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ASSESSMENT PROCEDURE

Reliability, validity, and responsiveness of pinch strength assessment: a systematic review

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ABSTRACT

Purpose: To summarize and critically appraise the quality of studies investigating psychometric properties of pinch strength assessment.

Methods: Medical literature up to February 2024 was searched for studies reporting on at least one measurement property of pinch strength assessment. The quality of the evidence and the risk of bias were rated using COSMIN 2018 guidelines.

Results: Thirty-three studies (1962 participants) were included. The majority (16/19) of reliability studies were of adequate to very good quality. Seven of 12 studies of validity were rated as adequate or very good. The quality of the eight responsiveness studies was adequate. Reliability was good to excellent (ICC > 0.75) for neurological conditions, and excellent (ICC > 0.90) for musculoskeletal disorders and healthy participants. Pinch strength showed strong to very strong correlations with grip strength (r=0.72–0.92), moderate to strong correlations with assessments of dexterity (r=0.78–0.80), and weak to moderate correlation with patient-reported outcome measures (r=0.03–0.50). Varied results were found for pinch strength responsiveness in a small number of studies.

Conclusions: Pinch strength assessment is reliable. Validity and responsiveness are less reported, but there is a strong correlation between pinch and grip strength, and a moderate correlation with dexterity.

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KEYWORDS
Pinch strength; assessment; reliability; psychometric properties; validity; responsiveness

IMPLICATIONS FOR REHABILITATION

- This review demonstrated that the reliability of pinch strength assessment is good to excellent.
- Clinicians can measure pinch strength and expect accurate results over repeated measurements and between raters.
- There is a strong correlation between pinch and grip strength, and a moderate correlation between pinch strength and hand dexterity.
- The low correlation between pinch strength and patient-reported outcome measures highlights the need to measure these outcomes independently of each other.

Introduction

A pinch grip is a prehensile movement of the hand [1] where an object is squeezed between the palmar surface of the fingers and the opposing thumb. In a pinch grip, the first metacarpophalangeal (MCP) joint may be partially flexed or fully extended with compression provided primarily by the extrinsic muscles [2]. The finger phalangeal rotational position is adjusted by the interossei and the lumbricals with compression assisted by the MCP flexion force of the interossei and flexor pollicis brevis and by the adducting force of the adductor pollicis [2]. Due to the complex kinematics and variability in muscle recruitment, many disease processes can affect pinch strength, including conditions such as carpometacarpal arthritis of the thumb, carpal tunnel syndrome, MCP joint instability, thumb and wrist fractures, and ulnar and anterior interosseous nerve palsy [3–5]. Pinch strength is routinely used as an outcome measure in clinical practice and research to assess hand function, disease progression, and effectiveness of therapeutic interventions in patients affected with upper extremity disorders [3,6–8]. It is measured more commonly than other occupation-based measures that take longer to administer [9]. Understanding the relationship between hand function and disability is essential and healthcare professionals often assess pinch strength as a surrogate measure of upper extremity function [10].

Three standard pinch strength tests are commonly performed within a clinical setting using a pinch dynamometer. These include tip-to-tip, lateral, and tripod pinch and are described in Figure 1. As a performance-based outcome measure, pinch strength has demonstrated reliability in test–retest and inter-rater designs within the context of a well-controlled protocol [11]. Confidence in clinical tools requires that they are not only reliable, but also measure what they are intended to measure (validity), and can

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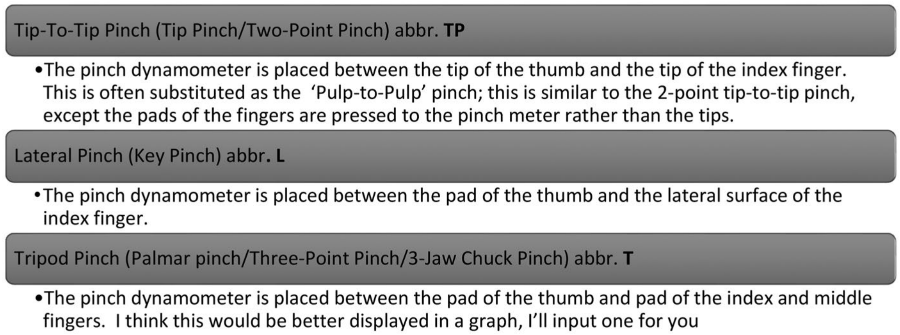

Figure 1. Types of pinch grip.

detect change (responsiveness). These psychometric properties determine the usefulness of a tool, scale, or outcome measure. The measurement properties of hand grip strength were the subject of a systematic review and meta-analysis by Bobos et al. [12]; however, to date, there has been no similar review for pinch strength. A detailed understanding of the psychometric properties of pinch strength assessment is essential for clinicians to be able to understand the validity and accuracy of measurement and to define meaningful change over time. A systematic compilation of available research that summarizes these psychometric properties will help researchers apply quantitative values to their work, and enhance clinicians' ability to make informed decisions with respect to individual patient results. The purpose of this study is to critically appraise and compare the quality of evidence for the reliability, validity, and responsiveness of pinch strength measurement for healthy participants and also for patients with musculoskeletal, neurologic, or systemic conditions.

Methods

Guidelines and protocol registration

This study design followed the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) 2018 guideline for systematic reviews of patient-reported outcome measures (PROMs) [13]. This guideline was developed specifically for PROMs and was adapted for systematic reviews of other outcome measurement instruments, such as performance-based outcome measures (PerFOMs) [14]. The study was registered publicly (ID CRD42023432472) on the International Prospective Register of Systematic Reviews (PROSPERO).

Study eligibility

No restrictions were placed on publication year, study language, country, age, or sex/gender of the participants. Randomized controlled trials and prospective and retrospective cohort studies that were published in peer-reviewed journals were included in this review. Populations included healthy participants and those with musculoskeletal, neurologic, or systemic conditions. Studies that met the aforementioned criteria regarding study design and population and included information regarding any reliability, validity, and/or responsiveness of pinch strength measurement were included. Studies with no data on measurement properties of pinch strength, those with a primary objective of measuring inter-instrument reliability, those that included pinch strength as an outcome but evaluation of psychometric properties was not a primary objective, conference proceedings, and gray literature were excluded.

Search strategy and study selection

The databases of MEDLINE, Embase, and Cumulative Index to Nursing and Allied Health Literature (CINAHL), Physiotherapy Evidence from inception until February 2024 were searched in order to identify studies on psychometric properties of pinch strength. The following keywords were used: (pinch strength OR pinch grip OR tip pinch OR key pinch OR palmar pinch OR two-point pinch OR tripod pinch OR three-point grip OR three-point pinch OR lateral pinch OR pinch gauge OR precision grip) AND (psychometric properties OR reliability OR validity OR responsiveness OR measurement OR dynamometer OR assessment). This strategy was used for all of the databases that were searched. Additional studies were identified by hand searching the reference lists of the selected studies. Four independent reviewers (D.A., A.S., J.K., M.S.) performed the systematic electronic searches of each database, subsequently identified and removed the duplicate studies, and then screened the titles, abstracts, and full-text studies. Each of the reviewers received identical results for each database within a 2-day period, thus validating the search strategy. An independent full-text review to assess final study eligibility was then performed. In case of disagreement, consensus was facilitated through discussion.

Data extraction and study interpretation

Once all studies were identified, data extraction was completed by three authors (D.A., A.S., J.K.). Data were cross-referenced and any disagreements were resolved *via* consensus through discussion. From each included study, the author, year, demographics, setting, sample size, psychometric property evaluated, type of device used, type of grip used (i.e., tip-to-tip, tripod, or lateral), and the test interval where applicable. For studies examining convergent validity, the comparator(s), as well as the values for any type of psychometric properties reported were extracted. For studies that examined reliability, test–retest (intraclass correlation coefficient [ICC], standard error of measurement [SEM], minimal detectable change [MDC] as well as their 95% CI), and internal consistency (Cronbach alpha) were extracted. ICCs were considered poor if less than 0.4, moderate between 0.4 and 0.75, and high if between 0.75–0.9, and excellent when greater than 0.9. For studies that examined validity, the type of validity (construct, content, factorial, criterion, known group, and floor/ceiling effects) was extracted along with the correlation coefficients (Pearson/Spearman) and their 95% CI. Correlation coefficients were

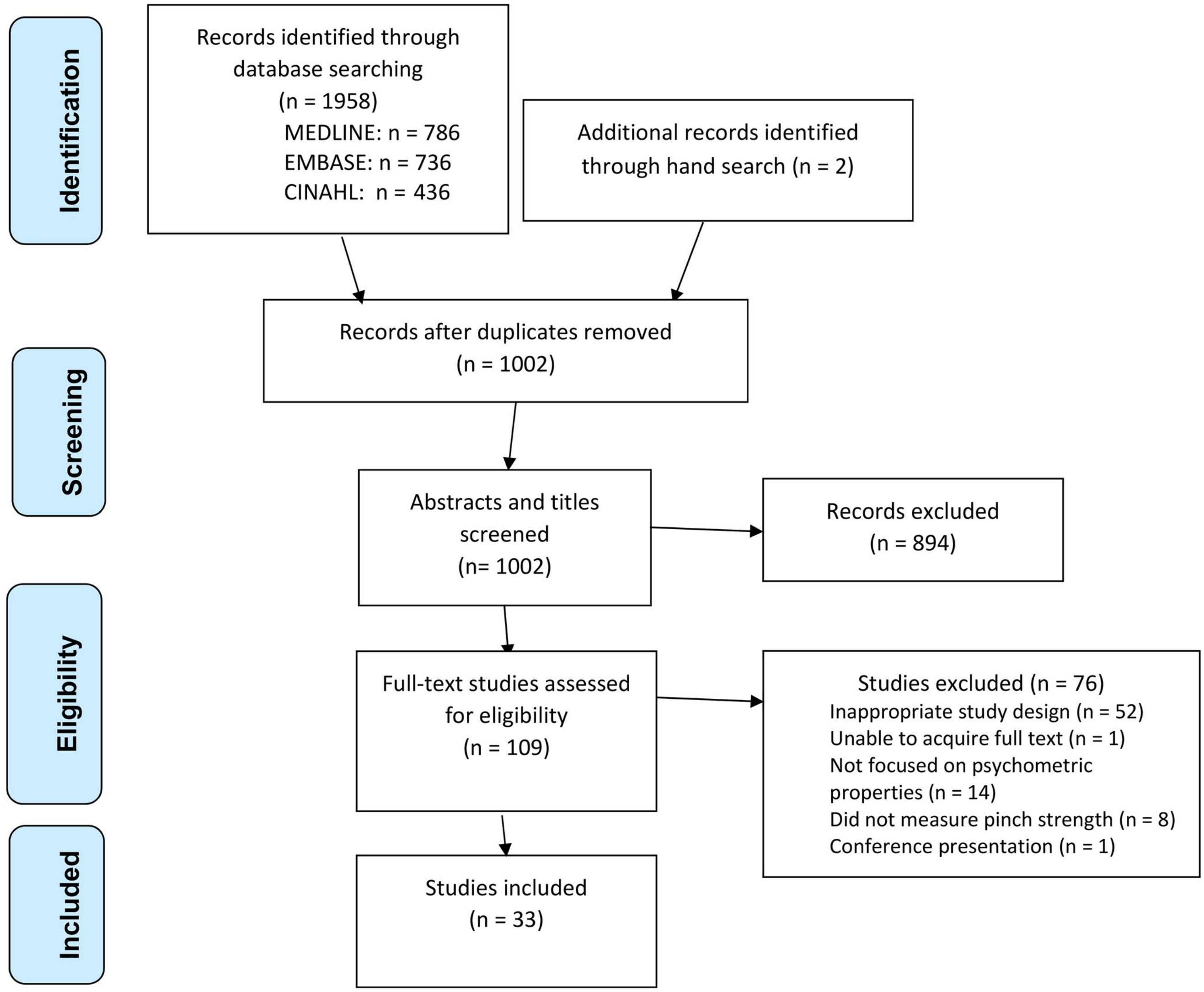

Figure 2. Selection of studies for inclusion.

considered weak (0–0.39), moderate (0.40–0.69), strong (0.70–0.89), or very strong (0.9–1.0) [15,16]. For studies that examined responsiveness of pinch strength, effect size [ES], standardized response mean [SRM], minimal clinically important difference [MCID], the method of MCID estimation (Anchor-Distribution-based methods), as well as their 95% CIs were extracted. Based on the work of Cohen [17], ESs were interpreted as very small (<0.2), small (0.2–0.49), moderate (0.5–0.79), and large (0.80 and higher).

Quality and risk of bias assessment

The included studies were critically appraised by two authors. For validity and responsiveness studies, the risk of bias was assessed using the COSMIN Risk of Bias Checklist [13]. For reliability studies, the COSMIN Risk of Bias Tool to Assess the Quality of Studies on Reliability and Measurement Error of Outcome Measurement Instrument (2020) was used. Studies were rated as "very good," "adequate," "doubtful," or "inadequate" for risk of bias. The results of each study were then rated by applying the updated criteria for measurement properties recommended in the COSMIN Guideline for Systematic Reviews of Patient-Reported Outcome Measures [13,14]. Each result was rated as either sufficient (+), insufficient (–), or indeterminate (?). The lower of the two ratings was taken in the event of disagreement.

Results

Search results

The database searches identified 1958 potential studies. After the removal of duplicates, 1002 remained and were screened using their title and abstract, leaving 109 for full-text review; from these, 33 were considered eligible [3,6–8,10,11,18–43]. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart of study selection is illustrated in Figure 2. The 33 eligible studies were published between 1994 and 2023, with sample sizes ranging from 10 to 209 participants or patients. There were 1962 participants (patients with musculoskeletal, neurologic, arthritic, pediatric, or systemic conditions, as well as healthy cohorts without these conditions). Nineteen of these studies included measurements of reliability (including measurement error), 12 measured validity, and eight measured responsiveness. Several studies measured multiple psychometric properties. A summary of all included studies is reported in Table 1.

Table 1. Summary of studies addressing psychometric properties of pinch strength.

Study	Sample size	Diagnosis	Age	Setting	Properties evaluated	Intervention	Retest interval	Pinch grip evaluated
Aguiar 2016	32	Patients diagnosed as having stroke (subacute phase)	63 (35–85)	Community	Reliability	N/A	1–2 weeks	PP, T, L
Alonso 2023	24; 24	Parkinson's disease; healthy participants	66.3 ± 9.6, 65.7 ± 9.1	Outpatient	Validity	N/A	N/A	TP
Beebe 2009	33	Patients with hemiparesis post-stroke	56.9	Department of Neurology	Validity, responsiveness	N/A	1, 3, and 6 months	L
Chen 2009	62	Patients post-stroke	61.0 (9.9)	6 hospital sites	Reliability	N/A	3–7 days	T, L
Dekkers 2020	65 for test–retest; 54 for inter-rater	Patients with unilateral spastic cerebral palsy	9 years 3 months	University	Reliability	N/A	2–4 weeks for test–retest; 30 min for inter-rater	L
Eberhardt 2008	49	Patients with rheumatoid arthritis	54.9 (12.2)	Department of Rheumatology	Validity, responsiveness	Anti-TNF therapy	1 year	TP
El-Katab 2016	209	Hemodialysis patients with advanced kidney disease.	64.2 (48.6–79.8)	Kidney Care Centre	Validity	N/A	N/A	NS
Fournier 2006	14	Unilateral de Quervain's tenosynovitis	49.3 ± 10.3	Rehabilitation Centre	Reliability, validity	N/A	1 h	TP
Gerhardsson 2014	123	Patients with hand-arm vibration syndrome; healthy participants	50.4 ± 12.4 years	Hospital	Reliability	N/A	2 weeks	T, L
Huang 2011	56	Patients post-stroke	61.9 (9.3)	School of OT	Reliability	N/A	3–7 days	T, L
Jerosch-Herold 2011	57 at 4 months, 55 at 8 months	Patients post-carpal tunnel decompression	60.4	University Hospital	Responsiveness	N/A	4 and 8 months	TP
Kierkegaard 2018	113	Patients with myotonic dystrophy type 1	Range: 29–85 years	Neuromuscular Clinic	Responsiveness	N/A	9 years	NS
Kotsis 2007	28	Patients post-open reduction internal fixation of distal radial fracture	48 ± 17 years	Medical School	Responsiveness	N/A	3 months, 6 months, P2 6 months, 1 year	NS
Lindstrom-Hazel 2009	73	Healthy participants	Not stated	University	Reliability	N/A	N/A	T, L
MacDermid 1994	38	Patients with cumulative trauma disorders	41 ± 14	Hand Clinic	Reliability	N/A	within 1 h	T, L
Mandanka 2020	10	Pediatric patients with spastic cerebral palsy	8.9 (5–16)	Rehabilitation Department	Reliability		3 min	TP, L
McQuillan 2016	23 healthy; 91 CMC OA	Patients with carpometacarpal (CMC) osteoarthritis (OA)	38.3–73.9	Outpatient	Validity	N/A	N/A	TP, T, L
Merlini 2002	33	Patients with spinal muscular atrophy type II or type III	5–65 years	Neuromuscular Clinic	Reliability	N/A	20 min	T
Myers 2011	55	Patients with musculoskeletal hand pain	50 years and over	Primary Care Centre	Reliability	N/A	1 month	PP, T, L
Plant 2016	25	Healthy participants	18–85	Medical School	Reliability	N/A	11.3 weeks ± 10.6	L
Rajkumar 2002	62	Patients with leprosy-associated denervation	36.1 ± 13.7	Research and Training Centre	Reliability, Validity	N/A	N/A	PP, T, L
Schreuders 2003	33	Patients with variable unilateral hand injuries	36 years	Department of Rehabilitation	Reliability	N/A	2–3 min	TP, L
Sferra da Silva 2018	121 Rheumatoid Arthritis; 121 healthy controls	Patients with rheumatoid arthritis	57.50 ± 10.75	Outpatient Clinic	Validity	N/A	1-min interval	TP, T, L
Solari 2008	40	Patients with Charcot–Marie–Tooth disease	42.4	Neurology Institute	Reliability	N/A	1 week	T
Song 2013	39	Patients with ulnar neuropathy at the elbow	18 years of age or older,	Orthopaedics Department (five centers)	Validity	Ulnar nerve de-compression	6 weeks and 3-, 6- and 12-month intervals	L
Svensson 2006	20	Patients with Charcot–Marie–Tooth disease	20–75	Department of Community Medicine and Rehabilitation	Reliability	N/A	1 week	TP
Szekeres 2015	77	Patients with cubital tunnel syndrome	20–81	Hand Clinic	Validity	N/A	N/A	L
Villafane 2014	27	Patients with carpometacarpal osteoarthritis	81.3 ± 4.7 years	University setting	Reliability	N/A	1 week	TP, T, L

(*Continued*)

Table 1. Continued.

Study	Sample size	Diagnosis	Age	Setting	Properties evaluated	Intervention	Retest interval	Pinch grip evaluated
Villafane 2017	110	Patients with carpometacarpal osteoarthritis; healthy controls	82.5 ± 7; 77.4 ± 7	University setting	Responsiveness	N/A	1 min	TP, T
Wachter 2018	25	Otherwise, healthy participants with simulated ulnar nerve lesion	31.9 years (23.2–44.5).	Hand Clinic	Responsiveness	Ulnar nerve block	N/A	TP, T, L
Werlauff 2014	52	Patients with spinal muscular atrophy type II	8–73	Registered with Danish SMA Registry	Validity	N/A	N/A	L
Wessel 1999	32	Pediatric patients with juvenile rheumatoid arthritis	6-15	Rehabilitation hospital	Reliability, validity		N/A	PP
Ziv 2008	32 OA; 25 healthy	Patients with primary osteoarthritis (OA) of the hand and healthy participants	70.4 ± 10.0	OT/PT department	Reliability	N/A	<1 week	TP, T, L

Quality appraisal

As detailed in Table 2, 16 out of 19 studies that measured reliability were of adequate to very good methodological quality regarding the risk of bias, and all of these had sufficient (+) results ratings. Validity studies proportionally showed a greater risk of bias, with five of the 12 studies rated as doubtful or inadequate, while results were variable, with four studies being sufficient, two studies insufficient, and six with indeterminate scores. The methodological quality of the eight responsiveness studies was generally high, with six of these being adequate or very good ratings; however, the results of these studies were lower quality, with six studies rating at insufficient (–) or indeterminate (?).

Results of individual studies

Reliability

Nineteen studies examined the reliability or measurement error of pinch strength (Table 3) [6,11,20,21,23–25,29–33,35,38,39,41,42,44,45]. Results were largely excellent (ICC ≥ 0.9) for inter-rater, intra-rater, and test–retest reliability in assessments of healthy individuals (four studies, 246 subjects) and of patients with neurological conditions (nine studies, 380 participants). In studies of people with musculoskeletal problems (eight studies, 354 participants), the results were high (ICC 0.75–0.9). A consistent difference in the quality of results was noted across studies that provided data for different numbers of test trials per participant. That is, the higher number of trials, the higher the ICC. This was demonstrated in all four studies that provided this data; however, only MacDermid et al. [11] commented on these differences, reporting that there was no statistical significance in all but one set of data.

Validity

There were 12 studies assessing pinch strength validity (Table 4) [3,7,8,18,19,22,23,33,36,40,41,46]. Of these, eight measured the correlation of pinch strength against other constructs such as grip strength and a variety of PROMs, and four measured the ability of pinch strength measurement to distinguish between groups or disease progression. Three studies demonstrated a strong or very strong correlation between pinch strength and grip strength. These studies investigated patients with rheumatoid arthritis ($r = 0.72$) [22], stroke ($r = 0.83$–0.92) [19], and patients undergoing hemodialysis ($r = 0.82$) [7]. Pinch strength was found to moderately correlate with grip strength in one study in patients with leprosy ($r = 0.56$) [33].

Using pinch strength to distinguish between healthy controls and Parkinson's disease patients, Alonso et al. [18] reported a specificity of 0.83 and a sensitivity of 0.50. Werlauff and Steffensen [40] assessed lateral pinch in patients with spinal muscular atrophy to determine whether pinch strength could distinguish between individuals at various stages of functional deterioration. Using the Brooke Upper Limb Scale as a comparator, they found that pinch strength could differentiate patients at Brooke levels two and three but not among other Brooke levels. The authors noted that only 62% of participants were able to overcome the minimum threshold force for measurement, thereby impacting the volume of data points available for statistical analysis due to floor effects.

Pinch strength demonstrated strong correlations with several PerFOMs that include pinch tasks and measure dexterity. These measures include the Action Research Arm Test ($r = 0.80$), the Jebsen–Taylor Test of Hand Function ($r_s = 0.79$), and the Nine-hole Peg Test ($r_s = 0.78$). Overall, correlation with PROMs such as the Childhood Health Assessment Questionnaire, the

Table 2. Results of studies on measurement properties: COSMIN 2018 guidelines for systematic reviews.

		Reliability			Validity			Responsiveness		
Study	Country	*n*	RoB[a]	Result[b] (rating)	n	RoB[a]	Result[b] (rating)	n	RoB[a]	Result[b] (rating)
Aguiar et al.	Brazil	32	Adequate	+						
Alonso et al.					24 24	Very good	–			
Beebe et al.	USA	33				Inadequate	?	33	Adequate	?
Chen et al.	Taiwan	62	Adequate	+						
Dekkers et al.	Netherlands	86	Adequate	+						
Eberhardt et al.	Sweden, Italy				49	Adequate	?	49	Very good	?
El-Katab et al.	UK				209	Doubtful	+			
Fournier et al.	Canada	14	Adequate	+	14	Inadequate	+			
Gerhardsson et al.	Sweden, Italy	47	Very good	+						
Huang et al.	Taiwan	56	Inadequate	–						
Jerosch-Herold et al.	UK	63	Adequate					63	Inadequate	?
Kierkegaard et al.	Sweden, Canada							113	Adequate	–
Kotsis et al.	USA	47							Adequate	?
Lindstrom-Hazel et al.	USA	73	Adequate	+						
MacDermid et al.	Canada	38	Adequate	+						
Mandanka et al.	India	11	Doubtful	+						
McQuillan et al.	USA				23 91	Adequate	?			
Merlini et al.	Italy	33	Adequate	+						
Myers et al.	UK	55	Very good	+						
Plant et al.	UK	5025	Adequate	+						
Rajkumar et al.	India	62	Inadequate	?	62	Inadequate	?			
Schreuders et al.	Netherlands	33	Adequate	+						
Sferra da Silva et al.	Brazil				242	Adequate	?			
Solari et al.	Italy	40	Adequate	+						
Song et al.	USA				39	Very good	+			
Svensson et al.	Sweden, Canada	20	Adequate	+						
Szekeres et al.	Canada				77	Very good	+	77	Very Good	+
Villafane et al. 2014	USA	27		+						
Villafane et al. 2017	USA							57 53	Adequate	+
Wachter et al.	Germany							25	Inadequate	?
Werlauff et al.	Denmark				52	Inadequate	–			
Wessel et al.	Canada	32	Adequate	+	32	Very good	?			
Ziv et al.	Israel	57	Inadequate	?						

RoB: risk of bias. UK: United Kingdom; USA: United States of America.
[a]Methodological quality of the included studies using the COSMIN Risk of Bias checklist. Each study was rated as Very good, Adequate, Doubtful, or Inadequate quality.
[b]Criteria for good measurement properties: "+" sufficient; "–" insufficient; "?" indeterminate.

Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH), the Disease Activity Score, the Health Assessment Questionnaire (HAQ), the Patient-Rated Ulnar Nerve Evaluation (PRUNE), and the Michigan Hand Questionnaire were all weak to moderate (−0.03 to 0.50).

Responsiveness

Eight studies that assessed responsiveness were included in this systematic review (Table 5). In 2017, Villafane et al. [4] determined that the minimal clinically important difference was 0.30 kg for tripod pinch, and 0.33 kg for tip pinch in patients with thumb carpometacarpal osteoarthritis. They indicated that changes greater than these numbers indicate real change over and above measurement error, and represent an important change over time. Szekeres et al. [3] demonstrated that changes in lateral pinch strength ($r = -0.30$) were more responsive to changes in function over a 2-year period following ulnar nerve transposition than either grip strength ($r = -0.28$) and recovery of sensory threshold ($r = 0.19$), when measured by change scores on the PRUNE. Wachter et al. [43] conducted nerve blocks on 25 healthy subjects to simulate an ulnar nerve lesion and measure the change in pinch strength, expressed as percent loss; they noted a loss of 57.5% pinch strength with a tip grip, 61% with a tripod grip, and 58.3% with a lateral grip when the ulnar nerve palsy was simulated ($p < .0001$).

Beebe et al. [19] used a single population ES method to calculate the response to change in 33 patients recovering from stroke. Using pinch strength measurements of patients' more affected hands, the authors reported an ES of 0.52 from 1 to 3 months and 0.56 from 1 to 6 months. In a study by Eberhard et al. [22], the SRM method was used to measure sensitivity to change in pinch strength in adults with rheumatoid arthritis. Forty-nine subjects in a large ongoing clinical observational study of patients receiving anti-tumor necrosis factor therapy were selected to test tip pinch strength changes over 1 year. Using the HAQ as the comparator, the SRM was 0.83. Using the DASH, the SRM was 0.88. Kotsis et al. [27] calculated the SRM in a prospective study of 47 patients who underwent open reduction and internal fixation for unstable distal radius fracture. A paired *t*-test was used to compare means between 3 and 6 months or between 6 months and 1 year. The number of subjects at each measurement interval varied, with data collected on 47 participants 6-month post-surgery (SRM = 1.1) and 37 participants 12-month post-surgery (SRM = 0.5). Using data from the 28 subjects available at all time points, the SRM was 0.9 at 6 months and 0.5 at 12 months. Kierkegaard et al. [28] studied responsiveness over a 9-year interval in 71 women and 42 men with myotonic dystrophy type 1 and calculated an AUC of 0.6 (95% CI 0.5–0.7); however, in this study, there were significant between-group differences in age and Muscular Impairment Rating Scale (MIRS) classification.

Table 3. Summary of reliability properties of pinch strength.

Study	Type of reliability	Parameters	Reliability estimates
Aguiar 2016	Inter-rater	*Unaffected side*	
		Pulp-to-pulp pinch	ICC = 0.70–0.85 (95% CI 0.41–0.94) SEM = 0.56–0.80 kg MDD 95% = 1.56–2.21 kg
		Tripod pinch	ICC = 0.86–0.95 (95% CI 0.69–0.98) SEM = 0.41–0.73 kg MDD 95% = 1.12–2.01 kg
		Lateral pinch	ICC = 0.88–0.95 (95% CI 0.80–0.98) SEM = 0.44–0.60 kg MDD 95% = 1.22–1.68 kg
		Affected side	
		Pulp-to-pulp pinch	ICC = 0.70–0.94 (95% CI 0.34–0.98) SEM = 0.35–0.73 kg MDD 95% = 0.96–2.01 kg
		Tripod pinch	ICC = 0.88–0.94 (95% CI 0.69–0.98) SEM = 0.53–0.79 kg MDD 95% = 1.47–2.19 kg
		Lateral pinch	ICC = 0.88–0.95 (95% CI 0.72–0.98) SEM = 0.46–0.70 kg MDD 95% = 1.26–1.95 kg
	Intra-rater	*Unaffected side*	
		Pulp-to-pulp pinch	ICC = 0.64–0.85 (95% CI 0.87–0.99) SEM = 0.50–0.79 kg MDD 95% = 1.38–2.20
		Tripod pinch	ICC = 0.84–0.95 (95% CI 0.60–0.98) SEM = 0.41–0.84 kg MDD 95% = 1.15–2.33
		Lateral pinch	ICC = 0.84–0.94 (95% CI 0.60–0.98) SEM = 0.50–0.82 kg MDD95% = 1.38–2.27
		Affected side	
		Pulp-to-pulp pinch	ICC = 0.82–0.90 (95% CI 0.51–0.97) SEM = 0.49–0.62 kg MDD95% = 1.36–1.73
		Tripod pinch	ICC = 0.85–0.95 (95% CI 0.57–0.98) SEM = 0.50–0.87 MDD95% = 1.39–2.39
		Lateral pinch	ICC = 0.91–0.96 (95% CI 0.74–0.99) SEM = 0.52–0.81 kg MDD95% = 1.45–2.26
Chen 2009	Test–retest	*Less affected side*	
		Tripod pinch	ICC = 0.96 (0.93–0.98) SRD = 1.3 (.0230)
		Lateral pinch	ICC = 0.98 (0.96–0.99) SRD = 1.0 (.311)
		More affected side	
		Tripod pinch	ICC = 0.96 (0.94–0.98) SRD = 1.2 (.9740
		Lateral pinch	ICC = 0.96 (0.94–0.98) SRD = 1.4 (.397)
Dekkers 2020	Inter-rater	*Unaffected side*	ICC = 0.967 (0.943–0.981) SEM = 0.54 kg SDC = 1.19 kg
		Affected side	ICC = 0.964 (0.938–0.979) SEM = 0.43 kg SDC = 1.51 kg
	Test–retest	*Unaffected side*	ICC = 0.937 (0.895–0.962) SEM = 0.51 kg SDC = 1.41 kg
		Affected side	ICC = 0.940 (0.896–0.965) SEM = 0.37 kg SDC = 1.03 kg
Fournier 2006	Test–retest	*Unaffected side*	Ep2 = 0.94–0.99 SEM = 0.21–0.46 kg
		Affected side	Ep2 = 0.88–0.96 SEM = 0.37–0.66 kg
Gerhardsson 2014	Test–retest	*Right hand*	LOA: 100% ICC = 0.98 (0.96–0.99) $r = 0.98$ ($p < 0.001$)
		Left hand	LOA: 96% ICC = 0.97 (0.93–0.99) $r = 0.97$ ($p < 0.001$)

(*Continued*)

Table 3. Continued.

Study	Type of reliability	Parameters	Reliability estimates
Huang 2011	Test–retest	*Unaffected side*	
		Tripod grip: one trial	ICC = 0.96, SRD = 1.4
		two trials (mean)	ICC = 0.98, SRD = 1.0
		two trials (highest)	ICC = 0.97, SRD = 1.2
		three trials (mean)	ICC = 0.98, SRD = 1.0
		three trials (highest)	ICC = 0.98, SRD = 1.2
		Lateral grip: one trial	ICC = 0.96, SRD = 1.7
		two trials (mean)	ICC = 0.97, SRD = 1.4
		two trials (highest)	ICC = 0.97, SRD = 1.4
		three trials (mean)	ICC = 0.98, SRD = 1.1
		three trials (highest)	ICC = 0.96, SRD = 1.7
		Affected side	
		Tripod grip: one trial	ICC = 0.41, SRD = 2.7
		two trials (mean)	ICC = 0.49, SRD = 2.5
		two trials (highest)	ICC = 0.53, SRD = 2.7
		three trials (mean)	ICC = 0.50, SRD = 2.4
		three trials (highest)	ICC = 0.52, SRD = 2.7
		Lateral grip: one trial	ICC = 0.61, SRD = 3.1
		two trials (mean)	ICC = 0.63, SRD = 3.0
		two trials (highest)	ICC = 0.59, SRD = 3.2
		three trials (mean)	ICC = 0.72, SRD = 2.5
		three trials (highest)	ICC = 0.72, SRD = 2.6
Lindstrom-Hazel 2009	Inter-rater	Tripod pinch	Average ICC = 0.973
		Lateral pinch	Average ICC = 0.978
		Combined	Average ICC = 0.976
MacDermid 1994	Inter-rater	*Unaffected side*	
		Tripod pinch, 1 trial	ICC = 0.87 (0.74–0.93)
		Tripod pinch, 3 trials (average)	ICC = 0.97 (0.94–0.98)[a]
		Lateral pinch, 1 trial	ICC = 0.93 (0.86–0.96)
		Lateral pinch, 3 trials (average)	ICC = 0.93 (0.86–0.96)
		Affected side	
		Tripod pinch, 1 trial	ICC = 0.88 (0.78–0.96)
		Tripod pinch, 3 trials (average)	ICC = 0.93 (0.86–0.96)
		Lateral pinch, 1 trial	ICC = 0.94 (0.88–0.97)
		Lateral pinch, 3 trials (average)	ICC = 0.97 (0.88–0.97)
Mandanka 2020	Inter-rater	*Unaffected side*	
		Tip pinch	ICC = 0.993
		Lateral pinch	ICC = 0.995
		Affected side	
		Tip pinch	ICC = 0.992
		Lateral pinch	ICC = 0.998
	Intra-rater	*Unaffected side*	
		Tip pinch	ICC = 0.979
		Lateral pinch	ICC = 0.986
		Affected side	
		Tip pinch	ICC = 0.977
		Lateral pinch	ICC = 0.993
Merlini 2002	Inter-rater		ICC = 0.92 (0.84–0.95)
	Intra-rater		ICC = 0.94 (0.89–0.97)
Myers 2011	Inter-rater	*Right hand*	
		Pulp pinch	ICC = 0.89 (0.82–0.94)
		Tripod pinch	ICC = 0.94 (0.90–0.97)
		Lateral pinch	ICC = 0.88 (0.81–0.93)
		Left hand	
		Pulp pinch	ICC = 0.89 (0.81–0.93)
		Tripod pinch	ICC = 0.93 (0.87–0.96)
		Lateral pinch	ICC = 0.87 (0.79–0.92)
	Intra-rater	*Right hand*	
		Pulp pinch	ICC = 0.92 (0.86–0.95)
		Tripod pinch	ICC = 0.93 (0.89–0.96)
		Lateral pinch	ICC = 0.88 (0.80–0.93)
		Left hand	
		Pulp pinch	ICC = 0.90 (0.84–0.94)
		Tripod pinch	ICC = 0.93 (0.89–0.96)
		Lateral pinch	ICC = 0.89 (0.81–0.93)
Plant 2016	Inter-rater	Manual gauge	ICC = 0.98 (0.95–1.0)
		Electronic gauge	ICC = 0.98 (0.94–0.99)
	Intra-rater	Manual gauge	ICC = 0.86 (0.69–0.94)
		Electronic gauge	ICC = 0.93 (0.83–0.97)
Rajkumar 2002	Inter-rater		No results provided
	Intra-rater		

(*Continued*)

Table 3. Continued.

Study	Type of reliability	Parameters	Reliability estimates
Schreuders 2003	Inter-rater	*Unaffected side*	
		Tip pinch	ICC = 0.84
			SEM = 5 N
			SDD = 14
		Lateral pinch	ICC = 0.86
			SEM = 7 N
			SDD = 20
		Affected side	
		Tip inch	ICC = 0.89
			SEM = 5 N
			SDD = 15 N
		Lateral pinch	ICC = 0.94
			SEM = 5 N
			SDD = 15 N
	Intra-rater	*Unaffected side*	
		Tip pinch: Experienced/Inexperienced Rater	ICC = 0.89/0.82
			SEM = 4 N/5 N
			SDD = 12 N/15 N
		Lateral pinch: Experienced/Inexperienced	ICC = 0.93/0.89
			SEM = 5 N/7 N
			SDD = 13 N/18 N
		Affected side	
		Tip inch: Experienced/Inexperienced	ICC = 0.93/0.92,
			SEM = 4 N/5 N
			SDD = 12 N/13 N
		Lateral pinch: Experienced/Inexperienced	ICC = 0.97/0.93
			SEM = 5 N/6 N
			SDD = 11 N/18 N
Solari 2008	Inter-rater		ICC = 0.95 (0.90–0.97)
	Intra-rater		ICC = 0.94 (0.89–0.96)
Svensson 2006	Test–retest	Right hand	ICC = 0.97 (0.91–0.99)
		Left hand	ICC = 0.96 (0.90–0.99)
Villafane 2014	Test–retest	*Unaffected side*	
		Tip pinch	ICC = 0.91 (0.81–0.96), SEM = 0.05 kg
		Tripod pinch	ICC = 0.96 (0.92–0.98), SEM = 0.04 kg
		Lateral pinch	ICC = 0.94 (0.87–0.97), SEM = 0.03 kg
		Affected side	
		Tip pinch	ICC = 0.93 (0.85–0.97), SEM = 0.06 kg
		Tripod pinch	ICC = 0.92 (0.83–0.96), SEM = 0.06 kg
		Lateral pinch	ICC = 0.99 (0.97–0.99), SEM = 0.01 kg
Wessel 1999	Inter-rater		ICC = 0.95–0.96, SEM = 0.58–0.66 lbs
	Intra-rater		ICC = 0.94–0.95, SEM = 0.62–0.77 lbs
Ziv 2008	Test–retest	*Healthy subjects*	
		Tip pinch – right hand, left hand	SEM = 0.20, 0.23
			SDD = 0.54, 0.63
		Tripod pinch – right hand, left hand	SEM = 0.17, 0.16
			SDD = 0.47, 0.40
		Lateral pinch – right hand, left hand	SEM = 0.14, 0.15
			SDD = 0.40, 0.42
		OA subjects	
		Tip pinch – right hand, left hand	SEM = 0.46, 0.41
			SDD = 1.27, 0.15
		Tripod pinch – right hand, left hand	SEM = 0.37, 0.34
			SDD = 1.02, 0.95
		Lateral pinch – right hand, left hand	SEM = 0.36, 0.43
			SDD = 1.00, 1.19

ICC: intraclass correlation coefficient (95% confidence interval); kg: kilograms; lbs: pounds; LOA: limits of agreement; N: Newtons; SDD: smallest detectable difference; SEM: standard error of measurement; SDC: smallest detectable change; SRD: smallest real difference.
[a]Significantly different from 1 repetition ($p < 0.05$).

Discussion

This was a systematic review of 33 clinical studies assessing the reliability, validity, and responsiveness of pinch strength in various populations. We were unable to conduct a meta-analysis due to high heterogeneity among studies. This high heterogeneity is due to differences in instrumentation, positioning, multiple types of pinch measured, and the number of different populations studied. This review demonstrated that the reliability of pinch strength assessment is good to excellent. There is a high correlation with grip strength, and moderate correlation with dexterity measures, but concurrent validity with selected PROMs is low. A moderate level of discriminate validity was shown in the ability of pinch strength to differentiate between individuals within various patient populations. The low number and insufficient/indeterminate results of studies measuring responsiveness suggest a clinical need to determine the responsiveness of this widely used measurement instrument through further research, particularly as it is known that some individuals with hand impairment lack the strength to register a reading on a standard pinch gauge. These floor effects might be overcome with a more sensitive device that reads lower values.

Table 4. Summary of validity properties of pinch strength.

Study	Type of validity	Comparators	Validity estimates
Alonso 2023	Discriminant	Parkinson's disease vs. healthy controls	AUC (95% CI) = 0.693 (0.544–0.841)
			Sensitivity (95% CI) = 50.0 (35.9–64.1)
			Specificity (95% CI) = 83.3 (72.8–93.9)
Beebe 2009	Convergent	Grip strength at 1, 3, and 6 months	r_s = 0.92, 0.89, 0.83
		ARAT at 1, 3, and 6 months	r_s = 0.79, 0.8, 0.65
		Jebsen at 1, 3, and 6 months	r_s = 0.72, 0.79, 0.60
		9HPT at 1, 3, and 6 months	r_s = 0.77, 0.78, 0.61
		SIS-Hand	r_s = 0.54, 0.69, 0.41
Eberhardt 2008	Convergent	SOFI vs. pinch strength	r_s = −0.56 ($p < 0.01$)
		Grip strength vs. pinch strength	r_s = 0.72 ($p < 0.01$)
		GAT vs. pinch strength	r_s = −0.35 ($p < 0.05$)
		HAQ vs. pinch strength	r_s = −0.48 ($p < 0.01$)
		DAS28 vs. pinch strength	r_s = −0.18 ($p < 0.01$)
El-Katab 2016	Convergent	Grip strength	$r = 0.82$ ($p < 0.001$)
Fournier 2006	Discriminant	Symptomatic vs. asymptomatic	ratio of 0.77 (0.23)
McQuillan 2016	Discriminant	Early thumb CMC OA vs. healthy controls: adjusted log odds ratio	Lateral grip: 0.41 (0.13–0.69)
			Tripod: 0.17 (0.00–0.50)
			Pulp-to-pulp grip: 0.41 (0.03–0.79)
Rajkumar 2002	Convergent	BADL vs. pinch grips P, L, T	correlation coefficients = 0.614, 0.559, 0.614
		Grip strength vs. pinch grips P, L, T	correlation coefficients = 0.584, 0.602, 0.556
SferradaSilva 2018	Convergent	HAQ vs. pinch grips P, L, and T (right hand)	r_s = 0.446, 0.505, 0.470
		HAQ vs. pinch grips P, L, and T (left hand)	r_s = 0.472, 0.501, 0.555
		DASH vs. pinch grips P, L, and T (right hand)	r_s = 0.453, 0.484, 0.444
		DASH vs. pinch grips P, L, and T (left hand)	r_s = 0.444, 0.486, 0.535
		CHFS vs. pinch grips P, L, and T (right hand)	r_s = 0.452, 0.496, 0.474
		CHFS vs. pinch grips P, L, and T (left hand)	r_s = 0.448, 0.474, 0.509
		Length of disease vs. pinch grips P, L, and T (right hand)	r_s = 0.171, 0.189, 0.187
		Length of disease vs. pinch grips P, L, and T (left hand)	r_s = 0.204, 0.217, 0.238
		DAS28 vs. pinch grips P, L, and T (right hand)	r = 0.473, 0.467, 0.341
		DAS28 vs. pinch grips P, L, and T (right hand)	r = 0.436, 0.424, 0.336
Song 2013	Convergent	CTQ Symptom Score vs. pinch strength	r_s = −0.27 (p = .12)
		CTQ Function Score vs. pinch strength	r_s = −0.13 (p = .49)
		DASH vs. pinch strength	r_s = −0.02 (p = .90)
		MHQ vs. pinch strength	r_s = −0.03 (p = .86)
Szekeres 2015	Convergent	PRUNE vs. lateral pinch	r = −0.22 ($p = 0.06$)
Werlauff 2014	Discriminant	Brooke levels 5–6	$p = 0.127$
		Brooke levels 4–5	$p = 0.127$
		Brooke levels 3–4	$p = 0.312$
		Brooke levels 2–3	$p = 0.050$
Wessel 1999	Convergent	CHAQ vs. pinch strength	$r = -0.33$ ($p = 0.07$)
		50-m run vs. pinch strength	r_s = −0.19 ($p = 0.32$)

ARAT: Action Research Arm Test; AUC: area under the curve; BADL: basic activities of daily living; CHAQ: Childhood Health Assessment Questionnaire; CHFS: Cochin Hand Functional Scale; CMC: carpometacarpal; DASH: Disabilities of the Arm, Shoulder, and Hand; DAS28: Disease Activity Score; GAT: Grip Ability Test; HAQ: Health Assessment Questionnaire; Jebsen: Jebsen–Taylor Test of Hand Function; MHQ: Michigan Hand Questionnaire: OA: osteoarthritis; SIS: Stroke Impact Scale; SOFI: Signals of Functional Impairment; 9HPT: Nine-hole Peg Test; PRUNE: Patient-Rated Ulnar Nerve Evaluation.

Table 5. Summary of responsiveness properties of pinch strength.

Study	Type of responsiveness	Responsiveness estimates
Beebe et al.	External	Change at 3 months: ES = 0.52
		Change at 6 months: ES = 0.56
Eberhardt et al.	External	Pinch strength against HAQ: SRM = 0.88
		pinch strength against DAS28: SRM = 0.83
Jerosch-Herold et al.	External	Change at 4 months: ES = 0.07, SRM = 0.14
		Change at 8 months: ES = 0.07, SRM = 0.12
Kierkegaard et al.	External	Construct approach pinch strength against grip strength r_s = 0.4
		Construct approach pinch strength against Purdue pegboard r_s = 0.3
		criterion approach AUC = 0.6 kg (0.5–0.7)
Kotsis et al.	External	6-month post-surgery: SRM = 0.9 kg
		12-month post-surgery: SRM = 0.5 kg
Szekeres et al.	External	Prediction in PRUNE score change ($r = -0.3$)
Wachter et al.	External, measured by percent loss	Tip: 57.5%; tripod: 61%; key: 58.3%

AUC: area under the curve (95% confidence interval); DAS28: Disease Activity Score; PRUNE: Patient-Rated Ulnar Nerve Evaluation; ES: effect size; HAQ: Health Assessment Questionnaire; *r*: Pearson coefficient; SDD: smallest detectible difference; SRM: Standard response mean.

With good to excellent reliability estimates, clinicians can measure pinch strength and expect accurate results over repeated measurements and between raters. The high reliability and ease of measuring pinch strength clinically make it a very common assessment tool for patients with hand injury [9]. Reliability was highest, as expected, in studies that measured normal participants, and lowest (but still good with ICC estimates greater than 0.75) in studies that measured patients with musculoskeletal conditions. This is likely due to the decreased variability in samples that measure normal populations which can artificially inflate reliability estimates.

During most prehensile activities, the use of precision and power is a dominant characteristic but not mutually exclusive, and the transition between power and precision grips is activity-dependent. Therefore, a recommendation is that further research should look to identify when maximal pinch grip is used or required vs. submaximal grip, and what type of grip is used. This might also limit the concurrent validity of pinch strength with PROMs, that often ask about real-world activities. This was highlighted by Szekeres et al. [3], who found that items on the PRUNE did not include many items requiring maximum pinch, limiting the correlation (−0.22) between pinch strength PRUNE scores during baseline measurements for patients with cubital tunnel syndrome. In addition, a pinch is not always required to be maximal in everyday tasks, so the current protocols do not reflect the kinematics of everyday activities. Similarly, a tripod pinch is assessed in a pronated position. In contrast, in daily actions using this grip, such as pulling a plug out of the wall, the wrist would most likely be neutral, involving different muscle recruitment and joint positioning. These differences could negatively impact concurrent validity of pinch strength measurement with PROMs.

The high correlations between pinch strength and grip strength were expected since these measure similar constructs and both depend on the forceful contraction of similar muscle groups. The rationale for the moderate correlations between pinch strength and dexterity is not as evident. Even though the dexterity tests that were included in the studies do not likely require a large amount of pinch strength, there is likely a relationship between the quality and speed of thumb motion and overall strength. The low correlations between pinch strength and several PROMs was an expected result since these outcome measures evaluate complex constructs that likely include strength, but also pain, sensibility, range of motion, and psychosocial factors.

Responsiveness was the least measured psychometric property of pinch strength assessment. The study by Villafane et al. [4], which determined an MCID of 0.30 kg for tripod pinch and 0.33 kg for tip pinch in patients with thumb carpometacarpal osteoarthritis provides a guideline for interpreting important change over time for that population. Since pinch strength changes over time were found to be more responsive than grip strength or one-point sensory threshold changes for patients with ulnar neuropathy, working on (and measuring) pinch strength has been recommended for patients with cubital tunnel syndrome [3]. Further high-quality studies are recommended that will improve the understanding of important clinical change for other populations.

Alonso et al. [18] highlighted a primary concern when interpreting results of pinch strength to assess hand function impairment in patients: maximum pinch strength and strength, in general, are sex-dependent, with males being, on average, stronger than females. They importantly conclude that this finding and the fact that strength is highly affected by sex speak against the use of maximum pinch strength as an outcome to inform researchers and clinicians about hand function impairment in individuals with Parkinson's disease, and this may be reflected in other populations. Their solution to this problem is to perform a ROC (receiver operating characteristic) curve analysis separately for males and females and obtain two different cutoffs; however, this would reduce statistical power. Subsequent studies must complete that analysis (i.e., ROC curve analysis) by separating groups by sex with a larger sample size. In addition, studies can be improved by measuring and statistically accounting for differences between affected vs. unaffected hands (or dominant vs. non-dominant), as well as the type of grip used.

Almost three decades ago, MacDermid et al. [11] commented that pinch strength measurement and its interpretation are complicated by the fact that there are several forms of pinch and that neither the positioning nor the terminology used for the description of types of pinch grip is consistent in the literature, and this continues to be a problem when attempting to synthesize the research. This lack of consensus regarding a standardized naming convention generates many inconsistencies in language and terminology; for example, different interchangeable terms are used for the three standard pinch grips. A pulp-to-pulp grip is very different from a tip-to-tip pinch regarding kinematics, surface contact, and muscle recruitment, yet they are used interchangeably. Moving forward, a consensus is required to ensure cohesion in the evidence base to accurately inform where further research is needed and how best to design these studies. This should include a review of current testing protocols and whether the hand positions reflect the everyday execution of functional pinch grasps.

A decision to only include articles published in relatively higher-quality study designs and in peer-reviewed journals was made in order to increase the validity of our findings and to increase the strength of our recommendations. This may have left out information from other sources such as case reports and conference proceedings. Studies that included statistical information about a pinch strength measurement property, but whose primary objective was something other than a measurement property of pinch strength were also excluded. These types of studies do not frequently report adequate information about the methodology or the outcome of psychometrics assessment and as such did not meet our inclusion criteria. As a result, studies that could have contributed to this review might have been excluded.

Conclusion

Pinch strength assessment is a reliable tool in many musculoskeletal, systemic, and neurological conditions. Clear conclusions with respect to validity and responsiveness of pinch strength measurement are difficult to establish, but based on the available research, there is a high correlation between pinch and grip strength, and a moderate correlation between pinch strength and hand dexterity. Since most PROMs only include a few items that require maximal pinch, correlations with these important assessments are low as expected. This low correlation highlights the need to include pinch strength assessment in addition to PROMs. Even though pinch strength assessment is faster to perform in the clinic, it is not necessarily a valid surrogate for PROMs. Future studies re-evaluating pinch grip protocols and their kinematics, along with further work on the responsiveness of pinch strength evaluation are recommended.

Disclosure statement

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