EDITOR'S CHOICE

The Impact of Social Deprivation and Hand Therapy Attendance on Range of Motion After Flexor Tendon Repair

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Purpose To examine the influence of social deprivation and hand therapy attendance on active range of motion (AROM) outcomes following flexor tendon repair.

Methods We performed a retrospective analysis of patients who underwent primary zone I−III flexor tendon repair between November 2016 and November 2020. Area deprivation index (ADI) was used to quantify social deprivation. Medical record review determined each patient's demographic characteristics, injury details, total hand therapy visits, and final AROM outcome. Active range of motion was converted to Strickland's percentage for analysis. Spearman correlation and simple and multivariable linear regression models were used to assess relationships between explanatory variables and outcomes.

Results There were a total of 109 patients, with a mean ADI of 53 and mean therapy attendance of 13 visits. Higher ADI and lower therapy attendance were correlated, and each was associated with significantly decreased Strickland's percentage. In the multivariable model, therapy attendance, ADI, zone 2 injury, and age maintained significant associations with Strickland's percentage.

Conclusions Socially deprived patients attend fewer therapy sessions and obtain poorer AROM after flexor tendon repair. Social deprivation is likely to contribute to poor outcomes both by its association with decreased therapy attendance and by other potential pathways that make it difficult for deprived patients to achieve good surgical outcomes. *(J Hand Surg Am. 2022;■(■):■−■. Copyright © 2022 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Prognostic IV.

Key words Flexor tendon, hand therapy, outcome, range of motion, social deprivation.

Despite innovations in surgical techniques and rehabilitation protocols, achieving optimal results after flexor tendon repair (FTR) remains challenging. Many physiological and biomechanical factors are known to be associated with outcomes, including age, zone of injury, repair strength, and postoperative management.[1−9] Intensive hand therapy is known to help minimize adhesions and optimize functional recovery in some cases, making accessibility of outpatient therapy services important after an FTR.[10−12]

Social and economic barriers may limit patient access to necessary postoperative care.[13−16] In recent hand surgery literature, the Area Deprivation Index (ADI) has emerged as a useful tool for measuring social factors that may facilitate or impede patients' access to care and health care literacy.[17,18] The ADI quantifies social deprivation based on home address

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by using 17 United States Census measures of education, employment, income, and housing quality within a particular census tract.

The ADI has been studied as an explanatory variable in populations with carpal tunnel syndrome, fractures, and general hand and wrist conditions.[18–23] Lower income and education level are highly predictive of pain, active range of motion (AROM), and disability after distal radius fracture, and higher rates of knee, hip, and hand arthritis are found in socially deprived areas.[24–29] Furthermore, increased socioeconomic deprivation in patients with carpal tunnel syndrome is associated with poorer physical function and higher anxiety, depression, and pain.[18,30] However, we are unaware of any studies exploring the influence of ADI specifically in patients undergoing FTR and rehabilitation. The aim of this study was to examine the impact of ADI and hand therapy attendance on digital AROM outcomes after an FTR. We hypothesized that high ADI is associated with low therapy attendance and that both high ADI and low therapy attendance are associated with inferior AROM outcome.

MATERIALS AND METHODS

This was a retrospective cohort study of patients who underwent primary zone I–III FTR between November 2016 and November 2020. This study was approved by the university institutional review board. Patients were identified by query of plastic and orthopedic surgical Current Procedural Terminology databases. Electronic records were queried to obtain patient demographic characteristics, addresses, injury details, surgical techniques, appointment histories, and outcomes (digital AROM at final follow-up). For patients who received therapy within our health care system, all encounters were visible in the medical record. Among the 39 patients who did not receive therapy within our health care system, appointment histories were obtained for the 30 patients whose complete external records were scanned into the chart. The exclusion criteria were age of <18 years; patients with incomplete therapy records or unclear outcome data; and concomitant fracture, dislocation, dysvascularity, extensor tendon injury, and/or postoperative follow-up duration of <8 weeks. Patients with <8 weeks of follow-up were not included in the analysis because their withdrawal from medical care suggests that outcome data would not be accurate or available. Patients who had associated digital nerve injuries were included.[31] Figure 1 illustrates the patient flow that led to the compilation of the study sample and identifies the number of patients excluded based on each criterion. For patients with >1 eligible finger, only the most ulnar digit was analyzed. For patients with ruptured tendon repair, AROM after rerepair was used as the final outcome.

Measures

Nine-digit zip code was used to determine the ADI, a measure of socioeconomic disadvantage based on a national percentile rank.[32] The ADI quantifies social deprivation by using 17 United States Census measures of education, employment, income, and housing quality.[19] After standardization, the ADI scores range from 1 to 100 (SD, 20), with higher scores indicating higher social deprivation.[17,18]

Digit AROM was collected retrospectively from the final visit with the physician or therapist. The total active motion was computed by the sum of flexion at the proximal and distal interphalangeal joints minus any extensor lag. Strickland's percentage (SP) was then calculated from the total active motion multiplied by 100 and then divided by 175, which generates a "percentage of normal motion"—a clinical measure of flexor tendon outcome supported by previous literature.[8,33,34] Strickland's percentage for thumb injuries was determined by the total active motion of the interphalangeal joint multiplied by 100 and then divided by 80, which is considered the normal range of interphalangeal joint flexion.[35] Strickland's percentage was used at the primary outcome variable.

Statistical analysis

Descriptive statistics were used to calculate the measures of central tendency and to assess the normality of distribution. Continuous variables are reported as mean ± standard deviation. Spearman correlation was used to evaluate the relationship between ADI and therapy attendance. In addition to ADI and therapy attendance, the additional variables of age, zone 2 injury location, flexor pollicis longus injury, the number of injured fingers, and follow-up duration were entered into the regression sequence because each of these may affect AROM and could confound the analysis if unaccounted for. Simple linear regression was used to measure the bivariate relationships between the explanatory variables and AROM. All variables with bivariate *P* values of <0.2 were entered into the multivariable analysis. Stepwise multivariable regression was used to assess the independent contributions of candidate explanatory variables to predict digital AROM. Statistical significance was defined as $P < .05$. An *a priori* power

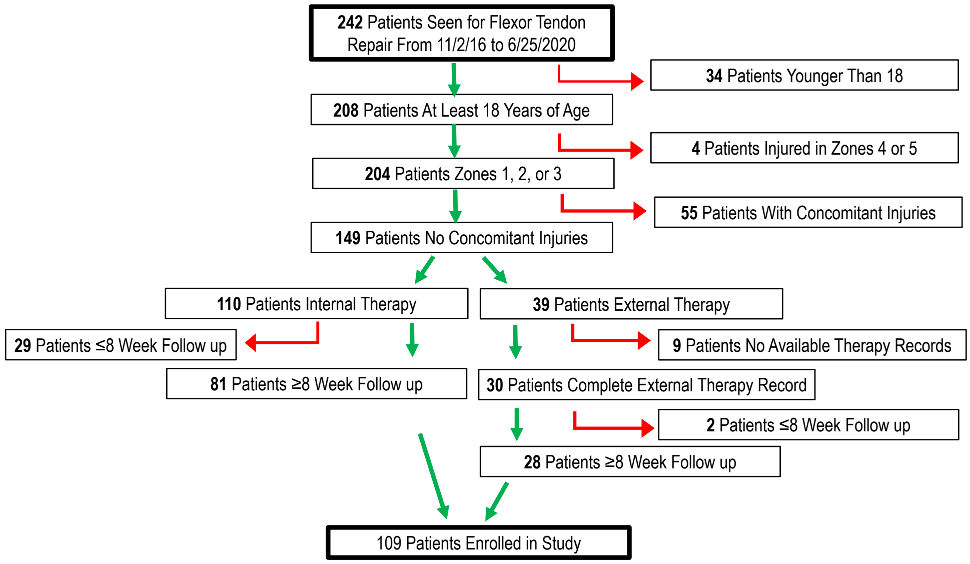

FIGURE 1: Patient recruitment algorithm.

calculation revealed that to obtain 80% power for the detection of a moderate effect size in a multivariable model with up to 7 entrant explanatory variables, a minimum sample of 103 subjects would be required.[36,37]

RESULTS

Our sample included 109 patients (73 men and 36 women) with a mean age of 32 ± 15 years. Patients excluded from the study for <8 weeks of follow-up had significantly higher ADI (n = 15, ADI = 78 ± 23) than the included patients (n = 109, ADI = 51 ± 25). The mean interval from injury to surgery was 7 ± 9 days. Most patients (78%) injured 1 digit, and the injury was in zone 2 (74%) (Table 1). Twenty-five patients had flexor pollicis longus injuries (n = 28, 26%). Of the 51 patients who injured both the flexor digitorum superficialis and flexor digitorum profundus (FDP) tendons, 9 (17.6%) patients had only the FDP repaired. The mean interval from surgery to the initiation of therapy was 5 ± 5 days. Patients spent 12 ± 6 weeks in hand therapy and attended 13 ± 9 therapy visits. The mean clinical follow-up duration was 20 ± 15 weeks. The mean ADI was 53 ± 25, and the mean SP was 54 ± 24. Tendon rupture with subsequent re-repair before the final outcome measurement occurred in 4 patients.

Area Deprivation Index and therapy attendance had a weak but statistically significant correlation (Spearman's rho = −0.27; $P = .005$), such that higher ADI was associated with fewer therapy visits. Bivariate linear regression analyses revealed that ADI, total therapy visits, and zone 2 injury each had significant associations with SP (Table 2). Age was not significantly associated but had a bivariate $P < .20$. As such, these 4 explanatory variables qualified for entry into the multivariable analysis. Follow-up duration, flexor pollicis longus injury, and the number of injured fingers were excluded from the multivariable model.

TABLE 1. Characteristics of Included Patients

Patient Characteristic	n (%)
Male	73 (67.0)
Multiple digits injured	24 (22.0)
Zone of injury	
Zone 1	22 (20.2)
Zone 2	81 (74.3)
Zone 3	6 (5.5)
Therapy visits attended	
0−5 visits	19 (17.4)
6−11 visits	28 (25.7)
12−18 visits	34 (31.2)
>19 visits	28 (25.7)

Multivariable analysis revealed that all 4 variables (ADI, therapy visits, zone 2 injury, and age) maintained significant independent predictive value for predicting SP. R^2 for the 4-factor model was 0.214 (Table 3).

DISCUSSION

Patients with limited socioeconomic resources are known to experience inferior musculoskeletal outcomes.[14,38−40] Although FTR is one of the most published topics in hand surgery, relatively little is

TABLE 2. Bivariate Analysis of SP: Simple Linear Regression

Model	Variable	R^2	Unstandardized β	Standard Error	Standardized β	*P* Value	Lower Limit Confidence Interval	Upper Limit Confidence Interval
1	ADI	0.066	−0.247	0.090	−0.257	.007*	−4.24	−0.069
2	Total therapy visits	0.073	0.751	0.261	0.271	.005*	0.235	1.269
3	Zone 2	0.051	−13.835	4.0020	−0.226	.001*	−21.540	−5.765
4	Age	0.019	−0.221	0.154	−0.137	.155	−0.526	0.085
5	Duration of follow-up	0.000	−0.003	0.022	−0.013	.890	−0.046	0.040
6	No. of fingers injured	0.010	2.427	2.362	0.099	.307	−2.257	7.110
7	Flexor pollicis longus injury	0.000	0.847	5.334	0.015	.874	−9.727	11.421

*$P < .05$.

known about how social circumstances influence outcomes.[41,42] Because FTR and rehabilitation are time- and resource-intensive, we suspected that outcomes would be highly sensitive to the social context of the patient's injury. Specifically, we hypothesized that higher social deprivation would be associated with decreased therapy attendance and that both social deprivation and decreased therapy attendance would each be associated with inferior digital AROM.

The first portion of the hypothesis was confirmed by the detection of a weak but statistically significant relationship between high ADI and low therapy attendance. It is notable that this study likely underestimates the strength of the association between ADI and therapy attendance because of its exclusion of patients who attended little or no therapy. Furthermore, bivariate analysis supported the second portion of the hypothesis, as both high ADI and low therapy attendance were significantly predictive of decreased total active motion. These significant relationships (ADI and therapy attendance both predicting outcome) were preserved even when controlling for potential confounders in the multivariable analysis. Given the literature supporting the importance of hand therapy after FTR, it is unsurprising that a significant and clinically important effect of therapy attendance was found. Additionally, the finding that socially deprived patients fare worse than those with social advantages is consistent with literature on other conditions.[5,6,14,37–39,43,44]

In addition to confirming that the relationship between ADI and therapy attendance with AROM is preserved even after controlling for several confounders, multivariable analysis also suggested that there is an additional depth to the relationship between ADI, therapy attendance, and AROM outcome. Because both ADI and therapy attendance were found to be significant in the stepwise multivariable model, we can conclude that the entirety of ADI's impact on outcome cannot be completely explained by variability in therapy attendance. This finding is in agreement with the finding that ADI and therapy attendance are only weakly correlated and supports the idea that therapy attendance is not simply a surrogate for ADI. In other words, the conventional thinking that high social deprivation leads to low therapy attendance, which leads to a poor outcome, seems to be oversimplified. Rather, it is clear that ADI maintains a relationship with outcome beyond what can be explained by therapy attendance, and there must be

TABLE 3. Multivariable Analysis of SP: Multiple Linear Regression

Model	R^2	Variable	Unstandardized β	Standard Error	Standardized β	t	*P* Value
1	0.214	ADI	−0.216	0.086	−0.226	−2.518	.013*
		Total therapy visits	0.736	0.247	0.265	2.983	.004*
		Zone 2	−12.916	4.870	−0.234	−2.652	.009*
		Age	−0.298	0.143	−0.185	−2.083	.040*

*$P < .050$.

other pathways through which ADI is associated with outcome.

Although this study did not specifically investigate other ways that ADI may relate to the outcome, one potential explanation is that patients living in areas of high social deprivation experience pressure to return to wage-earning or family responsibilities immediately. Another possibility is related to decreased compliance with and/or understanding of the home exercise program.[45–47] These factors may mean that even if patients attend therapy visits, performance of the home exercise program may be infrequent and/or ineffective. This alternative hypothesis could explain why patients with high ADI achieved inferior outcomes, even when controlled for therapy attendance and other confounding variables.

To provide clinically meaningful context for our analysis, it is possible to scale up the unstandardized β coefficients to roughly approximate the effect that clinically relevant variations in ADI and therapy attendance might have on an average patient's outcome. For example, based on a β of −0.216, a patient in the 75th percentile of ADI should expect SP 11 points lower than a patient in the 25th percentile of ADI. Similarly, based on a β of 0.736, a patient who attends 3 hand therapy visits should expect SP 11 points lower than a patient who attends 18 hand therapy visits. It should be emphasized that while this exercise is useful to demonstrate the potential clinical impact of these variables (either variation could easily change the Strickland functional category), these scaled examples make assumptions about the linearity of the relationships that are unlikely to be completely true and should be interpreted only as illustrative approximations.

There are several limitations to this study. First, we included patients with relatively permissive minimum of 8 weeks postoperative follow-up. Because most of the AROM data in this study came from the therapy record, stricter follow-up criteria would have excluded many patients who had more limited therapy attendance. Given that hand therapy attendance was 1 of the 2 primary explanatory variables being examined, a compromise was necessary. This could introduce a bias to underestimate the ultimate AROM outcomes of patients with less therapy attendance and overestimate the importance of hand therapy. Conversely, because we precisely required a minimum of 8 weeks follow-up, we necessarily excluded most patients who attended minimal or no hand therapy visits. This criterion similarly excluded patients who had higher levels of social deprivation (ADI = 78) than the included patients with a minimum of 8 weeks follow-up (ADI = 51). Therefore, our conclusions do not apply to this population.

Second, the regression analysis assumes a linear relationship between the principal explanatory variables and the dependent variable (SP). This strategy cannot describe how variability in ADI and therapy attendance may have more, or less, impact depending on the range in which this variability occurs. For example, it is possible that the difference between 5 and 10 therapy visits has an important impact on the outcomes, whereas the difference between 20 and 25 therapy visits is negligible. Third, although we controlled for multiple covariates that would otherwise be likely to confound the analysis, it is possible that other confounders have been omitted. For example, our analysis may have been affected by the proportion of patients who had both the flexor digitorum superficialis and FDP repaired versus only FDP. Similarly, this study did not account for a specific protocol followed by therapy, which may have had an impact on our findings. This may be an area of future study. Finally, because of this study's observational, retrospective nature, the substance of the hand therapy administered was uncontrolled, and we are unable to prove causality. Therapy attendance may be a surrogate for attentiveness to exercise; thus, our study cannot fully credit the therapist without additional experimental data.

Examining the interaction between ADI and the delivery of surgical and therapy care recognizes that, despite the availability of advanced techniques and protocols, a patient's ability to access and benefit from this care may be affected by the social context of their injury and life. In this study, social deprivation and low therapy attendance were correlated with each other, and each was significantly associated with AROM results after digital FTR. However, because both ADI and therapy contributed to the multivariable model, the entirety of the relationship between high ADI and inferior outcomes cannot be explained by the low therapy attendance. Additional studies are necessary to understand additional ways that social deprivation may have a negative impact on outcomes and how this effect may be mitigated. Specifically, understanding the impact of low ADI on patients' willingness and ability to comply with a home exercise program (even if they indeed attend therapy) may bring light to this issue and provide avenues to improve outcomes in our most vulnerable patients.

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