 11-point scale measuring pain intensity, ranging from 0 (no pain) to 10 (worst imaginable pain).[138]

The WAS is a single-item instrument, which measures the current work ability in relation to lifetime best.[139]

Construct validity

Construct validity is the degree to which the scores of the measurement are consistent with hypotheses.[86] Validity was determined by assessing construct validity because no gold standard was available. To determine construct validity, a total of 50 participants is required.[86]

Construct validity was assessed using correlation coefficients to determine the relationship between the HFS-DLV and the Dutch version of the QuickDASH, PRWHE, PDI, RAND-36, NRS pain, and WAS. The HFS-DLV focuses on upper extremity work task performance and disability; we therefore assumed a strong correlation of the HFS-DLV with the QuickDASH and PRWHE. With the PDI, RAND-36 (physical functioning), and the WAS, a moderate–strong correlation was assumed as these questionnaires assess (dis)ability in a similar matter as the HFS, but they do not focus on the upper extremities. Because the HFS does not focus on mental health and pain in particular, we assumed a weaker correlation with specific concepts of the RAND-36 and the NRS pain. Nine predefined hypotheses about the assumed correlation with other questionnaires were proposed (table 1).

Table 1 Assumed correlations of the HFS-DLV with other questionnaires.

Correlation*	Questionnaires
Strong–very strong	QuickDASH, PRWHE
Moderate–strong	PDI, RAND-36 (physical functioning), WAS
Weak–moderate	RAND-36 (social functioning, vitality), NRS pain
Weak	RAND-36 (mental health)

NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE Patient Rated Wrist/Hand Evaluation; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand outcome measure; WAS: Work Ability Score. *0.00–0.25 weak, 0.26–0.50 moderate, 0.51–0.75 strong, above 0.75 very strong.[100]

Furthermore, three predefined hypotheses for known groups validity were proposed, determined by a Mann-Whitney U test. Some of the tasks in the HFS-DLV have a higher PDC level and require strength, therefore, we assumed from a biological perspective that males would be able to do these tasks in an easier fashion and have a higher overall score as a result.[140] Second, it has been shown that younger age, better perceived general health, and higher beliefs of pain self-efficacy are associated with higher work ability and the continuance of work in patients with chronic non-specific musculoskeletal pain.[141] Therefore, we assumed that the employed population would experience less disability in work task performance and would score higher on the HFS as compared to unemployed persons. Third, it was proposed that when the dominant hand is affected, this will result, at least for some upper extremity conditions, in more functional disability.[142] Thus, we assumed a lower score on the HFS-DLV when the dominant side was affected, as also has been shown for the English HFS and the QuickDASH.[26,143] The HFS-DLV was considered valid when 75% of the hypotheses were met.

Internal consistency

Internal consistency is the degree of the interrelatedness among the items and was determined using Cronbach's α, where a value between 0.70 and 0.90 was considered acceptable.[86] To determine the internal consistency, a total of 434 participants is recommended by the COSMIN group (7 times the number of items; i.e., 7 × 62 items).[86]

Test-retest reliability

Reliability is the degree to which the measurement is free from measurement error. To assess test-retest reliability a total of 50 participants is recommended.[86] Consecutive participants included in the university hospital were asked to complete the HFS after 1–3 weeks for a second time, until the desired number of 50 participants was reached. This interval was assumed long enough to prevent recall and allow administration of questionnaires by mail, yet short enough to ensure no clinical change occurred. A test-retest procedure was used to calculate the intraclass correlation coefficient (ICC) for agreement (two-way mixed effects model) and limits of agreement (LoA) using the Bland-Altman method.[101] ICC was considered acceptable above 0.70 and good above 0.80.[86]

Responsiveness

Responsiveness is the ability to detect change over time in the construct to be measured. To assess responsiveness, a total of 50 participants is recommended.[86] Consecutive participants included in the peripheral hand therapy practices were asked to complete the questionnaire for a second time after 4–8 weeks of hand therapy provided by a certified hand therapist, until the desired number of 50 participants was reached. A criterion approach (anchor-based method) was used with a global rating scale (GRS) as a gold standard. At follow-up, participants were asked a question to indicate their overall perceived change on a 7-point scale, ranging from 1 (much better) to 7 (much worse). For the analysis, a score of 1 or 2 was considered an improvement, a score of 3, 4, or 5 was considered stable, and a score of 6 or 7 was considered as a decline in complaints.[97] The area under the ROC curve (AUC) was assessed, and an AUC of at least 0.70 was considered appropriate;[86] a minimal important change (MIC) was determined by a ROC cut-off point associated with optimal sensitivity and specificity.[102]

The standard error of measurement (SEM) was calculated by performing an ANOVA and taking the square root of the within groups mean square. The SEM was used to calculate the smallest detectable change (SDC) using the formula SDC = 1.96 × √2 × SEM. The SDC should be smaller than the MIC.[86]

Floor and ceiling effects

Floor and ceiling effects can occur when a high proportion of the total population has a score at the lower or upper end of the scale.[86] These were considered to be present if more than 15% of participants reached the maximum or minimum score.[86]

Statistical analysis

For the statistical analysis, SPSS (IBM SPSS Statistics for Windows 2013 v22.0, Armonk, NY: IBM Corp) was used. A $P < 0.05$ was considered to be of statistical significance. The distribution of the data was assessed by graphical methods (Q-Q plot) to determine the use of parametric or nonparametric tests.

Results

Part 1: cross-cultural adaptation of the HFS-DLV

During the translation process, problems with translating specific words emerged. The questionnaire was named HFS-DLV, since an adequate translation for HFS was not available. The main difficulty was finding the proper Dutch names for the tools and implements used (for example, T-handle wrench). Weights and distances had to be adjusted from imperial to metric system units (e.g., kilograms instead of pounds). Consensus for the T-12 was reached easily. The expert committee thoroughly examined and debated all the items before completing the prefinal version. A total of 40 participants completed the prefinal version of the HFS-DLV between April and August 2015 (table 2). During administration of the prefinal version, comments for 35 items were registered. Most concerned the activity itself and not the language used. Item 54 "dig a hole for a fence post with a post-hole digger", was commented on the most. For this activity, a different tool is used in the Netherlands; however, this tool does not resemble the instrument in the drawing. General comments included the items being too masculine (6 times) and that it was unclear which hand to use (11 times). Participants found that the pictures contributed to an understanding of the items. After discussion, we did not change any of the items nor the pictures, mainly because the alternatives provided by participants were not considered better and had already been discussed in the consensus meeting in which the prefinal version was completed.

Part 2: measurement properties of the HFS-DLV

Participants

The HFS was administered to 126 patients between December 2015 and August 2018 (table 2). Patients included from the university hospital and peripheral hand therapy practices are shown separately. These two samples are similar based on gender, age, employment status and affected side. The diagnosis did differ between these samples (more non-specific CANS in university hospital and more specific CANS in peripheral hand therapy practices).

Table 2 Participant characteristics of part 1: cross-cultural adaptation of the HFS-DLV and part 2: measurement properties.

	Part 1 (n = 40)	Part 2 (n = 126)		
UE-FCE tests		**Total (n = 126)**	**UH (n = 57)**	**PHTP (n = 69)**
Gender, n (%)				
Male	20 (50%)	46 (37%)	20 (35%)	26 (38%)
Female	20 (50%)	80 (63%)	37 (65%)	43 (62%)
Age (years), median (IQR)	53 (41–63)	48 (32–60)	47 (32–55)	52 (35–66)
Diagnosis, n (%)				
Specific CANS	9 (23%)	69 (55%)	21 (37%)	48 (70%)
Non-specific CANS	6 (15%)	57 (45%)	36 (63%)	21 (30%)
Post-traumatic complaints	19 (48%)	N/A	N/A	N/A
Osteoarthritis	6 (15%)	N/A	N/A	N/A
Dominant side affected, n (%)	26 (65%)	104 (83%)	48 (84%)	56 (81%)
Employed, n (%)	23 (58%)	73 (58%)	37 (65%)	36 (52%)
Questionnaire scores, median (IQR)				
HFS-DLV	N/A	145 (92–198)	151 (110–198)	141 (86–198)
QuickDASH	N/A	34 (20–50)	32 (19–50)	34 (20–51)
PRWHE	N/A	49 (25–68)	47 (23–67)	50 (29–72)

CANS: complaints of arm, neck, and shoulder; HFS-DLV: Hand Function Sort-Dutch Language Version; IQR: interquartile range; n: absolute number; N/A Not applicable; PHTP peripheral hand therapy practices; PRWHE Patient Rated Wrist/Hand Evaluation; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand outcome measure; UH university hospital.

Figure 1 shows the inclusion procedure for the different measurement properties and the total HFS-DLV questionnaires included. The internal reliability check of the HFS-DLV was used for determining if a questionnaire was reliable, marginal or unreliable (see Methods). Questionnaires completed by participants included for internal consistency (n = 119) were also used for construct validity (n = 52), test-retest reliability (n = 44), and responsiveness (n = 52).

Construct validity

In total, 6 out of 12 (50%) predefined hypotheses were accepted (table 3). The predefined hypotheses for the correlations between HFS-DLV and NRS pain, RAND-36 vitality, and RAND-36 mental health were not accepted. For all three, a slightly higher correlation then predicted was found. Spearman’s correlation coefficient was used since the HFS-DLV and most of the other six questionnaires were not normally distributed.

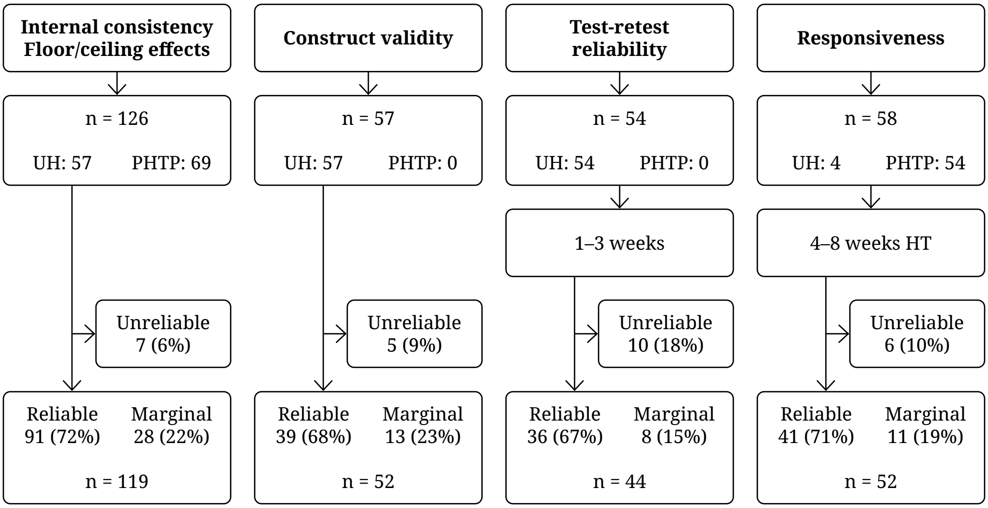

Figure 1 Flowchart inclusion procedure.

HT: hand therapy; PHTP: peripheral hand therapy practices; UH: university hospital.

The three predefined hypotheses for known groups validity were not accepted because differences were not statistically significant. The median scores of the HFS-DLV were higher in the predicted groups, so there was a trend in the right direction (table 3).

Internal consistency

Cronbach's α for internal consistency was 0.98 (n = 119).

Test-retest reliability

The median interval between the two completed questionnaires was 15 days (IQR 13–19). The ICC for test-retest reliability (n = 44) was 0.922 (95% CI: 0.861–0.956). The t-test of the difference between the first and second measurement of the HFS-DLV was not significant (*P* = 0.199). Using the Bland-Altman method, the mean difference between test and retest was 4.48 with 95% upper and lower limits of agreement of −40.18 and 49.14 (figure 2).

Responsiveness

The median interval between the two completed questionnaires was 41 days (IQR 35–56). The AUC was 0.752 (n = 52), with a ROC cut-off point and MIC of 37/248 (sensitivity 0.619, specificity 0.903). The SEM was 16.2 and the SDC was 45/248.

Floor and ceiling effects

No participants (0%) had the lowest possible score, and only one participant (1%) had the highest possible score of 248. No floor or ceiling effects were found.

Table 3 Spearman's correlation coefficient (ρ) for construct validity and known groups validity (n = 52).

	Spearman's correlation coefficient (ρ) HFS-DLV	95% CI	*P*-value	Predefined hypothesis	Hypothesis accepted
QuickDASH	−0.73	−0.57 to −0.84	<0.001	0.51–1.00	yes
PRWHE	−0.62	−0.42 to −0.77	<0.001	0.51–1.00	yes
PDI	−0.68	−0.50 to −0.80	<0.001	0.26–0.75	yes
WAS	0.61	0.40 to 0.76	<0.001	0.26–0.75	yes
RAND-36 physical functioning	0.58	0.37 to 0.74	<0.001	0.26–0.75	yes
RAND-36 vitality	0.57	0.35 to 0.73	<0.001	0.00–0.50	no
NRS pain	−0.52	−0.29 to −0.70	<0.001	0.00–0.50	no
RAND-36 social functioning	0.44	0.19 to 0.64	0.001	0.00–0.50	yes
RAND-36 mental health	0.43	0.17 to 0.63	0.002	0.00–0.25	no
HFS-DLV: median score (IQR)			*P*-value	Predefined hypothesis	Hypothesis accepted
Male (n = 19) 182 (110–207)	Female (n = 33) 151 (111–195)		0.38	Male > Female	no
Employed (n = 35) 171 (136–200)	Unemployed (n = 17) 129 (63–185)		0.077	Employed > Unemployed	no
Non-dominant hand affected (n = 9) 166 (109–206)	Dominant hand affected (n = 43) 151 (126–208)		0.521	Non-dominant side affected > Dominant side affected	no

95% CI: 95% confidence interval; HFS-DLV: Hand Function Sort-Dutch Language Version; IQR: interquartile range; NRS pain: numeric pain rating scale; PDI Pain Disability Index; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand outcome measure; WAS: Work Ability Score.

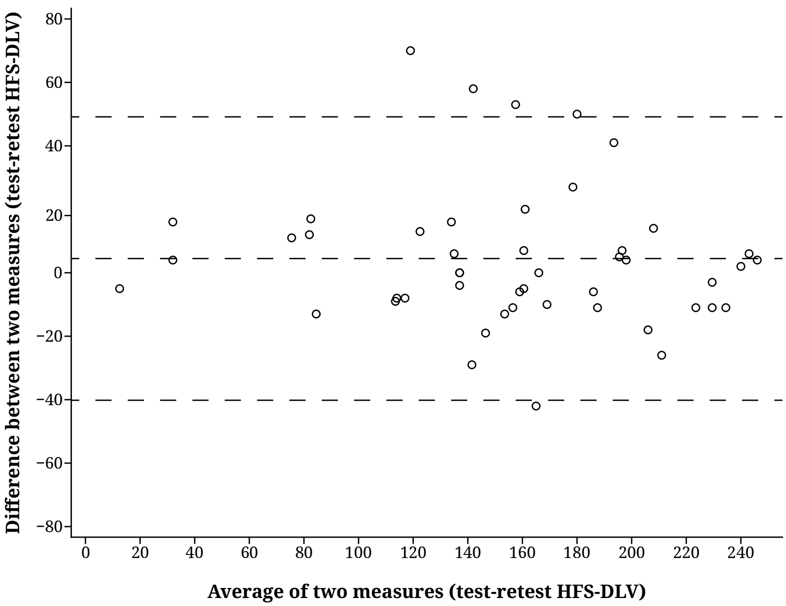

Figure 2 Bland-Altman plot. The middle dashed line represents the mean difference between the test and retest of the HFS-DLV. The upper and lower dashed lines represent the limits of agreement.

HFS-DLV: Hand Function Sort-Dutch Language Version.

Discussion

The cross-cultural translation and adaptation of the Hand Function Sort for Dutch-speaking patients was successfully performed in a thorough manner. As such, the HFS-DLV can be used for research purposes and in clinical practice. The psychometric properties of the HFS-DLS appeared to be good, although the construct validity needs further study.

Part 1: cross-cultural adaptation of the HFS-DLV

A careful procedure, such as the 5-step translation and adaptation process as applied in this study, should be followed. In testing the prefinal version of the HFS-DLV, 98% of the participants made comments about the items and the comprehensibility in general. In contrast, Konzelmann et al. stated that only 32% of participants made comments about the prefinal version of the French HFS.[128] Having a researcher present in our setting might explain this difference. Therefore, for future translations of questionnaires, the presence of a researcher orally receiving comments should be considered.

Participants frequently commented that it was unclear which hand to use for the described tasks. The developers of the HFS were consulted regarding this comment. They explained that the self-selection of the participants to either demonstrate their inability to perform the task with the injured hand or their ability to perform the task with their residual capacity is an important psychological variable. This cannot be identified if the participants were instructed which hand to use. Thus, allowing the participants to self-select gives the researchers the opportunity to consider whether and to what degree the participants may be magnifying their symptoms. We recommend adding an explanation to the examiner's manual about this concept of self-selection and a response to questions of participants regarding the usage of the injured or uninjured hand for the described tasks.

Another frequent comment was that several items were too masculine. This was also described by Konzelmann et al., who stated that the tasks depicted in items 53–62 are heavy activities more specific to men.[128] Overall, in the development of the HFS, the authors tried to balance gender.[26] Adjusting the HFS to make it less masculine would indicate more rigorous changes in the tasks and therefore the construct.

The HFS is a questionnaire developed in the early 1990s, using pictures from that era. In the past 25 years, some activities and tools have changed, for example, the use of a rotary opener and cash money is less common. The pictures should be updated to match the current time frame.

For testing the prefinal version of the HFS-DLV, part of the participants had a diagnosis not classified as specific or non-specific CANS. We assumed this would not affect the comments on the comprehensibility of the items. To prevent bias, none of the participants contributing to part 1 of the study were involved in the analysis for the psychometric properties of the final HFS-DLV, although we did not change any of the items.

Part 2: measurement properties of the HFS-DLV

In total, 6 out of 12 (50%) predefined hypotheses were accepted, which was below the goal of 75%. The highest correlation was found between the HFS-DLV and the QuickDASH, which is in line with the high correlation between HFS-F and the DASH.[128] The HFS-DLV was also strongly correlated to the PRWHE, which might be explained by the finding that the PRWHE and DASH strongly correlate due to the assessment of comparable constructs.[83]

Our hypotheses for the correlations between HFS-DLV and NRS pain, RAND-36 vitality, and RAND-36 mental health could not be accepted. For all three, a slightly higher correlation then predicted was found.

For the NRS pain, a weak to moderate correlation was predicted, but a strong correlation was found. The predefined hypothesis was based on previous literature and a recent study who found a weak correlation between the HFS and VAS pain (coefficient of −0.247).[128] The average score on the NRS pain was similar with 4.6 vs. 4.9 to Konzelmann.[128] On the other hand, the pathology underlying the pain was different, in the study of Konzelmann; more than half of the participants had shoulder pathology, and only one third had hand/wrist pathology.[128] For all items in the HFS, an individual needs the functionality of the hands and wrists; only a small portion of items require intensive use of the shoulders. This might explain why patients with pain from hand/wrist disorders show a stronger correlation with the HFS.

Our assumed correlation for the HFS-DLV with the RAND-36 vitality was weak–moderate, but we found a strong correlation, although this finding was marginally higher than expected. It might be that participants who experience more fatigue and who have less energy, experience more troubles performing the tasks in the HFS-DLV than predicted. For the RAND-36 mental health, a weak correlation was assumed, but a moderate correlation was found. Based on the biopsychosocial model,[144] it can be argued that not only hand/wrist function but also psychological well-being plays an important role for a person when determining his or her ability to perform a specific task. Konzelmann et al. found a weak correlation with the SF-36 mental component summary,[128] however their sample consisted almost completely of men (84%) and this might play a role in the observed difference.

All three hypotheses for known-groups validity were correct but not of statistically significant difference, although the employment state showed a trend toward significance. For the employment state, only participants with a paid job were included. Participants with voluntary employment and students were categorized as unemployed. This could have affected the outcome, since these participants potentially could be able to perform a paid job. Nearly half of the participants had complaints of both hands, which meant the dominant side was in almost all cases affected. It was, however, not known whether one hand was more affected than the other. Considering the relatively small number of participants, a significant difference might be hard to determine.

Since there was no gold standard to determine the validity of the HFS-DLV, using predefined hypotheses for construct validity seems eligible. Possibly the hypotheses were too strict, since the three hypotheses that were incorrect only slightly differed from the predicted correlations. Alternatively, the validity could be assessed by comparing the HFS-DLV to more objective manners to determine work capacity, such as the FCE testing, as has also been performed previously for the English version of the HFS by Matheson et al.[26]

The internal consistency of the HFS-DLV appeared to be higher than deemed acceptable. Although the recommended total of 434 participants was not reached, with 119 participants an adequate interpretation could be made. A remarkable finding was the very high Cronbach's alpha (0.98), which tends to be higher when a questionnaire has more items, suggesting redundancy. A similarly high internal consistency has been described before.[128] Since the HFS has 62 items, redundancy might indeed be present. A high number of items can lead to less motivation toward the end of the questionnaire, especially when all the questions have the same outline and instructions. Furthermore, for a quick evaluation of a person's functioning in clinical practice, less items are preferable. In further research, the assumed redundancy of the HFS-DLV should be investigated, for example, using factor analysis.

The test-retest reliability determined by the ICC was good and appeared to be comparable with previous research.[128] The Bland-Altman method showed a centered distribution, with limits of agreement slightly higher than those found by Konzelmann et al., who used a smaller interval (48 h instead of up to 3 weeks) between the two administrations of the HFS.[128] However, even though we did not actually assess whether or not change in the clinical situation occurred, we did not expect these patients to improve or deteriorate considerably within this interval because of their generally long-standing complaints and absence of treatment during this interval. Since it has a low degree of measurement error, this implies that the HFS-DLV can be used for repeated measures in clinical practice. We determined the measurement properties in a group of patients with CANS from an outpatient hospital and from peripheral hand therapy practices. The test-retest reliability of the original HFS was tested in 48 patients with various upper extremity impairments, including hand fractures, carpal tunnel syndrome, and lacerations.[26] Konzelmann et al. investigated a population of hospitalized patients admitted for rehabilitation with upper limb complaints.[128] In all these populations with various upper extremity diseases, the HFS was found to have reasonable to good test-retest reliability.

Responsiveness determined by the AUC was good, although the SDC and MIC were quite high (45/248 and 37/248, respectively). Our SEM of 16.2 is similar to that found by Benhissen et al., but the MIC reported by them is lower (26/248).[145] This might be explained by a different method to determine the ROC cut-off point or actual differences in MIC, e.g., due to differences in patient characteristics. Although the HFS is able to discriminate between subjects who have and who have not improved, an improvement in score between 37 and 45 points should be interpreted with caution.[86] A good responsiveness is clinically important to be able to use the HFS-DLV in daily practice or research to evaluate treatment effects, an important objective of PROs in general.

We observed that some participants filled in more than six question marks on the HFS-DLV, indicating that the questionnaires were marginally reliable. A question mark gives a similar score as if a person is unable to do the task. This could have given an underestimation of the participants' abilities. Answering with a question mark was not observed in testing the prefinal version of the HFS-DLV. It seemed to make a difference if a researcher was present or not. In the additional comments of the HFS-DLV, participants explained that they chose a question mark when they had never done the tasks stated in the questionnaire. In the current HFS participant instructions, it is not stated what a participant should fill in when they have never done the task before. The general procedure for administration of the HFS states that under guidance of an evaluator, the participant should complete the first two items of the questionnaire. If the evaluator is assured that the participant understands the instructions adequately, the participant can complete the remaining items independently. However, the first two items are frequently encountered tasks with which all participants are familiar. A statement that participants should make a good guess in case of tasks they never performed before could be a valuable addition to the instructions. It would be more practical and less time consuming if a participant could complete the HFS-DLV without the presence of an evaluator. Another possibility would be to exclude the option of the question mark, which would force people to make a choice, but this could lead to incomplete questionnaires. Unreliable questionnaires (≥4 points difference between the similar items of internal check) were more observed for the test-retest reliability and responsiveness analyses. This can be explained by the fact that participants had to complete the HFS-DLV twice. This observation is also an argument to try to reduce the number of items on the HFS.

The strength of this study was the adherence to COSMIN recommendations to assess measurement properties, in particular the use of a wide variety of 6 questionnaires to determine construct validity.

The limitations of this study include the high number of marginally reliable questionnaires, which could possibly be reduced if a researcher would be present at completion of the questionnaires. We investigated patients with specific and non-specific CANS in our study, so the presented results could possibly be less applicable to patients with hand/wrist pathology caused by trauma and/or systemic disease. Furthermore, the various measurement properties were not all assessed in the same sample, but generally in either a UH or PHTP group. While the majority of patient characteristics was similar, the distribution of diagnoses differed, which might limit generalization of the results. If that were the case this would probably hold true more for construct validity and responsiveness than for internal consistency and test-retest reliability. Further research might focus on determining or confirming the measurement properties of the HFS-DLV in other groups of patients.

Conclusions

The 5-step translation process and adaptation of the HFS into the HFS-DLV went according to plan, although some items were difficult to translate into Dutch. For the construct validity of the HFS-DLV, the presumed direction of the correlations was correct, but less than 75% of the hypotheses were confirmed. Internal consistency was high, suggesting redundancy. The test-retest reliability and responsiveness of the HFS-DLV were good. No floor or ceiling effects were found. Therefore, the HFS-DLV can be used in research and clinical practice for Dutch patients with CANS, e.g., to evaluate self-reported functional work ability.

Cross-cultural translation and adaptation of the HFS can also be useful for other languages than English, French, or Dutch, but we recommend investigating item reduction and updating the items to the current time frame before putting more effort into additional translations.

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A shortened upper extremity functional capacity evaluation for patients with complaints of hand, wrist, forearm, and elbow: composition and assessment of construct validity and test-retest reliability

Redmar J. Berduszek
Rienk Dekker
Corry K. van der Sluis
Michiel F. Reneman

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Abstract

Purpose

Upper extremity functional capacity evaluation (UE-FCE) contains tests covering aspects of upper extremity functioning. UE-FCE tests usually consist of multiple repeated trials. Shortened UE-FCEs with less trials per test have been proposed but never tested in patients. The aims of this study were (1) to compose a shortened UE-FCE (fewer trials per test) and (2) to assess construct validity and test-retest reliability when applied in patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm, and elbow.

Methods

Participants performed a UE-FCE, with original full-length tests, twice (1 to 3 weeks apart). A shortened UE-FCE, with fewer trials per test, was composed based on the agreement (ICC ≥0.90) between shortened and original UE-FCE tests. Consequently, construct validity and test-retest reliability of the shortened UE-FCE tests were assessed.

Results

UE-FCEs were performed by 45 participants. The proposed shortened UE-FCE included one-trial tests for hand grip and finger strength (instead of three-trial tests), two-trial tests for fingertip and hand/forearm dexterity (instead of three-trial and four-trial tests, respectively). Overhead lifting and working tests were already one-trial tests and remain unchanged. Construct validity was demonstrated for hand grip strength of the left hand, overhead lifting, and overhead working, but not for hand grip strength of the right hand, finger strength, fingertip dexterity and hand and forearm dexterity. Test-retest reliability was above 0.70 for all tests, except for fingertip dexterity of the dominant hand (0.59).

Conclusion

The shortened UE-FCE with fewer trials per test agreed strongly with the original UE-FCE. Using the shortened UE-FCE could save 18 min. Construct validity differed per UE-FCE test. Test-retest reliability was sufficient for all UE-FCE tests except fingertip dexterity of the dominant hand.

Introduction

Upper extremity musculoskeletal disorders, such as complaints of the arm, neck, and shoulders, are frequently occurring and often have a chronic course.[7] Limitations in daily life and sick leave from work have been reported by over 30% of patients with complaints of the arm, neck, and shoulders.[6,146] More functional limitations are associated with a poorer prognosis.[147] Functional capacity evaluation (FCE) has been considered relevant in the assessment of functioning of patients with hand disorders.[11,18,148]

FCE is a performance-based measurement to determine what a person can do safely, while considering that person's body functions and structures, environmental factors, personal factors, and health status.[27] Several FCE protocols, consisting of a different number and type of tests, have been described.[149] Selection of tests depends on the aim of the FCE, considering region or pathology (e.g., lower back, upper extremities, whiplash associated disorder) and/or job requirements (e.g., nurses, household waste collectors).[150–154] An upper extremity FCE (UE-FCE) consists of tests which cover different aspects of upper extremity functioning, such as joint mobility, muscle power, muscle endurance, and coordination of voluntary movements.[11,15,28]

Several UE-FCE tests consist of multiple repeated trials, e.g., grip strength and dexterity tests. In healthy subjects, a shorter UE-FCE (with one or two repetitions per test) has been found to be as valid as the original UE-FCE (with three to four repetitions per test).[29] A shortened UE-FCE is more time-efficient (net time reduction of 33% to 93% per UE-FCE test) and reduces burden on both patient and observer.[29] However, the measurement properties of UE-FCEs with fewer repetitions per test have not yet been assessed in patients.

The aims of this study were (1) to compose a shortened UE-FCE (with fewer repeated trials per test) and (2) to assess construct validity and test-retest reliability of shortened UE-FCE tests when applied in patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm, and elbow.

Methods

Study design

The design of this observational study was based on the recommendations of the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) initiative.[86,87] This study was approved by the Medical Ethical Committee of the University Medical Center Groningen (METc 2015/115) and the protocol has been registered in the Overview of Medical Research in the Netherlands (OMON) register (NL-OMON41867). All participants gave written informed consent.

Study sample

Participants were recruited from the outpatient clinic of the department of rehabilitation medicine of a secondary and tertiary care university hospital, between November 2015 and March 2020, using convenience sampling. Inclusion and data collection was terminated prematurely because appointments had to be canceled due to restrictions related to the COVID-19 pandemic. The intended sample size was based on COSMIN recommendations: at least 50 subjects to assess construct validity and reliability.[86]

Participants were eligible if they were 18 years or older and had musculoskeletal complaints of their hand, wrist, forearm, and/or elbow, which were not caused by acute trauma or by any systemic disease. These complaints were classified as specific or non-specific complaints of the arm, neck, and shoulders, according to the classification model for complaints of the arm, neck, and shoulders.[3] From a safety perspective, participants had to meet the criteria of the Physical Activity Readiness Questionnaire (PAR-Q). Because some FCE tasks are physically demanding, the PAR-Q was used to screen for possible risks of physical activity, including cardiovascular and musculoskeletal problems.[155] If PAR-Q question 5 ('Do you have a bone or joint problem that could be made worse by a change in your physical activity') was solely answered 'yes' because of those complaints of hand, wrist, and/or forearm for which the participant visited the outpatient clinic, we considered the criteria of the PAR-Q were still being met. Exclusion criteria were insufficient understanding of the Dutch language to fill out questionnaires and the presence of concomitant medical conditions causing considerate disability, such as neurological disorders (e.g., stroke, traumatic peripheral nerve damage).

Procedure

Measurements were taken during two visits, one to three weeks apart. Questionnaires were filled out prior to each visit. During each visit, a UE-FCE with original full-length tests was administered (figure 1). The shortened UE-FCE tests were not administered separately, but their scores were derived from the original UE-FCE test scores. UE-FCEs were administered by one of two FCE-trained certified hand therapists. Both UE-FCEs of an individual participant were observed by the same therapist. During the second visit, therapist and participant were blinded for the results of the first visit. Participants were asked to perform the UE-FCE tests to their maximum ability. Participants were informed that a pain response (increase of already existing complaints or another pain response) could be expected as a normal reaction of the musculoskeletal system to intensive exercise.[156]

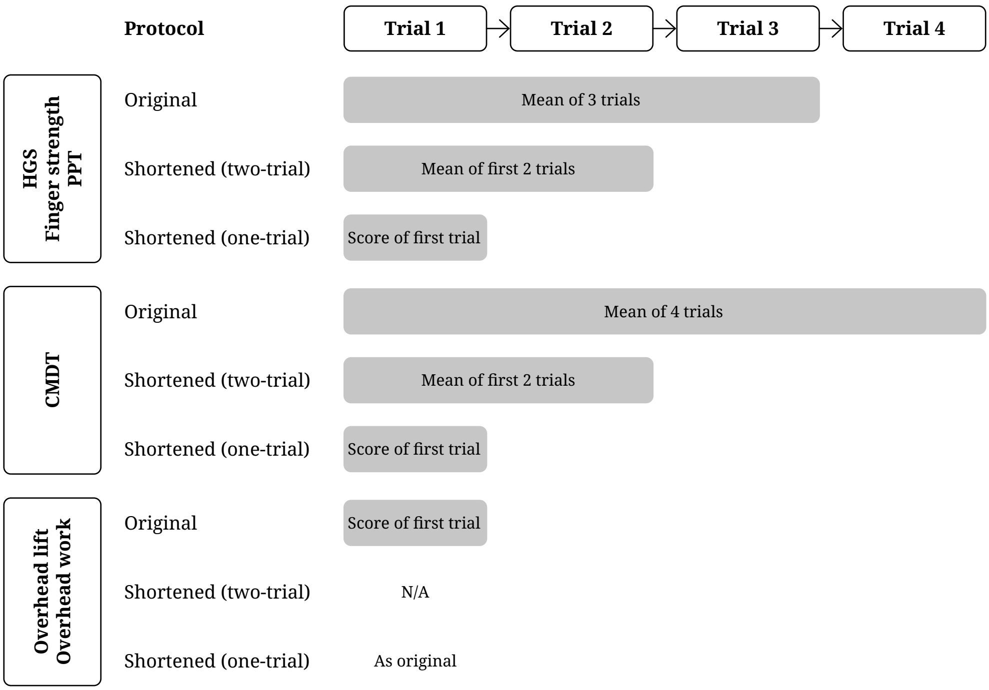

Figure 1 Original and shortened UE-FCE protocols.

CMDT: Complete Minnesota Dexterity Test; HGS: hand grip strength; N/A: not applicable; PPT: Purdue Pegboard Test.

Measurements

Demographic information (e.g., level of education, current work status) and patient characteristics (e.g., diagnosis, handedness (dominant hand)) were collected through questionnaires or retrieved from the medical record.

Primary measures: UE-FCE tests

The UE-FCE consisted of six different tests assessing arm and hand function: hand grip strength, finger strength, fingertip dexterity, hand and forearm dexterity, overhead lifting, and overhead working.[28]

Hand grip strength (hand dynamometer)

Hand grip strength (kgf) was measured using a hand dynamometer (Biometrics E-Link). The subject was seated with the shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, forearm and wrist in neutral position. Grip strength of both hands was assessed in five dynamometer handle positions (position 1–5).

Finger strength: tip, key and palmar pinch strength (pinch grip dynamometer)

Finger strength (kgf) was measured using a pinch dynamometer (Biometrics E-Link). The subject was seated with the shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, forearm and wrist in neutral position. Finger strength of both hands was assessed in three pinch positions: index fingertip on the thumb tip without facilitation of the middle finger (tip pinch), both index and middle fingertips on the thumb tip (palmar pinch) and thumb pad above the radial side of the index finger (key pinch).

Fingertip dexterity (Purdue Pegboard Test)

Fingertip dexterity was assessed using the Purdue Pegboard Test (PPT). The subject was seated in front of a table with the pegboard on it, placing pins as fast as possible in a 30 second trial. Fingertip dexterity was assessed for both hands. Subjects were given a short practice trial before performing the PPT, to get accustomed to handling the pins and test procedure.

Hand and forearm dexterity (Complete Minnesota Dexterity Test)

Hand and forearm dexterity was assessed using the Complete Minnesota Dexterity Test (CMDT). The subject was seated in front of a table with the test board on it, displacing 59 blocks in a predetermined way as fast as possible. Hand and forearm dexterity was assessed for both hands. Subjects were given a short practice trial before performing the CMDT, to get accustomed to handling the blocks and test procedure.

Overhead lifting

To assess overhead lifting, the subject had to lift a plastic receptacle from a table to a shelf at crown height and back, repeating this action five times within 90 seconds while standing. Using weights of 1 kg, 2 kg, and 4 kg, the weight was increased four to five times until the maximum weight was reached. Starting weight, weight increments, and maximum performance were assessed by the test administrator.

Overhead working

To assess overhead working, the subject was standing with hands at crown height, uninterrupted, manipulating nuts and bolts on an aluminum plate with 20 holes for as long as possible. The subject wore cuff weights of 1 kg each around the wrists. The duration for which this position was maintained was measured in seconds.

Secondary measures

The shortened version of the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) is an 11-item questionnaire measuring physical function and symptoms in persons with musculoskeletal disorders of the upper limb. The total score ranges from 0 to 100, a higher score indicating more pain and disability. Adequate measurement properties have been demonstrated in diverse upper extremity disorders, including those of hand and wrist.[23,81,157]

The Patient Rated Wrist/Hand Evaluation (PRWHE) is a 15-item questionnaire measuring pain and disability of the wrist and hand. It consists of two subscales (pain and function) which contribute to the total score equally. The total score ranges from 0 to 100, a higher score indicating more pain and disability. Its measurement properties have been demonstrated to be generally adequate.[24,157]

The Hand Function Sort (HFS) is a 62-item pictorial questionnaire developed to quantify the self-reported physical capacity to perform tasks across a range of physical demands, focusing on upper extremity performance in work tasks and other activities of daily living. An overall rating of perceived capacity score can be calculated with ranges from 0 to 248, a higher score indicating a better capacity. Its measurement properties have been demonstrated to be adequate in patients with complaints of hand and wrist.[158]

The Pain Disability Index (PDI) is a 7-item questionnaire measuring the impact of pain on the ability to perform daily activities. The total score ranges from 0 to 70, a higher score indicating greater disability due to pain. Its measurement properties have been demonstrated to be adequate in patients with different types of musculoskeletal pain.[91]

The numeric pain rating scale (NRS pain) is a valid and reliable single item scale to assess pain intensity during the past week. It is scored on an 11-point Likert scale ranging from 0 (no pain) to 10 (worst pain imaginable).[92]

The RAND 36-item Health Survey (RAND-36) is a valid and reliable questionnaire about physical, mental, and social health and used to measure health-related quality of life. It consists of eight subscales. While the complete RAND-36 was filled out, only the subscales physical functioning, social functioning, vitality and mental health were analyzed in this study. Subscale scores are calculated using an algorithm and range from 0 to 100, a higher score indicating a better health status.[93,136]

Data analyses

Statistical analyses were performed using IBM SPSS Statistics 28. Descriptive statistics were used to describe patient characteristics. Statistical significance was set at $P < 0.05$.

Part 1: Composing a shortened UE-FCE

Measurements collected during the first visit were used to evaluate the shortened UE-FCE. The shortened UE-FCE was not tested separately but derived from the data of the original UE-FCE: the one-trial protocol was based on the first trial of the original protocol and the two-trial protocol was based on the mean of the first two trials of the original protocol (figure 1).[29] Agreement between the original and shortened protocols was determined using intraclass correlation coefficients (ICC) for absolute agreement (one-way random effects model). An ICC ≥0.90 (indicating excellent agreement) was chosen to reflect sufficient agreement between the original (criterion) and shortened protocols. The final shortened UE-FCE consisted of UE-FCE tests with the least possible number of repetitions per test. Subsequently, measurement properties of this shortened UE-FCE were evaluated.

Part 2: Measurement properties of the shortened UE-FCE

The scores of the shortened UE-FCE tests were calculated based on the first (number of) attempt(s) of the original full-length UE-FCE tests for both visits (figure 1). Measurements collected during the first visit were used to assess construct validity, while measurements from both the first and second visits were used to assess test-retest reliability.

Construct validity

The construct validity of the tests of the shortened UE-FCE was evaluated using predefined hypotheses, based on the concepts being measured.

A total of 11 hypotheses were formulated: nine hypotheses about the relationship with questionnaires assessing hand function, pain and general health and wellbeing, and two hypotheses about differences in performance between men and women and between the symptomatic and asymptomatic side (known-groups validity). The first nine hypotheses were identical for all UE-FCE tests. The latter two hypotheses differed per test group: grip strength tests, dexterity tests and overhead lifting and working.

Strong to moderate correlations were expected with QuickDASH, PRWHE, and HFS, because these questionnaires directly assess self-reported upper extremity function. Moderate correlations were expected with PDI and RAND-36 physical functioning subscale, because these assess broader aspects of daily activities, not primarily influenced by upper extremity complaints. Moderate to weak correlations were expected with RAND-36 social functioning subscale and NRS pain, because an interaction with hand function was presumed to be present but not explaining all. Weak correlations were expected with RAND-36 subscales for vitality and mental health, because these assess well-being aspects indirectly related to functional capacity.

Regarding sex differences, men were expected to perform better in hand grip tests, overhead working and lifting, due to generally higher muscle mass and strength. No differences between men and women were expected in dexterity tests, as these are less dependent on muscle strength and more on fine motor skills. Regarding differences between the symptomatic and asymptomatic side (in unilaterally affected patients), better performance was expected with the asymptomatic hand compared to the symptomatic hand, based on the assumption that the functional capacity of the affected hand is diminished.

Spearman's rank correlation coefficients (ρ) were calculated to assess associations with other measurements. Correlation coefficients were interpreted as follows: 0.00–0.25 weak, 0.26–0.50 moderate, 0.51–0.75 strong, above 0.75 very strong.[100] Known-group differences were assessed using Mann-Whitney U tests. Construct validity was sufficient when at least 75% of the results were consistent with the predefined hypotheses.[86]

Test-retest reliability

An ICC for absolute agreement (two-way mixed effects model) was calculated, test-retest reliability was sufficient when ICC ≥0.70.[86]

Results

A total of 72 subjects gave consent to participate and were screened for eligibility. PAR-Q criteria were met by 60 participants who subsequently were included. Two participants were unreachable, two participants were planned for a UE-FCE which could not be carried out because of equipment unavailability, ten participants canceled their appointments stating logistical reasons and the appointments of one participant were canceled because of restrictions related to the COVID-19 pandemic. Of the included participants, 45 participants (75%) performed the original UE-FCE at T1 and

42 participants also performed the original UE-FCE at T2 (table 1). Three participants withdrew after T1, mentioning an increase of their complaints following the UE-FCE as the reason.

Table 1 Participant characteristics at T1.

	Participants who performed UE-FCE at T1 (n = 45)	Participants who also performed UE-FCE at T2 (n = 42)
Age (years) [mean (SD)]	44.6 (14.9)	44.9 (12.7)
Sex (male) [n (%)]	16 (36)	15 (36)
Diagnosis [n (%)]		
Specific complaints of the arm, neck and shoulders	21 (47)	20 (48)
Lateral epicondylitis	6 (29)	5 (25)
De Quervain's disease	5 (23)	5 (25)
Dupuytren disease	4 (19)	4 (20)
Trigger finger	6 (29)	6 (30)
Non-specific complaints of the arm, neck and shoulders	24 (53)	22 (52)
Handedness (dominant hand) [n (%)]		
Right-handedness	33 (73)	30 (71)
Left-handedness	9 (20)	9 (21)
Mixed or ambidexterity	3 (7)	3 (7)
Affected side [n (%)]		
Unilateral	26 (53)	22 (52)
Bilateral	21 (47)	20 (28)
Dominant hand affected (yes) [n (%)]	38 (84)	35 (83)
Employed (yes) [n (%)]	34 (76)	31 (78)
QuickDASH [0–100, median (IQR)]	26.1 (17.6)	25.0 (17.1)
PRWHE [0–100, median (IQR)]	34.3 (43.0)	34.0 (41.8)
NRS pain [0–100, median (IQR)]	4.0 (4.0)	4.0 (4.0)
WAS [0–100, median (IQR)]	7.0 (4.0)	7.0 (4.0)

NRS pain: numeric pain rating scale; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; UE-FCE: upper extremity functional capacity evaluation; WAS: Work Ability Score.

Part 1: Composing a shortened UE-FCE

Results of the agreement between the two shortened protocols (two trials and one trial per test) and the original protocol are shown in table 2. Hand grip strength was slightly higher in the shortened protocols, except for position 1 of both hands. Dexterity tests were scored better in the original protocol. For all hand grip strength and finger strength tests, the ICC was above 0.90 for both the one-trial and two-trial protocols. For dexterity tests, the ICC was above 0.90 only for the two-trial protocols. Therefore, the proposed shortened UE-FCE is composed of a one-trial test for hand grip strength and finger strength (tip, key and palmar pinch strength) and a two-trial test for fingertip dexterity (PPT) and hand and forearm dexterity (CMDT). Overhead lifting and overhead working were one-trial tests in the original protocol and remained unchanged in the shortened UE-FCE.

Table 2 Shortened UE-FCE protocols versus the original UE-FCE protocol.

UE-FCE tests	Original protocol Mean ± SD	Shortened (two-trial) versus original protocol Mean difference ± SD	Shortened (two-trial) versus original protocol ICC (95% CI**)	Shortened (one-trial) versus original protocol Mean difference ± SD	Shortened (one-trial) versus original protocol ICC (95% CI**)
Hand grip strength					
HGS pos 1 left	19.6 ± 9.6	−0.1 ± 1.0	0.99	−0.5 ± 2.5	0.97 (0.94–0.98)
HGS pos 2 left	27.4 ± 10.4	0.4 ± 0.9*	>0.99	1.1 ± 2.1*	0.98
HGS pos 3 left	25.9 ± 9.6	0.3 ± 0.7*	>0.99	0.3 ± 2.0	0.98
HGS pos 4 left	22.3 ± 8.9	0.3 ± 0.7*	>0.99	0.4 ± 1.8	0.98
HGS pos 5 left	18.9 ± 8.1	0.1 ± 0.6	>0.99	0.1 ± 1.3	0.99
HGS pos 1 right	20.7 ± 9.6	−0.1 ± 1.0	>0.99	−0.6 ± 1.9*	0.98
HGS pos 2 right	30.1 ± 11.7	0.5 ± 1.0*	>0.99	0.6 ± 2.0*	0.99
HGS pos 3 right	27.3 ± 10.7	0.3 ± 0.9*	>0.99	0.9 ± 1.8*	0.98
HGS pos 4 right	23.6 ± 9.6	0.3 ± 0.7*	>0.99	0.7 ± 1.4*	0.99
HGS pos 5 right	19.7 ± 8.6	0.2 ± 0.7*	>0.99	0.7 ± 1.5*	0.98
Finger strength					
Tip pinch left	4.1 ± 1.3	−0.0 ± 0.2	0.99	0.0 ± 0.4	0.97 (0.94–0.98)
Key pinch left	7.1 ± 2.2	−0.0 ± 0.3	0.99	−0.1 ± 0.5	0.97 (0.95–0.98)
Palmar pinch left	6.3 ± 2.3	0.0 ± 0.2	>0.99	−0.1 ± 0.4	0.98
Tip pinch right	4.3 ± 1.6	0.0 ± 0.2	>0.99	−0.0 ± 0.4	0.97 (0.94–0.98)
Key pinch right	7.2 ± 2.3	−0.0 ± 0.2	>0.99	−0.0 ± 0.5	0.98
Palmar pinch right	6.4 ± 2.2	−0.0 ± 0.3	0.99	−0.2 ± 0.7	0.95 (0.91–0.97)
Dexterity tests					
PPT dominant	15.2 ± 1.9	−0.4 ± 0.4*	0.96 (0.92–0.98)	−1.1 ± 1.2*	0.72 (0.54–0.83)
PPT non-dominant	14.2 ± 2.2	−0.2 ± 0.4*	0.98 (0.97–0.99)	−0.6 ± 0.6*	0.93 (0.88–0.96)
CMDT dominant	47.9 ± 6.5	1.7 ± 1.2*	0.95 (0.91–0.97)	3.3 ± 2.5*	0.83 (0.71–0.90)
CMDT non-dominant	50.9 ± 6.6	1.5 ± 1.6*	0.95 (0.91–0.97)	2.7 ± 2.8*	0.85 (0.74–0.91)

CMDT: Complete Minnesota Dexterity Test; HGS: hand grip strength; PPT: Purdue Pegboard Test. *Significant difference ($P < 0.05$); **95% confidence interval (CI) is only shown when lower limit was 0.95 or lower.

Part 2: Measurement properties of the shortened UE-FCE

Construct validity

For each shortened UE-FCE test, the percentage of results consistent with predefined hypotheses were: hand grip strength (left hand 82–100%, right hand 45–64%), finger strength (left hand 36–73%, right hand 27–45%), dexterity tests (PPT 45–73%, CMDT 50–58%), overhead lifting (90%), and overhead working (80%) (supplementary tables S1–S5, at the end of the chapter). This means that construct validity was demonstrated for hand grip strength of the left hand, overhead lifting, and overhead working, but not for hand grip strength of the right hand, finger strength, fingertip dexterity and hand and forearm dexterity.

Test-retest reliability

The ICC for test-retest reliability was above 0.70 for all tests, except for fingertip dexterity (PPT) of the dominant hand (0.59) (table 3).

Table 3 Test-retest reliability of the shortened UE-FCE.

UE-FCE tests	ICC (95% CI)
Hand grip strength (one-trial)	
HGS position 1 left	0.86 (0.75–0.92)
HGS position 2 left	0.91 (0.84–0.95)
HGS position 3 left	0.94 (0.88–0.96)
HGS position 4 left	0.91 (0.83–0.95)
HGS position 5 left	0.94 (0.89–0.97)
HGS position 1 right	0.85 (0.73–0.91)
HGS position 2 right	0.88 (0.77–0.93)
HGS position 3 right	0.93 (0.87–0.96)
HGS position 4 right	0.95 (0.91–0.97)
HGS position 5 right	0.93 (0.88–0.96)
Finger strength	
Tip pinch left	0.82 (0.69–0.90)
Key pinch left	0.89 (0.81–0.94)
Palmar pinch left	0.79 (0.64–0.88)
Tip pinch right	0.86 (0.76–0.92)
Key pinch right	0.88 (0.77–0.94)
Palmar pinch right	0.78 (0.63–0.88)
Dexterity tests (two-trial)	
PPT dominant	0.59 (0.21–0.79)
PPT non-dominant	0.79 (0.51–0.90)
CMDT dominant	0.70 (0.23–0.87)
CMDT non-dominant	0.79 (0.46–0.91)
Overhead lifting	0.86 (0.75–0.92)
Overhead working	0.75 (0.58–0.86)

CMDT: Complete Minnesota Dexterity Test; HGS: hand grip strength; PPT: Purdue Pegboard Test.

Discussion

This study composed a shortened UE-FCE (with fewer repetitions per test) and assessed its measurement properties (construct validity and test-retest reliability) when applied to patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm, and elbow. A one-trial protocol for hand grip strength and finger strength and a two-trial protocol for dexterity tests (PPT and CMDT) strongly correlated with the original test protocols. Overhead lifting and overhead working were already one-trial tests and remain unchanged in the shortened UE-FCE. Construct validity was confirmed for grip strength of the left hand, overhead lifting, and overhead working. Construct validity of position 2 of the hand dynamometer, which is most commonly used, seemed best for hand grip strength. Less than 75% of hypotheses were confirmed for grip strength of the right hand, finger strength, and dexterity tests. Test-retest reliability of all shortened UE-FCE tests was sufficient, except for the PPT of the dominant hand. However, it should be noted that the confidence intervals of the ICC of some UE-FCE tests, especially the dexterity tests, include 0.70. This indicates that there is a chance that the test-retest reliability of these test may be insufficient. Criteria for interpretation of the ICC values for reliability may differ per study or methodological source (e.g., an ICC of 0.75 instead of 0.70 as used in this study).[159,160]

Strong correlation between one-trial and original (multi-trial) UE-FCE protocols was already demonstrated in healthy subjects.[29] However, in healthy subjects it was found that a one-trial protocol, instead of a two-trial protocol, was also suitable for dexterity tests. This indicates that dexterity test results vary more over trials in the study population than in healthy subjects. For some UE-FCE tests construct validity could not be demonstrated, mainly due to lower-than-expected correlations with questionnaires assessing hand function (QuickDASH, PRWHE, and HFS). The strongest correlation with these questionnaires was found for overhead lifting and overhead working, possibly because performance during these UE-FCE tests depends on a combination of body functions more than other UE-FCE tests. A remarkable finding was the difference in the percentage of confirmed hypotheses of hand grip strength between the left and right hand, and to a lesser extent of finger strength between the left and the right hand. For these tests, construct validity was much higher for the left hand than for the right hand. Previously, much stronger correlations between either hand grip strength or finger strength and QuickDASH/PRWHE scores were found.[161,162] There is no obvious explanation for the difference between the left and right hand in these tests, but influence of an interaction between dominant hand and affected hand might be assumed. The fact that in most participants the dominant hand was affected might also explain that no differences were found between the symptomatic and asymptomatic side, where this was expected. Test-retest reliability of the shortened UE-FCE tests for hand grip strength and finger strength, as well as overhead lifting and overhead working, was similar to previous reports about the original protocol in healthy subjects.[151] This indicates that neither fewer trials nor application in the studied target population affected reliability of these tests. However, the test-retest reliability of dexterity tests (both PPT and CMDT) is known to decrease in tests with fewer trials due to learning effects.[151,163,164] A learning effect was also observed in dexterity tests administered in this study, despite practicing prior to actually performing these tests, influencing both the validity and test-retest reliability of a shortened test with fewer trials.

Strengths and limitations

As far as known, this is the first study assessing a shortened UE-FCE with fewer trials per test in the relevant target population of patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm, and elbow. The study has been designed and reported in accordance with COSMIN guidelines. Albeit the sample size in this study (45 subjects) was slightly below the COSMIN recommendation (50 subjects),[86] we do not expect relevant differences with a slightly larger sample, given the clear and statistically significant outcomes. However, a larger sample would enable analyzing subgroups based on potentially relevant parameters influencing test results, such as age, sex, handedness (dominant hand), and affected side. About 15% of potential participants could not be included because PAR-Q criteria were not met. It is unlikely that missing these subjects influenced the results, because a relationship between physical fitness and upper limb function was not found in a similar group of patients.[165] Nevertheless, it might hinder generalization to similar patients in clinical practice. No serious adverse events were recorded. A temporary pain response after an FCE, like other forms of physical exercise, is well known and considered a normal reaction.[156,166,167] However, three participants ended their participation prematurely because of increased complaints after the first UE-FCE.

Clinical implications and suggestions for further research

Using the shortened UE-FCE in clinical practice decreases the time required to administer these tests and lessens the burden on the patient: for the shortened UE-FCE composed in this study this could save an estimated 18 min (total administration time of the shortened UE-FCE tests can be reduced from 29 to 11 min).[29] Further research should focus on the construct validity of the individual UE-FCE tests, and especially the influence of age, sex, handedness (dominant hand), and affected side. Future research should also assess the structural validity of the (shortened) UE-FCE (e.g., factor analysis and covariance of (groups of) different UE-FCE tests). Depending on the constructs measured, further shortening by means of reducing the number of UE-FCE tests or better guidance towards UE-FCE test selection might be pursued. Also, there is a need to explore the influence of learning effects on the results of dexterity tests and how to deal with that (e.g., expansion and clarification of the number and duration of practice runs before the test trial). Other measurement properties (e.g., responsiveness) should also be evaluated. Eventually, there should be attention to involve patients who were not eligible to participate in this study, specifically those not meeting PAR-Q criteria, as these may represent patients with comorbidities that are relevant for daily clinical practice.

Conclusion

The shortened UE-FCE with fewer repeated trials per test correlated strongly with the original UE-FCE in patients with nontraumatic musculoskeletal complaints of the hand, wrist, forearm, and elbow. The shortened UE-FCE offers a time-efficient option for the use of UE-FCEs in clinical practice. Construct validity differed per UE-FCE test and was demonstrated for hand grip strength of the left hand, overhead lifting, and overhead working. Test-retest reliability was good for all UE-FCE tests except fingertip dexterity (PPT) of the dominant hand.

Supplementary table S1 Construct validity of the shortened UE-FCE: results of testing predefined hypotheses; hand grip strength.

Hand grip strength

		HGS left pos 1		HGS left pos 2		HGS left pos 3		HGS left pos 4		HGS left pos 5	
	expected |r|	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**
QuickDASH	0.26–0.75	−0.35	yes	−0.36	yes	−0.45	yes	−0.35	yes	−0.37	yes
PRWHE	0.26–0.75	−0.34	yes	−0.36	yes	−0.45	yes	−0.34	yes	−0.40	yes
HFS	0.26–0.75	0.26	yes	0.30	yes	0.27	yes	0.31	yes	0.25	no
PDI	0.26–0.50	−0.37	yes	−0.40	yes	−0.49	yes	−0.37	yes	−0.41	yes
RAND-36 physical functioning subscale	0.26–0.50	0.29	yes	0.22	yes	0.34	yes	0.26	yes	0.29	yes
RAND-36 social functioning subscale	0.00–0.50	0.32	yes	−0.30	yes	0.42	yes	0.35	yes	0.30	yes
RAND-36 vitality subscale	0.00–0.25	0.20	yes	0.19	yes	0.26	no	0.22	yes	0.21	yes
RAND-36 mental health subscale	0.00–0.25	0.15	yes	0.21	yes	0.25	yes	0.21	yes	0.20	yes
NRS pain	0.00–0.50	−0.38	yes	−0.34	yes	−0.34	yes	−0.35	yes	−0.36	yes
Score: male>female	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Score: asymptomatic>symptomatic side	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no
		confirmed: 100%		confirmed: 100%		confirmed: 91%		confirmed: 100%		confirmed: 82%	

		HGS right pos 1		HGS right pos 2		HGS right pos 3		HGS right pos 4		HGS right pos 5	
	expected |r|	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**
QuickDASH	0.26–0.75	−0.22	no	−0.26	yes	−0.20	no	−0.18	no	−0.21	no
PRWHE	0.26–0.75	−0.17	no	−0.23	no	−0.20	no	−0.19	no	−0.21	no
HFS	0.26–0.75	0.17	no	0.17	no	0.16	no	0.17	no	0.15	no
PDI	0.26–0.50	−0.19	no	−0.27	yes	−0.30	yes	−0.25	yes	−0.26	yes
RAND-36 physical functioning subscale	0.26–0.50	0.11	no	0.16	no	0.20	yes	0.13	yes	0.14	yes
RAND-36 social functioning subscale	0.00–0.50	−0.01	yes	0.17	yes	0.20	yes	0.12	yes	0.10	yes
RAND-36 vitality subscale	0.00–0.25	−0.05	yes	0.07	yes	0.12	yes	0.11	yes	0.07	yes
RAND-36 mental health subscale	0.00–0.25	0.00	yes	0.13	yes	0.13	yes	0.09	yes	0.09	yes
NRS pain	0.00–0.50	−0.20	yes	−0.17	yes	−0.14	yes	−0.14	yes	−0.18	yes
Score: male>female	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Score: asymptomatic>symptomatic side	yes	no	no	no	no	no	no	no	no	no	no
		confirmed: 45%		confirmed: 64%		confirmed: 64%		confirmed: 64%		confirmed: 64%	

HFS: Hand Function Sort; HGS: hand grip strength; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; RAND-36: RAND 36-item Health Survey; UE-FCE: upper extremity functional capacity evaluation.

Supplementary table S2 Construct validity of the shortened UE-FCE: results of testing predefined hypotheses; finger strength.

Finger strength

		Pinch left tip		Pinch left key		Pinch left palmar	
	expected |r|	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**
QuickDASH	0.26–0.75	−0.22	no	−0.24	no	−0.19	no
PRWHE	0.26–0.75	−0.22	no	−0.19	no	−0.21	no
HFS	0.26–0.75	0.29	yes	0.26	yes	0.24	no
PDI	0.26–0.50	−0.22	no	−0.31	yes	−0.22	no
RAND-36 physical functioning subscale	0.26–0.50	0.12	no	0.22	no	0.18	no
RAND-36 social functioning subscale	0.00–0.50	0.14	yes	0.33	yes	0.32	yes
RAND-36 vitality subscale	0.00–0.25	0.23	yes	0.28	yes	0.20	yes
RAND-36 mental health subscale	0.00–0.25	0.25	yes	0.32	yes	0.20	yes
NRS pain	0.00–0.50	−0.26	yes	−0.32	yes	−0.22	yes
Score: male>female	yes	yes	yes	yes	yes	no	no
Score: asymptomatic>symptomatic side	yes	no	no	yes	yes	no	no
		confirmed: 55%		confirmed: 73%		confirmed: 36%	

		Pinch right tip		Pinch right key		Pinch right palmar	
	expected |r|	**tested**	**confirmed**	**tested**	**confirmed**	**tested**	**confirmed**
QuickDASH	0.26–0.75	−0.22	no	−0.06	no	0.08	no
PRWHE	0.26–0.75	−0.15	no	0.01	no	0.16	no
HFS	0.26–0.75	0.19	no	0.13	no	0.04	no
PDI	0.26–0.50	−0.20	no	−0.10	no	0.05	no
RAND-36 physical functioning subscale	0.26–0.50	0.09	no	−0.01	no	−0.09	no
RAND-36 social functioning subscale	0.00–0.50	0.18	yes	0.09	yes	0.05	yes
RAND-36 vitality subscale	0.00–0.25	0.31	no	0.17	yes	0.01	yes
RAND-36 mental health subscale	0.00–0.25	0.31	no	0.21	yes	0.05	yes
NRS pain	0.00–0.50	−0.11	yes	−0.01	yes	0.12	yes
Score: male>female	yes	yes	yes	yes	yes	yes	yes
Score: asymptomatic>symptomatic side	yes	no	no	no	no	no	no
		confirmed: 27%		confirmed: 45%		confirmed: 45%	

HFS: Hand Function Sort; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; RAND-36: RAND 36-item Health Survey; UE-FCE: upper extremity functional capacity evaluation.

Supplementary table S3 Construct validity of the shortened UE-FCE: results of testing predefined hypotheses; fingertip dexterity.

			PPT dominant		PPT non-dominant	
		expected |r|	**tested**	**confirmed**	**tested**	**confirmed**
Fingertip dexterity	QuickDASH	0.26–0.75	−0.24	no	−0.34	yes
	PRWHE	0.26–0.75	−0.16	no	−0.23	no
	HFS	0.26–0.75	0.14	no	0.10	no
	PDI	0.26–0.50	−0.23	no	−0.26	yes
	RAND-36 physical functioning subscale	0.26–0.50	0.23	no	0.34	yes
	RAND-36 social functioning subscale	0.00–0.50	0.10	yes	0.19	yes
	RAND-36 vitality subscale	0.00–0.25	0.11	yes	0.26	yes
	RAND-36 mental health subscale	0.00–0.25	0.31	yes	0.35	yes
	NRS pain	0.00–0.50	−0.33	yes	−0.24	yes
	Score: male>female	no	no	yes	no	yes
	Score: asymptomatic>symptomatic side	yes	no	no	no	no
			confirmed: 45%		confirmed: 73%	

HFS: Hand Function Sort; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PPT: Purdue Pegboard Test; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; RAND-36: RAND 36-item Health Survey; UE-FCE: upper extremity functional capacity evaluation.

Supplementary table S4 Construct validity of the shortened UE-FCE: results of testing predefined hypotheses; hand and forearm dexterity.

			CMDT dominant		CMDT non-dominant	
		expected |r|	**tested**	**confirmed**	**tested**	**confirmed**
Hand and forearm dexterity	QuickDASH	0.26–0.75	0.11	no	0.29	yes
	PRWHE	0.26–0.75	−0.02	no	0.14	no
	HFS	0.26–0.75	−0.03	no	−0.19	no
	PDI	0.26–0.50	0.05	no	0.25	no
	RAND-36 physical functioning subscale	0.26–0.50	−0.08	no	−0.28	yes
	RAND-36 social functioning subscale	0.00–0.50	−0.11	yes	−0.26	yes
	RAND-36 vitality subscale	0.00–0.25	−0.13	yes	−0.24	yes
	RAND-36 mental health subscale	0.00–0.25	−0.19	yes	−0.28	no
	NRS pain	0.00–0.50	0.03	yes	0.17	yes
	Score: male>female	no	no	yes	no	yes
	Score: asymptomatic>symptomatic side	yes	no	no	no	no
			confirmed: 45%		confirmed: 55%	

CMDT: Complete Minnesota Dexterity Test; HFS: Hand Function Sort; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; RAND-36: RAND 36-item Health Survey; UE-FCE: upper extremity functional capacity evaluation.

Supplementary table S5 Construct validity of the shortened UE-FCE: results of testing predefined hypotheses; overhead working and overhead lifting.

			Overhead lifting		Overhead working	
		expected |r|	tested	confirmed	tested	confirmed
Overhead working and overhead lifting	QuickDASH	0.26–0.75	−0.24	no	−0.34	yes
	PRWHE	0.26–0.75	−0.16	no	−0.23	no
	HFS	0.26–0.75	0.14	no	0.10	no
	PDI	0.26–0.50	−0.23	no	−0.26	yes
	RAND-36 physical functioning subscale	0.26–0.50	0.23	no	0.34	yes
	RAND-36 social functioning subscale	0.00–0.50	0.10	yes	0.19	yes
	RAND-36 vitality subscale	0.00–0.25	0.11	yes	0.26	yes
	RAND-36 mental health subscale	0.00–0.25	0.31	yes	0.35	yes
	NRS pain	0.00–0.50	−0.33	yes	−0.24	yes
	Score: male>female	yes	yes	yes	no	no
			confirmed: 90%		confirmed: 80%	

HFS: Hand Function Sort; NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient Rated Wrist/Hand Evaluation; QuickDASH: shortened version of the Disabilities of the Arm, Shoulder, and Hand; RAND-36: RAND 36-item Health Survey; UE-FCE: upper extremity functional capacity evaluation.

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6

Health-related physical fitness in patients with complaints of hand, wrist, forearm and elbow: an exploratory study

Redmar J. Berduszek
Henk Geerdink
Corry K. van der Sluis
Michiel F. Reneman
Rienk Dekker

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Abstract

Objectives

Little is known about the physical fitness of patients with complaints of hand, wrist, forearm and/or elbow and its possible determinants. Aims were to assess health-related physical fitness (HRPF) in these patients, to compare HRPF with reference values of healthy persons, and to explore whether HRPF was correlated with symptom severity, upper limb function (ULF) and physical activity (PA).

Methods

Cardiorespiratory fitness, handgrip strength and body composition, self-reported symptom severity, ULF and PA were assessed in adult outpatients with complaints of hand, wrist, forearm and/or elbow diagnosed as CANS.

Results

Measurements were completed in 25 subjects (8 males) aged 46.1 ± 14.5 years, of which 44% had specific CANS and 56% had non-specific CANS.

Peak oxygen consumption (VO_2peak) of men was 2978 ± 983 mL/min and of women was 1978 ± 265 mL/min. Handgrip strength of men was 47.0 ± 11.1 kgf and of women was 32.4 ± 6.3 kgf. Body mass index (BMI) of men was 24.2 ± 2.6 kg/m^2 and of women was 27.4 ± 6.1 kg/m^2. VO_2peak of the study sample was lower than that of healthy adults (−414 ± 510 mL/min, $P < 0.001$). Handgrip strength and BMI were similar to reference values. VO_2peak was correlated with PA (r = 0.58, $P = 0.004$); BMI was correlated with disability (r = 0.48, $P = 0.022$). Other correlations between HRPF and symptom severity and ULF were non-significant.

Conclusions

Patients with CANS have lower cardiorespiratory fitness, but similar handgrip strength and body composition, compared with the healthy population. Cardiorespiratory fitness was correlated with PA and BMI was correlated with disability, no other correlations were observed with symptom severity and ULF.

Introduction

Upper limb disorders, such as complaints of arm, neck and/or shoulder (CANS), occur frequently and may lead to pain and disability.[5] CANS are musculoskeletal complaints of arm, neck and shoulder not caused by acute trauma or by any systemic disease. The point prevalence of CANS in the Netherlands is over 25%.[3,5] These disorders can result in limitations in a broad range of daily activities, such as work, hobbies and sports.[168] To be able to carry out the desired combination of those daily activities, one has to be physically fit.[169] However, little is known about the physical fitness in patients with CANS.

Physical fitness is defined as a set of attributes or characteristics individuals have or achieve that relates to their ability to perform physical activity. These characteristics are usually separated into health-related and skill-related components of physical fitness. Health-related physical fitness components are cardiorespiratory endurance, muscular strength, muscular endurance, body composition and flexibility.[169] Cardiorespiratory endurance is the ability of the heart and lungs to supply oxygen during sustained physical activity. Muscular strength is the ability to exert force, and muscular endurance is the ability to continue to perform without fatigue. Body composition is the relative amount of muscle, fat, bone and other vital parts of the body. Flexibility is the range of motion available at the joints. Skill-related physical fitness is important for performing the more technical aspects of many sports, such as agility, balance, coordination, power, reaction time and speed.

Health-related fitness components, especially cardiorespiratory endurance, muscular strength and muscular endurance, are consistently lower in patients with various chronic musculoskeletal complaints.[170–173] Lower levels of physical fitness are related with both lower levels of physical activity and the presence of musculoskeletal complaints.[31,171,174] Physical inactivity is also associated with the development of chronic CANS.[7] However, objectively measured physical fitness of patients with CANS has not been studied yet, nor has the relation between physical fitness and symptom severity and disability.

The primary aim of this exploratory study was to describe objectively measured health-related physical fitness in patients with complaints of hand, wrist, forearm and elbow (focusing on cardiorespiratory fitness, muscular strength and body composition). Secondary aims were to compare their health-related physical fitness with reference values of healthy persons, and to explore whether their health-related physical fitness was correlated with self-reported symptom severity and upper limb function and physical activity.

Methods

This cross-sectional study was performed at the Department of Rehabilitation Medicine of the University Medical Center Groningen, the Netherlands, between January 2016 and May 2017. All subjects gave written informed consent.

Participants

Eligible subjects were outpatients visiting our department, aged ≥18 years and suffering from complaints of hand, wrist, forearm and/or elbow classified as CANS.[3] Exclusion criteria were inadequate knowledge of Dutch language and the presence of other medical conditions causing considerable disability, such as neurological disorders or joint diseases. Subjects did not need to receive treatment for CANS, nor were they excluded if they did. All subjects were screened for the presence of contraindications for a cardiopulmonary exercise test (CPET) based on the ATS/ACCP statement on cardiopulmonary exercise testing.[175] While we were unable to calculate a sample size for this exploratory study, because necessary data were lacking, we aimed to include at least 25 subjects as a non-probability convenience sample.[176]

Measurements

During a single visit to the exercise laboratory of our department, measurements were taken to assess health-related physical fitness (cardiorespiratory fitness, muscular strength and body composition). Questionnaires to assess demographic, clinical and social characteristics, symptom severity and upper limb function and physical activity were filled out in the week prior to visiting the exercise laboratory.

Health-related physical fitness

Cardiorespiratory fitness

The gold standard for cardiorespiratory fitness is maximum oxygen consumption (VO_2max). For practical reasons, usually the highest achieved VO_2 during a CPET is used, termed VO_2peak. VO_2peak can be used as an estimate for VO_2max and these units are used interchangeably.[175]

To measure VO_2peak (mL/min and mL/min/kg), subjects performed a CPET on a cycle ergometer. A maximal incremental ergometry protocol was used, consisting of 1 min of rest, followed by 3 min of cycling without resistance, followed by a phase of increasing resistance.[175] This phase started with 10 W, 15 W, 20 W or 25 W and increased continuously with 10 W, 15 W or 20 W every 1 min (ramp protocol) until symptom limitation (e.g., exhaustion, breathlessness or leg discomfort) or test termination by the monitor. Both starting resistance and the incremental rate were dependent on the monitor's appraisal. CPET duration is about 8–12 min from the start of cycling with resistance. All tests were monitored by a certified exercise physiologist. Maximal effort was determined by a respiratory exchange ratio (RER) of >1.1 and/or maximum heart rate (HR) of >85% of predicted HR (maximum predicted HR = 220 − age (in years)).

Two sets of reference values were chosen. First, reference values based on the best-fitting polynomial regression model which was determined using cycle ergometry in a healthy Dutch population.[177] The equation of this model is $VO_2peak = -1469 + (673.00 \times sex) + (16.87 \times age\ (in\ years)) + (-0.47 \times age^2) + (0.07 \times height\ (in\ centimetres)^2) + (39.70 \times weight\ (in\ kilogrammes)) + (-0.16 \times weight^2)$, where male = 1 and female = 0. Second, the reference values of the American College of Sports Medicine (ACSM), which categorises cardiorespiratory fitness into one of six categories ranging from very poor to superior.[178] ACSM categories are based on VO_2max and dependent of sex and age.

Muscular strength (handgrip strength)

Handgrip strength (kgf) was measured with a digital dynamometer (JAMAR Plus+ digital hand dynamometer) in grip position 2.[179] The test was performed for both hands separately in the sitting position. The subjects were asked to hold the dynamometer parallel to the side of the body and the elbow in 90° and squeeze the handgrip dynamometer as hard as possible. The test was repeated three times for each hand, the maximum of these values was used (not necessarily of the dominant or affected hand). Reference values from a large British population were used for comparison, stratified by sex and age.[180]

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Body composition

Body mass index (BMI) is defined as a person's weight in kilogrammes divided by the square of the person's height in metres (kg/m^2). BMI was calculated using measurements of weight (wearing underwear only) and height (without shoes and socks). BMI is categorised as underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) and obesity (≥30 kg/m^2).[181] BMI categories based on self-reported height and weight by Dutch adults in 2017 were used as reference values.[182]

Fat-free mass (FFM) was assessed by bioelectrical impedance analysis, using the BIA 101 Anniversary Sport Edition and Bodygram Plus software (Akern Srl, Italy). Fat-free mass index (FFMI), the height-normalised index of FFM, was calculated by dividing FFM by height squared (kg/m^2). FFMI was assessed because BMI alone does not provide detailed information about body composition with regard to FFM and fat mass.[183] Reference values were derived from a study reporting FFMI of healthy Caucasian adults.[184]

Demographic, clinical and social characteristics

Patient characteristics

Subjects filled out a questionnaire with several questions about patient characteristics, including marital status, education, work, dominant arm and affected side. Diagnosis and duration of complaints were extracted from the electronic health record.

RAND-36

RAND-36 is a 36-item questionnaire about physical, mental and social health and is used worldwide to measure health-related quality of life, which has been shown to be reliable and valid.[93] RAND-36 consists of eight subscales measuring either physical or mental health. Subscale scores (scale 0–100) are calculated using an algorithm.[94] Higher scores reflect a better health status.

Symptom severity and upper limb function

Quick Disabilities of the Arm, Shoulder and Hand questionnaire

The Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) questionnaire (scale 0–100) is a self-reported questionnaire designed to measure physical function and symptoms in patients with musculoskeletal disorders of the upper limb.[81] A higher score indicates a greater symptom severity.

Patient-Rated Wrist/Hand Evaluation questionnaire

The Patient-Rated Wrist/Hand Evaluation (PRWHE) questionnaire (scale 0–100) is a self-reported questionnaire developed to assess pain and functional difficulties in activities of daily living during last week due to hand or wrist disorders.[89,185] A higher score indicates more pain and a greater symptom severity.

Pain Disability Index

The Pain Disability Index (PDI) (scale 0–70) is a self-reported questionnaire focusing on the impact of pain on a person's ability to participate in essential life activities.[91] A higher score indicates a greater disability in daily activities.

Numeric pain rating scale

The numeric pain rating scale (NRS pain) (scale 0–10) is a self-reported questionnaire to rate pain during the last week on an 11-point scale ranging from 'no pain' to 'worst pain imaginable'.[92] A higher score indicates a greater pain severity.

Physical activity

Nederlandse Norm Gezond Bewegen

The Nederlandse Norm Gezond Bewegen (NNGB, in English: Dutch Healthy Physical Activity Guidelines) advises on the minimal amount of physical activity to maintain and improve health.[186] In the NNGB, adults are advised to perform physical activity at least 30 min/day, at least at moderate intensity, at least 5 days/week. Subjects were asked if they met the criteria of the NNGB.

Fitnorm

The Dutch Fitnorm is based on recommendations about quantity and quality of exercise for developing and maintaining fitness in healthy adults.[187] To meet the Fitnorm, a person needs to exercise at least three times a week for 20 min at vigorous intensity. Subjects were asked if they met the criteria of the Fitnorm.

Statistical analyses

Descriptive statistics were used to describe measured components of health-related physical fitness, demographic information, symptom severity and upper limb function and physical activity. Continuous variables were presented as mean ± SD. Categorical data were presented as frequency and percentage.

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Cardiorespiratory fitness of the study sample was compared with reference values based on the best-fitting polynomial regression model. Using the equation mentioned above, the reference value (predicted VO_2max) was calculated for each subject, the mean of which was compared with the tested group using a paired t-test. Comparison of handgrip strength and body composition with reference values was reported using descriptive statistics. Spearman's partial correlations analyses were calculated between health-related fitness components and possible determining variables (controlling for sex and age).[188,189] The sample size was deemed too small to perform a multivariate regression analysis. Correlation coefficients were interpreted as negligible (0.00–0.10), weak (0.10–0.30), moderate (0.30–0.70), strong (0.70–0.90) or very strong (0.90–1.00).[190] The level of significance was set at $P < 0.05$. Statistical analyses were performed using IBM SPSS Statistics for Windows, V.23.0.

Results

Participants

In total, 33 subjects were included (figure 1). Five subjects withdrew before taking measurements and the CPET of one subject was terminated by the monitor before symptom limitation because of hypertension. Two subjects did not reach maximal effort during CPET (based on RER and maximum HR values) and were subsequently excluded from analyses concerning cardiorespiratory fitness using VO_2peak. Therefore, 25 subjects completed all measurements (table 1). The majority of the sample (68%) was female. Mean age of the total sample was 46.1 ± 14.5 years (44.3 ± 16.4 years for men and 46.9 ± 13.9 years for women). Complaints were diagnosed as specific CANS in 44% of subjects and as non-specific CANS in 56% of subjects. The mean QuickDASH score of the total sample was 28.2 ± 15.7 (22.2 ± 10.6 for men and 31.0 ± 17.2 for women) and the mean PRWHE score of the total sample was 36.6 ± 20.6 (29.8 ± 14.3 for men and 39.9 ± 22.6 for women).

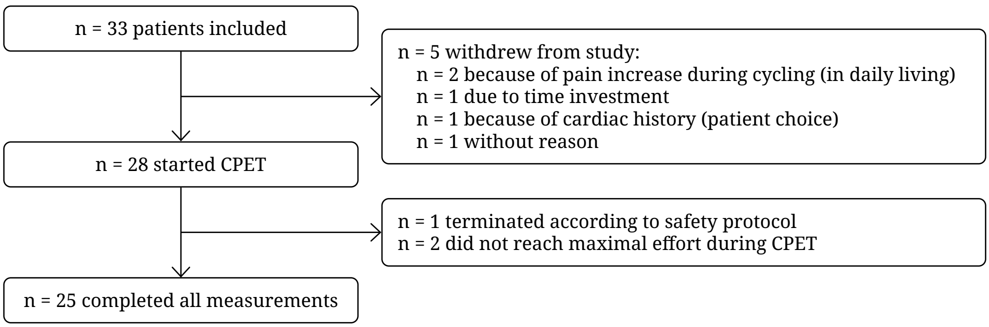

Figure 1 Selection of participants.

CPET: cardiopulmonary exercise test.

Three adverse events were reported, it concerned ECG abnormalities at maximal effort without further symptoms in all cases. In all three subjects, the ECG abnormalities resolved spontaneously after reducing effort. Subjects were advised to contact their general practitioner for further review and consider assessment by a cardiologist. No serious adverse events occurred during this study.

Health-related physical fitness: description and comparison with reference values

A detailed overview of the results of all measured aspects of health-related physical fitness (cardiorespiratory fitness, handgrip strength and body composition) for each subject is presented in table 2.

Table 1 Participant characteristics (n = 25).

Sex, n (%)	
Male	8 (32%)
Age (years), mean ± SD	46.1 ± 14.5
Duration of complaints, n (%)	
<3 months	0 (0%)
3–6 months	1 (4%)
6–12 months	9 (32%)
>12 months	18 (64%)
Dominant arm, n (%)	
Right	18 (72%)
Left	6 (24%)
Two-handed	1 (4%)
Affected arm, n (%)	
Right	7 (28%)
Left	3 (12%)
Both	15 (60%)
Diagnosis, n (%)	
Specific CANS	11 (44%)
Trigger finger	4
De Quervain's disease	3
Lateral epicondylitis	2
Dupuytren disease	2
Non-specific CANS	14 (56%)
Employed, n (%)	
Yes	16 (64%)
Current sick leave from work, n (%)	
Yes	4 (16%)
RAND-36, mean ± SD	
Physical functioning	77.2 ± 21.2
Social functioning	76.5 ± 26.3
Role limitations (physical problems)	54.0 ± 32.0
Role limitations (emotional problems)	70.3 ± 29.7
Mental health	66.0 ± 18.4
Vitality	52.3 ± 18.5
Pain	58.1 ± 17.8
General health perception	57.6 ± 22.2
Symptom severity and upper limb function, mean ± SD	
QuickDASH	28.2 ± 15.7
PRWHE	36.6 ± 20.6
PDI	17.8 ± 14.0
NRS pain	3.9 ± 2.1
Physical activity, n (%)	
NNGB (meeting criteria)[a]	17 (68%)
Fitnorm (meeting criteria)[b]	8 (32%)

CANS: complaints of the arm, neck and shoulder; NNGB: Nederlandse Norm Gezond Bewegen (Dutch Healthy Physical Activity Guidelines); NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient-Rated Wrist/Hand Evaluation questionnaire; QuickDASH: Quick Disabilities of the Arm, Shoulder and Hand questionnaire. [a]Criteria for meeting NNGB: perform physical activity at least 30 minutes per day, at least at moderate intensity, at least 5 days per week; [b]Criteria for meeting Fitnorm: exercise at least three times a week for 20 minutes at vigorous intensity.

Cardiorespiratory fitness

Mean VO_2peak of the study sample was 2298 ± 745 mL/min. According to the model to calculate individual reference values, the mean VO_2peak was expected to be 2712 ± 736 mL/min. Compared with this reference value, VO_2peak of study sample was

Table 2 Health-related fitness of individual subjects.

			Cardiorespiratory fitness										Muscular strength		Body composition			
Subject	Sex	Age (years)	VO_2 at AT (mL/min/kg)	VO_2peak (mL/min/kg)	VO_2peak (mL/min)	Load peak (W)	HR at AT	HR at RCP	HR peak	HR % of predicted	RER	MET at AT	Handgrip strength (kgf)	Handgrip strength percentile	BMI (kg/m²)	BMI category	FFMI (kg/m²)	FFMI percentile
1	M	25	28.6	44.2	3159	295	134	173	187	96	1.16	8.2	34.8	<P10	25.6	overweight	20.0	P75–P90
2	M	27	15.2	34.8	3201	272	123	181	196	102	1.31	4.3	32.5	<P10	23.4	normal	18.5	P25–P50
3	M	32	17.5	35.3	3765	322	113	150	184	98	1.22	5.0	60.6	P75–P90	29.8	overweight	21.4	>P95
4	M	36	32.6	51.8	3525	297	122	153	166	90	1.17	9.3	47.9	P25–P50	21.7	normal	18.3	P10–P25
5	M	53	24.2	34.4	3073	270	127	146	160	96	1.14	6.9	48.2	P50–P75	24.1	normal	18.9	P25–P50
6	M	55	15.2	21.7	1692	173	97	120	134	82	1.30	4.4	54.5	P75–P90	22.4	normal	18.5	P25–P50
7	M	56	31.8	50.3	4108	372	130	155	165	101	1.12	9.1	60.0	>P90	23.1	normal	20.9	P75–P90
8	M	70	11.2	18.0	1298	106	88	121	121	81	1.10	3.2	37.3	P25–P50	23.2	normal	19.2	P50–P75
9	F	21	20.4	30.3	1929	164	131	151	176	88	1.18	5.8	21.4	P10–P25	24.5	normal	17.28	P90–P95
10	F	25	22.2	35.2	2308	227	160	187	191	98	1.34	6.3	39.1	>P90	20.6	normal	16.0	P50–P75
11	F	32	19.2	25.3	1445	128	142	155	175	93	1.20	5.5	27.3	P25–P50	22.3	normal	15.6	P50–P75
12	F	36	11.8	20.4	2052	171	118	151	168	92	1.17	3.4	39.6	>P90	33.2	obesity	19.1	>P95
13	F	38	14.6	22.7	2255	173	146	179	182	100	1.06	4.2	34.7	P50–P75	35.0	obesity	20.5	>P95
14	F	39	16.3	29.3	2403	199	126	171	177	98	1.09	4.7	41.6	>P90	27.1	overweight	17.5	P75–P90
15	F	44	13.0	21.8	2107	186	104	139	159	90	1.17	3.7	36.3	P75–P90	31.2	obesity	19.1	>P95
16	F	47	16.4	30.2	2172	170	116	150	153	89	1.20	4.7	21.8	<P10	26.8	overweight	20.5	>P95
17	F	47	13.6	22.6	1739	148	109	141	146	84	1.20	3.9	30.6	P50–P75	29.1	overweight	18.0	P90–P95
18	F	50	9.8	16.3	2038	149	114	148	152	90	1.05	2.8	31.7	P50–P75	42.3	obesity	21.0	>P95
19	F	51	17.7	33.5	2178	197	105	134	155	92	1.24	5.1	30.5	P50–P75	19.2	normal	14.8	P10–P25
20	F	53	10.5	17.7	1827	136	109	142	151	91	1.19	3.0	40.0	>P90	34.0	obesity	19.5	>P95
21	F	58	12.7	25.1	1894	143	99	122	128	80	1.19	3.6	28.6	P50–P75	24.3	normal	17.0	P50–P75
22	F	58	15.6	29.7	2100	186	127	173	185	115	1.21	4.5	34.0	P75–P90	24.6	normal	17.5	P75–P90
23	F	63	13.3	28.0	1943	155	93	131	144	92	1.07	3.8	30.3	P75–P90	24.3	normal	17.5	P75–P90
24	F	68	15.0	24.2	1656	154	125	153	165	109	1.17	4.3	38.2	>P90	21.1	normal	16.6	P50–P75
25	F	68	12.8	22.0	1574	112	90	115	127	84	1.16	3.7	24.9	P50–P75	26.3	overweight	18.3	P75–P90

AT: aerobic threshold; BMI: body mass index; FFMI: fat-free mass index; HR: heart rate; MET: metabolic equivalent of task; RCP: respiratory compensation point (anaerobic threshold); RER: respiratory exchange ratio; VO_2: oxygen consumption.

on average 414 ± 510 mL/min lower than expected by the model ($P < 0.001$) (table 3). Mean VO_2peak of the study sample was 85% of the value predicted by the model.

According to ACSM categories, cardiorespiratory fitness was poor or very poor in 18 patients (72%), fair in 4 patients (16%) and good to superior in 3 patients (12%) (table 3).

Table 3 Cardiorespiratory fitness of patients with CANS compared with reference values.

	Study sample	Reference values*	Difference
VO_2peak (mL/min, mean ± SD)			
Total (n = 25)	2298 ± 745	2712 ± 736	−414 ± 510 ($P < 0.001$)
Men (n = 8)	2978 ± 983	3467 ± 635	−489 ± 764 ($P = 0.113$)
Women (n = 17)	1978 ± 265	2357 ± 466	−379 ± 362 ($P = 0.001$)
VO_2peak (mL/min/kg, mean ± SD)			
Total (n = 25)	29.0 ± 9.4		
Men (n = 8)	36.3 ± 12.3		
Women (n = 17)	25.5 ± 5.3		
ACSM category (n (%))			
Total (n = 25)			
Very poor	15 (60)		
Poor	3 (12)		
Fair	4 (16)		
Good	1 (4)		
Excellent	1 (4)		

ACSM: American College of Sports Medicine; CANS: complaints of the arm, neck and shoulder; VO_2: oxygen consumption. *Based on the best-fitting polynomial regression model determined using cycle ergometry in a healthy Dutch population.[177]

6

Muscular strength

Mean handgrip strength of men was 47.0 ± 11.1 kgf and of women was 32.4 ± 6.3 kgf. Handgrip strength of 25% of men and 12% of women was below P25 of the sex and age specific reference values (figure 2).

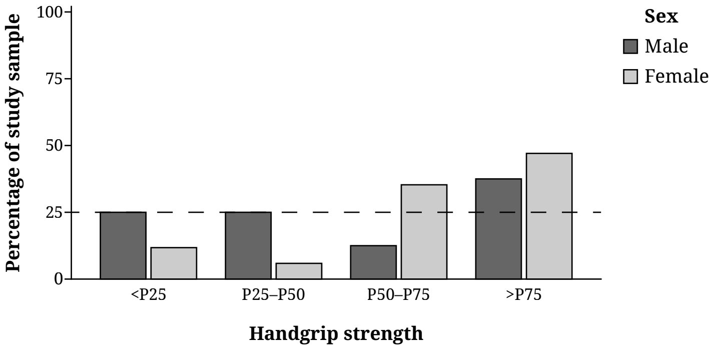

Figure 2 Handgrip strength: distribution over percentiles of reference values.

Body composition

BMI of the total study sample was 26.4 ± 5.4 kg/m² (24.2 ± 2.6 kg/m² for men and 27.4 ± 6.1 kg/m² for women). According to BMI categories, 44% of the study sample (25% of men and 53% of women) was overweight or obese (BMI ≥25 kg/m²). Compared with the general Dutch population, in the study sample, the proportion of overweight or obese men was lower and of overweight or obese women was slightly higher (figure 3). FFMI of 38% of men and 71% of women was above P75 of the sex and age-specific reference values (figure 4).

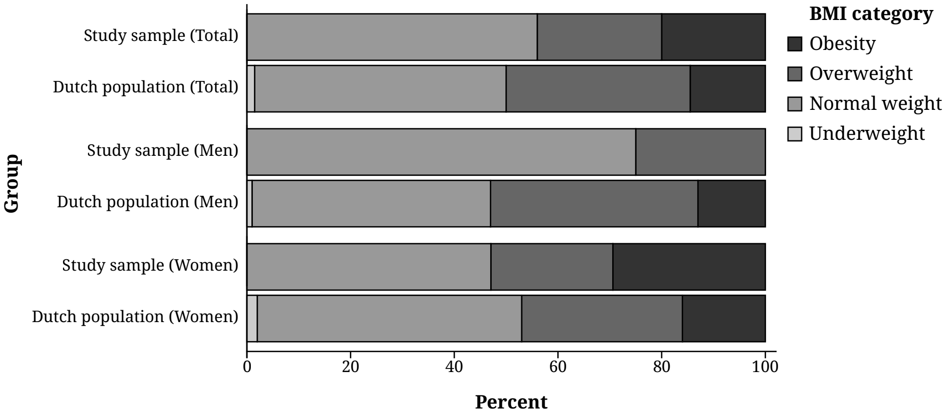

Figure 3 Comparison of BMI categories.

BMI: body mass index.

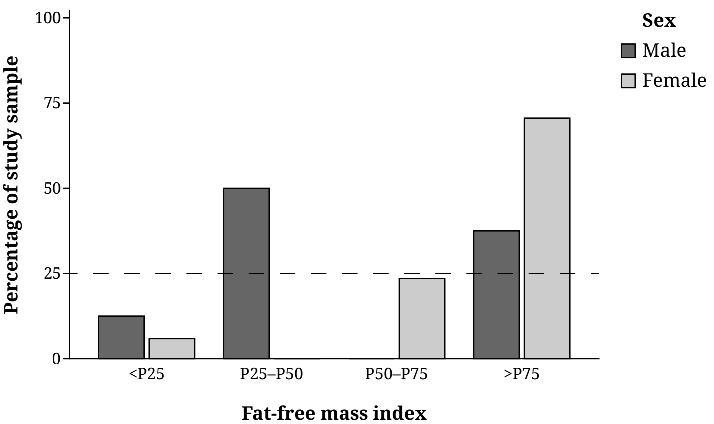

Figure 4 Fat-free mass index: distribution over percentiles of reference values.

Health-related physical fitness: correlations with symptom severity and upper limb function and physical activity

The relationship between health-related physical fitness components, symptom severity and upper limb function (QuickDASH, PRWHE, PDI and NRS pain) and physical activity (NNGB and Fitnorm) is presented in table 4. Correlations between health-related physical fitness components and self-reported symptom severity and upper limb function were not significant, apart from a moderate positive correlation between BMI and PDI. A moderate positive correlation was observed between cardiorespiratory fitness and physical activity measured by Fitnorm, but not NNGB. Physical activity was not significantly correlated with handgrip strength, nor with body composition.

Table 4 Spearman's partial correlations between health-related physical fitness, symptom severity and upper limb function and physical activity, controlled for sex and age.

	Cardiorespiratory fitness		Muscular strength	Body composition	
	VO_2peak	ACSM category	Handgrip strength	BMI	FFMI
Symptom severity and upper limb function					
QuickDASH	−0.31 (*P* = 0.155)	−0.26 (*P* = 0.227)	−0.24 (*P* = 0.268)	0.38 (*P* = 0.073)	0.17 (*P* = 0.444)
PRWHE	−0.19 (*P* = 0.376)	−0.21 (*P* = 0.340)	−0.24 (*P* = 0.269)	0.30 (*P* = 0.159)	0.21 (*P* = 0.344)
PDI	−0.30 (*P* = 0.167)	−0.20 (*P* = 0.353)	−0.21 (*P* = 0.349)	0.48 (*P* = 0.022)*	0.30 (*P* = 0.169)
NRS pain	−0.10 (*P* = 0.640)	−0.23 (*P* = 0.289)	−0.12 (*P* = 0.574)	0.24 (*P* = 0.268)	0.25 (*P* = 0.260)
Physical activity					
NNGB	0.20 (*P* = 0.354)	0.06 (*P* = 0.781)	−0.138 (*P* = 0.530)	−0.19 (*P* = 0.380)	−0.12 (*P* = 0.589)
Fitnorm	0.58 (*P* = 0.004)*	0.54 (*P* = 0.008)*	0.174 (*P* = 0.428)	−0.23 (*P* = 0.301)	−0.06 (*P* = 0.790)

ACSM: American College of Sports Medicine; BMI: body mass index; FFMI: fat-free mass index; NNGB: Nederlandse Norm Gezond Bewegen (Dutch Healthy Physical Activity Guidelines); NRS pain: numeric pain rating scale; PDI: Pain Disability Index; PRWHE: Patient-Rated Wrist/Hand Evaluation questionnaire; QuickDASH: Quick Disabilities of the Arm, Shoulder and Hand questionnaire.
*Statistically significant ($P < 0.05$).

Discussion

Cardiorespiratory fitness in patients with complaints of hand, wrist, forearm and elbow was lower than in matched healthy references, both by direct comparison of VO_2peak using a model and through categorisation, according to ACSM criteria.[178] These findings concur with a study reporting a lower VO_2max in patients with chronic low back pain.[170] Studies using submaximal methods to assess cardiorespiratory fitness also observed lower fitness levels in patients with musculoskeletal disorders compared with healthy controls.[172,191] Maximal handgrip strength in our sample seemed similar to the general population, with a fairly equal distribution of handgrip strength over reference value percentiles. This finding contradicts those of others, because lower handgrip strength is described in several hand conditions.[192,193] Even though the majority of the study sample indicated involvement of both hands, apparently handgrip strength of at least one of the hands is preserved. Also, a reduction in handgrip strength in the study sample might be too little to be detected by a change in quartiles. The use of a grip strength ratio seems valid to assess the difference in grip strength between both hands, but its usefulness in bilaterally affected patients is unknown.[192] The distribution of BMI categories in this study sample seems to differ slightly from the general Dutch adult population, with less overweight men and more obese women than expected from general population data.[182] FFMI in women in this study sample was higher than the reference values. This might be explained by their BMI, which was on average higher than in the reference population.[184] FFMI values will be higher with greater weight and BMI.[183]

The majority of correlations between the health-related physical fitness and self-reported symptom severity and upper limb function were absent or low. Others have reported a moderate association between poorer self-reported physical fitness and non-specific work-related upper limb disorders, in patients with seemingly lower symptom severity and shorter duration of complaints.[31] It is unsure why we did not find such a relationship, but the limited validity of self-reported physical fitness assessed in the previous study (compared with performance-based physical fitness) might be an explanation.[194]

Cardiorespiratory fitness and physical activity (Fitnorm) were moderately positively correlated, which is consistent with other study results.[195–197] The relationship between cardiorespiratory fitness and physical activity might be dose dependent, because cardiorespiratory fitness was better in patients meeting the Fitnorm criteria, but not in patients meeting the NNGB criteria. The most important difference between Fitnorm and NNGB is the exercise intensity, which is higher for the Fitnorm. More substantial increases of aerobic capacity have been reported with higher intensity training programmes.[198–200] The proportion of patients in our study meeting NNGB (68%) or Fitnorm (32%) corresponded to the Dutch general population, of which 59% meet NNGB criteria and 25% meet Fitnorm criteria.[182]

No relationship between handgrip strength and upper limb function was found. Moderate negative correlations between handgrip strength and both QuickDASH and PRWHE Questionnaires have been described before.[81,82] A probable explanation for the absence of a strong correlation in this study sample is the use of maximum handgrip strength of either hand instead of the affected hand. We found a moderate positive correlation between BMI and PDI in this study sample. A similar relationship between BMI and pain and disability has been found in patients with shoulder problems.[201] While the mechanisms need further unravelling, especially obese patients seem to be at risk for chronic musculoskeletal pain. The relationship between pain and obesity seems to play a role in both specific as non-specific conditions, but the mechanisms involved may differ.[202,203] Available models illustrate the complex interaction between obesity, pain, disability and many more factors.[204] We are unaware of reports on this matter in patients with complaints of hand, wrist, forearm and elbow to compare our results to.

Longitudinal studies investigating the relationship between health-related physical fitness in patients with musculoskeletal disorders are unknown and, therefore, one can only speculate about causality. Causality in both directions has been suggested: increased risk of CANS in persons with lower health-related physical fitness or reduced physical fitness due to activity limitations in patients with CANS. Association of better cardiorespiratory fitness with less musculoskeletal pain has been described before and physical activity might reduce musculoskeletal complaints.[173,205] Due to our cross-sectional design, we were unable to shed light on causality. However, the causal relationship needs attention in further research, since such data are needed to develop or adjust (preventive) treatment programmes.

Strengths and limitations

The most considerable methodological strengths are the simultaneous analysis of several aspects of health-related physical fitness, and especially the assessment of cardiorespiratory fitness using the gold standard, CPET, to measure VO_2peak during maximal effort. We are unaware of other studies reporting objectively measured cardiorespiratory fitness in patients with upper limb disorders. Because 93% of the subjects who started CPET reached maximal effort and no serious adverse events occurred, safety and tolerability of CPET in this patient sample are not refuted, given the protocol as applied here.

The small sample size might pose a limitation and the study might be underpowered to demonstrate statistically significant relationships between health-related physical fitness and parameters such as symptom severity and upper limb function. However, because this was an exploratory study, the results may be used to calculate sample sizes for future studies. Because of the exploratory nature of this study, we did not correct for a type I error, even though multiple correlations were explored. Other factors influencing health-related physical fitness can be determined that were not assessed in this study, such as the presence of cardiovascular and pulmonary comorbidity. Furthermore, self-report measures of physical activity might have limited validity.[206]

Reference values for components of health-related physical fitness appeared to be diverse or lacking (depending on source population characteristics) and this hindered comparison of the study sample to the general population. However, the description of multiple characteristics of individual subjects facilitates comparison with any desired reference value.

Conclusions

Cardiorespiratory fitness of this sample of patients with CANS was lower than reference values. Handgrip strength and body composition did not seem to differ from reference values. Cardiorespiratory fitness was positively correlated with physical activity. A higher BMI was correlated with greater disability, but most other relationships between health-related physical fitness and symptom severity and upper limb function were low or non-existent.

One might interpret very cautiously that, in this sample, levels of cardiorespiratory fitness seem to be determined by physical activity and not by symptom severity nor upper limb function.

Physicians and therapists should pay attention to health-related physical fitness (especially cardiorespiratory fitness and BMI) in patients with CANS. Even though the causal relationship is still unknown, interventions to improve physical activity (frequency, duration and intensity to meet the Fitnorm) could be considered.

Suggestions for further research include repetition of a similar study in a larger clinical sample, to assess changes in health-related physical fitness over the course of CANS (from onset to improvement) and to assess the effect of interventions aimed at improving health-related physical fitness (both on physical fitness itself as on symptom severity and upper limb function). The ability to engage in physical activity (e.g., work and sports) and the actual duration and intensity thereof might also be studied in greater detail.

6

7

General discussion

The overarching aim of this thesis was the evaluation of several aspects of the assessment of functioning and disability of patients with distal upper extremity musculoskeletal disorders (UEMSD). The results of the studies included in this thesis provide new insights which are relevant for the assessment of these patients, especially in hand therapy or rehabilitation medicine settings.

Main findings

In the comparison of patient-reported versus clinician-reported levels of pain and disability among patients with hand or wrist disorders (Chapter 2), clinicians consistently provided lower ratings than patients. The medical specialty of the assessing clinician influenced these evaluations: plastic surgeons reported lower levels of pain compared to rehabilitation medicine consultants, whereas rehabilitation medicine consultants reported lower levels of disability than plastic surgeons. Professional experience did not appear to affect these assessments, as no differences were observed between consultants and trainees in rehabilitation medicine in terms of their ratings of patients' pain and disability levels.

The measurement properties of three patient-reported outcome measurements were assessed, namely the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH), the Patient Rated Wrist/Hand Evaluation (PRWHE), and the Hand Function Sort (HFS) (Chapter 3 and 4). The HFS was successfully translated and culturally adapted into a Dutch language version, before its measurement properties were assessed. The measurement properties of the Dutch language versions of the QuickDASH, PRWHE, and HFS, applied in patients with distal UEMSD, were very similar. Internal consistency was best for the QuickDASH (Cronbach's $\alpha = 0.92$) and the PRWHE pain subscale (Cronbach's $\alpha = 0.93$), but too high for the PRWHE function subscale (Cronbach's $\alpha = 0.96$) and HFS (Cronbach's $\alpha = 0.98$). A very high Cronbach's α can indicate item redundancy. Construct validity could not be demonstrated for these questionnaires, as agreement with predefined hypotheses was below 75%. However, the order of the observed correlation coefficients corresponded to the anticipated ranking in terms of convergence and divergence. Test-retest reliability was good, with intra-class correlations between 0.87 and 0.92. Responsiveness was good for all questionnaires, but best for the QuickDASH, followed by the PRWHE and HFS. No floor or ceiling effects were found.

A shortened upper extremity functional capacity evaluation (UE-FCE) was developed, with fewer repeated trials per test than the original test protocols (Chapter 5). Based on the agreement between the shortened and original protocols, the proposed shortened UE-FCE included one-trial tests for strength tests (hand grip strength and finger strength) and two-trial tests for dexterity tests (fingertip dexterity as measured with the Purdue Pegboard Test (PPT) and hand and forearm dexterity as measured with the Complete Minnesota Dexterity Test (CMDT)). The tests overhead lift and overhead work remain unchanged in the shortened UE-FCE protocol, because these were one-trial tests in the original protocol already. The measurement properties of the shortened UE-FCE, applied in patients with distal UEMSD, differed per test. Construct validity was demonstrated for hand grip strength of the left hand, overhead lifting, and overhead working, but not for hand grip strength of the right hand, finger strength, fingertip dexterity and hand and forearm dexterity. Test-retest reliability was good, with intraclass correlation coefficient (ICC) values above 0.70 for all tests, except for fingertip dexterity of the dominant hand (ICC = 0.59).

The health-related physical fitness of patients with distal UEMSD was assessed (Chapter 6). These patients demonstrated significantly lower cardiorespiratory fitness compared to predictions based on a model for healthy adults (−414 ± 510 mL/min, $P < 0.001$). In contrast, hand grip strength and body composition were comparable to those of the healthy population. Better cardiorespiratory fitness was correlated with higher levels of physical activity. A moderate positive correlation was observed between disability, as measured with the Pain Disability Index (PDI), and body mass index (BMI). No other significant correlations were found between components of health-related physical fitness and symptom severity or upper limb function.

Implications for clinical practice

Assessment of functioning and disability is a key aspect of rehabilitation.[9] For the rehabilitation of patients with UEMSD, the International Classification of Functioning, Disability and Health (ICF) Rehabilitation and Hand Conditions Core Sets identify relevant components of functioning to acknowledge.[10,11] The measurement instruments studied in this thesis cover one or more of these components and therefore might be useful in the assessment of functioning and disability in these patients.

Assessing functioning in patients through clinical judgment is ubiquitous, but it is important to realize that the assessments made by a clinician do not necessarily correspond to the situation experienced by the patient with hand or wrist disorders.[207] While novel for this population, this is a consistent finding across different populations with other painful disorders.[18,208] Especially in multidisciplinary settings, of which rehabilitation is a prime example, it is important to consider the fact that assessments made by clinicians also differ depending on their specialty: it has been suggested that exposure, education and professional training influence this phenomenon.[17] This illustrates the relevance to explicitly capture the patient's perspective, through incorporating patient-reported and performance-based measurements into the assessment of patients with distal UEMSD.

Many measurement instruments, both patient-reported and performance-based, exist and have been advised for the use in patients with hand or wrist disorders.[14,148] There is no single instrument that captures the complete ICF framework, nor is there a gold standard for the assessment of functioning and disability.[209] This implies that measurement instruments should be chosen depending on the ICF domains and constructs of interest. Its measurement properties and feasibility to administer the instrument in the target population should be considered.[210]

Determination of the measurement properties of the QuickDASH, PRWHE and HFS supports their application for patients with distal UEMSD. Because the QuickDASH and PRWHE are similar in content and strongly correlated, making a choice to use either one of them has been advocated before.[211] Based on the results of chapter 3, the use of the QuickDASH seems most appropriate for use in patients with distal UEMSD. The QuickDASH covers multiple aspects of the ICF framework: body functions and structures, activities, and participation.[148,212] Its brevity makes it easy to apply this questionnaire into clinical practice, also for repeated measurements. Furthermore, it can be applied to patients with a range of upper extremity disorders (from the hand up to and including the shoulder), making it a suitable instrument for use in cases with more diffuse or unclear localization of complaints. The QuickDASH is available in many languages, which may facilitate its use in patients with limited Dutch proficiency.[213] Patients with low literacy levels may benefit from illustrations to better understand health information.[214] The HFS might not only be a useful tool to assess the ability to perform a wide range of activities, but this pictorial questionnaire could be specifically used for patients with low literacy levels. However, its length, illustrations which are outdated and sometimes culturally different, and more complicated scoring system limit the feasibility of the HFS.

The use of performance-based measurements for patients with hand or wrist disorders is very customary, especially hand grip strength and dexterity tests.[14,148] Usually these are administered as separate tests. In chapter 5, performance-based measurements were administered as an extensive and standardized test battery, known as an upper extremity functional capacity evaluation (UE-FCE).[28] The use of standardized FCE tests allow for comparison with other populations. Traditionally, performance-based measurements are executed several times, and the mean or maximum value of these repeated trials will be recorded. The results from chapter 5 indicate that no or less repeated trials are necessary without affecting reliability significantly. That might aid the implementation or expansion of the use of these performance-based measurements. While the construct validity of many UE-FCE tests could not be demonstrated based on the predefined hypotheses, the test overhead lifting had the most favorable measurement properties and the best construct validity. This is possibly a result of its content, covering more upper extremity regions and body functions than other UE-FCE tests.[28] Contemplating the construct of functioning and disability in patients with distal UEMSD, this could be explained by the fact that this is a heterogenous group of disorders where a diversity of body functions and structures is impaired: where in some patients pain prevails, in others joint mobility, muscle power or control of voluntary movements is more affected. Performance during overhead lifting could be influenced by any of these impairments associated with the distal UEMSD. These considerations, as well as the fact that overhead lifting is a bimanual task where performance is probably less influenced by which hand is affected, lead to the assumption that this test fits the construct of functioning in patients with distal UEMSD better than other FCE tests.[215] Overhead lifting might be used as a screening test to assess upper extremity function in patients with distal UEMSD, where the other UE-FCE tests can be used to assess more specific parts thereof. Insight in the aspects that contribute to the (im)possibility to perform certain activities may help in guiding an approach aimed at improving the ability to perform these activities or seek alternative methods to function at the desired level. The UE-FCE has the potential to become a useful tool, also outside the work-related context where FCE's are traditionally used.[216] An interesting development is that an FCE might not only serve to assess functional capacity, but also help patients better understand and utilize their functional capacity.[217] This suggests that an FCE is not merely a diagnostic instrument, but possibly also a therapeutic one.

The importance of assessing health-related physical fitness, especially cardiorespiratory fitness, in patients with distal UEMSD became apparent from the results from chapter 6. Cardiorespiratory fitness was better when patients with distal UEMSD were more physically active, which is not unique for these patients.[218] Reasons for physical (in)activity were not investigated, but the absence of a clear correlation between physical activity and symptom severity suggests that the distal UEMSD and its consequences on functioning (e.g., the ability to engage in physical activities such as sports) are not structurally contributing factors. This may indicate that there is no relationship between the severity of the disorder and its impact on functioning and disability and health-related physical fitness. Therefore, it may be advisable not only to address physical activity in patients who report disabilities regarding sports, but in all patients with distal UEMSD. Individualized coaching to improve physical activity, as well as other lifestyle aspects, may be beneficial.[219]

Methodological considerations

The studies in this thesis have both strengths and limitations to reflect upon. One of the strong aspects of the studies in this thesis regarding measurement properties (chapters 3, 4 and 5), is adherence to the COSMIN guidelines in design and conduct. At the same time, we notice that these criteria are dynamic and subject to fine-tuning over the years. This means that slightly different choices would have been made if this study would have been initiated today (e.g., regarding sample size). Also, the sample size did not allow a further analysis based on subgroups with different distal UEMSD. Questionnaires were filled out by two populations from different settings (university hospital and primary care hand therapy clinics) and most measurement properties were assessed in either one of those populations, hindering generalization across different health care settings.

Regarding the UE-FCE, about 20% of potential participants were ineligible to perform these tests, due to not meeting the criteria of the Physical Activity Readiness Questionnaire (PAR-Q). While safety of participants, and patients in general, is of the utmost importance, it can be questioned whether these criteria are too strict. This needs attention, as solely the use of cardiovascular medications (one of the Physical Activity Readiness Questionnaire criteria) is over 21% in the Dutch population, and as high as 35% in those aged 55–65 years.[220] So far, no detailed information about cardiovascular adverse events is available, other than that no such adverse events had occurred. In one study, a physician evaluated if performance of an FCE was considered safe when the participant did not meet PAR-Q criteria.[221] However, the method of this evaluation has not been described, nor if this was applicable to any of the participants in that study. Furthermore, it is of interest if the physical burden of the shortened UE-FCE protocol is less than that of the original protocol, and if this reduces the physiological pain response following the performance of these tests.

In chapters 3 through 6, patients with musculoskeletal disorders of the distal upper extremity (elbow, forearm, wrist, hand) were included. During the process of writing and publishing these studies, it became clear that there is no unambiguous terminology or classification for these distal UEMSD.[4,222,223] When using the term UEMSD, acute traumatic disorders are usually, but not by definition, excluded. The CANS model was used to clarify this, as this model excludes disorders which result from acute trauma.[3] However, this introduced another confusion, because CANS includes also more proximally located disorders such as neck and shoulder disorders. Also, the CANS model is not completely compatible with the International Classification of Diseases (ICD). To allow comparison between and generalization to different populations, the terminology to describe the population with distal UEMSD needs further clarification.[224]

Suggestions for further research

While new insights have been gained as result of the studies reported in this thesis, gaps in knowledge remain and new questions arose. It is recommended that future studies should aim to address the following aspects:

- Describe the population of patients with distal UEMSD better and more uniformly, amongst others to facilitate the comparison with other studies. This requires consideration and discussion of several aspects, such as etiology (e.g., idiopathic, rheumatic, traumatic), anatomic location (e.g., shoulder, upper arm, elbow, forearm, wrist, hand, fingers), possible mediating factors (e.g., physical (work) strain, psychosocial factors), and related impairments (e.g., pain, joint mobility and muscle functions). Use of both the ICD and ICF (especially the components from the relevant ICF Core Sets) is probably appropriate, but these do not cover all possibly relevant aspects.[225,226] Relevant mediating factors, even in the absence of an international classification, should be addressed as well.[227,228] For example, work strain on the upper extremity may be assessed using the revised Upper Extremity Work Demands (UEWD-R) scale.[229,230]

- Further assessment of the construct validity of the questionnaires studied (particularly the QuickDASH, which appears to be preferred for use in clinical practice), to better understand the constructs measured with these instruments in patients with distal UEMSD and possible differences with patients suffering from other hand and wrist disorders. Also, assessment of measurement properties in a broader range of health care settings is advised.

- Shortening and further adaptation of the HFS. Some images should be updated to reflect Dutch or European customs (e.g., tools depicted that are uncommon in the Netherlands) and modernized more generally (e.g., the type of computer depicted).

- Assessment of which UE-FCE tests are most relevant to assess functioning in patients with distal UEMSD and possibly reduce the number of tests which compose a UE-FCE.

- Assessment of factors influencing the reliability of UE-FCE tests, especially dexterity tests. These concern the reliability of repeated trials within one test moment, but also over test moments (test-retest reliability). Learning effects and warming up may be relevant factors. The effects of practice runs should be addressed.

- Establishment of norm values for UE-FCE tests relevant for patients with distal UEMSD. This should also include the assessment of the functional capacity required to perform specific activities. Even though work is an important aspect of rehabilitation, the scope of rehabilitation medicine to improve functioning is much broader. Relevant activities possibly affected by distal UEMSD include self-care, household tasks, hobbies, and sports. Therefore, given its relevance for rehabilitation, these norms should not be limited to vocational activities.

- Assess the safety of performing a UE-FCE in patients with a cardiovascular disease (i.e., not restrict measurements to patients meeting PAR-Q criteria).

- Demonstrate determinants of health-related physical fitness in a larger population of patients with distal UEMSD. Assess if there is a causal relationship between health-related physical fitness and these determinants, among which the possible influence of the development and course of distal UEMSD on health-related physical fitness and vice versa.

- Assess if interventions aimed at the improvement of health-related physical fitness (especially cardiorespiratory fitness) improve upper extremity function and overall functioning.

It is encouraging to note the promising development of the Rehablines cohort.[231] Rehablines is a further use databank of the University Medical Center Groningen, Center for Rehabilitation, in which routine clinical data are collected and stored for future research.[232] This includes data from clinician assessments, patient self-reports and performance-based assessments. Once a distinct set of measurements is incorporated into clinical practice and routinely collected, the resulting outcomes can be made available to address several of the formulated research questions. In turn, this can help to further refine recommendations regarding which components of functioning and disability to assess, and which measurement instruments to use.

Conclusion

Both patient-reported and performance-based measurements are relevant in the assessment of functioning and disability of patients with distal UEMSD. Measurement properties of the QuickDASH and PRWHE are similar, yet slightly better for the first. Because of that and its wider applicability, the QuickDASH seems to be the favorable patient-reported outcome measure to use in patients with distal UEMSD. While the HFS is a promising instrument to assess more physically demanding activities, item reduction needs attention before more extensive use in clinical practice. A shortened UE-FCE is suitable for use in clinical practice. Of the UE-FCE tests, overhead lifting demonstrated overall good measurement properties. The constructs measured by the UE-FCE tests in general and reliability of dexterity tests in particular require further study. Cardiorespiratory fitness is lower in patients with distal UEMSD and therefore deserves attention in clinical practice. Because of the relationship between cardiorespiratory fitness and physical activity, especially personalized interventions to improve physical activity should be considered.

These findings support clinicians in the assessment of functioning and disability of patients with distal UEMSD, through the selection of relevant ICF-components and proper measurement instruments.

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Summary

Persons with distal upper extremity musculoskeletal disorders (UEMSD) often experience impairments in body functions affecting hand function (e.g., pain, joint mobility, muscle power), which may lead to activity limitations and participation restrictions. Hand therapy and rehabilitation aim to improve functioning of individuals who experience disability because of these disorders. Assessment of functioning and disability is essential to establish a rehabilitation diagnosis, guide treatment, and monitor the effects of interventions. Available assessment approaches include clinician-reported measurements (involving clinical judgment), patient-reported measurements (usually from questionnaires), and performance-based measurements (tasks performed by the patient). Each approach has its own distinct advantages and disadvantages, but the measurement properties of these assessments are generally not well established in this population. Moreover, the evaluation of specific relevant aspects of functioning and disability in this population, such as exercise tolerance functions, requires further investigation.

The general aim of this thesis is to evaluate aspects of the assessment of functioning and disability of patients with distal UEMSD.

Chapter 1 gives a general introduction to the background, topics and research questions covered in this thesis. The measurement instruments studied are described and their constructs are related to relevant components from the Rehabilitation and Hand Conditions Core Sets of the International Classification of Functioning, Disability and Health (ICF) framework.

Clinician-reported and patient-reported levels of pain and disability were compared in chapter 2. A total of 250 patients with hand or wrist disorders and their physicians — consultants and trainees in rehabilitation medicine (RM), and plastic surgeons — rated pain and disability during consultations in a multidisciplinary outpatient clinic. Visual analogue scales (VAS) were used to assess both patient-reported and clinician-reported pain and disability. Differences between these ratings were evaluated through multilevel analyses. Clinicians reported lower levels of pain and disability than patients. Ratings also differed between medical specialties: pain was rated lower by plastic surgeons compared to RM consultants, while disability was rated lower by RM consultants compared to plastic surgeons. No differences between the ratings of RM consultants and trainees were found.

In chapter 3, measurement properties (internal consistency, construct validity, test-retest reliability, responsiveness, and floor and ceiling effects) of the Dutch language versions of the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) and the Patient Rated Wrist/Hand Evaluation (PRWHE), when applied to patients with distal UEMSD, were assessed according to COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations. Both questionnaires were completed by 132 patients. Internal consistency of both the QuickDASH (Cronbach's α = 0.92) and PRWHE (Cronbach's α = 0.97) was high. Construct validity was only partially supported, as 62% of the predefined hypotheses were confirmed for both the QuickDASH and PRWHE, falling short of the 75% threshold recommended by COSMIN. Test-retest reliability was good for both the QuickDASH and PRWHE (intraclass correlation coefficients (ICC) of 0.90 and 0.87, respectively). Responsiveness was also good, reflected by area under the curve (AUC) values of 0.84 for the QuickDASH and 0.80 for the PRWHE. No floor or ceiling effects were observed for either questionnaire.

The translation and cross-cultural adaptation of the Hand Function Sort (HFS) into Dutch and the assessment of measurement properties (internal consistency, construct validity, test-retest reliability, responsiveness, and floor and ceiling effects) of the resulting Dutch language version of the HFS are described in chapter 4. The translation (including adjustment of weights to the metric system) was completed without problems. Cross-cultural adaptation raised a few issues, because specific tools illustrated to perform activities differ between the United States (where the HFS originates) and the Netherlands. Illustrations were not adapted for the Dutch language version of the HFS. Measurement properties of the HFS were assessed according to COSMIN recommendations, when applied to patients with distal UEMSD. Internal consistency was very high (Cronbach's α = 0.98). Construct validity was not demonstrated with only 50% of the predefined hypotheses confirmed, which is below the 75% threshold recommended by COSMIN. Test-retest reliability (ICC 0.92) and responsiveness (AUC 0.75) were good. There were no floor or ceiling effects.

Chapter 5 describes the development of a shortened upper extremity functional capacity evaluation (UE-FCE) and the assessment of its measurement properties. A UE-FCE was performed twice (1–3 weeks apart) by 45 patients with distal UEMSD. The original UE-FCE protocol consisted of six different tests assessing arm and hand function, usually with multiple repeated trials per test: hand grip strength (hand dynamometer), finger strength (pinch dynamometer), fingertip dexterity (Purdue Pegboard Test (PPT)), hand and forearm dexterity (Complete Minnesota Dexterity Test (CMDT)), overhead lifting and overhead working. A shortened UE-FCE, with fewer repeated trials per test than in the original protocol, was composed based on analyses of the full UE-FCE tests. Based on the agreement (ICC ≥0.90) between original and shortened protocols, the proposed shortened UE-FCE included one-trial tests for hand grip and finger strength (instead of three-trial tests), two-trial tests for fingertip dexterity and hand and forearm dexterity (instead of three-trial and four-trial tests, respectively). Overhead lifting and working tests were already one-trial tests and remain unchanged in the shortened UE-FCE. Measurement properties (construct validity and test-retest reliability) of the shortened UE-FCE were assessed according to COSMIN recommendations. Construct validity was demonstrated for hand grip strength of the left hand, overhead lifting, and overhead working, but not for hand grip strength of the right hand, finger strength, fingertip dexterity and hand and forearm dexterity. Test-retest reliability was good (ICC >0.70) for all tests, except for fingertip dexterity of the dominant hand (ICC 0.59).

The health-related physical fitness of patients with distal UEMSD was assessed in chapter 6. Cardiorespiratory fitness (peak oxygen consumption (VO_2peak)), muscular strength (hand grip strength), and body composition (body mass index (BMI)) were assessed in 25 patients who achieved maximal effort during the cardiopulmonary exercise test. These outcomes were compared with reference values and related to symptom severity and upper limb function, and to physical activity levels.

VO_2peak was higher in men (2978 ± 983 mL/min) than in women (1978 ± 265 mL/min). Similarly, hand grip strength was greater in men (47.0 ± 11.1 kgf) compared to women (32.4 ± 6.3 kgf). BMI of men was 24.2 ± 2.6 kg/m^2 and of women was 27.4 ± 6.1 kg/m^2. Overall, VO_2peak in the study population was significantly lower than reference values for healthy adults (−414 ± 510 mL/min, $P < 0.001$), while hand grip strength and BMI were comparable to reference values. Cardiorespiratory fitness was positively correlated with physical activity, but showed no significant associations with symptom severity or upper limb function.

Chapter 7 contains a general discussion of the findings from the different chapters of the thesis, and the interpretation thereof given the aims of the thesis. Implications for clinical practice, methodological considerations, and suggestions for further research are addressed. The relevance of using both patient-reported and performance-based measurements to assess functioning and disability of patients with distal UEMSD is elaborated upon. The selection of relevant ICF components and corresponding measurement instruments is considered, to support clinicians in the assessment of functioning of patients with distal UEMSD. Further assessment of measurement properties of relevant instruments is recommended. A thoughtful selection and routine collection of measurements may populate a databank that can help answer these research questions in the future.

Samenvatting

Personen met musculoskeletale aandoeningen aan de distale bovenste extremiteit (*upper extremity musculoskeletal disorders,* UEMSD) ervaren vaak stoornissen in functies die de handfunctie beïnvloeden (zoals pijn, mobiliteit van gewrichten en spierkracht). Deze stoornissen kunnen leiden tot beperkingen in activiteiten en participatieproblemen. Handtherapie en revalidatie zijn gericht op het verbeteren van het functioneren van personen die door deze aandoeningen functioneringsproblemen ervaren. Het beoordelen van functioneren en functioneringsproblemen is essentieel voor het stellen van een revalidatiediagnose, het bepalen van de behandeling en om het effect van behandelingen te beoordelen. Beschikbare beoordelingsmethoden omvatten door de zorgverlener gerapporteerde metingen (middels klinische beoordeling), door de patiënt gerapporteerde metingen (meestal via vragenlijsten) en prestatiegerichte metingen (taken uitgevoerd door de patiënt). Elke benadering heeft eigen voor- en nadelen, maar de meeteigenschappen van deze beoordelingsmethoden zijn doorgaans onvoldoende vastgesteld in deze populatie. Daarnaast vereist de beoordeling van specifieke relevante aspecten van functioneren en functioneringsproblemen in deze populatie, zoals inspanningstolerantie, om nader onderzoek.

Het algemene doel van dit proefschrift is het evalueren van aspecten van de beoordeling van functioneren en functioneringsproblemen bij patiënten met distale UEMSD.

Hoofdstuk 1 geeft een algemene introductie van de achtergrond, onderwerpen en onderzoeksvragen van dit proefschrift. De onderzochte meetinstrumenten worden beschreven en hun constructen worden gerelateerd aan relevante componenten uit de *Rehabilitation* en *Hand Conditions Core Sets* van het *International Classification of Functioning, Disability and Health* (ICF) raamwerk.

Door de zorgverlener gerapporteerde en door de patiënt gerapporteerde niveaus van pijn en beperkingen werden vergeleken in hoofdstuk 2. In totaal beoordeelden 250 patiënten met hand- of polsaandoeningen en hun artsen — revalidatieartsen, arts-assistenten in opleiding tot revalidatiearts en plastisch chirurgen — pijn en beperkingen tijdens multidisciplinaire consulten op de polikliniek. Visueel analoge schalen (VAS) werden gebruikt voor zowel door de patiënt als door de zorgverlener gerapporteerde pijn en beperkingen. Verschillen tussen deze beoordelingen werden geanalyseerd met multilevelanalyses. Zorgverleners rapporteerden lagere niveaus van pijn en beperkingen dan patiënten. De beoordelingen verschilden ook tussen specialismen: pijn werd lager beoordeeld door plastisch chirurgen dan door revalidatieartsen, terwijl beperkingen lager werden beoordeeld door revalidatieartsen dan door plastisch chirurgen. Er werden geen verschillen gevonden tussen revalidatieartsen en arts-assistenten in opleiding tot revalidatiearts.

In hoofdstuk 3 zijn de meeteigenschappen (interne consistentie, constructvaliditeit, test-hertestbetrouwbaarheid, responsiviteit en vloer- en plafondeffecten) van de Nederlandstalige versies van de verkorte versie van de Disabilities of the Arm, Shoulder and Hand (QuickDASH) en de Patient Rated Wrist/Hand Evaluation (PRWHE) onderzocht bij patiënten met distale UEMSD, volgens de *COnsensus-based Standards for the selection of health Measurement INstruments* (COSMIN) aanbevelingen. Beide vragenlijsten werden ingevuld door 132 patiënten. De interne consistentie van zowel de QuickDASH (Cronbach's α = 0,92) als de PRWHE (Cronbach's α = 0,97) was hoog. Constructvaliditeit werd slechts gedeeltelijk ondersteund: 62% van de vooraf opgestelde hypothesen werd bevestigd, wat onder de door COSMIN aanbevolen drempel van 75% ligt. Test-hertestbetrouwbaarheid was goed voor zowel de QuickDASH als PRWHE (intraclass correlatiecoëfficiënt (ICC) respectievelijk 0,90 en 0,87). Responsiviteit was eveneens goed, zoals blijkt uit de oppervlakte onder de kromme (*area under the curve*, AUC) van 0,84 voor de QuickDASH en 0,80 voor de PRWHE. Er werden geen vloer- of plafondeffecten gevonden.

De vertaling en culturele aanpassing van de Hand Function Sort (HFS) naar het Nederlands en de beoordeling van de meeteigenschappen (interne consistentie, constructvaliditeit, test-hertestbetrouwbaarheid, responsiviteit en vloer- en plafondeffecten) van de uiteindelijke Nederlandstalige versie worden beschreven in hoofdstuk 4. De vertaling (inclusief aanpassing van gewichten naar het metrische systeem) verliep probleemloos. Bij de culturele aanpassing kwamen enkele kwesties naar voren, omdat specifieke gereedschappen die in de vragenlijst zijn afgebeeld en gebruikt worden voor het uitvoeren van activiteiten, verschillen tussen de Verenigde Staten (waar de HFS oorspronkelijk is ontwikkeld) en Nederland. Illustraties zijn niet aangepast voor de Nederlandstalige versie. Meeteigenschappen van de HFS zijn beoordeeld volgens COSMIN-aanbevelingen, bij patiënten met distale UEMSD. De interne consistentie was zeer hoog (Cronbach's α = 0,98). Constructvaliditeit werd niet aangetoond: slechts 50% van de vooraf opgestelde hypothesen werd bevestigd, wat lager is dan de door COSMIN aanbevolen drempel van 75%. Test-hertestbetrouwbaarheid (ICC 0,92) en responsiviteit (AUC 0,75) waren goed. Er waren geen vloer- of plafondeffecten.

Hoofdstuk 5 beschrijft de ontwikkeling van een verkorte functionele capaciteitsevaluatie voor de bovenste extremiteit (*upper extremity functional capacity evaluation*, UE-FCE) en de beoordeling van de meeteigenschappen daarvan. Een UE-FCE werd tweemaal uitgevoerd (met een interval van 1–3 weken) door 45 patiënten met distale UEMSD. Het originele UE-FCE protocol bestond uit zes testen voor het beoordelen van de arm- en handfunctie, meestal met meerdere herhaalde metingen per test: handknijpkracht (handdynamometer), vingerknijpkracht (vingerdynamometer), vingertopvaardigheid

(Purdue Pegboard Test), hand- en onderarmvaardigheid (Complete Minnesota Dexterity Test), bovenhands tillen en bovenhands werken. Een verkorte UE-FCE, met minder herhaalde metingen per test dan in het originele protocol, werd samengesteld op basis van analyses van de volledige UE-FCE testen. Op basis van de overeenkomst (ICC ≥0,90) tussen originele en verkorte protocollen, bestaat de voorgestelde verkorte UE-FCE uit testen met één meting voor handknijpkracht en vingerknijpkracht (in plaats van drie herhalingen per test) en testen met twee metingen voor vingertopvaardigheid en hand- en onderarmvaardigheid (in plaats van drie of vier herhalingen per test, respectievelijk). De testen bovenhands tillen en bovenhands werken bestonden al uit één meting en bleven ongewijzigd in de verkorte UE-FCE. Constructvaliditeit werd aangetoond voor handknijpkracht van de linkerhand, bovenhands tillen en bovenhands werken, maar niet voor handknijpkracht van de rechterhand, vingerknijpkracht, vingertopvaardigheid en hand- en onderarmvaardigheid. Test-hertestbetrouwbaarheid was goed (ICC >0,70), behalve voor vingertopvaardigheid van de dominante hand (ICC 0,59).

De gezondheidsgerelateerde fysieke fitheid van patiënten met distale UEMSD werd onderzocht in hoofdstuk 6. Cardiorespiratoire fitheid (hoogst gemeten zuurstofopname (VO_2peak)), spierkracht (handknijpkracht) en lichaamssamenstelling (*body mass index*, BMI) werden gemeten bij 25 patiënten die maximale inspanning bereikten tijdens een maximale cardiopulmonale inspanningstest. Deze uitkomsten werden vergeleken met referentiewaarden en gerelateerd aan de ernst van de symptomen, de functie van de bovenste extremiteit en het niveau van lichamelijke activiteit. De VO_2peak van mannen (2978 ± 983 mL/min) was hoger dan van vrouwen (1978 ± 265 mL/min). Evenzo was de handknijpkracht van mannen (47,0 ± 11,1 kgf) hoger dan van vrouwen (32,4 ± 6,3 kgf). De BMI van mannen was 24,2 ± 2,6 kg/m^2 en van vrouwen 27,4 ± 6,1 kg/m^2. In het algemeen was de VO_2peak significant lager dan referentiewaarden voor gezonde volwassenen (−414 ± 510 mL/min, $P < 0{,}001$), terwijl handknijpkracht en BMI vergelijkbaar waren met referentiewaarden. Cardiorespiratoire fitheid was positief gecorreleerd met het niveau van lichamelijke activiteit, maar niet met de ernst van de symptomen of de functie van de bovenste extremiteit.

Hoofdstuk 7 bevat een algemene bespreking van de bevindingen vanuit de verschillende hoofdstukken van het proefschrift en de interpretatie daarvan gezien de doelstellingen van het proefschrift. Implicaties voor de klinische praktijk, methodologische overwegingen en suggesties voor vervolgonderzoek worden behandeld. Het belang van het gebruik van zowel door patiënten gerapporteerde metingen als prestatiegerichte metingen voor het beoordelen van functioneren en functioneringsproblemen van patiënten met distale UEMSD wordt nader beschouwd. Overwegingen bij de selectie van relevante ICF-componenten en bijbehorende meetinstrumenten worden besproken, om zorgverleners te ondersteunen bij het beoordelen van het functioneren van patiënten met distale UEMSD. Verdere beoordeling van meeteigenschappen van relevante meetinstrumenten wordt aanbevolen. Een zorgvuldige selectie van meetinstrumenten en routinematige verzameling van metingen kan bijdragen aan het vullen van een databank, welke kan helpen om deze onderzoeksvragen in de toekomst te beantwoorden.

Contributions of the PhD candidate

The contributions of the PhD candidate, Redmar Juliusz Berduszek, to this thesis are detailed below for each chapter, using the Contributor Role Taxonomy (CRediT). Contributions are listed according to role definitions as established by the CRediT system (table 1).

Chapter 1: General Introduction
Conceptualization, Visualization, Writing — original draft, Writing — review & editing.

Chapter 2: Comparison between patient-reported and physician-estimated pain and disability in hand and wrist disorders
Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing — original draft, Writing — review & editing.

Chapter 3: Measurement properties of the Dutch versions of QuickDASH and PRWHE in patients with complaints of hand, wrist, forearm and elbow
Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing — original draft, Writing — review & editing.

Chapter 4: Cross-cultural adaptation and psychometric properties of the Dutch version of the Hand Function Sort in patients with complaints of hand and/or wrist
Conceptualization, Data Curation, Investigation, Methodology, Project Administration, Resources, Validation, Writing — review & editing.

Chapter 5: A shortened upper extremity functional capacity evaluation for patients with complaints of hand, wrist, forearm and elbow: composition and assessment of construct validity and test-retest reliability
Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing — original draft, Writing — review & editing.

Chapter 6: Health-related physical fitness in patients with complaints of hand, wrist, forearm and elbow: an exploratory study
Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing — original draft, Writing — review & editing.

Chapter 7: General discussion

Conceptualization, Writing — original draft, Writing — review & editing.

Table 1 CRediT Contributer Roles

Conceptualization	Ideas; formulation or evolution of overarching research goals and aims.
Data curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use.
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.
Funding acquisition	Acquisition of the financial support for the project leading to this publication.
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.
Methodology	Development or design of methodology; creation of models.
Project administration	Management and coordination responsibility for the research activity planning and execution.
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components.
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team.
Validation	Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs.
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/ data presentation.
Writing — original draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).
Writing — review & editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.

CRediT: Contributor Role Taxonomy (https://credit.niso.org/).

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About the author

English

Redmar Juliusz Berduszek was born on April 24, 1985, in Groningen, the Netherlands. After attending primary school in Nietap and secondary school in Leek, he studied Medicine at the University of Groningen, where he obtained his Bachelor's and Master's degrees (in 2006 and 2010, respectively). His interest in rehabilitation medicine was sparked during a clinical clerkship at Revalidatie Friesland in Leeuwarden in 2008. This led to the completion of both clinical and scientific clerkships at the department of Rehabilitation Medicine of the University Medical Center Groningen (*Universitair Medisch Centrum Groningen*, UMCG) in 2009–2010. After graduating, he entered the rehabilitation medicine residency program at the UMCG (supervisor: Dr. C.G.B. Maathuis). In 2014 he was registered as a rehabilitation physician. Since then, he has worked as a rehabilitation physician at the UMCG Center for Rehabilitation, with a previous part-time secondment to the Ommelander Hospital Group (*Ommelander Ziekenhuis Groep*, OZG) in Delfzijl (2014–2018) and Scheemda (2018–2019).

Over the years, his clinical work has increasingly focused on patients with neuromuscular diseases, especially in the context of outpatient interdisciplinary rehabilitation. He is a board member of the working group for neuromuscular diseases of the Netherlands Society of Rehabilitation Medicine. As *chef de clinique* at the department of Rehabilitation Medicine of the UMCG, he is responsible for the organization, coordination, and quality of patient care. Additionally, he is involved in supervising and training residents and contributes to educational activities. A particular interest is the optimal use of the electronic health record (EHR) and other digital developments. He has been actively involved in several projects aimed at further optimizing the EHR and its use, especially the Epic EHR. In 2021, he became Epic-certified as a Physician Builder. In his role as medical information officer (MIO), he serves as a bridge between clinical practice and the technical build of the EHR. His current focus areas include structured documentation, accurate data collection, and the retrieval of data to support clinical workflows and scientific research.

Nederlands

Redmar Juliusz Berduszek werd geboren op 24 april 1985 in Groningen. Na de basisschool in Nietap en de middelbare school in Leek studeerde hij Geneeskunde aan de Rijksuniversiteit Groningen, waar hij zijn bachelor- en masterdiploma's haalde (in 2006 en 2010, respectievelijk). Zijn interesse in revalidatiegeneeskunde werd gewekt tijdens een coschap bij Revalidatie Friesland in Leeuwarden in 2008. Dit leidde tot het doorlopen van zowel een klinische (semi-arts) als een wetenschappelijke stage bij de afdeling Revalidatiegeneeskunde van het Universitair Medisch Centrum Groningen (UMCG) in 2009–2010. Na zijn afstuderen begon hij aan de medische vervolgopleiding tot revalidatiearts bij het UMCG (opleider: dr. C.G.B. Maathuis). In 2014 werd hij geregistreerd als revalidatiearts. Sindsdien werkt hij als revalidatiearts bij het UMCG Centrum voor Revalidatie, met eerder een part-time detachering naar de Ommelander Ziekenhuis Groep (OZG) in Delfzijl (2014–2018) en Scheemda (2018–2019).

In de loop der jaren richtte zijn klinische werk zich toenemend op patiënten met neuromusculaire aandoeningen, met name in de context van poliklinische interdisciplinaire medisch specialistische revalidatie. Hij is bestuurslid van de werkgroep neuromusculaire aandoeningen van de Nederlandse Vereniging van Revalidatieartsen (VRA). Als chef de clinique van de afdeling revalidatiegeneeskunde van het UMCG draagt hij zorg voor de organisatie, coördinatie en kwaliteit van de patiëntenzorg. Daarnaast houdt hij zich bezig met de begeleiding en opleiding van arts-assistenten en levert hij bijdragen aan onderwijsactiviteiten. Een bijzonder interessegebied is het optimale gebruik van het elektronisch patiëntendossier (EPD) en andere digitale ontwikkelingen. Hij is actief betrokken geweest bij diverse projecten gerelateerd aan de verdere optimalisatie van het EPD en het gebruik daarvan, met name het Epic EPD. In 2021 werd hij Epic-gecertificeerd als Physician Builder. In zijn rol als *medical information officer* (MIO) fungeert hij als brug tussen de klinische praktijk en de technische inrichting van het EPD. Zijn huidige aandachtspunten zijn gestructureerde documentatie, nauwkeurige gegevensverzameling en het ontsluiten van gegevens ter ondersteuning van klinische werkprocessen en wetenschappelijk onderzoek.

https://orcid.org/0000-0001-7268-8762

https://www.linkedin.com/in/rjberduszek/