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Do Impairments Predict Hand Dexterity After Distal Radius Fractures? A 6-Month Prospective Cohort Study

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Abstract

Background: The relationship of routinely measured grip and motion measures may be related to hand dexterity. This has not yet been thoroughly examined following a distal radius fracture (DRF). The purpose of this study was to investigate if impairments in range of motion (ROM) and grip strength predict hand dexterity 6 months following a DRF. **Methods:** Patients with DRFs were recruited from a specialized hand clinic. Hand grip was assessed with a J-Tech dynamometer; ROM was measured using standard landmarks and a manual goniometer. Multiple regression analyses were performed to identify whether potential predictors (grip, ROM, age, hand dominance, and sex) were associated with 3-month or 6-month outcomes in large- and small-object subtests of the NK dexterity test in the affected hand. **Results:** Age, sex, and arc motion for radial-ulnar deviation were significant predictors of large-object hand dexterity explaining the 23% of the variation. For small-object hand dexterity, age and flexion-extension arc motion were significant predictors explaining 11% of the variation at 3 month after the fracture (n = 391). At 6 months post injury (n = 319), grip strength, arc motion for flexion-extension, and age were found to be significant predictors of large-object dexterity explaining 34% of the variance. For the small objects, age, grip strength, sex, and arc motion of radial-ulnar deviation explained 25% of the variation. **Conclusions:** Although this confirms that the impairments in ROM and grip that occur after a DRF can explain almost one-third of the variation in hand dexterity, it also suggests the need for dexterity testing to provide more accurate assessment.

Keywords: hand dexterity, grip strength, range of motion, distal radius fracture

Introduction

The annual incidence of distal radius fractures (DRFs) in the adult population is increasing.[24] DRF incidence peaks have been recorded in the literature for young children, middle-age men, and elderly women.[7] The reasons behind the peaks in the incidence rate of DRFs for certain age groups can be multi-factorial.[13] Restoring hand function after a DRF is the primary goal of rehabilitation. Understanding injury characteristics and presenting impairments plays an important role in customizing the rehabilitation program. Regardless of whether the fracture is treated surgically or not, patients with DRF are expected to gain back their optimum strength and their normal range of motion (ROM) by 6 months.[22] Despite the expectations for a positive outcome, this is not always consistently achieved.[9] Hand functioning can be determined by assessing the level of impairment in ROM, grip strength, hand dexterity, sensory perception, the absence or presence of pain, or other factors shown to be relevant. Most of the literature has focused on physical impairments in hand ROM or hand grip strength as functional outcome measures after a DRF.

Hand dexterity is a combination of different hand abilities that are required to manipulate objects efficiently; hence, time is used as an indicator measure. Hand dexterity has been used to identify neurological deficits after stroke[27] and many other neurological conditions[8,12,16] because it reflects the neurological abnormalities in body structure/function that impair coordination of movement.

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Hand dexterity is not addressed in either the American Academy of Orthopaedic Surgeons practice guideline,[4,5,11,18] or the Cochrane review of DRF rehabilitation.[10] This suggests that hand dexterity is not a major focus on the literature, or consequently, in rehabilitation programs. Furthermore, impaired grip strength and ROM after a DRF do not necessarily reflect the level of pain or disability.[20] By determining the relationship between physical impairments and functional hand performances following a DRF, we can better understand how impairment-based interventions are likely to affect hand function. This may lead to better therapeutic interventions. The purpose of this study was to investigate if physical impairments such as loss of ROM and grip strength predict hand dexterity followed by a DRF in a 6-month follow-up period.

Materials and Methods

Study Design

A prospective cohort study was conducted and was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline checklist.[29] All measurements took place in the Roth|McFarlane Hand and Upper Limb Centre, London, Ontario, Canada. Ethical approval was given by the Faculty of Health Sciences Ethics Committee of Western University.

Recruitment and Participants

Individuals between 18 and 75 years of age were eligible to participate in the study if they had a DRF. Patients with DRFs were excluded from the study if they had any neurological deficit or any other comorbidities that impaired their ability to manipulate large and small objects. Participants provided written informed consent prior to evaluation. A research assistant was responsible for recording demographics (age, sex, and dominant hand side) and taking impairment and dexterity measurements. In particular, 396 participants with DRF were recruited and agreed to participate in the study. Evaluations were performed at 3 and 6 months reflecting time points where significant impairment was expected and then should have substantially resolved. Demographic features such as sex, age, injured hand, dominant side, and mechanism of fracture were collected by self-report.

Study Outcome Measures: Dexterity

The dependent variable was hand dexterity and was measured by 2 different subtests of the NK dexterity test. The manipulation of large and small objects with the affected hand was recorded. Two repetitions were averaged. The independent variables were ROM, grip strength, age, sex, injured side, and hand dominant side.

The NK hand dexterity test (NKHDT) is a valid,[21] reliable,[28] and responsive test.[1] The NKHDT is a computerized timing assessment instrument that measures the speed of manipulation of 3 different groups of objects (small, medium, and large). Each group of objects requires different movements that include lift and place or screw-type tasks. For this study, only 2 subtests of the NKHDT were conducted (small and large objects), and only for the affected hand. The measurement testing protocol and procedure was performed as described by Turgeon et al.[28] Each patient was asked to sit at a comfortable distance facing the NKHDT board on a table. Each group of objects was measured separately and patients were instructed to move only 1 object and use only 1 hand (affected) per trial. The test was performed twice, and the mean of 2 trials was recorded with no time limit per trial.

Impairment Measures

Grip strength. The hand grip strength was measured with the J-Tech grip strength device (JTech Medical, Midvale, Utah). The tracker computerized grip dynamometer is a wireless grip device that provides reliable hand grip strength evaluation. The units of J-Tech medical grip strength device were displayed in kilograms of force. Test-retest reliability of the J-Tech device has been examined in previous studies[6,19] on 149 healthy and was found excellent (ICC = 0.95-0.97). Instructions for the testing procedure for the hand grip strength were given by the research assistant according to the testing protocol of Clerke et al. (2005).[6] Patients were tested in 3 trials and the mean of the 3 trials was calculated. A time break of 15 seconds among each trial was taken by the participants. For each trial, the grip squeeze lasted 2to 3 seconds to ensure that the maximum value of hand grip strength was achieved. Grip strength was measured in the affected hand with the J-Tech dynamometer using a standard position: elbow flexed and forearm/wrist neutral.[19]

Goniometry

Active ROM was measured with a manual goniometer in the affected hand and included the following movements: forearm supination and pronation, wrist flexion and extension, and ulnar and radial deviation.[2,3] The reliability, validity, and responsiveness of the manual goniometer of the elbow and forearm were reported to be high in previous studies.[2,3] The total arc motion was calculated by adding the degrees of ROM of wrist flexion with extension for the flexion-extension arc, supination with pronation for the

Table 1. Descriptive Analysis of Patients With Distal Radius Fracture.

	3 months after (DRF)		6 months after (DRF)	
N (sample)	391		319	
Sex	M (23%)	F (77%)	M (22%)	F (78 %)
Dominant Side (%)	Right (91%)	Left (9%)	Right (88%)	Left (12%)
	Mean	SD	Mean	SD
Dexterity- Large objects	27.1	9.4	24.6	6.5
Dexterity- Small objects	54.3	27.5	49.5	14.4
Arc flexion-extension	91.3°	23.6	102°	23.3
Arc supination-pronation	138.7°	38.5	146°	18.4
Arc ulnar-radius deviation	36.3°	12.4	40.4°	13.2
Age	58.5	12.8	58.8	12.2
Grip Strength	21.2	8.9	21.1	8.8

Note. DRF = distal radius fracture; M = male; F = female; SD = standard deviation.

rotation arc, and radius with ulnar deviation for the deviation arc.

Statistical Analysis

SPSS (version 23.0) software was used for the data analysis. Descriptive statistics were computed and inspected for normality for all variables. Physical impairments such as loss of grip strength and loss of ROM were the factors of interest, with age, sex, and hand dominant side as potential mediators that potentially could contribute in the overall model of dexterity scores. Therefore, a stepwise multiple regression was performed to identify which factors were associated with hand dexterity scores 6 months after a DRF. The probability level was set at $\alpha = 0.05$ with 95% confidence interval. Residual statistics and scatter plots were analyzed (see Supplemental Figures 1-8). We conducted the tests of normality, heteroscedasticity, multicollinearity, and linearity to make sure that all the assumptions of multiple regression were met prior to our analysis.

Results

At 3 months after the DRF, 391 patients (Table 1) participated in the study (males 23%, females 77%) with a mean age of 58.5 ± 12.8. The majority of the sample were right-hand dominant, with 44% injured on the right and 55% on left side and only the 1% injured both sides. The average completion time of hand dexterity for the manipulation of large objects was 27.1 ±9.4 seconds, whereas for the small was 54.3 ±27.5 seconds. The average arc of motion for flexion-extension was 91.3° ± 23.6°, for forearm rotation it was 138.7° ± 38.5°, and for deviation 36.3° ± 12.4°. The average grip strength was 21.2 ± 8.9 kg. At 6-month follow-up, 319 DRF patients (Table 1) completed the second assessment. The average time to completion for the large objects was 24.6 ±6.5 seconds, whereas for the small objects, it was 49.5 ±14.4 seconds. The average arc motion for flexion-extension was 102° ± 23.3°, for forearm rotation it was 146° ± 18.4°, and the deviation arc was 40.4° ± 13.2°. The average of grip strength at 6 months was 21.1 ± 8.8 kg of force.

Predictors of the Large and Small Hand Dexterity in the 3-Month Period

All the regression assumptions were met. Durbin-Watson statistics values ranged from 1.859 to 2.147 that indicates no presence of autocorrelation. The statistical power was 0.99 for the 3-month period and 0.97 for the 6-month period, with 391 and 319 DRF patients, respectively.

The stepwise multiple regression indicated that flexion-extension arc, age, sex, and radial-ulnar deviation were significant predictors of dexterity with large objects, explaining the 23.2% of the variability in the scores (Table 2; see Supplemental Figure 1). Age and flexion-extension arc were significant predictors for the manipulation of small objects explaining the 10.9% of the variability of the scores (Table 3; see Supplemental Figure 3).

Predictors of the Large and Small Hand Dexterity in the 6-Month Period

Multiple regression analysis indicated that grip strength, arc flexion-extension, and age explained 34% of the variability in large-object dexterity scores (Table 4; see Supplemental Figure 5). For the manipulation of small objects, our model found that age, grip strength, sex, and motion arc for ulnar-radius deviation explained 25% of the variability in scores (Table 5; see Supplemental Figure 7).

Table 2. Predictors of Large Hand Dexterity in the 3-Month Period.

		Unstandardized coefficients		Standardized coefficients		
R^2	Model	B	Std. error	Beta	t	*P*-value
0.142	(Constant)	40.86	1.76		23.13	*P* < 0.001
	Arc flex-extension	−0.15	0.01	−0.37	−8.03	*P* < 0.001
0.203	(Constant)	28.26	2.88		9.79	*P* < 0.001
	Arc flex-extension	−0.13	0.01	−0.32	−7.06	*P* < 0.001
	Age	0.18	0.03	0.25	5.40	*P* < 0.001
0.219	(Constant)	24.28	3.17		7.65	*P* < 0.001
	Arc flex-extension	−0.13	0.018	−0.33	−7.25	*P* < 0.001
	Age	0.16	0.03	0.22	4.72	*P* < 0.001
	Sex	3.04	1.05	0.13	2.89	0.004
0.232	(Constant)	24.27	3.15		7.70	*P* < 0.001
	Arc flex-extension	−0.09	0.02	−0.24	−4.26	*P* < 0.001
	Age	0.16	0.03	0.22	4.89	*P* < 0.001
	Sex	3.29	1.04	0.14	3.14	0.002
	Arc deviation[a]	−0.10	0.04	−0.14	−2.52	0.012

[a] Arc motion of ulnar-radius deviation.

Table 3. Predictors of Small Hand Dexterity in the 3-Month Period.

		Unstandardized coefficients		Standardized coefficients		
R^2	Model	B	Std. error	Beta	t	*P*-value
0.070	(Constant)	20.99	6.36		3.29	0.001
	Age	0.57	0.10	0.26	5.37	*P* < 0.001
0.109	(Constant)	47.32	8.94		5.29	*P* < 0.001
	Age	0.48	0.10	0.22	4.57	*P* < 0.001
	Arc flex-extension	−0.23	0.05	−0.20	−4.10	*P* < 0.001

Table 4. Predictors of Large Hand Dexterity in the 6-Month Period.

		Unstandardized coefficients		Standardized coefficients		
R^2	Model	B	Std. error	Beta	t	*P*-value
0.219	(Constant)	31.98	0.84		37.91	*P* < 0.001
	Grip Strength	−0.34	0.03	−0.46	−9.42	*P* < 0.001
0.279	(Constant)	38.04	1.43		26.58	*P* < 0.001
	Grip Strength	−0.27	0.03	−0.37	−7.37	*P* < 0.001
	Arc flex-extension	−0.07	0.01	−0.26	−5.14	*P* < 0.001
0.340	(Constant)	28.11	2.30		12.21	*P* < 0.001
	Grip Strength	−0.19	0.03	−0.26	−5.09	*P* < 0.001
	Arc flex-extension	−0.07	0.01	−0.26	−5.48	*P* < 0.001
	Age	0.14	0.02	0.26	5.37	*P* < 0.001

Discussion

This study found that grip and active ROM partially explain dexterity scores in patients recovering from a DRF at both 3 and 6 months during recovery. However, even after controlling for demographics, more than two-thirds of the variability remains unexplained indicating that though grip and motion measurements provide insights into hand dexterity, other factors must be important as well. In this study, we focused on grip and motion as these are the traditionally measured impairments. Following DRF, other factors that might have influenced dexterity include pain, motor

Table 5. Predictors of Small Hand Dexterity in the 6-Month Period.

		Unstandardized coefficients		Standardized coefficients		
R^2	Model	B	Std. error	Beta	t	*P*-value
0.142	(Constant)	23.29	3.71		6.27	*P* < 0.001
	Age	0.44	0.06	0.37	7.23	*P* < 0.001
0.200	(Constant)	39.52	4.93		8.01	*P* < 0.001
	Age	0.32	0.06	0.27	5.02	*P* < 0.001
	Grip Strength	−0.43	0.09	−0.26	−4.79	*P* < 0.001
0.242	(Constant)	61	7.04		8.66	*P* < 0.001
	Age	0.31	0.06	0.26	5.02	*P* < 0.001
	Grip Strength	−0.66	0.10	−0.40	−6.40	*P* < 0.001
	Sex	−8.89	2.13	−0.25	−4.17	*P* < 0.001
0.253	(Constant)	62.71	7.05		8.89	*P* < 0.001
	Age	0.32	0.06	0.26	5.07	*P* < 0.001
	Grip Strength	−0.61	0.10	−0.37	−5.69	*P* < 0.001
	Sex	−7.76	2.18	−0.21	−3.55	*P* < 0.001
	Arc deviation[a]	−0.12	0.05	−0.10	−2.11	0.035

[a] Arc motion of ulnar-radius deviation.

control, edema, and psychological factors. These were not addressed in this study.

A 2016 systematic review and meta-analysis[30] found that a small sample size was one of the main limitations in research on investigating predictors after a DRF. Our power analysis (power = 0.97-0.99) indicated that our sample size was sufficient to obtain adequate power, despite the fact that 72 patients dropped out during the 6-month period.

The multiple regression analysis at 3 months indicated that ROM was a significant predictor of dexterity in manipulating large objects with the flexion-extension and deviation arcs of motion explaining approximately 15% of the variation. The fact that motion was a significant predictor for the large-object subtest may reflect the nature of the activities, as a greater hand span was required to grip larger objects and the objects had to be moved through greater distances. Previous studies have shown that supination improves more slowly than pronation following a DRF[26] and showed that supination ROM predicts hand patient–related disability after a DRF.

The ability to manipulate small objects was predicted by age and flexion-extension arc, but only 11% of the variability in scores was explained and 7% of his was attributable to age. Therefore, motion was less related to dexterity on the small-object subtest, as it accounted for only 4% of the variability scores. Potential reasons for this are that finger motion may have been more important than wrist movement in manipulating small objects, but was not measured, or that coordination of movement was more important than arc of available ROM in determining dexterity.

By 6 months, the regression models explained a greater amount of variation. This might reflect the fact that pain and edema would be less likely to affect dexterity at this point, making residual impairments in motion and strength more significant. That is because motion and strength may be mediated by factors like pain and edema early in the recovery, and once these mediating effects are removed, the effects of strength and motion impairments can be more directly related to dexterity. Large-object dexterity was explained by 3 variables (grip strength, ROM flexion-extension, and age) explaining 34% of the variation. For the small objects, significant predictors of dexterity were age, grip strength, sex, and deviation arc, explaining 25.3% of the variation. Grip may contribute to small-object dexterity as the finger flexors must tightly hold an object for stability, for example, for screwing a small threaded pin into a socket. The findings support a focus on restoring grip and motion as part of the rehabilitation process following a DRF, and suggest that these would contribute to better hand dexterity later in the recovery process.

However, even at 6 months much variation in dexterity scores is unexplained. Although self-report measures give us insights into hand function, the role of performance-based tests of hand function is less clear in the research literature and in practice recommendations. Dexterity is an integration of sensory and motor skills that requires more complex motor control than the simple actions performed during grip or ROM measurement. It seems counterintuitive that given the importance of the hand in manipulating objects and tasks of daily life, dexterity has had such little focus in the literature. As the literature may influence practice, and vice versa, this appears to be a gap. Practice surveys confirm this, as dexterity or performance-based hand function tests are rarely included in assessment by hand therapists.[25] Furthermore, practice guidelines do not address dexterity.[17] Potentially dexterity and motor control problems are being under addressed during recovery following a DRF.

We found consistent findings with other studies[23] that there is an association with increasing age and poorer hand dexterity. As age-related sensory and motor deficits are expected, decreasing dexterity with age is a natural consequence. However, individuals that practice greater hand dexterity in their daily tasks[14] like musicians[15] do not display the same age-related reduction in hand dexterity. This would suggest that some of the age-related changes might be related to lack of use. If this is the case, emphasizing dexterity exercises in older clients may help prevent age-related loss of dexterity.

Our study has some limitations that should be considered when interpreting our findings. The percentage of males was low in our study that is only partially explained by higher female fracture rates. There also seems to be some volunteer bias, where females were more likely to volunteer. The male proportion in our sample size makes it difficult to be confident in our findings with respect to males. Another limitation of our study is that data collection was done prospectively whereas the data analysis and the research question were generated retrospectively. For this reason, additional details that might have been useful predictors of dexterity, such as the nature of the person's work tasks, were not collected. Moreover, the lack of gold standard about hand dexterity measurement means our results may be affected by our use of the NK dexterity test as compared with the many other options for assessing performance-based hand function. A benefit of the NK dexterity test is that it allowed us to separate large and small objects. A downside to using this test is that it is no longer in production and is quite expensive meaning it is unlikely to be adopted broadly in clinical practice. The paucity of literature addressing hand dexterity as a functional outcome after a DRF, and different measurement approaches make the comparison between our data and other studies difficult. Also, another limitation that must be taken into consideration is the visual acuity of each participant. Poor visual acuity may affect the scores of hand dexterity as they would affect the person's ability to locate and move objects, particularly smaller objects. This may have contributed to lower associations and small objects as compared with large objects. Finally, the assumption that time-based dexterity tests quantify hand function may be faulty. It may be that quality of task performance, or ability to do it "normally" are more valued by people following a DRF than is speed of movement, that is, dexterity may be a faulty, or at least, incomplete, measure of hand function. Nevertheless, it does represent the ability of the person to quickly coordinate movement that is important to understand when assessing motor control or hand function.

Conclusions

Following a DRF, dexterity can be partially explained at 3 months by deviation and flexion- extension arcs of motion. At 6-month follow-up, hand dexterity is better explained by grip strength and the flexion-extension arc. As at least two-thirds of the variation in dexterity is unexplained, more attention in the clinical literature and rehabilitation guidelines is warranted. Clinicians could consider monitoring dexterity recovery and prescribing dexterity exercises to optimize recovery, particularly in older clients where dexterity may be more impaired.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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