SCIENTIFIC ARTICLE

Validity and Responsiveness of Forearm Strength Measurements in the Evaluation of Distal Radioulnar Joint Implant Arthroplasty

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Purpose To assess the responsiveness of forearm strength tests and to correlate the change to grip strength and a patient-reported outcome measure used for evaluation of distal radioulnar joint (DRUJ) implant arthroplasty.

Methods We performed a retrospective review of 18 patients treated with Herbert (n = 12) and Scheker (n = 6) DRUJ implants. Patients who had undergone the various measurements of arm and grip strength both before surgery and after a minimum follow-up of 1 year were included. Our primary aim was to compare the responsiveness of grip strength with our new methods for measuring forearm torque and lifting strength. The secondary aim was to correlate observed changes in strength measurements to change in a patient-reported outcome measure with use of the patient-reported wrist evaluation (PRWE). Measurements of grip strength, forearm torque, and lifting strength were performed with the Jamar dynamometer and the Kern and Baseline instruments. Preoperative values were compared with 1-year values.

Results Standardized response mean and effect size values were higher for forearm torque than for grip strength. Change in forearm torque and lifting strength had a moderate to strong correlation with change in PRWE. The correlation between grip strength and PRWE was weak.

Conclusions Forearm torque measurements were better than grip strength in detecting changes after DRUJ arthroplasty. It also had a stronger correlation to patient-reported outcome, measured with the PRWE.

Clinical relevance Forearm torque testing may add further information to the evaluation of DRUJ disorders and their treatments. These tests can provide quantifiable data on the patient's ability to perform various tasks requiring physical strength. *(J Hand Surg Am. 2020;■(■):1.e1-e7.*

Key words Distal radioulnar joint, implant arthroplasty, forearm torque, lifting strength, responsiveness.

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THE OUTCOME OF TREATMENTS for distal radioulnar joint (DRUJ) disorders has traditionally been assessed by determining range of motion, grip strength, radiographic criteria, and a subjective evaluation by the examiner. Visual analog scales and patient-reported outcome measurements (PROMs) are often added. The Patient-Reported Wrist Evaluation (PRWE) questionnaires is 1 of the most commonly used instruments.[1]

Grip strength is the most frequent physical measurement used by both hand surgeons and researchers to determine overall upper extremity function. The test is easy to perform and normative values, as well as reliability, are well established. However, regarding validity and responsiveness for wrist conditions, published reports are rare.[2–4]

The PRWE instrument was developed to quantify disability after wrist trauma, but it has demonstrated high reproducibility and responsiveness for many other forearm disorders.[5–8] There are few data on the validity of the PRWE related to the DRUJ, but Omokawa et al[9] reported that the PRWE was highly responsive in detecting clinical change for patients with ulnocarpal abutment syndrome. They also found a significant correlation between changes in PRWE scores and improvements in patient satisfaction, as well as between the PRWE functional subscale and improvements in forearm rotation. However, they found no significant correlation between the PRWE and grip strength. Other investigators have also found weak associations between self-reported measurements and physical measurements.[2,10]

Because important features of the DRUJ include the transmission of load and facilitating forceful forearm rotation, we hypothesized that measurements of lifting strength and forearm torque could offer a more valid assessment of DRUJ impairment than grip strength. To investigate this, we recently developed 2 test methods to measure lifting strength and forearm torque in the clinical situation. The instruments used in these tests, Baseline and Kern dynamometers, proved to be accurate and the methods were shown to be both reliable and valid.[11]

The primary aim of this study was to compare the responsiveness of grip strength with our new methods for measuring forearm torque and lifting strength when used for the assessment of DRUJ function. We also compared the change in various strength measurements with changes of a PROM in patients treated with DRUJ implants.

If any of the strength tests showed a high correlation with clinical improvement as reported by the patient, 1 year after wrist arthroplasty, such a test could be suitable as a clinically relevant outcome measure after operation with DRUJ arthroplasty. In this analysis, PRWE was used as the PROM and reference standard because this instrument only relates to the operated wrist and is more focused on pain than the Disabilities of the Arm, Shoulder, and Hand questionnaire, which is also a commonly used PROM for wrist disorders.

METHODS

Institutional review board approval was obtained and all patients signed a written consent.

Patients

Eighteen of 21 patients treated with DRUJ implant arthroplasty between June 2012 and March 2016, with a minimum follow-up of 1 year, and assessed before surgery for forearm torque, lifting strength, and grip strength were included (n = 18). Two patients without preoperative data and 1 patient revised within ` year were excluded. Twelve of the 18 patients were treated with a Herbert ulnar head prosthesis (Herbert UHP; Martin Medizin Technik, Tuttlingen, Germany) and 6 with the Scheker total DRUJ implant (Aptis, Louisville, KY). There were 9 men and 9 women with an average age of 56 years (range, 24−72 years). Eleven patients had undergone at least 1 previous surgical procedure (mean, 2; range, 1¯5) in the DRUJ area. Five patients had a history of previous fractures and 3 of ligament injuries. The indications for the DRUJ implant arthroplasty were primary osteoarthritis (n = 3), secondary osteoarthritis (n = 3), rheumatoid arthritis (n = 6), recurrent instability (n = 2), instability and osteoarthritis (n = 3, or previous DRUJ implant failure (n = 1). Nine patients had previous or concomitant surgeries performed in the adjacent joints or the nearby area (ie, total wrist fusion or total wrist arthroplasty).

The surgical techniques and postoperative treatment that were used followed standard procedures, as previously described.[12,13]

Assessments

One of 2 senior hand surgeons (P.A. and A.I.S.) performed all the assessments. Preoperative recordings were compared with 1-year recordings for all patients.

Strength measurements: Single-effort peak-strength values were recorded and all measurements were completed in the standing position with the elbow in 90° of flexion (Fig. 1). Grip strength was measured with a Jamar dynamometer (Sammons Preston, Inc., Bolingbrook, IL). The second handle position was used. Forearm torque was measured with the Baseline digital wrist dynamometer (Fabrication Enterprises, White Plains, NY). The instrument was equipped with a shovel handle and attached to vertical wall-mounted rails in order to facilitate adjustments to the patient's height. Testing was performed with the handle in the vertical position, first in the supinating and then in the pronating direction. Specific

FIGURE 1: Test of lifting strength and forearm torque.

information on torque testing included avoiding leaning the trunk or letting the elbow leave the side of the body. Lifting strength was measured by a hanging scale dynamometer (KHCB 50 kg/20 g; Kern & Sohn GmbH, Balingen, Germany) in 3 different positions. Recordings were made in the order of neutral forearm rotation, maximum supinated position, and maximum pronated position. Specific instructions relating to lifting strength testing included maintaining a straight wrist position and avoiding elevation of the shoulder or leaning of the trunk. For details regarding the test procedures and normative data, see Axelsson et al.[11,14]

Patient-reported outcome measurements (PROMs): Patient-reported outcome was recorded with the PRWE instrument.

Statistical methods

Responsiveness for the strength tests, as well as the PRWE, was examined by calculating the standardized response mean (SRM: mean change/SD of the change) and effect size (ES: mean change/SD of initial value). Both parameters are recognized and used to gauge the responsiveness of scales to clinical change or to provide direct information on magnitude of change in the measure.[15] We used Wilcoxon signed rank test to compare preoperative and 1-year follow-up values. *P* values of less than .05 were considered significant.

Spearman rank correlation (*r*) was used to explore relationships between the changes in variables. Data were plotted in scatter diagrams and/or presented in boxplots. Correlation coefficients were interpreted as negligible, 0.00 to 0.10; weak, 0.10 to 0.39; moderate, 0.40 to 0.69; strong, 0.70 to 0.89; or very strong: 0.90 to 1.00

RESULTS

The PRWE and strength tests all improved after arthroplasty. The average change between preoperative values and results at the 1-year follow-up can be seen in Table 1 and Figure 2. The changes were significant for PRWE and Torque, but not for grip and lifting strength. All patients improved in terms of torque to some extent, whereas the change for grip and lifting strength showed large variability and a decrease for some patients. Compared with PRWE, the torque measurements were only slightly less responsive, whereas grip and lifting strength had a markedly lower sensitivity (Table 1).

Changes in PRWE proved to have a moderate to strong correlation to torque and lifting strength, but not to grip strength (Table 2 and Fig. 3). Notably, the correlations between changes in grip strength and

TABLE 1. Test Differences and Responsiveness*

	SRM	ES	Preoperative (SD)	1 Y (SD)	Difference (SD)	*P* Value†
PRWE	−1.01	−1.48	65 (17)	40 (24)	−25 (25)	<.05
Grip (kg)	0.39	0.49	21.0 (8.6)	25.2 (13.2)	4.2 (10.7)	.21
Lift, neutral (kg)	0.35	0.40	8.1 (4.7)	10.0 (5.4)	1.8 (5.3)	.18
Lift, supine (kg)	0.32	0.33	7.6 (4.5)	9.0 (5.4)	1.5 (4.7)	.27
Lift, prone (kg)	0.41	0.54	5.9 (2.5)	7.2 (3.5)	1.3 (3.2)	.11
Torque, supinated (Nm)	0.95	0.78	3.4 (1.5)	4.6 (1.8)	1.1 (1.2)	<.05
Torque, pronated (Nm)	0.70	0.75	2.8 (1.2)	3.7 (1.8)	0.9 (1.3)	<.05

*Mean values before surgery, at 1 y, and change.
†*P* values for Wilcoxon signed rank test.

changes in other outcome variables were negligible or weak (Table 2).

DISCUSSION

The growing interest in DRUJ disorders and their treatments underlines the need for more quantitative and accurate evaluations of clinical results. So far, there are no standards to evaluate the results after interventions for DRUJ disorders. For evaluation of DRUJ joint arthroplasties, clinical documentation instruments should include measurements of pain, stability, function, and strength all with focus on the wrist joint as far as possible. Concerning the last parameter, determination of forearm torque seems to be appropriate to include according to our observations. Grip strength and range of motion are usually the only physical parameters recorded, but little is known about their relevance to DRUJ dysfunction. We hypothesized that measuring forearm torque and lifting ability could be more valid and provide additional information on DRUJ function in comparison with grip strength testing because they more adequately reflect the dysfunction that may cause the patient to seek medical attention.

We found that improvements in forearm torque mirrored patient-reported outcome after DRUJ arthroplasty more consistently than grip strength. This observation supports use of torque testing before DRUJ arthroplasty and at follow-up. Our values for responsiveness for grip strength (SRM, 0.39; ES, 0.49) were lower than previously reported by Kim and Park[16] in a study of grip strength changes after the treatment of ulnar abutment syndrome (SRM, 0.68; ES, 0.59). They compared changes in percentages of the opposite limb, whereas we used preoperative values on the side subjected to surgical treatment, which may account for these differences. In our study, changes in grip strength had a weak association with changes in PRWE. Moreover, Omokawa et al[9] found a low correlation between grip strength and disability measured with the PRWE after the treatment of ulnar abutment syndrome. However, Kim and Park[16] found a small yet significant improvement in grip strength after treatment of the same condition, and grip strength has been shown to be a valid measurement for other wrist conditions.[2,17,18] Only a few studies of DRUJ implant arthroplasty have included statistical analyses for changes in grip strength. van Schoonhoven et al,[12] Savvidou et al,[19] and Rampazzo et al[20] reported significant improvements, as did Reissner et al.[21] Several studies[13,22–24] did not report any significant improvement and Sauerbier et al[25] even reported a significant loss of grip strength. The diverging results reported in these studies might indicate a variable outcome, but they could also indicate that the relevance of grip strength measurements as an outcome variable for DRUJ treatments is limited. We believe that forearm torque is a more valid parameter because optimizing torque is a major function of the DRUJ. That expressing force, during static grip testing, requires little of DRUJ function might also explain the poor correlation to other strength parameters observed in this study.

Andersson et al[26] observed improved pronation and supination torque after the reinsertion of the triangular fibrocartilage complex (I B injuries) in 11 patients, using the same testing method as that used in our study. The clinical results were claimed to be good and all the patients returned to their original occupation and leisure activities. The findings in this study support the hypothesis that measurements of torque could be an effective way of obtaining quantitative measurements of function after the treatment of various conditions of the wrist joint.

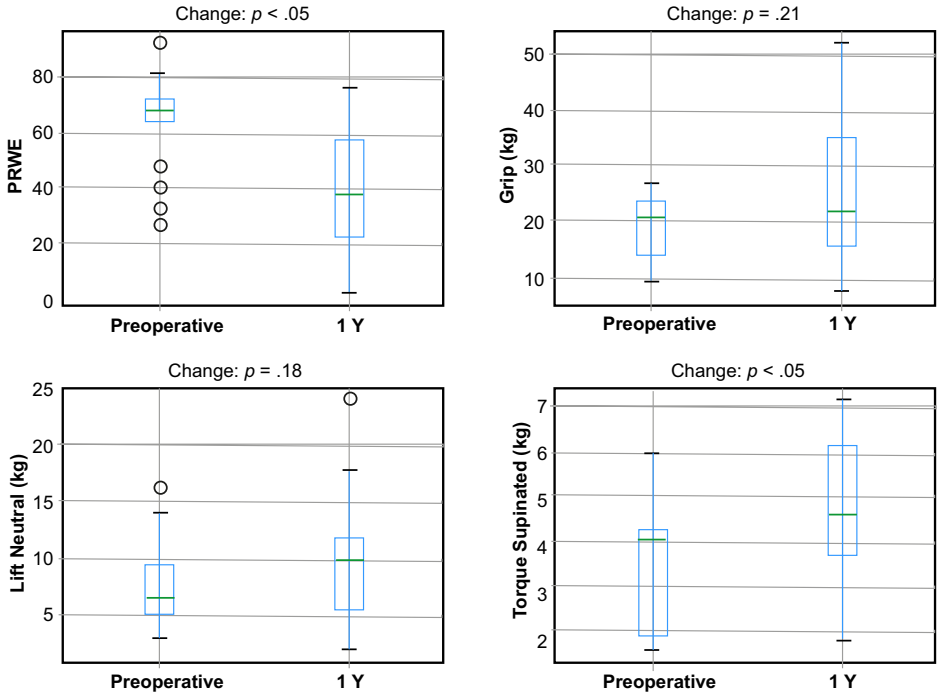

FIGURE 2: Boxplots show examples of changes in test results.

TABLE 2. Spearman's Rank Correlation Coefficients Between PRWE and Strength Measures*

	Lift, n†	Lift, s‡	Lift, p§	Torq, s‖	Torq, p¶	Grip
PRWE	**−0.60**	**−0.68**	**−0.47**	**−0.62**	**−0.70**	−0.22
Lift, n†	.	**0.88**	**0.83**	**0.50**	**0.40**	−0.12
Lift, s‡		.	**0.86**	**0.66**	**0.65**	−0.03
Lift, p§			.	0.38	**0.42**	−0.12
Torq, s‖				.	**0.71**	0.08
Torq, p¶					.	0.21

*Lifting, neutral position.
†Lifting, supinated position.
‡Lifting, pronated position
§Torque, supinating direction.
‖Torque, pronating direction.
¶A threshold of 0.4 has been arbitrarily chosen to help the reader identify the largest correlation coefficients, which are highlighted in **bold**.

We found that tests of lifting strength in various positions of the hand and both directions of forearm torque tests had a moderate to strong correlation to changes in PRWE scores. We are not aware of any investigations that have used forearm torque measurements in the evaluation of DRUJ arthroplasty, but a few studies have measured changes in lifting ability after Scheker implant arthroplasty.[19–21] However, the methods used, lifting heavier and heavier weights, have not been validated.

Our results for the responsiveness of the PRWE after DRUJ arthroplasty had a lower SRM (1.01) than previously reported by Kim and Park[16] after ulnar shortening (PRWE-SRM, 1.64), but the effect sizes were similar. The reason for this difference and its potential clinical importance are not known.

Our study only included 18 patients, which is a small sample. There were a wide range of indications, difference in associated surgeries, heterogeneous demographics, and an uneven distribution of the implants used. Some associated surgeries like wrist arthroplasty or wrist fusions might have influenced the outcomes; however, because our aim was not to assess arthroplasty results, but to explore the

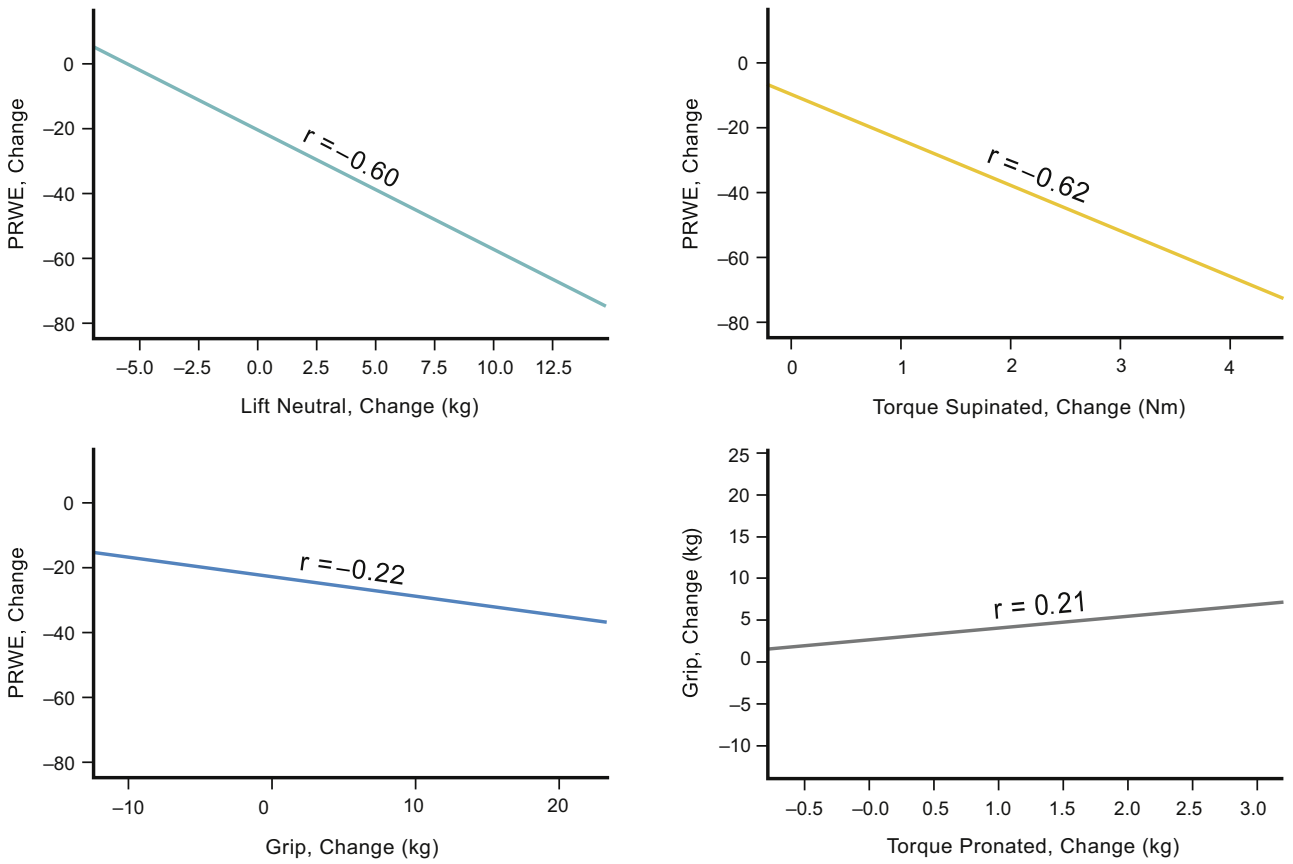

FIGURE 3: Scatterplots show examples of correlations in test results.

performance of the muscle strength measures and a clinical outcome measure and the associations between them, we think that this heterogeneity is less important. It could even be favorable for our main purpose by being more representative for individuals who undergo this procedure and opens up the possibility of its use in a wider context.

We were able to show that grip strength was less effective in mirroring improvements in clinical outcome than forearm torque. This finding needs to be confirmed in larger studies but it suggests that torque is the most important strength parameter and should be included in outcome assessment of DRUJ dysfunction.

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