Journal of Hand Surgery Global Online 4 (2022) 8–13

Contents lists available at ScienceDirect

Journal of Hand Surgery Global Online

journal homepage: www.JHSGO.org

Original Research

Evaluation of a Grip-Strengthening Algorithm for the Initial Treatment of Chronic, Nonspecific Wrist Pain in Adolescents

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ARTICLE INFO

Article history:
Received for publication August 31, 2021
Accepted in revised form September 22, 2021
Available online 22 October 2021

Key words:
Grip strengthening
Occupational therapy
Wrist pain

Purpose: Chronic, nonspecific wrist pain in adolescents can be challenging to assess and treat. We hypothesized that an algorithmic approach beginning with grip strengthening can alleviate pain, improve function, and identify patients in need of further intervention.
Methods: We retrospectively reviewed the results of a grip-strengthening protocol for adolescents with chronic, nonspecific wrist pain. Before and after treatment, grip strength was measured using handheld dynamometry, and patient-reported pain and function were measured using the adolescent self-reported Pediatric Outcomes Data Collection Instrument's (PODCI's) Pain/Comfort and Upper Extremity Function domains (PODCI/pain and PODCI/UE, respectively).
Results: Thirty-two patients (28 female, 4 male) were included, with a mean age of 14 years (range, 10–18 years) and the dominant hand affected in 19, nondominant hand in 9, and bilateral impacts in 4. The mean symptom duration prior to presentation was 9 months (range, 1–63 months); 17 patients had undergone prior immobilization and 5 prior occupational/physical therapy. Grip-strengthening treatment, lasting a mean of 40 days (range, 21–82 days) with a median of 4 therapy visits (range, 2–6), was associated with significantly improved grip strength (mean, 32–48 lbs), PODCI/pain scores (mean, 49.0–78.2 points), and PODCI/UE scores (mean, 78.2–91.2 points). Improvements in grip strength correlated with improvements in PODCI/pain and PODCI/UE scores ($r = 0.64$ and 0.70, respectively). Eight patients (25%) had either no or incomplete pain relief: 5 underwent successful further intervention (2 ganglion cyst excisions, 1 triangular fibrocartilage complex repair, 1 arthroscopic debridement, 1 steroid injection), 2 received ongoing pain management for generalized pain syndromes, and 1 was lost to further follow-up. No pretreatment variables were identified that predicted failure.
Conclusions: Grip strengthening relieves pain and improves function in the majority of adolescents with chronic, nonspecific wrist pain. Systematic use of this protocol helps to identify patients who require further intervention.
Type of study/level of evidence: Therapeutic IV.

Wrist pain is a common chief complaint among adolescents presenting to hand specialists. In many cases, a thorough history, physical examination, and plain radiographs can elucidate a specific etiology of the pain, such as a fracture, ligamentous or triangular fibrocartilage complex injury, tenosynovitis, or arthritis. For such diagnoses, specific evaluation and treatment methods are established. However, a common presentation is global, nonspecific wrist pain with no etiology evident from physical examination and radiographic findings. This clinical presentation can be challenging to diagnose and treat.[1–3]

Acute nonspecific wrist pain may follow an injury and be labeled as a "wrist sprain."[4] Alternatively, nonspecific pain may have an insidious onset and chronic course, without an attributable inciting event. Chronic nonspecific wrist pain has been reported in musicians and in athletes, such as gymnasts, cheerleaders, divers, and

Declaration of interests: No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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https://doi.org/10.1016/j.jhsg.2021.09.001

Table 1
Inclusion and Exclusion Criteria Used to Define the Study Sample

Criteria	Included, n	Excluded, n
Inclusion/exclusion criteria		
10–18 years of age, presenting to OT for wrist pain, weakness	209	
Exclusion criteria (patient-specific)		
Specific pain etiology identified on clinical evaluation*		119
Absent or abnormal pretreatment plain radiographs†		6
Confounding diagnosis‡		9
Eligible patient population with unexplained wrist pain	75	
Exclusion criteria (treatment-specific)		
Failure to follow-up after initial OT evaluation		17
Incomplete pre- or posttreatment grip strength measurements or PODCI scores§		26
Final study sample	32	

* All clinical evaluations were performed by an attending physician, and subjects were excluded for provocative physical examination testing indicating a specific etiology (eg, Watson test for scapholunate ligament pathology, ulnar-sided pain with forearm rotation indicative of triangular fibrocartilage complex pathology).
† All subjects underwent plain radiographic evaluation, and subjects were excluded if pretreatment radiographs were unavailable or positive for fracture (including a healed fracture), ligamentous injury, arthropathy, or other conditions (eg, Madelung).
‡ Patients were excluded for concomitant diagnoses of complex regional pain syndrome, cerebral palsy, brachial plexus palsy, or a congenital condition.
§ Patients were excluded if records were missing the grip-strength measurement, PODCI/pain score, or PODCI/UE score pretreatment or after at least 4 weeks of treatment, even if complete pre-and posttreatment scores were available over a shorter time frame.

those in other sports that involve loading through the wrist.[5–10] Nonetheless, such pain can occur without any of these typical risk factors, further limiting the development of a systematic approach to evaluation and treatment. Therefore, effective, validated treatment strategies for chronic, nonspecific wrist pain in adolescents remain elusive.

A common feature of the normal adolescent musculoskeletal system is physiologic joint laxity, which peaks at age 15 years in girls, even without pathological hypermobility.[11] Thus, adolescent athletes are at increased risk of joint injuries, such as knee ligament injuries, prior to maturation of neuromuscular strength and control, with multiple studies demonstrating a reduced risk of knee ligament injury in adolescent athletes following neuromuscular strengthening and training programs.[12–14] In fact, such programs have become commonly used in youth sports for injury prevention, most notably the worldwide FIFA +11 program for lower extremity ligament injury prevention in soccer.[15]

Our approach to chronic nonspecific wrist pain in adolescents has been modeled after such programs, providing strength training to the muscles that dynamically stabilize the wrist.[16] Because isotonic strength training, such as using weights or resistance bands, could exacerbate the symptoms when moving a painful joint, we developed a treatment algorithm that includes a grip-strengthening protocol that isometrically strengthens the wrist flexors and extensors, taking advantage of their synergistic activation with gripping.[17] We employ an occupational therapist–directed grip-strengthening protocol using graded isometric wrist strengthening exercises. We use validated patient-reported outcome measures to assess the success of treatment, as failure to improve can indicate the need for further evaluation or treatment.

The purpose of the current retrospective study is to review patient-reported outcomes of this treatment algorithm to test the hypothesis that use of the algorithm can alleviate pain, improve function, and identify patients in need of further intervention among adolescents with nonspecific wrist pain.

Materials and Methods

Subject characteristics

Following institutional review board (Cincinnati Children's Hospital) approval with waiver of informed consent, occupational therapy (OT) records were queried retrospectively for all patients between 10 to 18 years of age presenting to OT seeking treatment for acute or chronic nonspecific wrist pain between January 1, 2011, and December 31, 2016. Medical records from OT and the referring provider, as well as other hospital records, were reviewed to identify and apply the exclusion criteria outlined in Table 1. Once the subject population was defined, medical records were reviewed and data were extracted for baseline characteristics: age, sex, hand dominance, sports participation, musical instrument playing, history of trauma, duration of pain, prior immobilization, prior occupational/physical therapy, and prior surgery. Pretreatment plain radiographs were reviewed, and pretreatment magnetic resonance imaging (MRI) results were reviewed if obtained prior to referral.

Grip-strengthening therapy protocol

All subjects in this study were systematically treated according to our algorithm for managing nonspecific wrist pain, further outlined in Figure 1. When the hand surgeon or physician assistant's clinical examination resulted in a diagnosis of nonspecific wrist pain, as a diagnosis of exclusion, subjects were referred to OT and underwent a predefined protocol of grip strengthening at our institution as follows.

Patients are first assessed with the Pediatric Outcomes Data Collection Instrument's (PODCI's) Pain/Comfort and Upper Extremity Function domains (PODCI/pain and PODCI/UE, respectively). The PODCI has been established as reliable for discriminating changes in pain and function in children with chronic musculoskeletal conditions and acute hand and wrist injuries.[18,19] The PODCI/pain domain assesses current and recent pain and the impact of pain on the patient's life. The PODCI/UE assesses ease of completing activities of daily living using the upper extremities. The adolescent self-report version is used for patients aged 11 years or older, and the parent/proxy version is used for patients aged 10 years or younger. Grip strength is also measured using the second setting of a handheld Jamar Dynamometer (Lafayette Instrument), previously validated for grip-strength assessments in adolescents.[20] Three trials are recorded and averaged for each hand.

Patients are then instructed in a home program for grip strengthening with therapeutic putty. Exercises are first performed under supervision to determine the duration patients are able to perform the exercises without increased pain. They are instructed to begin performing the exercises for this length of time and gradually increase to 5 minutes twice per day. Patients with

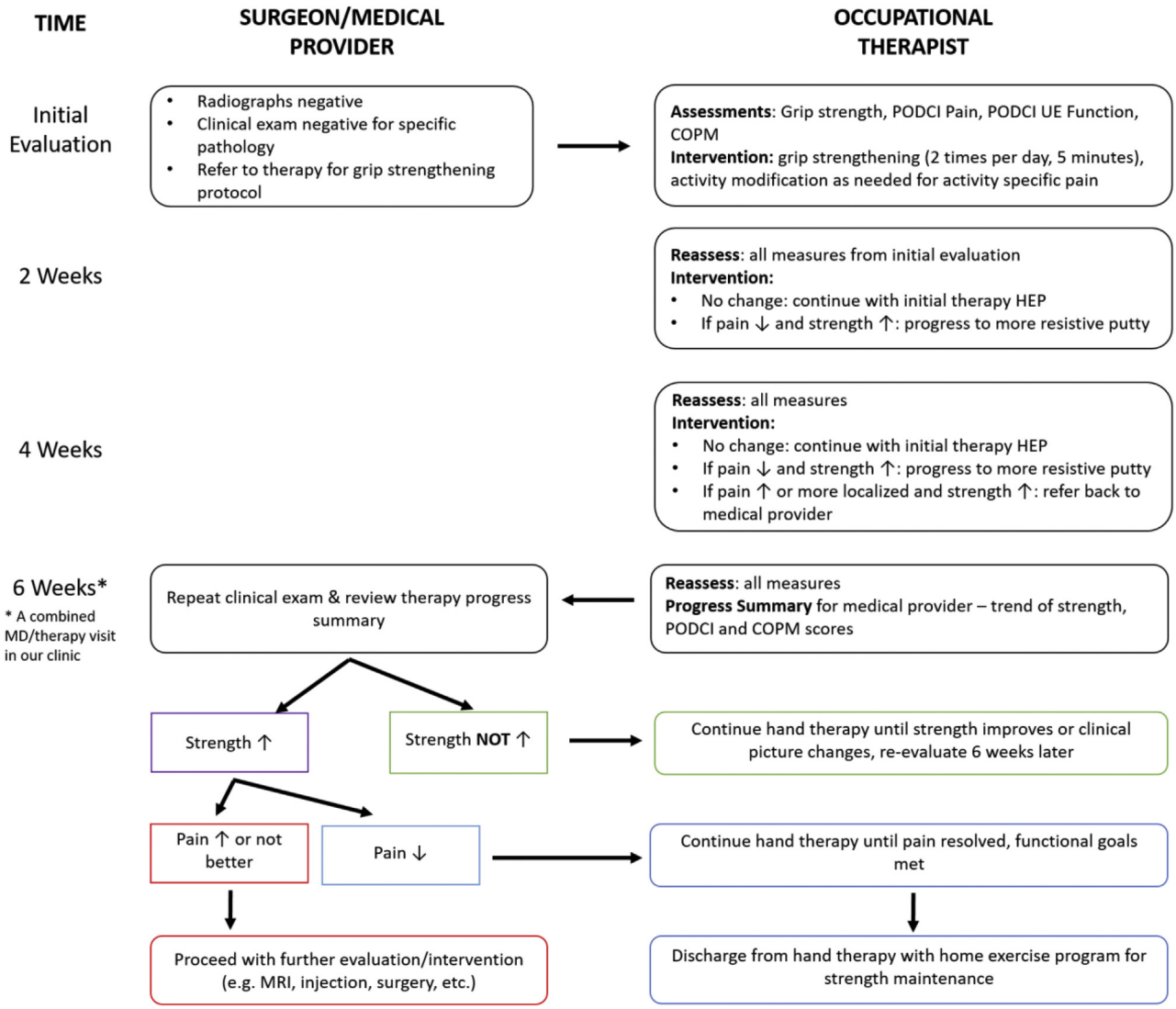

Figure 1. Wrist pain treatment algorithm. COPM, Canadian Occupational Performance Measure; HEP, home exercise program.

unilateral pain are advised to perform grip-strengthening exercises bilaterally if the grip strength on the unaffected side is below age-appropriate norms. No other therapeutic interventions (active/passive range of motion, weights, modalities, etc) are employed, although patients with pain associated with specific activities are taught activity modifications for activities that trigger pain.

Patients are instructed to return to therapy at 2, 4, and 6 weeks following the initial evaluation. At these appointments, strength, pain, and functional performance are reassessed. Patients with improving strength and pain are progressed to more resistive putty. In cases where strength is not increasing, patients continue with the previously established home program. If strength is increasing but pain and/or functional limitations are increasing as well, the patient is instructed to return to the referring hand surgeon or provider.

For the 6-week follow-up appointment, both the OT and the referring provider see the patient, often simultaneously. The referring provider, therapist, patient, and caregiver review the trends of change in strength, pain, and function and use our treatment algorithm (Fig. 1) as a decision guide for further care. Those patients who have experienced improved strength and resolution of symptoms, and who report satisfaction with functional outcomes, are discharged. For patients who are demonstrating improving strength and function and resolving pain, therapy is continued until they reach the same criteria for discharge. If the patient is demonstrating improved strength but unchanged or worsened pain and/or function, the case is considered a failure of the grip-strengthening protocol and additional evaluation (eg, MRI if not already obtained) or intervention (eg, injection/arthroscopy) is considered. At the 6-week follow-up visit, if the patient is demonstrating no change in strength and/or function, the grip-strengthening protocol is continued for another 6 weeks and the patient is reassessed. Upon reassessment, if strength and pain remain unimproved the case is considered a failure of the grip-strengthening protocol.

Outcomes and statistical analysis

For the purposes of this study, continuous outcome variables included PODCI/pain and PODCI/UE scores and grip-strength measurements pretreatment, posttreatment, and at interim visits, when available. Failures of the grip-strengthening protocol were categorically defined as follows: (1) unchanged or worse PODCI/pain scores from pre- to posttreatment, (2) posttreatment PODCI/

Table 2
Characteristics of Included Patients

Patient Characteristics	n
Sex	
Female	28
Male	4
Dominance of affected upper extremity	
Dominant affected	19
Nondominant affected	9
Bilateral involvement	4
Extracurricular activities	
Athlete	19
Musician	1
Athlete and musician	3
Neither athlete nor musician	9
Prior intervention	
Immobilization	17
Occupational therapy or physical therapy	5

pain scores remaining more than 2 standard deviations below age-appropriate norms for the general pediatric population, or (3) further intervention required for the wrist pain (eg, surgery, injection) noted upon review of subsequent medical records.[19] Continuous outcome variables were tested for normality using the Shapiro-Wilk test. Continuous variables were compared pre- and posttreatment using paired *t* tests when normally distributed and Wilcoxon signed-rank tests when not normally distributed. Correlations between continuous variables were evaluated with correlation coefficients. Linear regression was used to identify predictors of grip strength, PODCI/pain scores, PODCI/UE scores, and changes thereof. Predictors of categorical failure of the grip-strengthening protocol were identified with logistic regression. Statistical significance was set at a P value <.05. All findings are presented in adherence to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Results

Thirty-two patients (28 female, 4 male) with a mean age of 14 years (range, 10–18 years) were included in this study. Patient characteristics are listed in Table 2. The dominant hand was affected in 19, nondominant hand in 9, and bilateral impacts in 4, for a total of 36 wrists treated. A history of injury was present for 13 wrists. The mean duration of symptoms prior to patients seeking treatment for their wrist pain at our institution was 9 months (range, 1–63 months). Although not ordered as part of the protocol, a pretreatment MRI was available for 6 patients and was abnormal in 5 (occult radiocarpal ganglion cyst in 3, nonspecific synovitis in 1, nonspecific carpal marrow edema in 1). Because these MRI findings are of pathologies that could symptomatically improve with conservative treatment, these patients were not excluded from our study.

Grip-strengthening treatment, lasting a mean 40 days (range, 21–82 days) with a median of 4 therapy visits (range, 2–6 visits), was associated with improved grip strength, PODCI/pain scores, and PODCI/UE scores (Table 3). Improvements in grip strength correlated with improvements in PODCI/pain and PODCI/UE scores (r = 0.64 and 0.70, respectively; Fig. 2). Multiple linear regression found greater improvements in grip strength to be associated with lower pretreatment grip strength ($P \leq .001$; B = −0.72). Greater improvements in PODCI/pain scores were associated with worse pretreatment PODCI/pain scores and a greater change in grip strength ($P = .003$ and <.001, respectively; B = −0.40 and 0.51, respectively). Greater improvements in PODCI/UE scores were associated with nonathletes, worse upper extremity function at baseline, and greater change in grip strength ($P = .030$, $P < .001$, and $P = .004$, respectively; B = −0.24, −0.56, and 0.35, respectively). Strength improved on the unaffected side when strengthening was performed bilaterally in patients with unilateral pain, albeit less than it improved on the affected side.

Eight patients (25%) met the criteria for failure of the grip-strengthening protocol (Table 4). Of these 8 failures, 5 underwent further intervention (2 ganglion cyst excisions, 2 triangular fibrocartilage complex repairs, 1 steroid injection) with symptom relief, 2 received ongoing pain management for generalized pain syndromes, and 1 was lost to further follow-up. Logistic regression identified no pretreatment variable that predicted failure of the grip-strengthening protocol as defined categorically.

Among the 6 patients with a pretreatment MRI available, 3 met the criteria for categorical failure of the grip-strengthening protocol (1 with an occult ganglion cyst, 1 with nonspecific synovitis, and 1 with no MRI abnormalities). The remaining 3 patients with an MRI available (2 with occult ganglion cysts, 1 with nonspecific carpal marrow edema) had symptom resolution with the grip-strengthening protocol. When the 5 patients with pretreatment MRI abnormalities were excluded post hoc, no changes were found in any of the study's statistical results.

Discussion

Nonspecific wrist pain in adolescents is a common problem, yet is difficult to assess and treat, with limited level 5 evidence as guidance.[2,3,8,21,22] Grip strengthening has been recommended by others as a component of rehabilitation for wrist pain in pediatric athletes, but this recommendation was made without published outcomes data.[23] Others have presented a sensorimotor control–based exercise program as a therapeutic approach to manage chronic wrist pain, yet outcomes data are also unavailable with this approach.[3] Conversely, the present study provides validated strength and patient-reported outcome measures to support a grip-strengthening protocol for managing nonspecific wrist pain in adolescents. We found that approximately 75% of patients have resolution of their pain and functional limitations after implementation of the protocol. An increase in grip strength over the course of treatment was identified as a predictor of improvement in both pain and function, consistent with a therapeutic utility of grip strengthening. Additionally, our overall treatment algorithm can identify a subset of patients who require further intervention, which is particularly important given that we did not find notable pretreatment predictors of categorical success or failure of grip strengthening.

It is important to note that, by definition, the diagnosis of nonspecific wrist pain is a diagnosis of exclusion. Evaluation should begin with a thorough history, physical examination, and plain radiographs. Ulnar-sided wrist pain or distal radioulnar joint symptoms (as opposed to global or mid-dorsal pain that is typical of the current study population) can be addressed using evaluation and treatment strategies well described in the literature.[24–30] Sources of dorsal/central wrist pain, such as scapholunate injury, ulnar abutment from distal radius growth arrest, Kienböck disease, or Madelung deformity, are often discernable on physical examination and plain radiographs.[31–35] However, no consensus exists regarding strategies to further evaluate chronic, nonspecific global and mid-dorsal wrist pain with negative radiographs.[2] Some authors have recommended routine magnetic resonance or computed tomography imaging, whereas other recommend diagnostic arthroscopy.[4,27,36,37] Neither MRI nor arthroscopy were routinely used in the assessment of the patients in this series, so we cannot specifically comment on their diagnostic utility. Six patients in this study did have a pretreatment MRI available, ordered by other providers. These patients were included in the group analysis since

Table 3
Pre- and Posttreatment Grip Strength, PODCI/Pain, and PODCI/UE Scores

Assessment	Pretreatment		Posttreatment		*P* Value*
	Mean	95% CI	Mean	95% CI	
Grip strength, lb affected side†	32.2	29.5–38.8	47.9	42.9–52.9	<.001
Grip strength, lb unaffected side‡	43.4	36.7–50.0	50.4	44.0–56.9	<.001
PODCI/pain	49.0	42.8–55.2	78.2	70.8–85.7	<.001
PODCI/UE	78.2	72.7–83.7	91.2	87.1–95.5	<.001

* *P* values are from paired *t* tests. Although the PODCI/pain and PODCI/UE scores were normally distributed pretreatment, histograms revealed a ceiling effect in the UE function due to the fact that many patients reached the scores of 100. Therefore, the comparison of pre- and posttreatment PODCI scores were repeated with Wilcoxon signed-rank tests with significant differences still evident (*P* <.001).
† Affected side measurements included both sides when pain was bilateral.
‡ Unaffected side measurements were only available when pain was unilateral.

the presence of an MRI abnormality, which would be unknown in the majority of patients, was not used as an exclusion criterion for our grip-strengthening protocol or for this study. Nonetheless, no changes in the results of this study were identified when the 5 patients with pretreatment MRI abnormalities were excluded from the analysis post hoc. Nonetheless, we can conclude that having an MRI abnormality, such as an occult ganglion cyst, does not preclude a successful outcome from the grip-strengthening protocol, as 2 of the 3 patients with MRI-proven occult ganglion cysts pretreatment were successfully treated with grip strengthening.

Similarly, having had prior unsuccessful attempts at conservative treatment does not preclude success of the grip-strengthening protocol. Eighteen wrists in 17 patients had undergone immobilization prior to presentation and initiation of the grip-strengthening protocol. Of these 18 wrists, 6 (33%) wrists failed to improve in our protocol, but the remaining 12 improved. Similarly, of the 6 wrists in 5 patients that had been treated unsuccessfully with prior occupational or physical therapy, 4 improved and 2 (33%) failed to improve. Therefore, we recommend a trial of grip strengthening even in patients with a history of unsuccessful prior conservative treatment. This recommendation is in contrast to a report that recommends routine arthroscopy after attempts at immobilization or therapy, although the specifics of the preoperative conservative therapies were not described in this series, and no validated outcomes were reported.[37]

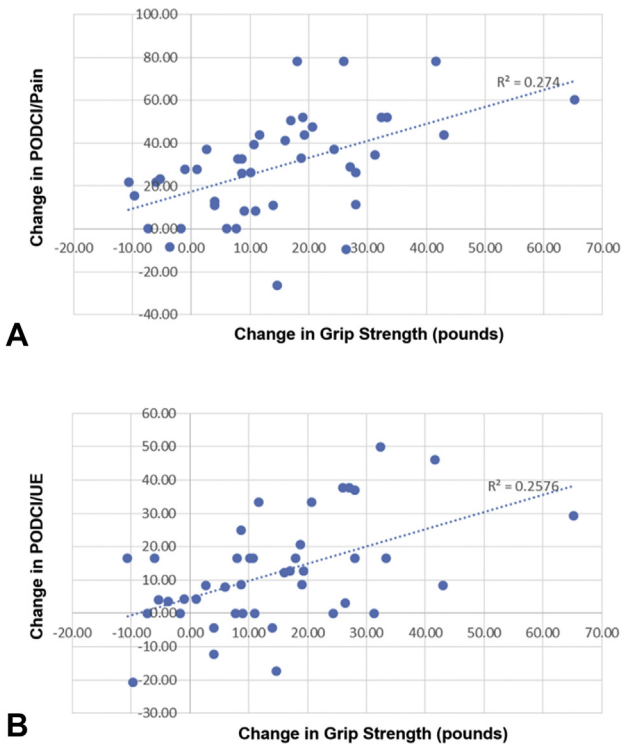

Figure 2. Correlations between improvements in grip strength and improvements in **A** PODCI/pain and **B** PODCI/UE scores.

Despite offering the first validated patient-reported outcomes data for a treatment approach for nonspecific adolescent wrist pain, our study has several important limitations, including those inherent in a retrospective review. For instance, the study design is limited by having no comparison group, such as untreated controls or surgically treated patients, as our historical approach to nonspecific wrist pain has not routinely included simple observation or invasive intervention at the outset of treatment. Moreover, the association between grip-strength improvement and improved pain does not prove causation, given possible reciprocal effects of pain relief on grip strength. Nonetheless, the improvements seen over the short course of treatment following long periods of symptoms suggests a likely treatment effect rather than coincidental spontaneous resolution. Furthermore, compliance with the exercises, although assessed by the OT though patient and family reports at interim OT visits, cannot be objectively measured and can only be inferred from the objective grip-strength measurements used in this study. In addition, the follow-up period was short, as patients were discharged at the conclusion of the protocol unless they required further evaluation or treatment. Therefore, the current study cannot provide information on long-term resolution of symptoms or the potential for recurrent pain. Also, PODCI/pain scores are not specific for wrist pain, and can be affected by generalized pain syndromes, which were not systematically assessed in this study. However, this score describes the effect of the pain on the patient's quality of life and is sensitive to changes in pain over the course of treatment in hand and wrist injuries in adolescents.[19] Moreover, our study did not specifically assess psychosocial mediators of pain.[38] Nonetheless, working with an occupational therapist supervising the patients' participation in the protocol, as opposed to simply using a self-directed home protocol, can extend the team's ability to identify challenges to successful treatment and, in several cases in this study, prompted a referral for formal psychological evaluation and treatment. Finally, we did not perform a formal evaluation of ligamentous laxity. However, since generalized laxity is physiologic in this population, we did not evaluate for pathological laxity as an indication for the grip-strengthening protocol, nor did we expect alteration in joint laxity as a result of the treatment.[11] Wrist range of motion was only recorded qualitatively as "normal" for many patients. Nonetheless, among patients with quantitative range of motion values, the total wrist flexion-extension arcs ranged from 125° to 180°. Therefore, stiffness is not a hallmark of this population. With these limitations

Table 4
Failures of the Grip-Strengthening Protocol

Failure reason	n
Unchanged or worse PODCI/pain scores despite gains in grip strength	4
PODCI/pain scores greater than 2 standard deviations below age-matched norms	2
Further invention pursued despite improvement in PODCI/pain score within 2 standard deviations of age-matched norms	1

in mind, it must be underscored that this study represents a starting point for research in this area, with the algorithm presented herein representing a starting point in the management of patients with this particularly challenging clinical problem.

This study outlines a treatment algorithm that employs an OT-led grip-strengthening protocol for adolescents with chronic, nonspecific wrist pain. Our findings provide preliminary evidence with validated patient-reported outcome measures that this protocol can resolve pain and restore function. Although this protocol does not relieve all adolescent unexplained wrist pain, it provides an approach with which to initiate treatment. With minimal burdens to the patients, families, and providers, a treatment algorithm using this protocol successfully treats the majority of patients with this difficult problem and can be used to identify the minority of patients who need further work-up or intervention.

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