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# The effect of diabetes on functional outcomes among individuals with distal radial fractures

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ABSTRACT

*Study Design:* Prospective cohort study.
*Introduction:* Diabetes is reported to adversely affect outcomes; however, its effect on distal radial fractures (DRF) is not well examined.
*Purpose of the Study:* This study investigated the effect of diabetes on pain, hand function, physical health status, grip strength, and wrist and forearm range of motion among patients with DRF.
*Methods:* A total of 479 patients with DRF were classified into patients with and without diabetes based on self-report. Patient-Rated Wrist Evaluation assessed pain and hand function. The Short Form-12 assessed physical health status. Both questionnaires examined DRF recovery at baseline, 3 month, and 1 year.
*Results:* There was a significant improvement in Patient-Rated Wrist Evaluation scores over time (69 [19] to 25 [22]; 76 [15] to 20 [20] for patients with and without diabetes respectively, $P < .01$) with a significant interaction between time and diabetes ($P < .01$), indicating that patients with diabetes recovered more slowly than the rest of the cohort. There was an improvement over time on physical status (36 [12] to 45 [12]; 39 [9] to 50 [9], $P < .01$), grip strength (16 [7] to 24 [10]; 15 [9] to 24 [10], $P < .01$), and range of motion (flexion [42 {14} to 49 {15}; 43 {15} to 54 {14}, $P < .01$], extension [45 {11} to 52 {11}; 46 {13} to 53 {12}, $P < .01$], pronation [73 {10} to 77 {9}; 73 {11} to 78 {9}, $P < .01$], and supination [58 {17} to 65 {14}; 61 {17} to 70 {12}, $P < .01$]) for patients with and without diabetes, respectively. Patients with diabetes did not differ significantly in these secondary outcomes compared to the rest of the cohort.
*Discussion and Conclusion:* Although individuals with diabetes had good outcomes, their recovery was slower than the rest of the cohort. This may be due to the adverse effect of hyperglycemia on bone tissues and small blood vessels. Future studies are required to assess how severity and duration of diabetes affect outcomes after DRF.



## Introduction

Diabetes affects a substantial portion of the population around the world. By 2030, it is estimated that about 14% of the North American population will have diabetes.[1] Epidemiological studies indicate that diabetes is associated with an elevated risk of fracture.[2,3] Patients with type 2 diabetes have a higher risk of hip fractures (relative risk: 2.1–2.8) and distal radial fractures (DRF) (relative risk: 1.4–2.2) for both men and women despite generally normal bone mineral density values.[2,3] This increased risk of fracture may be due to long-term hyperglycemia that impairs bone quality.[2,3] Neuropathy and impaired vision are common risk factors for falls which may increase the risk of fractures in people with diabetes.[4]

Although diabetes is associated with an increased risk of fractures, less is reported on how it affects outcomes. Diabetes is known to impair bone and soft tissue healing after injury[5,6] and limit joint mobility leading to impairment of activities of daily living, suggesting that poorer outcomes might be expected.[7] Patients with type 2 diabetes are known to have reduced muscle strength and poor physical function compared to those without diabetes.[8,9] Furthermore, diabetes is reported as a risk factor for restricted range of motion (ROM) and poor clinical outcome after knee arthroplasty[10] and is considered an indicator of poor prognosis after ankle fracture.[11] However, the impact of diabetes on

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pain, hand function, and physical health status after DRF has not been well examined.

Diabetes was found to have an adverse effect on functional outcomes after DRF in study by Lee et al.[12] These outcomes were assessed using the Disability of Arm, Shoulder and Hand (DASH) questionnaire. In this study of 89 patients with DRF, patients with diabetes ($n = 15$) had poorer hand function as indicated by a 7.2-point higher DASH score.[12] Conversely, when functional outcomes were assessed in 279 patients using the Patient-Rated Wrist Evaluation (PRWE) questionnaire, diabetes was not associated with higher pain and hand disability ($n = 10$) compared to patients without diabetes.[13] However, the sample size of patients with diabetes in both of these studies was small,[12,13] which suggests that the findings may be imprecise. This may explain the conflicting conclusions.

## Purpose of study

The purpose of this study was to determine the following in patients followed for 1 year after DRF:

1. Are there differences in pain, hand disability, physical health status, grip strength, or wrist and forearm ROM between patients with and without diabetes when measured at baseline, 3 month, and 1 year?
2. Are the outcomes from purpose 1 moderated by age, sex, other medical problems, or education level?

## Material and methods

### *Design*

A repeated-measures cohort study design assessed a total of 479 patients with DRF seen at a tertiary care referral center. Patients' details were recorded into a computerized database at the time of their first-hand clinic visit (2-7 days after fracture) and on each follow-up session up to 1 year. Information about demographic characteristics (age, sex, and education level) was gathered. Participants in the cohort had injuries that represented a mix of intraarticular and extraarticular fractures and those with/without surgical reduction. Finally, they were classified into 2 groups: patients with/without diabetes based on self-report. Functional outcomes and physical health status were examined across 3 time points: baseline, 3 month, and 1 year. Where 3-month or 1-year data were missing, a carry forward of 2-month or 6-month data, respectively, was used. Ethical approval was provided by the University of Western Ontario.

### *Outcome measures*

#### *Primary outcome*

The primary outcome was pain and hand function, as measured by the PRWE questionnaire.[14] The PRWE has been shown to be a valid, reliable, and responsive measure of wrist/hand pain and disability.[15] The PRWE consists of 2 subscales: pain and function. The pain subscale is rated on scale from 0 (no pain) to 10 (worst pain ever) with an overall score of 50. The function subscale is subdivided into 2 sections: specific activity (6 questions) and usual activity (4 questions). The wrist-related activities are rated from 0 (no difficulty with the activity) to 10 (unable to perform the activity). The function score is calculated out of 50 by adding the scores for the 10 items and dividing by 2. An overall score of 100 is calculated by adding pain score to function score in which pain and function are weighted equally.

#### *Secondary outcomes*

The secondary outcomes measured physical health status, grip strength, and wrist and forearm ROM. Physical health status was assessed using Short Form-12 (SF-12) questionnaire.[16] This questionnaire was developed to assess health status and consists of 12 items that produces 2 component summary scores representing the physical health status and mental health status. The summary scales of these 2 components are scored using norm-based methods in which physical and mental regression weights and a constant for both measures come from the general United States population.[17] After creating an indicator variable (1/0) for each item response choice, the computation of the physical health status scores is achieved by multiplying each indicator variable by its respective physical regression weight and summing the 35 products; the same is applied for mental scores. Next, the physical and mental scores are transformed and standardized to have a mean of 50 and a standard deviation of 10 to be interpreted in relation to the distribution of scores in the general United States population; scores above average indicate a better health state.[17] Only physical health status was analyzed in the present study. This questionnaire has been shown to be a valid and reliable assessment tool[16] and has been used to assess patients with DRF.[18]

Grip strength was assessed using N–K DIGIT-Grip device using a standard protocol with established reliability.[19] Wrist and forearm ROM were assessed in flexion/extension, radial/ulnar deviations, and pronation/supination directions using standardized procedures with known high reliability (intraclass correlation coefficients $> 0.80$).[20-22] Wrist flexion and extension ROM were obtained with dorsal placement of the goniometer.[21] Wrist ulnar and radial ROM were measured by placing the axis of the goniometer over the center of the wrist joint in neutral. The movable hand of the goniometer was aligned over the third metacarpal and the other hand along the radius. Finally, forearm pronation and supination ROM were measured by placing the goniometer axis just distal to the ulnar head and align 1 goniometer hand with the vertical plane. The goniometer movable arm was aligned over the wrist crease on the dorsal surface for pronation and on the volar surface for supination measurement.[20,22] Grip strength and wrist and forearm ROM were assessed at 2 time points: 3 month and 1 year.

### *Inclusion and exclusion criteria*

Patients were included if they completed a comorbidity questionnaire, the PRWE questionnaire, and/or SF-12 questionnaire at baseline, 3 month, and 1 year and if their grip strength and wrist ROM were measured at 3 month and 1 year. Exclusion criteria included inability or refusal to complete tests/measures.

## Statistical analysis

Statistical analyses were performed using SPSS, version 23 (SPSS Inc, Chicago, IL). All values are reported as mean and standard deviation, unless otherwise specified, and an alpha level ($\alpha$) of 0.05 was used to indicate statistical significance. Descriptive statistics were performed to evaluate normality using the Kolmogorov–Smirnov test. Descriptive statistics were calculated for the characteristics of the participants and for each outcome measure at each time point. Mauchly's test was used to assess the assumption of sphericity. When sphericity was violated, degrees of freedom ($df$) were corrected using Huynh-Feldt estimates of sphericity.[23] General linear models with repeated measures were used to check for significant differences in the primary and secondary measures over time and between patients with and without diabetes and patients

without diabetes across 3 time points (baseline, 3 month, and 1 year). A second general linear model was used to test for differences while controlling for the covariates: age, sex, comorbidity (all medical problems except diabetes), and education level. Significant interactions were followed by pairwise comparisons using a Bonferroni correction.

## Results

### *Descriptive statistics*

Patients with DRF who met the inclusion criteria were included in the analysis of PRWE ($n = 479$), SF-12 ($n = 289$), grip strength, and ROM scores ($n = 550$). The demographic characteristics of the patients are summarized in Table 1. Among all patients included in this cohort, 10.6% of the patients were treated with orthotic device, 65% of the patients were treated with plaster cast, and 26.8% of the patients had surgery.

### *Effect of the intervention*

#### *Primary outcome*

Table 2 presents the means and the standard deviations of the responses for the PRWE total score and for each subscale score at each point in time. There was a significant improvement over time, and between each time point ($P < .01$), on the PRWE total score (69 [19] to 25 [22]; 76 [15] to 20 [20], $P < .01$) for patients with and without diabetes respectively, and on each PRWE subscale (pain [31 {12} to 14 {12}; 33 {10} to 12 {11}, $P < .01$], specific activity [51 {11} to 14 {14}; 55 {10} to 14 {14}, $P < .01$], and usual activity [27 {10} to 7 {8}; 31 {8} to 6 {8}, $P < .01$]) for patients with and without diabetes, respectively. There was a significant interaction between time and diabetes for the total PRWE scores ($P < .05$) and each PRWE subscale ($P < .01$), indicating that patients with diabetes recovered more slowly than the majority nondiabetic cohort throughout the recovery time despite the lower scores reported by patients with diabetes at baseline and 3 month (Fig. 1).

The improvement over time and the interaction between time and diabetes remained significant when additional demographic and comorbid health problems were controlled for, suggesting that the impact of diabetes was not confounded by age, sex, education level, or health problems that might be associated with diabetes. In this model, there was a significant interaction between time and age ($P < .01$), indicating that older patients reported less pain ($r = -0.15$, $P < .05$), when sex, education level, and comorbidity were controlled for.

**Table 1**
Demographic characteristics of patients with distal radial fractures (DRF)

| Characteristics | PRWE | SF-12 | Grip strength and ROM |
|---|---|---|---|
| Total number (*N*) | 479 | 289 | 550 |
| Age | 55 ± 14 (18-87 y) | 60 ± 12 (20-87 y) | 57 ± 14 (18-83 y) |
| Sex | | | |
| Male | 122 (25.5%) | 60 (20.8%) | 136 (24.7%) |
| Female | 357 (74.5%) | 229 (79.2%) | 414 (75.3%) |
| Medical problems | | | |
| Diabetes disease | 48 (10%) | 20 (6.9%) | 43 (7.8%) |
| Heart disease | 32 (6.7%) | 21 (7.3%) | 41 (7.5%) |
| Hypertension | 82 (17.1%) | 75 (26.0%) | 99 (18.0%) |
| Lung disease | 22 (4.6%) | 14 (4.8%) | 25 (4.5%) |
| Ulcer/stomach disease | 12 (2.5) | 12 (4.2%) | 11 (2.0%) |
| Kidney disease | 4 (0.8%) | 3 (1.0%) | 3 (0.5%) |
| Anemia/blood disease | 10 (2.1%) | 10 (3.5%) | 11 (2.0%) |
| Cancer | 13 (2.7%) | 13 (4.5%) | 15 (2.7%) |
| Depression | 37 (7.7%) | 39 (13.5%) | 42 (7.6%) |
| Osteoarthritis | 99 (20.6%) | 86 (29.8%) | 119 (21.6%) |
| Back pain | 62 (12.9%) | 72 (24.9%) | 82 (14.9%) |
| Rheumatoid arthritis | 15 (3.1%) | 16 (5.5%) | 20 (3.6%) |
| Other medical problems | 142 (29.6%) | 110 (38.1%) | 154 (28.0%) |
| Education level | (*N* = 476) | (*N* = 280) | (*N* = 523) |
| Did not complete high school | 84 (17.6%) | 31 (10.7%) | 90 (16.3%) |
| Completed high school | 112 (23.4%) | 55 (19.0%) | 114 (20.7%) |
| Some postsecondary | 189 (39.4%) | 131 (45.3%) | 222 (40.3%) |
| Finished postsecondary | 91 (18.9%) | 63 (21.9%) | 97 (17.6%) |

PRWE = Patient-Rated Wrist Evaluation; SF-12: Short Form-12 questionnaire; ROM = range of motion.

**Table 2**
One-year changes in functional outcomes, physical health status, grip strength, and wrist and forearm ROM for patients with diabetes and the rest of the cohort

| Variable | Baseline | | 3 months | | 1 year | |
|---|---|---|---|---|---|---|
| | Diabetes | | Diabetes | | Diabetes | |
| | Yes | No | Yes | No | Yes | No |
| PRWE | | | | | | |
| Pain | 31(12) | 33 (10) | 19 (11)[a,b] | 19 (11)[a] | 14 (12)[a,b] | 12 (11)[a] |
| Specific activities | 51 (11) | 55 (10) | 21(15)[a,b] | 23 (16)[a] | 14 (14)[a,b] | 10 (13)[a] |
| Usual activities | 27 (10) | 31 (8) | 11 (9)[a,b] | 12 (10)[a] | 7 (8)[a,b] | 6 (8)[a] |
| Total PRWE | 69 (19) | 76 (15) | 35 (21)[a,b] | 37 (22)[a] | 25 (22)[a,b] | 20 (20)[a] |
| SF-12 | | | | | | |
| Physical health status | 36 (12) | 39 (9) | 44 (10)[a] | 45 (8)[a] | 45 (12)[a] | 50 (9)[a] |
| Grip strength | – | – | 16 (7) | 15 (9) | 24 (10)[a] | 24 (10)[a] |
| ROM (°), affected side | | | | | | |
| Flexion | – | – | 42 (14) | 43 (15) | 49 (15)[a] | 54 (14)[a] |
| Extension | – | – | 45 (11) | 46 (13) | 52 (11)[a] | 53 (12)[a] |
| Radial deviation | – | – | 16 (7) | 15 (6) | 18 (7)[a] | 17 (7)[a] |
| Ulnar deviation | – | – | 21 (8) | 20 (8) | 25 (7)[a] | 24 (8)[a] |
| Pronation | – | – | 73 (10) | 73 (11) | 77 (9)[a] | 78 (9)[a] |
| Supination | – | – | 58 (17) | 61 (17) | 65 (14)[a] | 70 (12)[a] |

PRWE = Patient-Rated Wrist Evaluation; SF-12: Short Form-12 questionnaire; ROM = range of motion; SD = standard deviation.
Values are given in mean (SD).
[a] Significant effect of time ($P < .05$).
[b] Significant interaction between time and diabetes ($P < .05$).

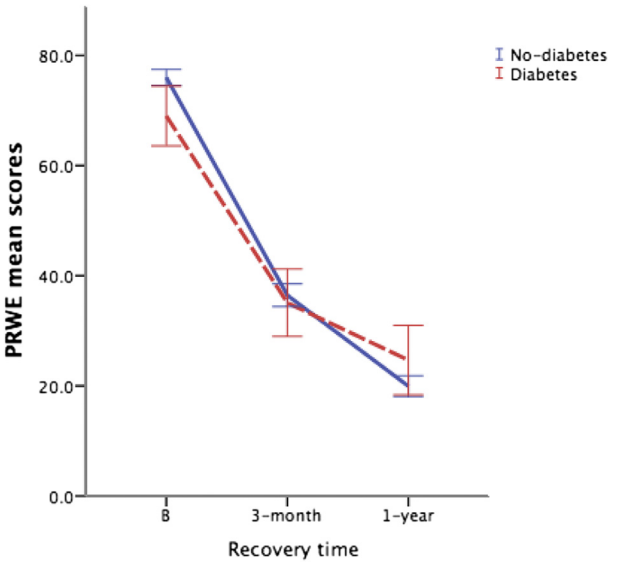


**Fig. 1.** Scores of functional outcomes for patients with diabetes vs patients without diabetes assessed using the Patient-Rated Wrist Evaluation (PRWE) questionnaire at baseline, 3 mo, and 1 y after distal radial fractures with 95% CI error bars. CI = confidence interval.

*Secondary outcomes*

There was a significant improvement over time and between each time point ($P < .05$), on the physical health status ($P < .01$), grip strength ($P < .01$), and wrist and forearm ROM ($P < .01$) for patients with and without diabetes as summarized in Table 2. Despite the insignificant interaction between diabetes and time on these secondary outcomes, patients with diabetes had poorer physical health status (Fig. 2) and less ROM in flexion/extension and pronation/supination was achieved at the 1-year time point as compared to the rest of the cohort.

In the second model, when additional demographic (age, sex, and education level) and comorbid health problems were controlled for, the improvement over time remained significant and the interaction between time and diabetes remained nonsignificant for the physical health status and grip strength. In the physical health status model, there was a significant interaction between time and age ($P < .03$), indicating that older patients reported lower physical health status ($r = -0.18$, $P < .05$). In the grip strength model, there were significant interactions between time and age ($P < .02$), and between time and sex ($P < .01$), indicating that older ($r = -0.41$, $P < .01$) and female patients ($r = -0.61$, $P < .01$) had weaker grip strength.

## Discussion

This study found that slower recovery occurs in patients with diabetes after DRF. This is consistent with previous research, which found an adverse effect of diabetes on hand function, measured 1-year following DRF using DASH questionnaire.[12] However, this study included only patients with DRF who were treated with surgical fixation with volar locking plate and had a much smaller subsample of patients with diabetes ($n = 15$). Similarly, Savas et al[24] assessed hand function in patients with diabetes, but without DRF, using a self-report Duruoz hand index, and reported hand disability in their diabetic patients. Conversely, another study that assessed DRF recovery at 1 year using PRWE questionnaire found no difference between patients with diabetes and patients without such comorbidity; however, the study included only patients with extraarticular DRF and the sample size included only 10 patients with diabetes.[13] This suggests that a lack of power may explain the null findings in that study. Extraarticular fractures may be less complicated, which might also have contributed to these findings.

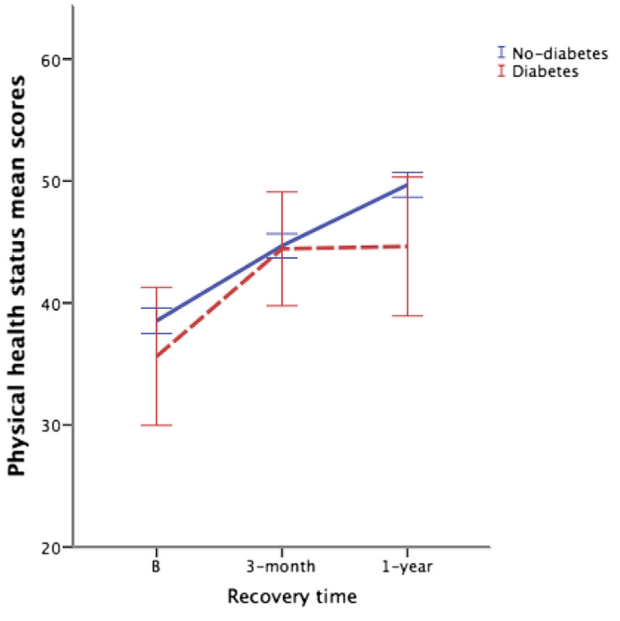


**Fig. 2.** Scores of physical health status for patients with diabetes vs patients without diabetes assessed using Short Form-12 questionnaire at baseline, 3 mo, and 1 y after distal radial fractures with 95% CI error bars. CI = confidence interval.

The rationale for adverse outcomes in patients with diabetes has been supported by several studies. Pathologies such as microvasculopathy, neuropathy, limited joint mobility, and poor bone quality associated with diabetes represent potential causal pathways for the slower recovery found in our study.[5,25,26] It is well established that hyperglycemia, over time, damages small blood vessels resulting in tissue hypoxia. The impaired circulation contributes to osteoporosis and delayed bone healing[5] that lead to structure degeneration and functional impairment.[27] Moreover, tissue ischemia causes neuropathy through the deterioration of the axons myelin sheath leading to sensory symptoms and muscle weakness.[28] Joint stiffness is frequently reported in patients with diabetes because of the increased collagen cross-links and the production of dense collagen.[7] These diffused collagen abnormalities alter the mechanical properties of tissues[29] and result in a thickened capsule and scar tissue that contribute to limited joint mobility and functional impairment.[7]

Our finding that overall physical health status was poorer in patients with diabetes than the remaining fracture cohort is consistent with other studies where patients with diabetes are compared to patients without diabetes in hip fracture cohorts,[30,31] in which physical health status was assessed using the American Society of Anaesthesiologists grading score[30,31] at 1-[31] and 2-year[30] follow-up period. Poor physical health status in people with diabetes[8,9,32] has also been reported when people are compared to population norms. This reduction in physical health status in patients with diabetes was explained by the diminished muscle flexibility, poor standing balance, and muscle weakness of lower extremity secondary to peripheral neuropathy, as well as decreased aerobic capacity.[8,9,32] Therefore, an evaluation of physical health status is recommended when exercise programs are designed for patients with diabetes.[8,32] This might have implications for rehabilitation after DRF, since poorer physical health may elevate risk of future falls and fractures[33], and exercise tolerance and capabilities should be considered when designing home programs.

As expected, recovery of grip strength after fracture, for the entire cohort, was good (Table 2). The final grip strength improvement was 10% lower for patients with diabetes, but this was not statistically significant. Lee et al.[12] also reported improvement in grip strength in DRF cohort after 1 year; however, this study did not compare the improvement in patients with diabetes in relation to the rest of their cohort. Poor grip strength has been reported in patients with diabetes as compared to healthy subjects.[24,34] The authors have suggested that diabetic factors that contribute to lower grip strength may include limited joint mobility, stiffness of subcutaneous tissue, or neuropathy.[24] Wrist and forearm ROM improved throughout the DRF recovery which is consistent with other research[22,35]; however, the improvement in the ROM of patients with diabetes was a few degrees less than the rest of the cohort (Table 2). The adverse effect of diabetes on joints ROM was reported in a different context, where patients with diabetes had restricted knee ROM after total knee arthroplasty that was explained by limited joint mobility and abnormal collagen fibers,[10] which would concur with the potential explanatory pathways for DRF patients.

Controlling for age, sex, comorbid health problems, and education level did not change our conclusions about the recovery of functional outcomes of patients with diabetes reported using PRWE, in which the recovery of patients with diabetes remained

slower than the rest of the cohort, suggesting that these factors were not confounders. However, age was an important factor affecting pain scores, physical health status, and grip strength; older patients reported less pain, poorer physical health status, and weaker grip strength. As expected, grip strength was lower in female patients throughout the recovery. These findings are consistent with studies reporting that increasing age is associated with poorer functional outcomes,[35,36] weaker grip strength,[12,36] and less wrist ROM.[12]

## Strength and limitations

The strength of the present study is that its data were prospectively collected using valid and reliable outcome measures; and the PRWE and SF-12 questionnaires have been commonly used to evaluate functional outcomes and physical health status after DRF. We examined a large cohort of patients with DRF and were able to add additional information to what is known about DRF outcomes in patients with diabetes. Unlike other studies which have only reported patient-reported outcomes, we have also included impairment in grip and motion. Furthermore, we examined the effect of some common confounders such as age, sex, comorbidity, and education level. However, several limitations of this study should be recognized. First, while the data were collected prospectively; this was a retrospective cohort design since the research question was identified after the data were collected. This means that we could only classify diabetes based on patient self-report, and no clarifications or assessments of severity were possible. Thus, we were unable to test the effects of the type of diabetes, duration, and treatment methods used to control the diabetes. A longer duration of diabetes and insulin deficiency are reported to have a negative effect on functional outcomes in patient with diabetes.[25,27] Testing for dose–response looking at severity and duration of diabetes would have strengthened causal assumptions. Second, the physical health status was assessed in smaller subgroup of patients with diabetes. This could explain the nonsignificant interaction between time and diabetes of this questionnaire compared to PRWE questionnaire. Third, the recovery of DRF is known to be affected by several factors such as the type of fracture, variety of surgical and treatment interventions, and the extent of soft tissue injury.[37] We did not control for these in our analyses. Furthermore, our sample was predominantly female, as is DRF. Although we did consider sex as a covariate, we did not have sufficient sample size to do a sex-disaggregated analysis for males and females and thus are less confident how our findings apply to males. Finally, diabetic status was self-reported and while we expect that this health problem would be clear to the patients, self-report is subject to reporting errors. Since any misclassification would have reduced our ability to find associations, this does not undermine our main conclusions but may have reduced the strength of our observed associations.

## Conclusion

The present study showed that diabetes is associated with slower recovery and poorer physical health status after DRF. The differences are small but persist even after controlling for potential confounders. Diabetes should be considered a negative prognostic indicator for recovery but does not preclude good outcomes. Prospective studies which investigate how severity and duration of diabetes, and how careful control of blood sugars during fracture healing affect outcomes are needed.

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## Quiz: # 640

**Record your answers on the Return Answer Form found on the tear-out coupon at the back of this issue or to complete online and use a credit card, go to *JHTReadforCredit.com*. There is only one best answer for each question.**

# 1. The study design was
   a. RCTs
   b. case series
   c. prospective cohort
   d. retrospective cohort
# 2. Hand function was assessed with the
   a. PRWE
   b. Quick Dash
   c. ASHT hand function assessment tool
   d. Purdue Pegboard Test
# 3. The investigators looked at the effects of diabetes on patients with DRFx relative to
   a. ROM
   b. grip
   c. pain
   d. all of the above
# 4. Physical health status was measured with the
   a. DASH
   b. WHO survey
   c. SF-12
   d. Mayo Clinic index of general health
# 5. The data suggest that patients with diabetes recover more slowly following DRFx
   a. false
   b. true

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