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Clinical Practice Guidelines
Linked to the International Classification
of Functioning, Disability, and Health
from the Academy of Orthopaedic Physical Therapy and American Academy of Sports
Physical Therapy of the
American Physical Therapy Association

Table of Contents

2

SUMMARY OF RECOMMENDATIONS

PROGNOSIS

C

Clinicians may use age, high baseline levels of disability, third-party compensation, and comorbid psychosocial factors (particularly depression) as potential predictors of poor outcomes related to functional disability.

C

Clinicians may use female sex, high baseline levels of pain, and comorbid psychosocial factors (particularly depression) as potential predictors of poor outcomes related to the development of persistent pain symptoms, including CRPS-1.

EXAMINATION

OUTCOME - Activity Limitations; Self-reported Measures

A

Clinicians should administer joint-specific measure of PRWE to assess pain experience and functional disability of the wrist or administer either the DASH or MHQ to assess region-specific disability of the upper extremity at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

C

Clinicians may use the JTHFT to assess the performance in completing ADL tasks that require wrist/hand use at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

OUTCOME - Physical Impairment Measures

A

Clinicians should use wrist/forearm ROM and grip strength assessments to assess movement and strength deficits of the wrist at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

C

Clinicians may use pinch strength and wrist JPS in assessing precision in handling small objects and proprioceptive ability respectively at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

OUTCOME - Fall Risk Screening

F - Clinicians may administer TUG for fall risk screening in individuals with DRF and consider TUG scores of >12 seconds as the threshold for increased fall risk.

F - Clinicians may administer ABC for screening fear of falling in individuals with DRF and consider ABC scores of < 67% as the threshold for increased fall risk.

F - Clinicians may administer 5-seconds CST for screening lower extremity muscle strength in individuals with DRF and consider CST scores of >12 seconds as the threshold for impaired lower extremity muscle strength.

INTERVENTIONS – THERAPY INITIATION TIMING

A

Clinicians should initiate early therapy that consists of hand, wrist, and shoulder AROM exercises along with light daily activity within the first 3 weeks after surgery to improve short-term (up to 3 months) pain, wrist AROM, grip strength, and functional outcomes, and long-term (≥ 6 months) wrist AROM and grip strength.

B

Clinicians should initiate gradual strengthening, which may consist of light towel and putty isometric squeezing and light-load gripper exercises at 2 weeks following surgery or during the second week of cast immobilization to improve short-term (up to 6 months)

5

pain, wrist AROM, grip strength, and functional outcomes without significant risk to increase of compromising proper fracture healing.

INTERVENTIONS – THERAPY SUPERVISION AND DOSAGE

B

Clinicians should have older (≥ 60 years) patients or those with complications and comorbidities following operative and/or non-operative treatments after a DRF attend a SupT program at a frequency of ≥ 1 weekly session and supplemented by an iHEP to improve short- and long-term wrist pain, AROM, grip strength, and function.

A

Clinicians (PTs or OTs) should be the primary instructors of iHEP that are provided to DRF patients following operative and/or non-operative treatments to improve short- and long-term wrist pain, AROM, grip strength, and function.

D

Based on limited or conflicting evidence, a recommendation cannot be made regarding whether younger patients without complications and comorbidities following non-operative or operative DRF management should attend a weekly SupT program or perform daily iHEP or no-therapy for optimum short- and long-term outcomes on wrist pain, AROM, grip strength, and function.

INTERVENTIONS – EDEMA CONTROL METHODS

C

Clinicians may perform a combination of edema control techniques that may include MLD and other manual edema mobilization, exercises, elevation, compression gloves, low-stretch bandaging, and iHEP instruction, to induce short-term (2-6 weeks) benefits on hand swelling, AROM, function, and pain following non-operative and operative DRF management.

INTERVENTIONS – MANUAL THERAPY TECHNIQUES

B

Clinicians should use manual therapy techniques (MWM, accessory joint mobilizations, oscillations, sustained stretching) as part of a multi-modal management strategy for short-term improvements in wrist pain, AROM and upper limb function following operative and non-operative DRF treatments.

INTERVENTIONS – THERAPEUTIC EXERCISES

B

Clinicians should use properly timed therapeutic exercises including PROM, AROM, tendon gliding, motor control, functional and progressive bilateral resistive exercises that include the scapula, to improve pain, AROM, strength, and function following DRF.

INTERVENTIONS – SENSORIMOTOR TRAINING

A

Clinicians should integrate all three elements of GMI with conventional therapy to improve short-term outcomes in pain, AROM, and patient-reported function during the early rehabilitation stage (6-8 weeks) following non-operative and operative treatment for DRF.

D

Based on limited evidence, a recommendation cannot be made regarding whether a multimodal SM training approach consisting of sensory stimulation techniques (e.g., vibration) and other proprioceptive exercises in conjunction with conventional therapy to improve short-term outcomes in pain, AROM, and function during the initial rehabilitation stage (6-8 weeks) following operative treatment for DRF.

INTERVENTIONS – ORTHOSIS MANAGEMENT FOR STIFFNESS

F

Clinicians may utilize orthoses in conjunction with standard care to improve wrist AROM primarily for certain subgroups of DRF patients who present with difficulty reaching their functional goals due to persistent wrist stiffness.

INTERVENTIONS – THERAPEUTIC MODALITIES

B

Clinicians should utilize physical agents including LT, PEMF, WWP, HP, CP in conjunction with conventional therapy to improve short-term outcomes in pain, edema, sensation, wrist AROM, grip strength, and function following non-operative and operative treatment for DRF.

D

Based on conflicting or limited evidence a recommendation cannot be made regarding whether mechanical agents including CPM, IPC, and BFR are more beneficial than conventional therapy alone to improve wrist pain, edema, wrist AROM, grip strength, and function following non-operative and operative treatments for DRF.

List of Abbreviations

AAOS: American Academy of Orthopedic Surgeons

ABC: Activities-Specific Balance Confidence Scale

ADLs: Activities of Daily Living

AHUEPT: Academy of Hand and Upper Extremity Physical Therapy

AOPT: Academy of Orthopaedic Physical Therapy

AROM: Active Range of Motion

ASIF: Swiss Association for the Study of Internal Fixation

AUC: Area Under the Curve

BFR: Blood Flow Restriction

CA: Cronbach's Alpha

CES-D: Centre of Epidemiologic Studies Depression scale

CHT: Certified Hand Therapists

CI: Confidence Interval

cm: Centimeter

COPM: Canadian Occupational Performance Measure

CP: Cold Pack

CPG: Clinical Practice Guideline

CPM: Continuous Passive Motion

CRPS-1: Complex Regional Pain Syndrome (type 1)

CST: Chair Stand Test

DASH: Disabilities of the Arm, Shoulder, and Hand questionnaire

DRF: Distal Radial Fracture

DRUJ: Distal Radial Ulnar Joint

ES: Effect Size

FOF: Fear of Falling

g: Gram

GDG: Guideline Development Group

GMI: Graded Motor Imaging

HEP: Home Exercise Program

HP: Hot Pack

Hz: Hertz

ICC: Intraclass Correlation Coefficient

ICF: International Classification of Functioning, Disability, and Health

iHEP: Independent Home Exercise Program

IPC: Intermittent Pneumatic Compression

JPS: Joint Position Sense

JTHFT: The Jebsen Taylor Hand Function Test

JOSPT: Journal of Orthopaedic & Sports Physical Therapy

Kg: Kilogram

Lb: Pound

LEMS: Lower Extremity Muscle Strength

LT: Laser Therapy

mmHg: Millimeters of mercury

ml: Milliliter

mm: Millimeter

MCID: Minimal Clinically Important Difference

MD: Mean Difference

MDC: Minimal Detectable Change

MOS: Medical Outcomes Study

MEP: Movement-Evoked Pain

MHQ: Michigan Hand Questionnaire

MMWS: Modified Mayo Wrist Score

MLD: Manual Lymphatic Drainage

MSK: Musculoskeletal

MWM: Mobilization With Movement

n: number

NRS: Numerical Rating Scale

OLS: One Leg Stand Test

ORIF: Open Reduction And Internal Fixation

OR: Odds Ratio

OT: Occupational Therapy/Therapist

PAR: Pain At Rest

PCL-C: Post Trauma Stress Disorder Civilian Checklist

PEM: Pulsed Electromagnetic Frequency

PROM: Passive Range of Motion

PRWE: Patient Rated Wrist Evaluation

PRWHE: Patient-Rated Wrist/Hand Evaluation

PSFS: Patient-Specific Functional Scale

PT: Physical Therapy/Therapist

QDASH: Quick Disabilities of the Arm, Shoulder, and Hand Questionnaire

QoL: Quality of Life

r: Pearson Correlation Coefficient

RCJ: Radiocarpal Joint

RCT: Randomized Controlled Trial

ROM: Range Of Motion

RR: Relative Risk

rs: Spearman's Rank Coefficient

TFCC: Triangular Fibro-cartilaginous Complex

TUG: Timed Up and Go Test

UCJ: Ulnocarpal Joint

Sec: seconds

SEM: Standard Error of Measurement

SF: Short Form

SM: Sensorimotor

SRM: Standardized Response Means

SupT: Supervised Therapy

TENS: Transcutaneous Electrical Nerve Stimulation

UEMSK: Upper Extremity Musculoskeletal Conditions

UVLT: Ultraviolet Light Therapy

VAS: Visual Analog Scale

INTRODUCTION

Aim of the Guidelines

The Academy of Hand and Upper Extremity Physical Therapy (AHUEPT) and Academy of Orthopaedic Physical Therapy (AOPT) of the American Physical Therapy Association (APTA) have an ongoing effort to create evidence-based practice guidelines for the management of patients with musculoskeletal impairments described in the World Health Organization's International Classification of Functioning, Disability, and Health (ICF) [74].

The purposes of these clinical guidelines are to:

- Describe evidence-based practice including diagnosis, prognosis, intervention, and assessment of outcomes of musculoskeletal disorders commonly managed by orthopedic, sports, and hand physical therapists
- Classify and define common musculoskeletal conditions using the World Health Organization's terminology related to impairments of body function and body structure, activity limitations, and participation restrictions
- Identify interventions supported by current best evidence to address impairments of body function and structure, activity limitations, and participation restrictions associated with common musculoskeletal conditions

- Identify appropriate outcome measures to assess changes resulting from physical therapy interventions in body function and structure as well as in activity and participation of the individual

- Provide a description to policymakers, using internationally accepted terminology, of the practice of orthopaedic, sports, and hand physical therapists

- Provide information for payers and claims reviewers regarding the practice of orthopaedic, sports, and hand therapy for common musculoskeletal conditions

- Create a reference publication for clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of orthopaedic and sports physical therapy and hand rehabilitation

Statement of Intent

These guidelines are not intended to be construed or to serve as a standard of care for physical therapists. Standards of care are determined on the basis of all clinical data available for an individual patient and are subject to change as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered guidelines only. Adherence to them will not ensure a successful outcome for every patient, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular clinical procedure or treatment plan must be made in light of the clinical data presented by the patient; the diagnostic and treatment options available; and the patient's values, expectations, and preferences. However, we

16

suggest that significant departures from accepted guidelines should be documented in the patient's medical records at the time the relevant clinical decision is made.

Scope and Rationale of the Guideline

Distal radius fracture (DRF) is one of the most common fall-related fractures in middle-aged and older adults [215]; [284];[224]; [254] with incidence ranging between 18-44% of all fractures seen in emergency orthopedic settings [46]; [254]; [304]. Females 50 years of age and older have a projected 16% life risk of sustaining an osteoporotic wrist fracture with an incidence ratio over 6:1 as compared to similar-aged males [126]. Given the projected increase in the elderly (or aging) population, the number of individuals expected to sustain a DRF is likely to increase, thereby adding to the costs associated with managing this condition [269]. While most patients fully recover following a DRF [101], as many as 15-20% of individuals continue to experience chronic pain and functional deficits after DRF [185]; [207]. Distal radius fracture is also a sign of poor bone health and a predictor of subsequent hip fracture, especially in older adults [60]; [127].

This clinical practice guideline (CPG) synthesized the literature concerning physical therapy management of DRF using a systematic review methodology and has provided practice recommendations for the management of DRF in outpatient rehabilitation settings. Oftentimes, patients with DRF are also managed by occupational therapists who are credentialed as certified hand therapists. While this proposed CPG intends to equip physical therapists with the required evidence to provide state-of-art rehabilitation

17

to their patients with DRF, this CPG will assist the hand therapy community at large to provide evidence-based care to patients who seek rehabilitation following DRF. Specifically, aspects of DRF management including epidemiology, pathophysiology, orthopedic classification of DRF injury, clinical course, prognosis, outcome measurement, and interventions are included. This CPG included literature concerning extra- as well as intraarticular DRF managed using operative or non-operative approaches. This CPG excluded literature that described the management of 'wrist fracture' with no specific emphasis on DRF being the patient group. The literature where patient groups had a DRF along with other fractures in the wrist or had concomitant injuries to the distal radial ulnar joint (DRUJ) was also excluded. This CPG also excluded literature on DRFs occurring in the pediatric population. Lastly, this CPG excluded literature focusing on orthopedic or pharmacological management of DRF, since they are beyond the domain of physical therapist practice.

METHODS

This guideline integrated published literature from January 1995 to November 30, 2023. This CPG will be subject to revision in 2029, or earlier if a large volume of crucial literature becomes available. Updates to this CPG will be shown on the AOPT and AHUEPT of the APTA websites: www.orthopt.org and www.handpt.org.

Levels of Evidence

Individual clinical research articles were graded according to criteria adapted from the Centre for Evidence-Based Medicine, Oxford, UK (**http://www.cebm.net**) for the studies related to prognosis and interventions (Oxford CEBM 2011). In teams of two, each reviewer assigned a level of evidence and evaluated the quality of each article using a critical appraisal tool (see **APPENDICES D** and **E** for the levels-of-evidence table and details on procedures used for assigning levels of evidence, available at **www.jospt.org**). If the two content experts did not agree on a grade of evidence for a particular article, a third content expert was used to resolve the issue. The evidence update was organized from the highest level of evidence to the lowest level of evidence. An abbreviated version of the grading system is provided in **TABLE 1 and TABLE 2**.

TABLE 1. LEVELS OF EVIDENCE FOR INTERVENTION STUDIES

I	Evidence obtained from systematic reviews, high-quality diagnostic studies, prospective studies, or randomized controlled trials
II	Evidence obtained from systematic reviews, lesser-quality diagnostic studies, prospective studies, or randomized controlled trials (e.g. weaker diagnostic criteria and reference standards, improper randomization, no blinding, less than 80% follow-up)
III	Case-control studies or retrospective studies
IV	Case series

V	Expert opinion

TABLE 2. LEVELS OF EVIDENCE FOR PROGNOSTIC STUDIES

I	Evidence obtained from systematic reviews of inception cohort studies
II	Evidence obtained from high-quality inception cohort studies
III	Cohort studies or control arm of randomized trials
IV	Case series, case-control studies, or poor quality cohort studies
V	Expert opinion

Strength of Evidence and Grades of Recommendation

The strength of the evidence supporting the recommendations was graded according to the established methods provided below (**TABLE 3**). Each team developed recommendations based on the strength of evidence, including how directly the studies addressed the question relating to plantar fasciitis. In developing their recommendations, the authors considered the strengths and limitations of the body of evidence and the health benefits, side effects, and risks associated with the interventions.

TABLE 3: GRADES OF RECOMMENDATION

Grades of Recommendation		Strength of Evidence	Level of Obligation
A	Strong Evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study	Must or should
B	Moderate Evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation	Should
C	Weak Evidence	A single level II study or a preponderance of level III and IV studies, including statements of consensus by content experts, support the recommendation	May
D	Conflicting Evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies	
E	Theoretical/ Foundational	A preponderance of evidence from animal or cadaver studies, from	

	Evidence	conceptual models/principles, or basic sciences/bench research supports this conclusion	May
F	Expert Opinion	Best practice based on the clinical experience of the guideline development team	May

Guideline Review Process and Validation

The AOPT selected consultants from the following areas to serve as reviewers throughout the development of these CPGs:

- ● Athletic training

- ● Claims review

- ● Coding

- ● Guideline methodology

- ● Medical practice guidelines

- ● Manual therapy

- ● Movement science

- ● Occupational therapy clinical practice

- ● Orthopaedic physical therapy clinical practice

- ● Orthopaedic physical therapy residency education

- Orthopaedic surgery

- Outcomes research

- Patients with distal radius fracture

- Physical therapy academic education

- Physical therapy patient perspective

Identified reviewers who are experts in the management and rehabilitation of those with DRF reviewed a pre-publication draft of this CPG content and methods for integrity, accuracy, validity, usefulness, and impact. Any comments, suggestions, or feedback from the expert reviewers were delivered to the author and editors for consideration and appropriate revisions. These guidelines were also posted for public comment on the AOPT website (**www.orthopt.org**), and a notification of this posting was sent to the members of the AOPT. Any comments, suggestions, and feedback gathered from public commentary were sent to the authors and editors to consider and make appropriate revisions to the guidelines, prior to submitting them for publication to the *Journal of Orthopaedic & Sports Physical Therapy* (JOSPT).

Dissemination and Implementation Tools

In addition to publishing these guidelines in the *JOSPT*, these guidelines will be posted on the CPG (free access) areas of the *JOSPT* and AOPT websites and submitted for free access on the ECRI Guidelines Trust (**guidelines.ecri.org**) and the Physiotherapy Evidence Database (**www.PEDro.org.au**). The planned implementation tools for

patients, clinicians, educators, payers, policymakers, and researchers, and the

associated implementation strategies are listed in **TABLE 4**.

TABLE 4. PLANNED STRATEGIES AND TOOLS TO SUPPORT THE

DISSEMINATION AND IMPLEMENTATION OF THIS CPG.

Tool	Strategy
JOSPT's "Perspectives for Patients" and "Perspectives for Practice" articles	Patient- and clinician-oriented guideline summaries available at www.jospt.org
Mobile app of guideline-based exercises for patients/clients and health care practitioners	Marketing and distribution of the app via www.orthopt.org and www.handpt.org
Clinician's Quick-Reference Guide	Summary of guideline recommendations available at www.orthopt.org and www.handpt.org
JOSPT's Read for CreditSM continuing education units	Continuing education units available for physical therapists at www.jospt.org
Webinars and educational offerings for healthcare practitioners	Guideline-based instruction available for practitioners at www.orthopt.org and www.handpt.org
Mobile and web-based app of	Marketing and distribution of the app

guidelines for training of health care practitioners	via www.orthopt.org
Non-English versions of the guidelines and guideline implementation tools	Development and distribution of translated guidelines and tools to JOSPT's international partners and global audience via www.jospt.org
APTA CPG+	Dissemination and implementation aids

ORGANIZATION OF THE GUIDELINE

When systematic reviews were conducted to support specific actionable recommendations, summaries of studies with the corresponding evidence levels were followed by evidence synthesis and rationale for the recommendation(s) with harms and benefits statements and gaps in knowledge. Topics for which a systematic review was conducted and recommendations provided include prognosis, examination, and interventions during physical therapy episodes of care for DRF. A summary of the literature is provided for other topics where a systematic review was outside the scope of this CPG. This includes injury mechanism and epidemiology, biomechanical and pathoanatomical features, and clinical course. The management of DRF from the perspective of orthopedic and hand surgeons is also briefly summarized, including the DFR classification, diagnosis, imaging considerations, and operative versus non-operative management to stabilize a fracture.

25

INJURY MECHANISM AND EPIDEMIOLOGY

A DRF is a metaphyseal bone fracture that occurs within the distal 3-5 cm of the radius [39; 70] and affects mostly active functionally independent adults [70; 244]. Those with a DRF comprise approximately 1.5-2.5 % of all emergency orthopedic-care cases [15; 215] and encompass nearly 18% of all adult fractures [15]. There are also over 643,000 DRF claims with an estimated $385-535 million annual healthcare cost in the United States [194]. It is considered the second most frequent fracture, only behind hip fractures, and the most prevalent upper extremity fracture among adults. [194] DRF affects mostly women with a 4:1 female:male age-adjusted ratio [220; 291].

The incidence of DRFs present as a bimodal distribution among younger (peak at 10-18 years) and older (peak at 70-80 years) populations [15; 137; 280], A DRF is caused by both high- and low-energy injury mechanisms [102], which involve an abruptly applied impact or compression force at the wrist. [39]. High-energy trauma is the leading cause among pediatric and young adult groups, especially among males [15; 39] who sustain a DRF while playing sports, falling from heights, driving a motorcycle, sustaining a car accident, or engaging in activities with high physical demands. Low-energy trauma is the leading cause among older aged groups [39; 102], especially females with poor balance, decreased bone mass density [70; 226] who unexpectedly fall on an outstretched arm from a standing height. [102]. It should be noted that each year in the United States, 30% of older (> 65 years) adults sustain a standing-height fall. These falls are associated with DRF rates of 237/100,000 and 58/100,000 among females and males, respectively [270].

Following a DRF, the odds for significant functional decline increase by 48% [70] and although death is an infrequent consequence in this population, a 6%, 7%, and 8% mortality rate has been documented at 1, 3, and 5 years, respectively, among older adults [270].

Overall, DRF incidence is influenced by sex and advancing age [275; 291]. The incidence of a DRF is the lowest among young adults (18-39 years) with incidence rates of 9-23 and 6-10 per 10,000 cases among males and females respectively [220; 275]. During this period, males might be up to 2 times more likely to sustain a DRF than females [275]. This trend reverses during mid-adulthood (40-65 years) when the incidence of DRF among females sharply rises to 71% as compared to males [15]. During this time, male and female DRF incidence rates are estimated to be 6-10 and 17-46 per 10,000 cases, respectively [220; 275]. By the age of 50 years, females present a 51% remaining lifetime probability of having a DRF as compared to 20% for men [172]. For older adults (> 65 years), the gender-based DRF incidence disparity increases further with females being 85% more likely to sustain a DRF than males, attaining an incidence rate of 57-116 per 10,000 cases [143; 220; 275; 304]. By the age of 85, the DRF incidence for females may peak at 120 per 10,000 persons [291]. In contrast, DRF incidence rates for adult males are relatively stable (6-23 per 10, 000 person years) then slightly increase at the age of 65 to nearly 30 per 10,000 cases [220; 275] and peak by the age of 85 to near 33 per 10,000 persons [291].

BIOMECHANICAL AND PATHOANATOMICAL FEATURES

The distal radius forms an important base of support for the wrist joint, which is a multi-articular system involving the radiocarpal (RCJ), ulnocarpal (UCJ), and DRUJ [24]. Ultimately, the wrist joint encompasses an important anatomic bridge between the hand and the forearm, allowing axial compressive loading to be effectively transmitted during the upper extremity open and closed kinetic-chain function [68]. The RCJ and UCJ are anatomically adjacent joints between the distal radius and ulna and the proximal carpal row [24]. Both are supported by a contiguous synovial joint capsule, which is formed by strong extrinsic volar and dorsal radiocarpal and ulnocarpal ligaments [299]. At the ulnar sigmoid notch the distal radius articulates with the ulnar head, forming the DRUJ and supported by strong volar and dorsal DRUJ capsular ligaments as well as the triangular fibro-cartilaginous complex (TFCC) [9; 34; 300]. Besides its role as a strong DRUJ connective tissue, the TFCC allows the RCJ and UCJ to share a continuous articular relationship with the proximal carpal row. It also isolates the DRUJ to function as a separate synovial articulating system outside the RCJ confines [24]. In normal DRUJ alignment, the ulna head is positioned within a ± 2 mm relative to the distal radius articular surface [34]. This normal ulnar variance greatly depends on forearm position and may increase or decrease during pronation and supination, respectively [9].

Axial force distribution at the wrist is largely dictated by its unique articular geometry along its RCJ, UCJ, and DRUJ. At the DRUJ the distal radius articular surface slopes 22° ulnary (radial inclination angle) and 11º palmary (palmar tilt angle) between the

28

radial styloid process laterally and sigmoid notch medially. The radial styloid also extends distal to its medial-most articular surface by 11 mm, a distance known as the distal radius height [34]. Within these articular margins, wrist axial force distribution follows a 3-column system. The lateral column at the scaphoid fossa forms an osseous buttress due to its greater cross-sectional articular surface and ligamentous strength. The intermediate column at the lunate fossa is a central articular point for the greatest compressive force propagation [243]. Both of these columns are aligned with the radiocarpal articulation and accept nearly 80% of compression forces during wrist function [24]. Lastly, the medial column at the distal ulna supports the forearm rotation mechanism with the DRUJ [243], and accepts only 20% of axial force transmission [24]. Because of these complexities, a DRF may greatly impact the biomechanical role and disrupt the normal force distribution through this intricate column system [243].

A DRF occurs at the inertly weaker metaphyseal region of the distal 3-5 cm of radius. [39; 102]. Within this region, a 2 mm thin subchondral bone plate shields the distal radius sub-articular surfaces from incoming axial loads [17]. The majority (50-70 %) of its remaining metaphyseal bone mass normally consists of a weaker core of trabecular bone [58], which is designed to absorb and transmit articular impact. This weaker bone region is filled with a network of trabecular bone arches that resemble a bridge. The apexes of these arches support the subchondral bone plate and their bases conjoin with a more proximal cortical diaphyseal region [17]. The dorsal metaphyseal region of the distal radius contains a greater amount of trabecular bone as compared to its volar region, forming another vulnerable zone to fracture [58]. This distal radius trabecular region is

significantly weaker, especially among pre-and post-menopausal women [18]; [252]. In contrast, its adjacent diaphyseal cortex consists of 95% stronger cortical bone mass and offers greater bone-yield resistance to incoming axial compressive forces [274]. Based on the distal radius bone morphology, abrupt compressive forces can elicit distinct fracture lines through its thin subchondral bone plate and more cancellous metaphyseal region [Bain 2017], where various extra- or intra-articular fracture patterns may form within a 10 mm region from the articular surface [Simic 2003].

The mechanism of a DFF involves the transmission of axial forces through the radio-carpal articular surface, commonly due to a fall with a pronated and hyper-extended wrist. This frequently results in a dorsally displaced and comminuted DFR with or without articular involvement and is known as a "Colles" fracture [39]; [101]. A less frequent mechanism of a DFR entails a wrist bending moment with a hyper-flexed wrist at the impact point, leading to a palmar fragment displacement known as a "Smith" fracture [193]. A shearing axial force with a laterally bending moment could also occur, causing either a volarly or dorsally subluxed articular fragment known as a "Barton" fracture [26]; [237]. Such a shearing force may also induce an oblique and radially displaced fracture of the radial styloid known as a "Chauffeur" fracture [237]. Radial styloid fractures could be further complicated by an unopposed brachioradialis muscle proximal-directed force [179]. Regardless of the mechanism, a DRF would occur when a 1-7% of the distal radius bone-tissue yield strain point (1000-2000 N of force) is surpassed at the impact point [232]. At the fracture site, various extra- and intra-articular complex fracture-line patterns may form and propagate proximally depending on the injury-force severity and existing bone-

density quality [305]. Fracture patterns may implicate and compromise the stability of the RCJ, UCJ, and DRUJ [32; 251] affecting the dynamic [115; 212] and static wrist stabilizing structures, rendering them vulnerable to future potential injury. [39; 85]

DRFs are frequently associated with significant wrist deformities and complications that vary between 6-80%, depending on the injury severity and type of fracture treatment. Such complications may lead to abnormal wrist biomechanics as well as persistent pain and disability [192]. Following a DRF, a common anatomical deformity is dorsal radius angulation combined with various degrees of radial shortening [51; 272]. This deformity is frequently associated with loss of normal radial height, and distortion of normal radial-inclination and palmar-tilt angles [51, 52], which can potentially disrupt normal joint congruency and cause abnormal force distribution through the wrist during functional loading [4; 235]. Radial shortening due to dorsal radial angulation alters the balance of normal axial forces transmitted through the RCJ and UCJ [235; 272]. More specifically, a dorsal angulation of 10-45° disrupts normal ulnar variance mechanics and increases UCJ axial loading up to 67% [272]. Thus, it may cause increased TFCC strain [39], greater potential for TFCC compression injury [4], and DRUJ instability [171]. Dorsal angulation of ≥ 10° along with loss of a normal radial palmar-tilt angle may further disrupt normal intercalated carpal biomechanics, [39; 230] promoting mid-carpal joint strain and instability [288]. Radial shortening with dorsal angulation may also distort the wrist extrinsic muscles' normal length-tension relationships [301], resulting in a long-term grip strength deficit [55]. Wrist articular congruency alteration is another important concern following complex intra-articular DRFs [39] due to implications for developing post-traumatic osteoarthritis [35];

31

[235]. Considering that the average radiocarpal joint cartilage thickness is < 1mm [236], an intra-articular step-off deformity of ≥ 2 mm has been associated with a greater risk of developing long-term RCJ arthrosis [235] It should be noted the reliably measuring this step-off deformity has presented challenges. [111]. Malunion associated with one of the aforementioned fractures may create undesirable anatomical deformities and is considered the most common post-DRF complication. This may be especially problematic following conservative treatment [192], with an incidence of deformity as high as 35-50% [267; 323].

Complications other than malunion and anatomical deformities have been reported following DRF. These complications vary depending on the injury severity and selected treatment methods and may be influenced by patient factors such as lifestyle, age, mental attitude, social support, compliance with treatment [192], and socioeconomic status [43]. Complex regional pain syndrome (CRPS-1), infections, and wrist tendon attrition may be encountered following DRFs, regardless of the treatment mode. The incidence of CRPS-1 has been reported to vary between 1-32% and may be more prevalent among female patients [65; 124; 295]. Soft-tissue or bone infections might occur with mostly post-surgical DRF interventions and vary between 1-33% depending on whether the treatment mode entailed an internal or external fixation option [192; 295]. Tendon complications may present various severity levels and encompass injuries that range from minor tendon irritation to tendon attrition and complete rupture [12; 13; 192]. Although such injuries may be induced both by prominent malunited bone fragments or surgical hardware components, an internal fixation approach may induce nearly 6 times higher

32

tendon attrition injuries than conservative management [192]. Overall, the incident levels of tendon complications following DRF may vary between 1 -16% [12]; [281]; [295]. A TFCC tear is a very frequent complication following DRF [84] with reported incident rates near 40-50% depending on the type of DRF pattern [253]. Other common complications following DRF might include wrist ligament sprains [32], with the scapholunate and lunotriquetral ligaments being affected most frequently [87]; [322]; nerve injury, with the median nerve being the most commonly injured structure [50]; and loss of wrist and hand mobility due to persistent edema, pain [155]; [227] and arthrofibrosis [89]; [259]. Incidence rates for ligament sprains, nerve injury, and joint hypomobility following DRF have been reported to be as high as 98%, 17%, and 31%, respectively [295].

FRACTURE CLASSIFICATION AND DIAGNOSIS

Assessment after a DRF involves a multifaceted process that aims to determine the best overall management for optimal functional outcome [39]. In this process, orthopedic surgeons need to consider not only the level of fracture severity, but also patient functional demands, and concomitant patient co-morbidities [117]. Management of a DRF has been traditionally guided by radiological assessment, to diagnose, classify, and grade fracture severity. In addition to standard anteroposterior, oblique, and lateral x-ray film views, advanced imaging techniques (e.g., three-dimensional computed tomography) have also led to enhanced interpretation of DRF morphology and characteristics, ultimately guiding clinical decisions towards more sophisticated and advanced post-fracture interventions [274]. Radiological findings (e.g., altered radial

33

inclination, loss of palmar tilt, radial shortening, increased dorsal angulation, presence of articular step-off, and level of distal radius comminution) are commonly used by orthopaedic surgeons to guide post-fracture treatment decisions.[162].

The early DRF classification included the term "Colles' fracture". This was described as a dorsally displaced and comminuted fracture, resulting in a shortened radius with a dorsal wrist angulation known as "dinner fork deformity" [162]. In 1838, the "Barton's fracture" description was introduced to describe a dorsally displaced unstable intra-articular DRF with carpus subluxation. A "reverse Barton's fracture" classification was reserved for only the volarly displaced Barton's fractures [290]. Volarly displaced non-articular DRFs without carpus dislocation were later sub-classified as "Smith fracture" [217]. Advancing radiological techniques have been used to describe other DRF patterns. Improvements in the description of the DRF morphology were intended to determine severity levels and guide after-fracture management better [39]; [117]. These include the Gartland and Werley [91]; [170, 223, 88, 202, 131]; Swiss Association for the Study of Internal Fixation (AO/ASIF) group [225]; Universal Classification [51, 52]; and Fernandez [82] classification systems. The Frykman and AO/ASIF classification systems are the most frequently documented in current literature as they reflect a broader framework of fracture characteristics, including fracture types through the distal ulna, various degrees of distal radius comminution, and displacement through both extra- and intra-articular patterns [321].

Overall, the DRF classifications are primarily used for academic research purposes and are not typically used in clinical practice by an orthopaedic surgeon. The most practical classification would be the AO/ASIF whereby fractures are broadly classified as (A) extra-articular, (B) partial articular, or (C) intra-articular. Each of these is further subclassified based on the degree of comminution namely simple (1), fragmentary (2), and multi-fragmentary (3). As the alphanumeric order increases, the complexity of the fractures also increases [321]. The overall reliability of this system is considered to be moderate. However, the reliability of this system decreases as further categories of subclassification are added[233]. Despite the distinct advantages of the AO/ASIF classification system, limited and/or equivocal evidence exists to substantiate its predictive value for functional recovery following DRF [43; 139]. Karnezis et al. found no correlation between the AO/ASIF classification system and patient-reported outcomes (e.g. Patient-Rated Wrist Evaluation questionnaire (PRWE)) following DRF treatment [139]. The other commonly used classification, Frykman, was found to have a moderate correlation with the PRWE questionnaire when a radiographic assessment was conducted upon fracture union following after-fracture treatment [20]. However, the poor intra- and inter-rater reliability of the Frykman classification system has negatively impacted its clinical usefulness as a prognostic and diagnostic tool. [11]. Using radiological evidence to determine whether proper anatomy has been restored post-fracture intervention is more clinically meaningful. Attaining a satisfactory anatomic reduction and joint congruency has been positively linked to improved long-term functional outcomes following DRF treatment interventions [43; 195; 279; 293].

35

DIAGNOSTIC CRITERIA AND USE OF IMAGING

Fracture management decisions are multi-dimensional. While patient characteristics are considered, in most cases, imaging criteria play the most important role. Imaging can be used to assess important factors such as alignment parameters, fracture comminution, and degree of articular involvement [312]; [321]. While the relevant components are captured in the classification systems, alignment parameters are assessed individually as a potential predictor of outcome. Both the pre- and post-reduction radiographs are assessed to determine the optimal treatment strategy. They allow the surgeon to appreciate the degree of deformity and overall fracture stability [110]; [321]. To determine whether the alignment is acceptable, articular incongruity or step deformity is considered, as is the degree of dorsal tilt, loss of radial height, radial inclination, and comminution [117]. Many clinical guidelines have been published regarding the acceptable cut-off for each of these measures, with age being often used as a modifier of the alignment criteria [221].

The American Academy of Orthopedic Surgeons (AAOS) utilizes the following guidelines [133] as indications of surgical fixation for DRFs:

1. In non-geriatric patients (< 65 years) moderate evidence level supports that operative intervention can improve outcomes for fractures with >3mm of post-reduction radial shortening, > 10˚ dorsal tilt, and/or >2mm of intraarticular displacement or step-off.

2. In geriatric (≥ 65 years) patients, strong-moderate evidence level supports that operative treatment may lead to only short-term (3-6 months) improved patient-reported outcomes, mainly with volar locked plating. However, no long-term (> 1-year post fracture) advantage to operative fixation was detected among this aged-based population.

In these guidelines, the non-operative arm of many of the studies considered in this CPG included only stable fractures. These studies did not necessarily represent malunions or suggest that malunited DRFs have a similar long-term outcome as compared to well-aligned fractures. There is conflicting evidence related to the correlation of alignment and outcome in the population aged >65. Also, the terms 'geriatric' and 'non-geriatric' were simply used as a proxy for functional demand. A high-functioning patient with high functional demands may benefit from operative fixation based on the literature, regardless of their chronologic age. Thus, treatment decisions should be based on an understanding of the patient's functional demands. [133] In addition to the post-reduction alignment of a DRF, the stability of the fracture also needs to be considered. LaFontaine's criteria [156] have been well established and are used to determine fracture stability. Five basic criteria suggestive of instability have been identified: 1) dorsal angulation > 20° at presentation, 2) dorsal comminution, 3) extension of the fracture into the radiocarpal joint, 4) associated ulnar fracture, and 5) age over 60 years. In cases where three or more of these criteria are present, the fracture is considered unstable. This suggests that although the alignment of the fracture may be acceptable at the time of radiographic evaluation, the likelihood of

losing reduction is high, and this may direct the surgeon towards early operative intervention [Kamal 2022].

Once the initial images are assessed and a management plan devised, serial radiographs can be used to monitor bone healing and ensure the DRF remains well aligned [39]. When treating fractures with casting only, there can be a risk of re-displacement. The decision to accept a certain degree of malunion needs to be made with the patient based on their functional demands [139; 133]. At times, based on the results of subsequent radiographs, a decision may be made to abandon cast treatment and shift to operative intervention [158; 251]. Radiographs are also used to confirm union and once union is achieved, to confirm the degree of union [117; 312]. This becomes relevant when making decisions that may be useful to guide the timing of therapy initiation, the intensity of therapy exercises, and other clinical decisions such as return to work and contact sports [64; 150].

CLINICAL COURSE

The clinical course following a DRF requires a multidisciplinary approach to management and is typically divided into two periods: initial fracture treatment period and rehabilitation management period. The initial fracture and rehabilitation periods are primarily directed by the orthopedic medical team. The rehabilitation management period involves a team of rehabilitation specialists, which may include physical and/or occupational therapists. Whether a physical or occupational therapists are the involved

rehabilitation specialist, it is preferably they specialize in hand and upper extremity rehabilitation [101]; [150].

ORTHOPAEDIC SURGERY MANAGEMENT

Initial treatment of a DRF depends on the overall bony alignment [158]. If the alignment is deemed acceptable, immobilization is indicated and typically achieved with the use of a short arm cast for 4-6 weeks. If the alignment is not acceptable, a closed reduction will be performed before casting. If reduction can be maintained with casting alone, 6 weeks of immobilization is typically sufficient to achieve bony union [110]. If the alignment post-reduction is not acceptable, or the fracture is deemed unstable, then surgical intervention is required to maintain the alignment [156]. Surgical approaches vary and depend on the severity of the injury, the underlying bone stock, and associated injuries. Surgical techniques range from closed reduction and percutaneous pinning with or without an external fixator to open reduction and internal fixation with a volar locking plate [321]. The AAOS CPG [266] states that there are no significant differences in radiographic or long term patient-reported outcomes between fixation techniques for complete articular or unstable DRFs. However, volar locking plates typically lead to earlier recovery of function in the short term (3 months). Although fixation methods other than the volar-locked plate are still used (i.e., pins and plaster, dorsal plating, arthroscopic assisted fixation, external fixation, and bridge plating) they are not as common the volar-locked plate [110]; [221]. For severely comminuted or unstable fractures, external fixation may also be included as an intervention. However, the dorsal spanning

39

bridge plate is seen as an alternative to external fixation as it allows for all fixation to remain internally thereby reducing the risk of pin site infections. Also, unlike a traditional external fixator, it is possible to weight bear through a bridge plate [266]; [221]. Regardless of the method of stabilization chosen, rehabilitation following a DRF is key to ensuring a full recovery for most patients [101]; [150].

REHABILITATION MANAGEMENT

Although therapy has been variable [101], traditionally DRF rehabilitation follows a similar paradigm regardless of the fracture-treatment approach used by an orthopaedic surgeon. In either non-operative or operative DRF cases, most patients are first managed with an early protective mobilization phase. Then, they progress into a wrist-mobilization phase, before they initiate the final strengthening phase, which extends until they are discharged from therapy and transition to an independent home exercise program (HEP) [54]; [277]. The early protective mobilization phase is often initiated during the initial fracture-treatment protection period. Such a protective period allows for proper bone-tissue physiological healing to occur at the fracture site following non-surgical and surgical DRF treatment approaches. During this time, the wrist is fully immobilized either in a cast or a splint with any wrist ROM being contraindicated [241]. Yet, patient education for self-directed active or passive ROM at the digits of the affected hand and other proximal joints at the elbow and shoulder is advised [155]. This early protective mobilization phase may start immediately after surgery or cast immobilization to prevent unwanted stiffness that may adversely affect the rehabilitation outcomes [239]. The

40

utilization of an edema compression glove may also be advisable during this early protective phase [203] for select DRF patients whose hand mobility and pain levels are negatively affected by persistent edema.

The wrist mobilization phase is initiated when a satisfactory DRF healing level has been confirmed by the orthopaedic surgeon. This allows for exercise loading to be safely imposed across the involved wrist fracture site. At that time, the patient may be referred to supervised therapy or monitored via an independent HEP, based on the orthopaedic medical team's clinical discretion. For DRF patients who are managed conservatively, this phase is initiated immediately after their 4-6 weeks cast immobilization period [54]; [135]; [150]. For surgically repaired DRF patients with rigid internal fixation, this phase may start at an earlier time point and within the first 2 weeks (i.e., accelerated rehabilitation approach) [239]; [282] or at 4-6 weeks (i.e., delayed-standard rehabilitation approach) [30]; [174] following surgery, depending on fracture healing and stability. Thus, a distinct difference in the therapeutic management approach following DRF treatment is the duration of the early protective mobilization phase and the time when the wrist-mobilization phase is initiated. Regardless of whether there is an accelerated or delayed-standard rehabilitation approach, at minimum, early finger range of motion should be emphasized. Early wrist ROM should also be considered in the setting of operative stabilization. If there are any signs of extreme finger stiffness, hand hypersensitivity, and/or trophic changes in the skin, an urgent consult with a hand rehabilitation specialist should be initiated.

The focus of the wrist-mobilization phase is to manage pain and edema while optimizing active and passive ROM at the wrist, in addition to the hand, wrist, elbow, and shoulder [98; 286; 287]. In this phase, emphasis is also given to improving wrist and hand sensibility and sensorimotor control via improving conscious proprioception [317]. Submaximal isometric exercises can be used to improve pain, joint dynamic stability, and motor control in all joints. During this phase, therapy goals are achieved via both active and passive-mobilization methods, that may include joint [205; 292] and soft-tissue mobilization techniques [149] as well as patient education for a daily HEP [31]. If excessive joint stiffness persists and wrist ROM goals are not satisfactorily met, the application of static or dynamic mobilization splinting [129; 176] might be used for select patients despite its weak evidence. For the implementation of this treatment option, a physician's approval is typically required. Thus, through this entire rehabilitation phase, communication and collaboration between the therapist and the orthopaedic surgeon are critical to ensure the best therapy continuity and optimum outcomes. The strengthening phase typically starts around 6-8 weeks following the initiation of fracture treatment and requires adequate fracture healing and stability. [42; 47]. It usually encompasses progressive resistance exercises via isotonic, eccentric, power gripping, and perturbation training with increasing loading levels through the wrist and the entire upper extremity. A focus of the strengthening phase is to promote optimal neuromuscular control, unconscious proprioception, and functional retraining which is aimed at each patient's specific functional expectations [134]. This phase prepares patients to resume full daily and vocational activities safely. It is important to note that the aforementioned rehabilitation

42

progression timelines may vary among patients and be dependent on physical demands and functional impairment levels as well as comorbidities and post-fracture complications.

Currently, there are several debated questions in the literature regarding the initial course of DRF rehabilitation. First, there are no clearly delineated criteria on which subgroups of DRF patients would benefit from a referral to supervised rehabilitation services as compared to being managed via an independent home exercise program (iHEP) alone or having no therapy at all. The latest AAOS CPG on DRF medical management [266] concluded that, based on insufficient evidence, supervised rehabilitation does not warrant benefit to all DRF patients, and only a subset of patients might benefit from supervised therapy services. However, these guidelines do not offer any insights into the subgroups of patients who would benefit from therapy nor do they offer any information concerning specific patient or injury-related factors that orthopaedic surgeons should consider when determining the appropriateness of unsupervised therapy versus supervised rehabilitation. Often supervised rehabilitation is elected for patients with significant hand and wrist ROM limitations who require a greater level of supervision. Current literature has indicated several prognostic factors that may influence short- and long-term functional outcomes in patients with a DRF and, therefore, should be considered in the guiding of clinical decisions in this debated issue. These prognostic factors are discussed in the 'Prognosis after DRF' section of this CPG. It should be noted that the presence of one or more of certain factors could adversely affect a patient's outcomes after DRF [Lyngcoln 2005] and therefore trigger a

43

referral to supervised rehabilitation. The evidence synthesis and recommendations for the comparison between supervised therapy (SupT) versus independent HEP (iHEP) are presented in detail within the intervention section of this CPG.

Another issue related to DRF rehabilitation is determining who should be directing and monitoring the iHEP during the early protective phase. In several studies, an iHEP is directed primarily by the supervising orthopaedic surgeon with or without any contribution of a participating therapist [44; 153; 283]. Yet, most other studies have implemented iHEP education strictly using dedicated hand therapists [31; 48; 100; 142; 297]. There is also a lack of information on how an iHEP is best monitored and assessed over time. Thus, the available evidence is insufficient to derive clear conclusions on these issues due to study design heterogeneity and methodological limitations. Rational clinical judgment suggests that patient education towards any iHEP provision should be directed and monitored by certified hand therapists or orthopaedic physical therapy specialists.

Finally, the optimum time to initiate the wrist-mobilization rehabilitation phase following DFR surgery is not fully agreed upon among surgeons. Several studies have compared the accelerated to delayed-standard rehabilitation approaches following DRF surgery [30; 62; 239; 282; 311;324]. The evidence synthesis and recommendations for this important topic are also presented in detail within the Intervention section of this CPG.

CLINICAL GUIDELINES

PROGNOSIS

There are important outcomes that need to be considered when attempting to predict a patient's prognosis after a DRF. These outcomes include function and disability, chronic pain/CRPS-1, wrist/hand related impairments, general health/quality of life, and return to work.

Outcome Predictors for Wrist/Hand Function and Disability

Age

Level I

Based on multivariable regression analysis, Roh et al [246] reported in a prospective cohort of 157 patients (mean age = 62 years; 63% female) that older age (β = -0.75; 95% CI: -1.08, -0.42) was significantly associated with poorer functional recovery at 12-months after DRF treated with volar plate fixation.

Level II

In a systematic review, Babatunde et al [16], included 7 prospective and 6 retrospective cohort studies and identified age greater than 65 years as a risk factor for poorer functional outcomes with a moderate level of evidence. Within this systematic review, however, a large prospective study (n = 360; mean age = 59 years; 78% female) reported a low correlation between age and Disabilities of the Arm, Shoulder, and Hand

questionnaire (DASH) scores at the 3-month (r = 0.33) and 12-month (r = 0.28) follow-up. [2]

Level III

Four lower level prospective cohort studies [19; 43; 72; 79], one cross-sectional study [207], and two retrospective studies [55; 159] found significant associations between age and function at 12- to 18-months after DRF. In a sample of 2571 patients (mean age = 62 years; 80% female), Landgren et al [159] reported a correlation coefficient of r = 0.24 (p < 0.001) between age at fracture and 1-year DASH score. Using multivariable regression analysis, Barai et al [19] estimated that function decreased by 0.14 (95% CI: 0.02, 0.26) points on the DASH for every 1-year increase in age. Similarly, Chung and colleagues [43] found a 0.29 (95% CI: 0.04, 0.53) point decrease in Michigan hand Questionnaire (MHQ) score for every 1-year increase in age.

Female Sex

Level I

A prospective cohort study of 364 patients (73% female; median age = 65 years) reported that the female sex was a strong predictor (β = 3.35; 95% CI: 1.80, 4.63; p < 0.001) of functional limitation at 6-9 months post-injury as measured by the QuickDASH. [121] In the study by Roh et al, [246] univariable analysis revealed that female sex was not a significant predictor of outcome based on MHQ scores at 12-months after surgery.

Level II

The systematic review by Babatunde [16], found moderate quality evidence from 12 studies (5 prospective and 7 retrospective) indicating that being female is a predictor of poorer functional outcomes after wrist fracture. Two other prospective cohort studies not included in that systematic review [96; 97] reported no influence of gender on functional outcome in patients after wrist fracture. In the largest study, no significant association between gender and PRWE (p = 0.45) scores was found among 222 patients (78% female; mean age = 55.2 years) followed for 12- months after extra-articular DRF. [97]

Level III

Results from three retrospective studies [130;159 206] indicated that female sex was significantly associated with poorer outcomes. Using logistic regression, Jung et al [130] in a sample of 54 patients (57% female; mean age = 51 years) assessed 12-months after operatively treated DRF found women were at much greater risk of poor Modified Mayo Wrist Score (MMWS) than men (OR = 27.75; 95% CI: 2.88, 267.29; p = 0.004). In contrast, one retrospective study of 386 patients (72% female; mean age = 52.4 years) reported no significant association between gender and 1-year PRWE scores (p = 0.18). [325] A lack of association (p = 0.50) was also reported between sex and QuickDASH scores at 12-months after operative treatment for DRF in a case-control study of 211 patients by McQuillan et al. [196]

Baseline Pain or Function

Level III

One prospective study (n = 250; 66% female; mean age not reported) found that baseline scores for both the DASH and PRWE questionnaires during the first visit to a hand clinic (within the first week after primary care) were significant predictors of 1-year scores on those same questionnaires.[183] However, the regression model explained only 21% of the variability in 1-year scores for these measures.[183]

Level III

In a secondary analysis of a prospective cohort (n = 229; mean age = 52 years; 69% female), Farzad et al [81] reported that higher movement-evoked pain (MEP) assessed at 2-months after injury was significantly predictive of higher disability at 6-months after DRF (OR = 2.28; 95% CI: 1.18, 4.42; p = 0.014). MEP was defined by the mean score on two pain-related items on the function subscale of the PRWE, including pain during repetitive wrist motion and while lifting heavy items. A cutoff score ≥ 7/10 for these two items was found to have 58% sensitive and 81% specific (Area Under the Curve [AUC] = 0.79) for ongoing disability, defined as a PRWE function subscale score ≥ 12.5/50 at 6-months. Pain at rest (PAR) ≥ 3/10 was also associated with disability at 6-months (AUC = 0.82; sensitivity = 0.51; specificity = 0.91).

Level III

Iitsuka et al [116] retrospectively divided a sample of 45 patients (mean age = 54 years; 67% female) into two groups based on whether the minimal clinically important

difference (MCID) for the DASH (17 points) was achieved by 8-weeks post-operatively. Logistic regression analysis found that baseline scores obtained at 4-weeks were independent predictors of DASH scores at 8-weeks (OR = 1.193; 95% CI: 1.046, 1.360; $p < 0.01$)

Psychosocial Factors

Level I

Among 140 patients (mean age = 67 years; 70% female) followed prospectively, Luk et al [177] found that psychological status measured at the time of cast removal (mean duration = 38.7 days) was the most important predictor of self-perceived disability after nonoperative treatment for DRF. Multivariable analysis revealed that scores on the Hospital Anxiety and Depression Scale explained 16.8% ($p < 0.001$) of the variance in DASH scores at 24 weeks post-injury.

Level I

Goudie et al [95] measured symptoms of psychological distress prospectively using the Post Trauma Stress Disorder Civilian Checklist (PCL-C) in 129 patients (mean age = 57 years; 71% female) within 3-weeks of injury. PCL-C scores were significantly associated with DASH scores at 6-months ($\beta = 0.3$; $p = 0.011$). In a more recent study by the same authors, multivariable regression analysis identified several psychological factors as potential predictors of higher disability after DRF. [96] Among 216 patients (mean age = 57 years; 75% female) followed for 9 months, increased levels of depressive symptoms ($\beta = 0.2$; $p < 0.05$), social deprivation ($\beta = 0.2$; $p < 0.05$), and a belief in an external

49

locus of control (β = -0.1; p < 0.05) measured within 4 weeks of injury were associated with higher scores on the DASH.[96]

Level I

In a study of 364 patients (median age = 65 years; 73% female), use of anti-depressants (β = -9.79; 95% CI: -12.78, -6.79; p < 0.001) and higher scores on the Pain Catastrophizing Scale (β = -1.71; 95% CI: -2.81, -0.64; p = 0.002) at less than 1-week after injury were correlated with greater functional limitations at 6-9 months as measured by PROMIS-UE scores (β = -9.79; 95% CI: -12.78, -6.79; p < 0.001). [121] In the same study, greater fear of movement scores on the Tampa Scale of Kinesiophobia-11 scale contributed to lower function on the PROMIS-UE (β = -1.86; p < 0.001), QuickDASH (β = 5.8; p < 0.001), and PRWE (β = 3.21; p < 0.001) outcome measures. [121]

Level II

A baseline depression score of ≥ 16, measured within 10 days of injury using the Centre of Epidemiologic Studies Depression (CES-D) scale, was one of the strongest predictors of DASH scores in a prospective sample of 228 patients (mean age = 67 years; 89% female) 1-year after injury (β = -2.7; 95% CI: -6.4, -1.0; p = 0.0078).[320]

Level III

In a prospective study of 291 patients (mean age = 56.1 years; 68% female), higher baseline levels of self-reported social support, as measured by the Medical Outcomes

Study Social Support Survey, were found to be significantly correlated (r = -0.22; p < 0.05) with improved PRWE ratings 12 months after injury. [285]

Level III

Changes in anxiety scores (β = 0.42; p = 0.049) and change in self-efficacy scores (β = -0.45; p = 0.044) from 1- to 4-weeks were significantly associated with a change in PRWE scores from 1- to 12-weeks in 21 patients (mean age = 60 years; 67% female) after volar plate fixation. [112] In a retrospective study of 319 patients (mean age = 60 years; 81% female) by Modarresi et al [206] latent growth curve analysis of PRWE scores indicated that the proportion of patients with depression was higher in the non-recovery class (24%) than in the slow- (16%; p = 0.04) or rapid-recovery (8%; p = 0.03) classes. In a case-control study of 211 patients (mean age = 59 years; 86% female), McQuillan et al [196] reported that receiving active treatment for depression at the time of injury (n = 50) was associated with a small increase (β = 6.53; 95% CI: 1.31, 11.75; p = 0.01) in QuickDASH scores at 12-months after surgery.

Compensation Status

Level II

In a prospective study of 120 patients (mean age = 52 years; 70% female) by MacDermid et al [181], injury compensation accounted for 16% of the total variance in PRWE scores at 6-months. Grewal et al [97] also found that 12-month mean PRWE scores for subjects involved with third-party claims were 35.5 points compared to 15.0

points for those not involved in any claims (p = 0.006). Overall, injury compensation contributed 10.6% of the total variability in 1-year PRWE scores.

Level III

Two studies, one low level prospective [183] and one retrospective [310], found injury compensation to be a factor predictive of functional outcome. MacDermid et al [183]reported mean 12-month PRWE scores for patients receiving compensation to be 34 points, compared to 13 points for those receiving no compensation. Walsh et al [310] showed that workers' compensation claimants demonstrated worse function (β = 16.5; 95% CI: 8.7, 24.3) as measured by the DASH at 12-months after DRF.

Education Level

Level II

In the prospective study by MacDermid et al, [181] a lower baseline level of education was significantly associated with poorer PRWE scores (r = 0.25; p < 0.006) at 6-months after injury. In the study by Grewal, multivariable analysis revealed that not having a high school diploma accounted for approximately 5% of the total variance in PRWE scores (p = 0.002) after 12 months. [97]

Level III

In a study of 227 patients (mean age = 55 years; 66% female), Paksima et al [229] evaluated education as an indicator of socioeconomic status by categorizing it into one of five levels, from not completing high school to having completed at least some

postgraduate college education. Over a follow-up period from 3- to 12-months, DASH scores improved slightly more than twice as much for patients at the highest education level compared to those at the lowest education level (β = -2.16; p = 0.001). [229] Using the MHQ, Shauver et al [268] found no significant association between education level and functional outcome at 12-months (p = 0.08).

Grip Strength

Level I

Roh et al [246] showed that low hand grip strength of the unaffected hand at baseline (< 26 kg for men and < 18 kg for women) was an independent predictor of lower scores on the MHQ at 12-months after volar locking plate fixation (β = 1.01; 95% CI: 0.65, 1.31), after adjusting for low appendicular lean mass and age.

Level III

Grip strength, expressed as a ratio of sides and adjusted for hand dominance, was shown to be significantly associated with PRWE score (β = -1.09; 95% CI: -1.76, -0.42; p < 0.01) measured prospectively at 6-weeks after injury among a group of 35 patients (mean age = 46 years; 61% female) managed non-operatively. [138] In 207 patients (mean age = 50 years; 67% female) followed prospectively after volar plate fixation, Shauver et al [268] found that the difference in grip strength (adjusted for hand dominance) between injured and uninjured sides was the only variable associated with MHQ score (β = -0.69; 95% CI: -1.06, -0.33; p < 0.001) at 3-months after surgery.

Dominant Side Injury

Level I/II/III

The side of injury was not a significant predictor of functional outcome among any of the studies reviewed, regardless of the measure used to assess these outcomes or the level of evidence. [16; 41; 97; 207; 246]

Osteoporosis/Osteopenia

Level III

Among 90 postmenopausal women (mean age = 64 years, range = 50-88) studied retrospectively after DRF operatively managed with volar plating, neither DASH (r = -0.03, p = 0.79) nor MMWS (r = -0.02, p = 0.82) were found to be associated with the presence of osteoporosis (T-score ≤ -2.5) at baseline. [41] Egund et al [72] defined outcome as good (DASH score < 15) or poor (DASH score ≥ 15) in 133 men (mean age = 54 ± 18) followed prospectively for 1 year after DRF. Osteoporosis was diagnosed in 18% of the sample and was not a significant predictor of poor outcome (OR = 2.39; 95% CI: 0.86, 6.64; p = 0.556) based on logistic regression analysis.

Diabetes

Level III

Alsubheen et al [8] found in a prospective sample of 479 patients (mean age = 55 years; 75% female) that after adjusting for age, sex, education level, and other health problems, diabetes was associated with slower recovery and poorer overall health

54

status at 12-months follow-up after DRF. A larger improvement in DASH scores was evident in people without diabetes (mean change of 56 points) versus those who had diabetes (mean change of 44 points). Similarly, Lee et al [167] reported that after controlling for age, diabetes was a significant predictor of poor DASH scores ($\beta = 7.191$; $p = 0.025$).

Other Medical Comorbidities

Level II/III

Conflicting conclusions regarding the relationship between functional outcome and other medical comorbidities in patients with DRF were reported in three prospective studies using the DASH. [95]; [96]; [320] In one study, the number of comorbidities was associated with DASH scores at 6-months after injury (N = 129; $\beta = 0.3$; $p < 0.001$), although the method used to record comorbidities was not specified. [95] Conversely, a second study found no relationship between Katz Comorbidity Index scores and functional limitations captured using DASH scores at 1 year (N = 228; $\beta = 0.18$; $p = 0.53$). [320] Having more than 3 other comorbidities contributed only 2.8% of the total variance in PRWE scores in 222 non-operatively managed patients at 12-months. [97]

Outcome Predictors for Chronic Pain/CRPS-1

Female Sex

Level I

Using multivariable regression analysis, two prospective studies [124]; [245] found that

55

female sex was a significant predictor for the development of CRPS-1 after DRF. Jellad et al [124] followed 90 patients (mean age = 52 years; 62% female) and managed non-operatively. By the final follow-up at 9-months, 29 patients (32.2%) had been diagnosed with CRPS 1. Being female was significantly associated with the occurrence of CRPS-1 (OR = 5.774; 95% CI: 1.391, 23.966; p = 0.016).[124] Among 477 patients (mean age = 54 years; 55% female) treated operatively and followed for 6-months, Roh et al [245] reported that female sex was one of the factors most predictive of developing CRPS-1 (OR = 2.172; 95% CI: 1.492, 6.034).

Level III

Neither female sex nor age were found to be associated with an outcome of CRPS-1 in a large prospective (n = 1549; mean age = 43 years; 51% female) study by Moseley et al. [210]

Baseline Pain or Function

Level I

In the prospective cohort study by Luk et al [177], numerical pain ratings measured at the time of cast removal (mean duration = 38.7 days) accounted for 28.6% (p < 0.001) of the variance in pain scores at 24 weeks post-injury.

Level II

In a systematic review, Rolls et al [248] included three studies that identified baseline pain as a prognostic factor for persistent pain or CRPS-1 after DRF. The authors reviewed

56

one prospective study with a low risk of bias in which pain intensity within 1-week of injury was found to be a strong predictor (OR = 3.3; 95% CI: 2.5, 4.3) of developing CRPS-1 by the 4-month follow-up. [210] Another study included in the review was a retrospective analysis of 386 patients showing that pain intensity within 2 weeks of injury, measured using the PRWE pain subscale, predicted 22% of the variance in pain scores 12-months after DRF. [197] A baseline PRWE pain score of 35 or greater out of 50 points was 85% sensitive and 79% specific for the development of chronic pain.

Level II

Using a visual analogue scale (VAS), Farzad et al [80] measured pain levels in 57 patients (mean age = 50 years; 53% female) within two weeks after fracture reduction. By the 12-month follow-up, 10 patients (17%) were diagnosed with CRPS-1. Baseline pain was significantly correlated with development of CRPS-1 (r = 0.47; p < 0.01). Logistic regression revealed that the odds of developing CRPS-1 increased 1.5 times for every 1-point increase in baseline pain on VAS (p < 0.01).

Level III

In the retrospective analysis by Farzad et al, [81] PAR and MEP assessed at 2-months after injury was predictive of chronic pain at 6 months. A score ≥ 3/10 for PAR was 75% sensitive and 88% specific (AUC = 0.90) for severe pain (PRWE pain subscale score ≥ 35/50), while a score ≥ 6/10 for MEP was 67% sensitive and 79% specific (AUC = 0.78) for moderate to severe pain (defined as a pain subscale score ≥ 12.5/50).

Psychosocial Factors

Level I

Kinesiophobia ($\beta = 0.2$; $p = 0.042$) and post-traumatic stress ($\beta = 0.3$; $p = 0.008$) measured within 3-weeks of injury were significantly associated with higher pain levels at 6-months based on NRS. [95]

Level II

Baseline depression scores ≥ 16 on the CES-D scale were significantly associated with symptoms of CRPS-1 in a prospective sample of patients at 3-months after injury ($p = 0.0017$). [320]

Outcome Predictors for Wrist/Hand Impairment

Age and Female Sex

Level I

In a prospective cohort of 240 patients (mean age = 60 years; 81% female), Bobos et al [29] found that increasing age was associated with slower hand dexterity scores for large ($\beta = 0.32$; $p < 0.001$), medium ($\beta = 0.43$; $p < 0.001$), and small ($\beta = 0.46$; $p < 0.001$) object manipulation tasks at 12-months. Female sex ($\beta = 0.11$; $p = 0.017$) was also a predictor of slower hand dexterity scores at 12-months, but only for large object manipulation tasks. Multivariable regression analysis indicated that age and female sex together explained approximately 14% of the variance in scores on the NK hand dexterity test. In a similar study involving 319 patients (mean age = 59 years; 78%

female), age was a predictor of dexterity scores at 6-months for large (β = 0.26; p < 0.001) and small (β = 0.26; p < 0.001) object manipulation, while female sex was associated only with small object manipulation (β = -0.21; p < 0.001). Age, wrist range of motion, and grip strength together explained 34% of the variability in large-object dexterity scores. [28]

Level III

Retrospective analysis identified age as the only factor influencing wrist range of motion (p = 0.012) and grip strength (p = 0.024) at 12-months after DRF in a study by Lee et al. [167] Other retrospective studies have also found significant associations between age and grip strength [55;165] (p < 0.001), as well as hand stiffness [71] (OR = 1.03; p = 0.04) between 6- and 16-months after injury. Weaker grip strength has also been reported as a significant predictor (p < 0.001) for hand dexterity at a 2-year follow-up. [214]

Education Level

Level III

Level of education was associated with both wrist ROM (p < 0.002) and grip strength (p = 0.026) in a prospective series of patients with DRF over 12-months. [229] The authors suggested that poorer outcomes related to the level of education were likely a reflection of lower socioeconomic status and less access to healthcare resources.

Psychosocial Factors

Level I

Pain catastrophizing was reported to be associated with decreased finger motion in 96 patients at 6-weeks after surgery, as measured goniometrically (β = -5.9; 95% CI -11, -1.3; p = 0.012) and by the distance from the fingertips to the most distal palmar crease (β = 0.40; 95% CI 0.22, 0.59; p < 0.001). [289]

Outcome Predictors for General Health/Quality of Life

Level II

Moderate to very-low quality evidence was summarized in a systematic review by Babatunde et al [16] indicating that age greater than 65 years, female sex, and presence of comorbidities may be factors that influence the quality-of-life outcomes after wrist fracture.

Level III

Using the EuroQoL questionnaire, Abimanyi-Ochom et al [1] estimated the quality-adjusted life year loss in 263 patients (mean age = 66.5 years; 85% female) after DRF. Pre-fracture EuroQoL score was the only variable found to be predictive of quality of life at 12-months (β = 0.410; 95% CI: 0.314, 0.508). Four other studies [78; 113; 209; 247] used components of the Short-Form (SF)-36 or SF-12 to examine the influence of DRF on general health and quality of life. Included among the significant predictors of lower QoL

were low patient expectations for recovery [78], lower pre-fracture physical activity level [113], age, and level of education [209] [247].

Outcome Predictors for Return to Work

Level III

Patients who had higher baseline DASH scores within the first week after injury (r = 0.36; p < 0.01) and greater occupational demand (r = 0.33; p < 0.001) were found to be at greater risk of prolonged work loss. [184] Together, occupational demand and DASH scores explained 27% of the variation in time to return to work over a 1-year period in 227 patients. A more recent study by Egund et al [72] reported similar findings in a sample of 88 men (mean age = 45 years) after DRF. In that study, scores for pain, disability (DASH), and physical health (SF-36 PCS subscale) at 6-8 weeks after injury were the strongest predictors for the duration of sick leave, explaining 37% of the variance after accounting for age, comorbidities, work demand, and type of treatment.

Evidence Synthesis

Predicting patient outcomes after DRF remains challenging due to the heterogeneous nature of wrist fractures and the variety of operative and non-operative management strategies used, the inconsistency of measurement methods and analytical techniques, and the limited number of high-quality studies available. Based primarily on level II evidence, the variables most consistently found to be associated with lower wrist/hand function within 6- to 18-months after DRF include increasing age (greater than 65

61

years), third-party compensation, and the presence of comorbid psychosocial factors. Level III evidence found high baseline scores on the PRWE or DASH obtained within 1-week to 2-months of injury were also identified as potentially useful predictors of outcome at 6- to 12-months. Level III evidence was also found for diabetes as a factor associated with slower recovery in these patients. Conflicting evidence was found regarding the importance of other medical comorbidities, education level, and female sex as predictors of wrist/hand function. No studies identified osteoporosis or side of injury (dominant vs. non-dominant) as factors that influence outcome.

Higher baseline pain intensity (assessed within 1-week to 2-months of injury) was associated with chronic pain, including CRPS-1, in both prospective (level I and II) and retrospective (level III) studies. However, the tools and methods used to obtain baseline measures of pain and the optimal cutoff values that define increased risk have yet to be validated. While it is unclear which aspects of emotional and mental health are most important, psychological factors were often associated with poorer outcomes across all outcome categories, including chronic pain. No conclusion can be made regarding the following factors because evidence of their relationship to persistent pain is limited and/or conflicting: age, female sex, diabetes, and other medical comorbidities.

Evidence from a single level I study suggests that increasing age may delay recovery of some impairments, such as dexterity, range of motion, and grip strength. Whether female sex, education level, or psychosocial factors play a role in impairment-related outcomes after DRF remains in question. The overall strength of evidence regarding

factors related to quality of life and return to work was found to be low based on the risk of bias assessment and imprecision of the results.

Gaps in Knowledge

At present, the proportion of the variability for outcome that can be explained by any single or combination of potential predictor variables is low and imprecise. Improving the accuracy and individualization of outcome prediction after DRF will require future development and validation of robust prognostic models that enable clinicians to identify those patients at high risk of poor outcomes. In addition, further investigation on the optimal timing, duration, and content of rehabilitation protocols to enhance functional recovery would facilitate the delivery of more tailored and effective care for these patients.

Recommendations

C

Clinicians may use older age (greater than 65), high baseline levels of disability, third-party compensation, and comorbid psychosocial factors (particularly depression) as potential predictors of poor outcomes related to functional disability.

C

Clinicians may use female sex, high baseline levels of pain, and comorbid psychosocial factors (particularly depression) as potential predictors of poor outcomes related to the development of persistent pain symptoms, including CRPS-1.

EXAMINATION

Outcome - Activity Limitations; Self-Report Measures

Overview

Patient-reported outcome measures (PROMs) that capture activity limitations in patients with DRF have been widely assessed for their utility in patients with DRF. The PROMs with the most prevalent usage in clinical practice and research studies in people with DRF [314] include PRWE, DASH or its shorter version (QuickDASH), and MHQ. There is also sufficient evidence concerning the measurement properties of assessments of pain such as the Numeric Pain Rating Scale (NPRS) in people with wrist/hand impairments [175]. A synthesis of measurement properties for these measures in individuals with DRF is shown in Tables 5-8.

Outcome – Activity Limitations; Performance Measures

Overview

Measures assessing performance in performing functional tasks involving the wrist/hand in people with musculoskeletal (MSK) conditions are limited. The Jebsen Taylor Hand Function Test (JTHFT) [123] is one such test that examines performance in completing 7 common activities of daily living (ADLs) tasks that involve the use of wrist/hand. These tasks include writing, turning over a page, picking up small objects, simulated feeding, stacking checkers, picking up large light objects, and picking up large heavy objects [75]. The Gartland and Werley score, which examines wrist/hand function based on self-report, clinician assessment, residual deformity, and complications, has also been utilized to assess overall outcome after DRF [36]. However, its usage has been primarily limited to the practice of orthopedic surgeons, therefore, it was excluded from the recommendations.

Evidence Synthesis

There is sufficient research evidence from high-quality clinical measurement studies to suggest that PROMs assessing activity limitations such as PRWE, DASH, and MHQ have sufficient evidence to suggest excellent test-retest reliability, construct validity, as well as high responsiveness in assessing change in wrist/hand functions specifically in the context of DRF. The values reflecting minimal detectable change (MDC) or MCID values have been reported for PRWE (11.5 points) and DASH (7 points) in people with

65

DRF, which can significantly contribute to developing short-term goals and monitoring the recovery in respective constructs. In addition, measures for assessing pain experience such as NPRS or VAS have sufficient evidence concerning their measurement properties in MSK conditions affecting UE. The Patient Specific Functional Scale (PSFS) has been recommended in the previous CPG for Lateral Elbow Pain for assessing limitations in higher-level functions tasks such as work or athletic performance [175]. The measurement properties of the PSFS have not been assessed specifically in the context of DRF, therefore it is not prudent to recommend it for assessing impairments in the DRF population. In patients who demonstrate ceiling effect for the PRWE or the DASH, the optional work/sports module of the DASH can be used, especially for patients who may be engaged in occupations requiring the use of wrist/hand for specific high-level tasks.

Measures that examine the performance of the wrist/hand in completing functional tasks are limited. The test-retest as well as interrater/intrarater reliability and construct validity of the JTHFT have been well-established in MSK conditions affecting the wrist/hand. While the measurement properties of the JTHFT have not been specifically examined in the DRF population, it can be argued that people with DRF experience similar functional deficits that are experienced by the people with MSK conditions of the wrist/hand in whom the JTHFT has been validated. Therefore, the JTHFT can be used as a performance measure to assess activity limitations after DRF.

Patient-reported outcome measures serve to capture the severity of impairments, provide a basis to prognosticate the recovery trajectory, and facilitate the assessment of recovery in patients presenting for rehabilitation. They can be used during the initial assessment and at a clinically relevant time point (for example 3-4 weeks after the initial assessment) to determine response to interventions, and again towards the end of care to ascertain appropriateness for discharge.

Gaps in Knowledge

The literature concerning the test-retest reliability and construct validity is deficient for QuickDASH. Future studies should focus on developing comprehensive evidence concerning the measurement properties of the QuickDASH in the context of DRF. In addition, there is a lack of evidence for MCID for the MHQ when assessing changes in wrist/hand function in people with DRF, which can be examined in future studies. The PSFS can serve as an excellent tool considering its unique ability to capture impairments that are relevant to patients, necessitating the efforts to develop an evidence pool for the measurement properties of the PSFS in the DRF population. Lastly, the JTHFT has shown promise in assessing performance in completing ADLs that require wrist/hand use in MSK conditions affecting the wrist/hand. However, test-retest reliability, construct validity, responsiveness, and MCID for the JTHFT in the context of DRF should be examined. This will enable clinicians to put patient-rated function deficits of the wrist/hand in the context of their actual performance.

Recommendations

A

Clinicians <u>should</u> administer joint-specific measure of PRWE to assess pain experience and functional disability of the wrist or administer either the DASH or MHQ to assess region-specific disability of the upper extremity at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

C

Clinicians <u>may</u> use the JTHFT to assess the performance in completing ADL tasks that require wrist/hand use at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

Table 5. Patient-Rated Wrist/Hand Evaluation (PRWE)

ICF Category	Activity Limitations and Participation Restrictions
Description	The PRWE was primarily developed to capture pain and functional disability in individuals with DRF [186]. The PRWE consists of 15 questions, 5 of which examine pain experience and 10 examine

	functional impairment (6 assessing impairments in usual activities and 4 assessing impairments in specific activity) in activities requiring the use of wrist/hand. Each item is rated on a numeric scale of 0-10, with 0 indicating no pain/disability and 10 indicating the worst pain/disability. The administrative burden of completing the PRWE is reported to be between 3-4 minutes [199].
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using intraclass correlation coefficient [ICC]) Short retest interval (2-7 days)	<u>Pain scale:</u> ICC ranging between 0.76-0.93 for two assessments [109 200 144 148 249] <u>Function scale:</u> ICC ranging between 0.85-0.94 for two assessments [109 200 144 148 249] <u>Total score:</u> ICC ranging between 0.81-0.99 for two assessments [108 109 200 249 257 260 173 262]
Longer retest interval (>7 days)	<u>Pain scale:</u> ICC of 0.96 with a retest interval of up to 3-months [144] <u>Function scale:</u> ICC of 0.95 with a retest interval of up to 3-months [144] <u>Total score:</u> ICC of 0.46-0.98 with retest interval of

Absolute reliability (assessed using standard error of measurement [SEM])	up to 205 days [6] [144] [147] [173] [93] Pain scale: SEM of 3.3 [200] Function scale: SEM of 4.3 [200] Total score: SEM of 5.4 [200]
Internal consistency (assessed using Cronbach's alpha [CA])	Pain scale: CA between 0.81-0.93 [200] [144] [109] [249] Function scale: CA between 0.85-0.98 [200] [144] [109] [249] Total score: CA between 0.89 - 0.98 [6] [200] [109] [144] [147] [249] [315]
Construct validity (relationships with other measures assessed using Pearson Correlation Coefficient (r)	Pain scale: DASH: r = 0.62 [144] and 0.50 [294] QuickDASH: r = 0.67 [257] and r = 0.59 [294] Pain measures (NPRS, VAS): r values between 0.59-0.74 [144] [200] [109] Grip strength: r = 0.35 [200] Function scale: DASH: r = 0.76 [144] and r = 0.64 [294] QuickDASH: r = 0.74 [257] and r = 0.62 [294]

	Pain measures (NPRS, VAS): r values between 0.53-0.68 [144] [200]
	Grip strength: r = 0.64 [144] and r = 0.64 [200]
	Total score:
	DASH: r values between 0.59-0.86 [109] [144] [294] [315]
	QuickDASH:: r values between 0.65-0.75 [6] [257] [294]
	Pain measures (NPRS, VAS): r values between 0.69-0.74 [144] [200]
	Grip strength: r = 0.56 [144] and r = 0.60 [200]
Structural validity (using Rasch analysis of factor structure)	Pain scale: showed good fit with Rasch model after a) deleting pain item 'when it is at its worst', b) and collapsing response categories from 11 categories (0-10 scale) to 8 categories (0-10 scale). [73]
	Function scale: showed good fit with Rasch model after a) eliminating items 4 and 6 (showed differential item functioning) and items 9 and 10 (disordered threshold) in 382 patients [73]

71

	<u>Total score:</u> factor analysis resulted in the extraction of one factor that explained 66.26% of the total variance [147]
Responsiveness (assessed using effect size [ES] or standardized response means [SRM]) Retest interval 0-3 months after the injury	<u>Pain scale:</u> ES = 1.87 [182] and ES = 2 [200] SRM = 1.52 [182] and SRM = 2.07 [200] <u>Function scale:</u> ES = 1.95 [182] and ES = 1.85 [200] SRM = 1.6 [182] and SRM = 2.38 [200] <u>Total score:</u> ES ranging between 0.62-3.16 [182] [200] [262] [79] SRM ranging between 0.90-2.66 [79] [182] [200]
Retest interval from 3-months up to 6-months after the injury	<u>Pain scale:</u> ES = 0.86 and SRM = 0.93 [144] <u>Function scale:</u> ES = 0.73 and SRM = 0.77 [144] <u>Total score:</u> ES ranging between 0.43-1.3 [144] [257] [315] SRM ranging between 0.54-2.19 [144] [257] [315] [294]
Minimal detectable change (MDC)	<u>Pain scale:</u> ranging between 2.7-6.5 points change [144] [200] [249] [308] <u>Function scale:</u> ranging between 2.4-9.9 points

	change [144, 200 249 308]
At 90% confidence level (MDC$_{90}$)	Total score: ranging between 4.4-12.5 points change [144 200 249 308]
At 95% confidence level (MDC$_{95}$)	Pain scale: 8.4 points [249] and 9 points [200] change Function scale: 7.79 points [249] and 12 points [200]change Total score: 13.74 points [249], 20.47 points, [147], or 15 points [200] points change
Minimal Clinically Important Difference (MCID)	Pain scale: 1.5 points between two assessments conducted with 0-40 weeks retest interval [308] Function scale: 10 points between two assessments conducted with 0-40 weeks retest interval [308] Total scale: 11.5 points between two assessments conducted with 0-40 weeks retest interval [308] and 8.5 points with a 6-months retest interval [37]
Translated versions:	The following translations are available: Arabic [107], Brazilian Portuguese [92], Brazilian [59],

	Chinese [306], Czech [92], Danish [103; 262], French [92], German [109], Hindi [200], Hungarian [92], Italian [76; 92], Korean [144], Persian [80; 108], Russian [92], Spanish [249 ; 6], Swedish [315], Thai [14], Turkish [228], Ukrainian [92]
Variations/alternate names	The PRWE has also been referred to as the Patient-rated Wrist/hand Evaluation (PRWHE). This is due to an emerging volume of research providing evidence concerning measurement properties of the PRWE in people with hand injuries. The PRWHE also includes a question on satisfaction with the appearance of the hand. However, this additional question is not integrated into scoring. Therefore, the scoring is based on the original 15 questions included in the PRWE.

Table 6a. Disabilities of Arm, Shoulder, and Hand (DASH)

ICF Category	Activity Limitations and Participation Restrictions
Description	The 30-item DASH was developed to examine impairments in activities and participation resulting from MSK injury affecting the upper extremities [114]. The DASH also consists of modules to assess participation restrictions in work or art as well as sports performance; however, these modules are optional and are not part of scoring. Responses to each of the 30 questions on the DASH are rated on a Likert scale of 1-5, where 1 indicates no difficulty and 5 indicates an inability to perform the task. There has been sufficient research to validate the use of the DASH in assessing MSK impairments following DRF.
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using ICC) Short retest interval (2-7 days)	ICC = 0.89 [263]; ICC = 0.83 [173]

Longer retest interval (>7 days)	ICC = 0.91 [147]
Absolute reliability (SEM)	SEM = 5.3 (calculated from the ICC values of 0.91) [147]
Internal consistency (assessed using CA)	CA = 0.96 [263]; CA = 0.97 [147]
Construct validity (relationships with other measures assessed using Pearson Correlation Coefficient (r)	Physical mobility domain of Nottingham Health Profile: r = 0.60 [263] SF-36: r = -0.56 [37] Data for the relationships of the DASH with PRWE and impairment measures such as grip and wrist ROM, if available, are shown in respective tables for those measures.
Responsiveness (assessed using ES or SRM)	
Retest interval 0-3 months after the injury	ES = 1.86 and SRM = 2.01 [182]
Retest interval >3 months	ES = 2.32 and SRM = 2.52 [182]

after the injury	SRM = 2.13 [294]
Minimal Clinically Important Difference (MCID)	6.8 points with a 6-months retest interval [37]

Table 6b. A shortened version of the Disabilities of Arm, Shoulder, and Hand (QuickDASH)

ICF Category	Activity Limitations and Participation Restrictions
Description	The 11-item QuickDASH was developed to reduce item redundancy in full-length DASH, brevity, and ease of administration in a clinic [22]. This shortened version of the DASH has a similar scope of assessing impairments in activities and participation resulting from MSK injury affecting the upper extremities. Since the 11 items in QuickDASH were retained in the original DASH, the responses to these 11 questions are similar to the DASH. The research

	concerning the measurement properties of the QuickDASH in DRF is emerging and not comprehensive.
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using ICC) Longer retest interval (>7 days)	ICC = 0.94 [261]
Construct validity (relationships with other measures assessed using Pearson Correlation Coefficient (r)	Data for the relationships of the DASH with PRWE and impairment measures such as grip and wrist ROM, if available, are shown in respective tables for those measures.
Responsiveness (assessed using ES or SRM) Retest interval 0-3 months	ES = 0.81 and SRM = 1.27 [257]

after the injury	
Retest interval >3 months after the injury	SRM = 2.17 [294]
Minimal detectable change (MDC) At 90% confidence level (MDC$_{90}$)	25.3 points [276]
Minimal Clinically Important Difference (MCID)	25.8 points after 12 visits for rehabilitation [276]
Translated versions:	The DASH and QuickDASH have been translated into multiple languages and cultural contexts. A detailed list of these translations is available (DASH webpage 2020)

Table 7. Michigan Hand Questionnaire (MHQ)

ICF Category	Activity Limitations and Participation Restrictions
Description	The MHQ consists of 62 questions, of which 25 are repeated for both right/left hands (37 original questions), across 6 scales. These six scales assess hand function, ADL, work, pain, aesthetics, and satisfaction [45]. Scores for each scale are calculated separately by converting the raw score for each scale on a scale of 0-100, where higher scores indicate better status with the exception of the pain scale where higher scores indicate worse pain. The total scores for MHQ can also be obtained by reversing scaling for pain score, adding scores for all scales, and then obtaining the average [45]. Due to the high burden of administration for 62-question, a shortened version (Brief MHQ) consisting of 12 items from the original MHQ was conceived [309]. The existing evidence concerning the measurement properties of the original MHQ in

	the context of DRF is summarized below.
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using ICC) Short retest interval (2-7 days)	ICC = 0.92 [27] for Swedish version of MHQ
Absolute reliability (SEM)	SEM = 4.7 (calculated from the ICC = 0.92) for the Swedish version of MHQ [27]
Internal consistency (assessed using CA)	CA for six scales of the Swedish version of MHQ ranged from 0.81 (hand function) to 0.96 (work performance) [27] CA for four scales (Function, ADL, Work, Satisfaction) was>0.90, and CA for Pain and Aesthesis were 0.89 and 0.75 respectively [122]

Construct validity (relationships with other measures assessed using Spearman's Correlation Coefficient (r)	PRWE: r = -0.66, -0.72, 0.75 respectively with a pain scale, functional, and total score of the PRWE [27] VAS-pain: -0.55 [27] Relationships of the MHQ and impairment measures such as grip and wrist ROM, if established, are shown in respective tables for those measures.
Structural validity (using Rasch analysis of factor structure)	With the exception of Function and Work scales, all other scales had several items that showed disordered thresholds (21 of 37 original items in MHQ) requiring several adjustments to response thresholds for these items.[122] Single factor structure for each scale was verified with the exception of the Aesthetics scale [122]
Responsiveness (assessed using ES or SRM) Retest interval >3 months	SRM = 0.8 for Work scale and total score, 0.7 for hand function and pain scale, and < 0.5 for ADL, Aesthetics, and Satisfaction [152]

after the injury	SRM = 0.73 for total score [309]

Table 8. Jebsen-Taylor Hand Function Test

ICF Category	Activity Limitations and Participation Restrictions
Description	The JTHFT was conceived to examine impairments in completing ADLs that require the use of hand. The JTHFT consists of 7 tasks, six of which are performed using both hands, and 1 (writing a sentence) is completed only using the dominant hand. The time taken to complete the tasks is calculated for each task and the total score for completing all tasks is calculated for the dominant and non-dominant side. A lower score (i.e. lesser time to complete all tasks) indicates better function. It takes between 15-20 minutes to complete the JTHFT [273].

	Below table provides existing evidence concerning measurement properties of the JTHFT in DRF as well as other MSK conditions affecting wrist/hand such as RA, trauma, or other injuries.
Evidence Concerning Measurement Properties	
Test-retest, Intrarater, and Interrater reliability (assessed using ICC) Short retest interval (2-7 days)	Test retest ICC = 0.88 and 0.99 respectively for dominant and non-dominant hands in females with RA [168] Interrater ICC = 0.90 and 0.87 respectively for dominant and non-dominant hands in females with RA [168] ICC = 0.82 and 0.82 respectively for dominant and non-dominant hands in patients with MSK conditions affecting upper extremity (UEMSK) [218] ICC ranged from 0.42 (pick up small common object) to 0.99 (Stacking checkers) for non-

	dominant hand, and from 0.42 (pick up small common object) to 0.96 (Stacking checkers) for dominant hand in people with RA [258]
	Intrarater
	ICC of 0.81 and 0.98 respectively for dominant and non-dominant hands in patients with UEMSK conditions [218]
	ICC ranged from 0.35 (Writing 24-letter) to 0.93 (Stacking checkers) for the non-dominant hand, and from 0.63 (Writing 24-letter) to 0.97 (moving 1 lb cans) for the dominant hand in people with RA [258]
Construct validity (relationships with other measures assessed using Spearman's Correlation Coefficient (r)	Grip:
	r = -0.50 and -0.45 respectively for dominant and non-dominant hand in females with RA [168]
	r between -0.14 to -0.50 for non-dominant hand and -0.23 to -0.59 for the dominant hand for

	JTHFT tasks in people with RA [258]
	r between -0.10 to -0.39 for the tasks of the JTHFT using the injured hand and r between -0.01 to -0.17 for the tasks of the JTHFT using the uninjured hand in people with hand injuries [273].
	<u>With MHQ</u>
	r = -0.38 for the total score of JTHFT in people with DRF

Physical Impairment Measures

Summary

People with DRF receiving rehabilitation after DRF commonly exhibit impairments in movements of the wrist/distal forearm, painful limitation in gripping larger or smaller objects with the affected hand, or the proprioceptive ability of the affected wrist joint. Impairments in these domains have been examined using standardized tests and measures that are commonly utilized not just in people with DRF but also in people with other MSK conditions affecting the wrist and hand area. These measures include grip strength (Table 9), pinch strength (Table 10), joint ROM for the wrist and forearm (Table 11), and wrist joint position sense (JPS) (Table 12). The evidence of measurement properties for these measures in conditions other than DRF has been comprehensively

summarized in previously published CPG by an AOPT/AHUEPT group aimed at managing lateral elbow pain [175]. In providing recommendations for these measures during the examination of people with DRF, we considered the totality of evidence for these measures in MSK conditions affecting the wrist and hand.

Evidence Synthesis

There is sufficient evidence for wrist/forearm ROM, grip strength, and pinch strength concerning test-retest reliability and intra- or interrater reliability in people with DRF or those with MSK conditions affecting the wrist/hand. In addition, wrist/forearm ROM, grip strength, and wrist JPS have demonstrated expected concurrent relationships with other self-reported or performance measures in wrist/hand conditions validating their use to assess constructs of movement, strength, and proprioception impairments in the wrist respectively. Measures used in clinical practice must show good sensitivity to capture changes in patient's status. Wrist/forearm ROM, grip strength, pinch strength, and wrist JPS all showed acceptable sensitivity to change in people with MSK conditions of the hand including DRF. Lastly, MDC and MCID values have been reported for grip (6.5 kg) and wrist JPS 5 degrees) in people with DRF, which can significantly contribute to developing short-term goals and monitoring the recovery in respective constructs. Clinicians providing rehabilitation to people with DRF should consider circumstances such as potential contraindications, stage of healing, or highly irritable pain level in administering these measures since testing in such circumstances can either harm the patient or further aggravate symptoms.

Gaps in Knowledge

While pinch strength or dexterity are commonly utilized in people with DRF, the body of evidence concerning their measurement properties is not comprehensive with important statistics such as MDC or MCID missing. In particular, the evidence concerning measurement properties of dexterity is scarce not just in people with DRF but even in people with other MSK conditions affecting the wrist/hand. The tests of dexterity have been widely used and have robust evidence for assessing hand function in people with neurological conditions [94]. Lastly, the evidence for performing wrist JPS in people with DRF is emerging and not yet conclusive. There are clear gaps that need to be addressed in future research. They include assessing rater-dependent and test-retest reliabilities, validity, responsiveness, and MDC values for administering pinch strength, dexterity, and wrist JPS specifically in the context of DRF.

Recommendations

A

Clinicians <u>should</u> use wrist/forearm ROM and grip strength assessments to assess movement and strength deficits of the wrist at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

C

Clinicians <u>may</u> use pinch strength and wrist JPS in assessing precision in handling small objects and proprioceptive ability respectively at the initial assessment and two other clinically relevant follow-up time points, one of which can be discharge, in people presenting for rehabilitation of DRF.

Table 9. Grip Strength (GS)

ICF Category	Measurement of Impairment of Body Function: Power of muscle groups
Description	Grip strength is commonly assessed in people who are treated for rehabilitation of DRF. Grip strength assesses force produced while gripping a testing device such as a handheld dynamometer (HHD). The American Society of Hand Therapists has provided a clear protocol for assessing GS [180]. This table provides existing evidence concerning the measurement properties of GS in DRF.
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using ICC) Short retest interval (2-7 days)	ICC = 0.85 [200] ICC = 0.98 between manual and electronic dynamometers [234] ICC = 0.99 [157]

Absolute reliability (SEM)	SEM = 1.75 kg [200]
Construct validity (relationships with other measures assessed using Spearman's Rank Coefficient (rs)	PRWE: r = -0.35, -0.64, and -0.60 respectively with a pain scale, functional, and total score of the PRWE [200] DASH: r = 0.17 with grip assessed as a percentage of the unaffected side (Forward et al, 2007); r = -0.53 when assessed with items 22-30 of DASH [25] Patient's rating of change in grip strength: r = 0.51 [145] Gross and fine motor tasks of hand: r = -0.72 with putting a stocking over hand; r = -0.03 with picking up coins and putting them in a purse [23]
Responsiveness (assessed using ES or SRM) Retest interval < 3 months	ES = 1.67 and SRM = 1.34 [200] ES = 0.94 and SRM = 1.52 [182] SRM = 1 [152]

after the injury	SRM = 0.05 [10]
Minimal detectable change (MDC) At 90% confidence level (MDC$_{90}$)	MDC = 4.1 kg (Mehta 2012); MDC = 6.5 Kg [145]
Minimal Clinically Important Difference (MCID)	6.5 Kg change at 1-year follow-up [145]

HHD, handheld dynamometer; Kg, kilogram

Table 10. Pinch Strength Test

ICF Category	Measurement of Impairment of Body Function: Power of muscle groups
Description	Pinch strength examines precision and strength in handling a small object in three different positions using a pinch gauge. They include two-point pinch (pinching the gauge using the tip of the thumb and tip of the index finger), three-point pinch (pinching the gauge using the pulp of the thumb and pulp of

	the index and middle fingers) and lateral pinch (pinching the gauge using the radial side of the index finger and thumb) [53]. While the literature on measurement properties of pinch strength testing in the DRF population is scarce, there is sufficient literature on measurement properties of pinch strength in MSK conditions affecting the wrist/hand [303]. This evidence is described below.
Evidence Concerning Measurement Properties	
Test-retest, Intrarater, and Interrater reliability (assessed using ICC) Short retest interval (< 7 days)	<u>Between two types of pinch gauge</u> ICC = 0.29 and 0.53 respectively in healthy men and women using electronic and mechanical pinch gauge [146] <u>Test retest</u> ICC between 0.71-0.90 and 0.87 for all three types of pinch forces in healthy adults [169] <u>Intra-rater</u>

	ICC = 0.93 and 0.97 respectively for tip and key pinch in people with hand conditions [264]
	Inter-rater
	ICC = 0.89 and 94 respectively for tip and key pinch in people with hand conditions [264]
Long retest interval (>7 days)	Intra-rater
	ICC between 0.89-0.93 for all three pinch positions in people with hand pain [211]
	Inter-rater
	ICC between 0.87-0.94 for all three pinch positions in people with hand pain [211]
Absolute reliability (SEM)	SEM = 0.43 for the electronic gauge and = 0.50 for the mechanical gauge for assessing lateral pinch [146]

Construct validity (relationships with other measures assessed using Spearman's Correlation Coefficient (r)	Grip: r = 0.72 for in people with RA [69]
Responsiveness (assessed using ES or SRM)	
Retest interval < 3 months	SRM = 0.9 in people with DRF [152]
Retest interval >3 months	SRM = 0.5 in people with DRF [152]
	SRM = 0.88 in people with RA [69]
	ES = 0.07 for pinch strength after carpal tunnel decompression [125]
	SRM = 0.14 for pinch strength after carpal tunnel decompression [125]

Table 11. Wrist and Forearm Range of Motion (ROM)

ICF Category	Measurement of Impairment of Body Function: Joint Mobility
Description	Wrist joint movements such as flexion, extension, ulnar deviation, and radial deviation are commonly assessed to determine the overall mobility of the wrist joint in all planes. Assessment of distal forearm movements of pronation/supination is affected after DRF and requires assessment to determine wrist/hand functioning. The starting position for assessing wrist flexion/extension involves placing the elbow at 90° of flexion, the forearm fully pronated, and the wrist in neutral flexion/extension. The movable arm of a universal goniometer is placed along the fifth metacarpal, fulcrum at triquetrum, and fixed arm along the forearm. For assessing ulnar deviation and radial deviation, the elbow is kept at 90° of flexion, the forearm fully pronated, the wrist in neutral flexion/extension, and all digits are kept extended

	and adducted. The movable arm of a universal goniometer is placed along the third metacarpal, the fulcrum along the capitate, and the fixed arm along the forearm. For assessing forearm pronation/supination, the elbow is kept at 90° of flexion, the arm is kept alongside the chest wall, and the forearm is kept in the neutral position. The fixed arm of a goniometer is kept parallel to the humerus. For assessing supination, the movable arm is kept along the ventral aspect of the wrist, whereas for assessing pronation, the movable arm is kept along the dorsal aspect of the wrist. For active movement in each direction, the patient is asked to move as much as possible. Joint movement is recorded for respective movement in degrees. A detailed overview of intrarater/interrater reliability, concurrent validity, and responsiveness of assessing wrist and forearm movements in people with UE pathology or asymptomatic individuals has been provided. This table includes the evidence of measurement properties of

	assessing wrist and forearm movements specifically in the DRF population. The totality of evidence for assessing wrist and forearm movements using a goniometer should be understood in the context of this data and summary provided in previous CPG that outlined the management of lateral elbow pain [175].
Evidence Concerning Measurement Properties	
Test-retest reliability (assessed using ICC) Short retest interval (0-7 days)	ICC of 0.95 and 0.99 for wrist flexion and extension respectively between electronic and manual goniometers [234] ICC of 0.94 and 0.97 for pronation and supination respectively between electronic and manual goniometers [234] ICC of 0.71 and 0.87 for wrist ulnar and radial deviation respectively between electronic and manual goniometers [234]

Long retest interval (>7 days)	ICC ranging between 0.63-0.71 for wrist flexion and extension for intrarater reliability [128]
	ICC ranging between 0.68-0.47 for forearm supination and pronation for intrarater reliability [128]
Absolute reliability (SEM)	Calculated from ICC values shown in Plant et al 2016
	SEM of 2.3° and 1.7 respectively for wrist flexion and extension
	SEM of 1.4° and 1.8 respectively for pronation and supination
	SEM of 9.1° and 3 respectively for wrist ulnar and radial deviation
Construct validity (relationships with measures assessed using Spearman's Coefficient (r)	With PRWE: r values between 0.40-0.70 for all ROM with pain and function scales of the PRWE [186]

Responsiveness (assessed using ES or SRM) Retest interval of 3 months after the injury	ES of 0.67 and SRM of 0.84 for total wrist ROM (sum of all ROM [182] SRM of 1.08 for total wrist ROM [10] SRM of 0.7 for total wrist ROM [152]

Table 12. Joint Position Sense test

ICF Category	Measurement of Sensory Function: Proprioception
Description	The joint position sense (JPS) test examines the proprioceptive ability of the wrist in presence of pain or sensory impairments affecting the wrist joint. For the assessment, patients are seated facing an exam table with elbow flexed, forearm in neutral and kept vertical to the exam table, and wrist in neutral. The examiner moves patient's wrist passively into a 20° extension using a

	universal goniometer and holds the position for 3-seconds to allow the patient to 'memorize' this angle. Patient is then asked to move the wrist in a fully flexed position, following which is asked to assume the memorized position of the wrist (i.e. 20° extension). The examiner measures the wrist extension angle using the goniometer and records any difference in this memorized angle and 20° extension. The difference, if any, is considered to be indicative of the JPS deficit. The mean of two trials is recorded as the JPS deficit score [136]. Below is the evidence concerning the measurement properties of the JPS in the DRF population.
Evidence Concerning Measurement Properties	
Construct validity (relationships with other measures assessed using Spearman's Coefficient (r)	PRWE: r = -0.35 at 8-weeks follow-up [136]; r = 0.65 at initial PT assessment [135]

Responsiveness (assessed using ES or SRM) Retest interval < 3 months	ES between 1.42 to 2.36 with a reassessment period 8–12 wk [136] SRM between 1.22 to 2.75 with a reassessment period 8–12 wk [136]
Minimal detectable change (MDC) At 95% confidence level (MDC$_{95}$)	4° - 5° with a reassessment period 8-12 wk [136]
Minimal Clinically Important Difference (MCID)	4° to 7° with a reassessment period 8-12 wk [136]

Outcome – Fall Risk Screening

Overview

There is sufficient evidence to suggest that DRF, especially in older individuals (≥65 years of age), is associated with poor bone health [219], [302] and is often a risk factor for subsequent hip or spinal fractures [57], [127], [40]. The risk for subsequent major fragility fractures after a DRF, such as those involving the spine or hip, is compounded in individuals who have an increased risk for falls due to impaired physical functions, including poor balance, fear of falling (FOF), or decreased lower extremity muscle strength (LEMS) [63], [86] The importance of risk screening for subsequent falls and concomitant fragility fractures is recognized but unfortunately not implemented in medical [250] or rehabilitation practice [64], [201]. Screening the risk profile for subsequent falls after DRF, including impaired balance as well as FOF, is well within the scope of physical therapists and aligns well with their expertise as movement specialists.

Evidence Synthesis and Gaps in Knowledge

While the presence of physical function impairments in individuals who sustain DRF, especially in those ≥65 years of age is well understood [63], [86], the literature concerning the measurement properties of common measures for assessing these impairments in context of DRF is scarce. One study with a very small sample size (N=21) and exclusively female participants showed preliminary evidence of reliability and validity of commonly used measures for screening balance impairments, FOF, and LEMS in DRF

population [198]. Results of this study supported the reliability and validity of the Timed Up and Go test (TUG) and One Leg Stand Test (OLS) for assessing balance deficits, Activities-Specific Balance Confidence Scale (ABC) to assess FOF, and Chair Stand Test (CST) for assessing LEMS [198]. This preliminary evidence has not been substantiated in any subsequent study. A much larger pool of studies with a higher sample size are needed to understand the usefulness of these common measures in screening the risk of balance impairments, FOF, or LEMS after DRF. Our recommendations below are primarily based on the prevalent use of these measures in community-dwelling older adults for screening these impairments as contextualized evidence for their use in DRF is developed [178], [208].

Recommendations

F

Clinicians <u>may</u> administer TUG for fall risk screening in individuals with DRF and consider TUG scores of >12 seconds as the threshold for increased fall risk.

F

Clinicians <u>may</u> administer ABC for screening fear of falling in individuals with DRF and consider ABC scores of < 67% as the threshold for increased fall risk.

F

Clinicians <u>may</u> administer 5-seconds CST for screening lower extremity muscle strength in individuals with DRF and consider CST scores of >12 seconds as the threshold for impaired lower extremity muscle strength.

INTERVENTIONS

As described in the clinical course section, DRF management involves an early protective phase whether treated operatively or non-operatively. This protective phase includes either cast or orthosis immobilization to facilitate proper bone-tissue physiological healing while allowing mobility exercises at the hand and proximal joints. The length of this early protective phase may vary depending on whether a non-operative or operative fracture treatment was utilized. Non-operatively managed DRF patients are typically immobilized in a cast for 4-6 weeks before they initiate wrist mobilization exercises [54]. Following DRF surgery (i.e., open reduction internal fixation, external fixation, or percutaneous pinning), the early protective immobilization period is variable (i.e., a few days to several weeks) depending on fracture healing and stability, as well as surgeon's preference [30], [241]. Thus, the timing for initiating wrist exercises after surgery is not universally agreed upon and typically starts when the physician verifies that a satisfactory healing level has been attained via radiographic evidence and exercise loading can be safely imposed across the fracture site. Regardless of fracture treatment type, when proper fracture healing has occurred, three different rehabilitation

approaches have been proposed: Supervised therapy (SupT) along with advice for an independent home exercise program (iHEP), an iHEP alone, or simply no therapy [298], [31]. The typical recommendation for SupT is one to three clinic weekly visits, where therapeutic interventions can be performed under the supervision of a clinician. In addition to SupT, an iHEP is important for performing daily exercises at home under the initial instruction and distant monitoring of a clinician or sometimes a physician. An alternative to SupT or iHEP may be no therapy, which may involve initial advice for only self-care and management of daily activities, and it allows patients to self-train without the provision of specific instructions. Currently, no clearly defined guidelines exist on which subgroups of DRF patients would benefit from the utilization of any of these rehabilitation approaches. Selection mainly depended on the surgeon's preference or the severity of a patient's physical and functional impairment levels. Traditional DRF rehabilitation commonly entails multimodal therapeutic intervention programs using both SupT and iHEP. No gold-standard multimodal rehabilitation approach exists to date, and DRF therapy programs are usually based on a therapist's discretion. Commonly utilized rehabilitation interventions for DRF include therapeutic modalities, edema control techniques, AROM and strengthening exercises, sensorimotor and proprioceptive training, joint mobilization, and orthosis application for joint stiffness management. [101] The following section offers an analysis of the currently available research evidence for these commonly employed intervention approaches along with several evidence-based recommendations.

Therapy Initiation Timing

This section will discuss the controversial topic related to the timing for wrist therapy initiation (i.e., accelerated vs. delayed approach) after operative DRF treatment, and the timing for initiating strengthening exercises regardless of the type of fracture treatment. Traditional postoperative therapy approaches delay initiation of therapy until after 4-5 weeks of immobilization while strengthening exercises start after 6 weeks post-operatively [296], [239]. Conversely, an accelerated therapy approach has been described as initiating wrist AROM and strengthening exercises within the first 2-3 weeks after surgery [30]. For non-operative DRF treatment, strengthening usually starts after the end of a 6-week cast-immobilization period [54]. This section aims to present the currently available evidence on these topics.

Accelerated vs. Delayed Approach after Surgery

Level I

Deng et al [Deng 2021] conducted a systematic review and meta-analysis to compare various accelerated and delayed therapy initiation approaches following operative intervention with volar plating. The nine included RCTs compared early wrist therapy initiation at ≤ 3 weeks of immobilization to a traditional approach with therapy initiation at ≥ 4 weeks of immobilization. Early finger and elbow or shoulder exercises were implemented immediately after surgery in all studies. Watson et al [Watson 2018] (N=133; 64% female; mean age 52 years) compared three different wrist therapy initiation times, 1, 3, and 6 weeks. The 1-week group had only a removable wrist

orthosis while the 3- and 6-week groups were managed via cast immobilization before wrist therapy initiation. All groups completed a 6-week SupT program along with an iHEP. A small RCT by Quadlbauer et al [Quadlbauer 2017] (N=28; 86% female; mean age 54 years) compared wrist therapy initiation within the first week to therapy initiation after five weeks of cast immobilization. Both groups progressed through SupT which lasted for an average of 3 months. Lozano-Calderon et al [Lozano-Calderon 2008] (N=60; 65% female; mean age 53 years) compared early therapy initiation at eight days to traditional therapy initiation at 6 weeks following surgery. A removable thermoplastic orthosis was used for both groups prior to the initiation of wrist therapy. Brehmer et al [Brehmer 2014] (N=81; 73% female; mean age 52.5 years) compared an accelerated protocol of initiating early wrist PROM and light strengthening at two weeks to a standard protocol that delayed these exercises until 6 weeks following surgery. In both groups, wrist AROM was initiated along with early finger exercises within 3-5 days post-operatively, a removable thermoplastic orthosis was used, and therapy lasted for up to twelve weeks. Clementsen et al.[Clementsen 2019] (N=119; 90% females; mean age 55 years) compared two early (3 days and 2 weeks) therapy initiation groups. Both groups utilized a removable thermoplastic orthosis and the same HEP. The "earlier group" initiated SupT at 3 days while the "later group" initiated an iHEP at 2 weeks. Sorensen et al. [Sorensen 2020] (N= 95, %; gender not reported, mean age 67 years) also compared two early (1 day and 2 weeks) therapy initiation groups. Both groups performed early active finger exercises. The early group used a removable orthosis and started wrist AROM immediately postoperatively. The delayed group was treated with a

108

plaster cast immobilization for 2 weeks before progressing to wrist AROM with a removable wrist orthosis. Both groups followed an iHEP, and performed light daily activities while wearing their orthosis until 6 weeks. Dennison et al. [Dennison 2020] (N=33; 94% females; mean age 54 years) compared the early therapy initiation group at 2 weeks to a delayed therapy initiation group at 5 weeks after DRF surgical repair with volar plating. Both groups utilized early digit AROM exercises during their cast immobilization periods prior to initiating the same SupT program with wrist AROM and strengthening exercises under the supervision of a hand therapist. Zeckey et al. [Zeckey 2020] (N=50; 94% females; mean age 81 years) compared early therapy initiation immediately after surgery to delayed therapy initiation at 4 weeks after surgery with volar plating. Both groups used an orthosis for four weeks. The early group was allowed to remove the splint postoperatively and perform wrist exercises. All patients had SupT along with a HEP. Andrade-Silva et al [Andrade-Silva 2019] (N=39; 56% females; mean age 49.3 years) compared two early (1 day and 2 weeks) therapy initiation groups after surgery with volar plating. A forearm thermoplastic orthosis was used by the delayed group for 2 weeks as compared to only soft post-surgical dressings for the early group. Both groups followed an iHEP, and performed light daily activities until they initiated SupT at 2 weeks postoperatively.

Outcome measures analyzed in this systematic review included upper limb function (DASH), wrist function (PRWE), pain (VAS), wrist AROM, grip strength, and rates of complications. Variable short- (2-12 weeks) and long-term (≥ 6 months) assessment times were reported. Group differences favored early therapy initiation for function,

AROM, and grip strength. Pooled effect sizes showed significant DASH score differences at 6 weeks (MD = 10.15, CI -15.74 to -4.57, P < 0.01) and 6 months (MD = 1.77, CI -3.09 to -0.45, P < 0.01). Significant PRWE differences were found at 6 weeks (MD = 12.47, CI -18.10 to -6.84, P < 0.01). Significant AROM differences were found at 6 weeks for wrist flexion (MD = 10.87, CI 2.30 to 19.45, P = 0.01), extension (MD = 9.06, CI 3.24 to 14.88, P < 0.01), pronation (MD = 3.93, CI 1.37 to 6.50, P < 0.01), supination (MD = 5.63, CI 2.10 to 9.16, P < 0.01) and radial deviation (MD = 1.99, CI 0.46 to 3.51, P = 0.01). Significant group differences in grip strength were found at 2 (MD = 2.30, CI 1.10 to 3.51, P < 0.01) and 6 weeks (MD = 3.11, CI 1.27 to 4.95, P < 0.01), postoperatively. Group differences in pooled effect sizes for pain scores were not significant (P > 0.05). A trend of higher but not significant rate of fracture re-displacement complications existed for the early therapy initiation group as compared to the delayed therapy approach (RR = 3.00, CI 1.02 to 8.83, P = 0.05). Differences in total complication rates were not statistically different (RR = 1.16, CI 0.72 to 1.87, P = 0.54) between groups.

Level I

Lee et al [Lee 2023] conducted another systematic review and meta-analysis to compare the accelerated and delayed wrist therapy initiation approaches following operative intervention with volar plating. The four included RCTs [Lozano-Calderon 2008], [Quadlbauer 2017], [Watson 2018] were also included in the previous systematic review [Deng 2021]. All four studies reported outcomes on upper limb function (DASH), wrist AROM, and grip strength. Pain (VAS) was assessed in 3 studies [Lozano-

110

Calderon 2008], [Quadlbauer 2017], [Watson 2018]. Wrist function (PRWE) was assessed in only two studies [Quadlbauer 2017], [Watson 2018]. Variable short- (6-12 weeks) and long-term (≥ 6 months) assessment times were reported. Group differences favored early therapy initiation for function, AROM, and grip strength. Summary effect sizes showed significant DASH score differences at 6 weeks (MD=12.3, 95% CI, -16.25 to -8.35; P < 0.001) and 3 months (MD=2.87, 95% CI, -5.45 to -0.30; P =0.029). Significant AROM differences were found at 6 weeks for wrist flexion (MD=16, 95% CI, 11.14 – 20.93; P < 0.001), pronation (MD=5.8, 95% CI, 0.43-11.17; P =0.016), and supination (MD=7.57, 95% CI, 1.39 - 13.76; P =0.034), and at 3 months for flexion (MD=8.29, 95% CI, 3.38 - 13.21; P =0.001) and extension (MD=5.61, 95% CI, 0.13 - 11.10; P =0.045). Significant group differences in grip strength were found only at 6 months (MD= 3.75, 95% CI, 0.50 - 6.99; P =.024). Group differences in pain scores were not significant. Risk-ratio of complication rates between the early therapy (N = 120, RR=14.1%) and the traditional (N=111, RR=10.8%) groups were not significant (RR range 0.94 – 0.97, P > 0.05) at all follow-up times. This systematic review did not summarize the effect size for PRWE outcomes. In the two studies that assessed wrist function, significant PRWE scores (MD=13-17, P < 0.05) were found at 6 weeks, favoring the early therapy initiation approach [Quadlbauer 2017][Watson 2018].

Level III

Collis et al. [Collis 2020] conducted a lower-quality systematic review to compare the efficacy and safety between early and delayed initiation of light daily activities in conjunction with wrist therapy following a volar plating operative intervention. Six of the

111

analyzed RCTs [Quadlbauer 2017], [Valdes 2009], [Watson 2018], [Lozano-Calderon 2008], [Clementsen 2019], [Andrade-Silva 2019] were also included in the previous two systematic reviews. [Lee 2023] [Deng 2021] Two low-level case-control retrospective studies [Iitsuka 2016], [Duprat 2018]) were also included in the analysis. Variable short- (6-12 weeks) and long-term (≥ 6 months) assessment times were reported for Pain (VAS), function (DASH, PRWE), and wrist AROM. Effect sizes for each study were only labeled as either no reported, small, medium, or large without any statistical values on the group differences. Pooled effect size estimates for group differences were not reported. It was concluded that commencing early light activities with wrist exercises without a splint prior to 2 weeks postoperatively is safe and leads to greater wrist function and AROM at up to 8 weeks than when is delayed for 2 or more weeks.

Level I

Laohaprasitipornt et al. [Laohaprasitiporn 2022] compared early therapy initiation immediately after surgery with volar plating (N=24; 63% females; mean age 54.4 years) to therapy initiation at 2 weeks (N=24; 67% females; mean age 56.2 years) after surgery. The early group initiated finger, shoulder, and wrist AROM exercises the day after surgery. The delayed group performed finger and shoulder exercises while the wrist was immobilized with an orthosis and initiated wrist AROM at 2 weeks when the orthosis was removed. Group differences in pain (VAS), wrist AROM, grip strength, and self-reported function (DASH and PRWE) were not significantly (P< 0.05) different when assessed at 2, 6, and 12 weeks as well as at 1 year for the PRWE alone. Post-operative

112

complication rates were 12% (N=3) for each group while there was no significant group difference in fracture radiographic parameters at 2, 6, and 12 weeks following surgery.

Level I

Quadlbauer et al. [Quadlbauer 2022] compared early therapy initiation one day after surgery with volar plating (N=56; 69% females; mean age 56 years) to a delayed therapy initiation at 5 weeks after surgery (N=60; 75% females; mean age 58 years). The early group was treated with a removable orthosis and started wrist AROM immediately after surgery. The delayed group received a non-removable cast for 5 weeks. Both groups had comparable SupT programs with HEP. A significant difference in total wrist flexion/extension AROM was found at 6 weeks and up to 1 year (MD range: 10.2-36.8°; P < 0.01). A significant difference in total supination/pronation AROM was found at 6 and 9 weeks (MD range: 13.4-23.5°; P < 0.01). These differences favored the early therapy group, which also showed better wrist function between 6 weeks and 6 months (PRWE MD range: 6.5-17.4% and QDASH MD range:7.3-18.6%; P < 0.01) and grip strength at up to 1 year (MD range: 3.8-5.8 kg; P < 0.01) following surgery. Comparable complication rates were reported for the early (13%) and delayed (15%) therapy groups.

Level IV

Driessens et al. [Driessens 2013] conducted a retrospective case-control study, which compared therapy initiation within the first week (mean initiation time = 4 days; N=37; 51,4% females; mean age 46.5 years) to therapy initiation after the first week (mean

initiation time = 24 days; N=70; 54.3% females; mean age 50.1 years) following surgery. Both groups had similar SupT (median = 9 visits; total therapy 11-12 weeks) programs with orthosis, edema control, scar management, AROM, progressive strengthening, and HEP education. No significant (P > 0.05) group differences in wrist AROM were found at the time of discharge (≥ 12 weeks). Post-operative group complication rates were not reported.

Level IV

Valdes [Valdes 2009], also conducted a small retrospective case-control study to investigate whether early therapy initiation at 1 week (N=14; 78% females; mean age 62.8 years) may result in better wrist AROM, grip strength, function (Upper Limb Functional Index), and lower number of therapy visits/days to achieve functional AROM as compared to delayed therapy initiation at 6 weeks (N=9; 66% females; mean age 55.2 years) following surgery. Both groups were treated with a volar wrist orthosis and comparable SupT with iHEP programs. Therapy ended when patients completed at least 2 weeks of strengthening and achieved functional wrist AROM (flexion and extension 40°, supination and pronation 50°). At discharge (≥ 8 weeks), no significant differences were found in all outcomes except for the total number of visits (MD 10; P < 0.05) and total number of days to reach functional AROM (MD 37; P < 0.05), which favored the early therapy initiation group.

Strengthening Initiation Timing

Level II

Brehmer et al [30] conducted a RCT to compare an accelerated protocol of initiating early wrist strengthening along with wrist PROM at 2 weeks (N=36; 73% females, mean age 49.8 years) to a standard protocol that delayed strengthening and PROM exercises until 6 weeks (N=45; 73% females; mean age 55.3years) following a DRF repair with volar plating. Both groups initiated early finger exercises 3-5 days following surgery, performed hand therapy up to 12 weeks, and used a thermoplastic orthosis up to the time strengthening exercises began. Significant group differences in function (DASH) were noted between 2-12 weeks (MD range = 3-10%; $P < 0.05$) in favor of the accelerated group. These results were clinically meaningful (MCID = 10%) at 4 and 6 weeks. Both groups had comparable DASH scores at 6 months (MD=2%, P= 0.19). The accelerated group showed significantly (P< 0.05) better AROM results for flexion (MD range: 5-8°) between 2-24 weeks; extension (MD range: 5-6°) between 3-8 weeks; and supination (MD range: 6-11°) between 3-8 weeks. Significant group differences in grip strength existed at 6 (MD=12 Lb, P=0.02) and 24 weeks (MD=12 Lb, P=0.02) in favor of the accelerated group. No adverse effects to the fracture alignment were reported in either group and all fractures were healed by 3 months.

Level II

Nguyen et al. [216] investigated whether an early hand strengthening program during immobilization may result in better pain, grip strength, and functional (QDASH)

115

outcomes as compared to a standard strengthening program among older (≥ 60 years) patients following nonoperative DRF management with a 6-week cast immobilization. The early strengthening group (N=22; 86% females; mean age 79 years) initiated submaximal isometric finger flexion exercises, and soft rubber ball grip strengthening exercises (10 repetitions, 5x/day, every other day) between weeks 2-6. The standard strengthening group (N=26; 73% females; mean age 80 years) received only instructions for finger AROM and initiated strengthening exercises following cast removal at 6 weeks. Both groups were managed with a HEP. Significant group differences in pain were found at 2 weeks (MD 2.0; P=0.006) and 12 weeks (MD 2.0; P=0.046). Significant grip strength (ratio to uninjured side) existed at 6 weeks (MD 15%; P=0.004) and 12 weeks (MD 30%; P= 0.003), which was also clinically meaningful (MCID = 19.5%). These differences favored the early strengthening group. No significant group differences were found in function although a 15%-point mean difference existed at 12 weeks, which was clinically meaningful (MCID = 10%) in favor of the early strengthening group. No significant group difference in radiographic fracture findings were noted at 6 weeks.

Level V

Kaji et al. [132] conducted a retrospective case-control study to compare early grip strengthening initiation immediately after surgery (N=20; 95% females; mean age 68.8 years) to delayed grip strengthening at 6 weeks after surgery (N=19; 89% females; mean age 70.3 years). Therapy was initiated for both groups on the first postoperative day with AROM exercises, light isometric towels, and putty squeezes. The early

116

strengthening group also performed hand-gripper exercises with progressing loads between 1.5 -11 lbs up to week 6. The delayed strengthening group started gripper exercises after 6 weeks. Both groups followed SupT (2-3 visits/week) and a HEP. The early strengthening group had significantly higher grip strength (ratio to uninjured side) at 3 months (MD=9%, P< 0.05) and 6 months (MD=12%, P< 0.01). Wrist flexion AROM was significantly better (MD=9°, P< 0.05) in favor of the early strengthening group at 3 months. Group differences in function (QDASH) were not significant (P> 0.05) and there were no significant group differences in radiographic fracture alignment at 6 months.

Evidence Synthesis

The optimum time to initiate rehabilitation following an operative DRF treatment is still not fully agreed upon. Shorter immobilization time with early (within 1-3 weeks) exercises consisting of AROM of the hand, wrist, elbow, and shoulder appear safe and may lead to noticeably quicker functional gains when compared to the traditional delayed approach (≥ 4 weeks). Two high-quality systematic reviews [166], [61] and one low-quality systematic review [49] (included 8 Level I-II, and 1 Level III RCTs) indicated that early therapy initiation at ≤ 3 weeks leads to better short-term (6-12 weeks) function, wrist AROM, and grip strength as well as long-term (6 months) function and grip strength outcomes as compared to delaying therapy to ≥ 6 weeks.

The 4 studies not included in the aforementioned systematic reviews (2 Level I [160], [240], and 2 Level IV [296], [67] further supported that therapy initiation within the first 2 weeks post-operatively leads to superior short-term (6-week) functional, wrist AROM, and grip

117

strength outcomes than initiating therapy ≥ 4 weeks after surgery. The Laohaprasitiporn [160] study (Level I) indicated that there are no extra benefits on pain, AROM, grip strength, and functional outcomes when therapy is initiated within the first postoperative week as compared to 2 weeks after surgery. The Quadlbauer [240] study (Level I) indicated that significant functional gains may persist for up to 6 months while significant AROM and grip strength gains can last up to 1 year after surgery. Two low-quality (Level IV) case-control studies [296], [67] did not find any benefits on function, AROM, and grip strength for initiating therapy early in the first postoperative week as compared to ≥ 4 weeks. However, the Valdes (2009) [296]study showed that early therapy initiation at week 1 may lead to fewer therapy visits, and potentially help to lower healthcare costs as compared to starting therapy at 6 weeks. Two systematic reviews [166], [61] indicated a trend for a slightly greater risk rate (RR = 3.0 - 3.3%) of postoperative complications or adverse effects on fracture union when therapy is initiated earlier than when delaying wrist therapy for 4 or more weeks. However, this increased risk was found not to be significant. The other debated issue this section addressed was the efficacy of early strengthening exercises starting following operative treatment in patients with DRF. One Level II study [30] and one very low-level (Level V) study [132] results indicated that initiating early strengthening within the first two weeks after surgery safely facilitates short-term functional gains (up to 12 weeks) as well as AROM and grip strength gains (up to 6 months) compared to following a traditional approach of waiting to start strengthening after 5 weeks after surgery. One Level-II study [216] also supported that early strength exercises during the second week of the cast-immobilization period following a non-

118

operative DRF treatment provide a significant short-term (6-12 weeks) benefit on grip strength for older (> 60 years) patients with a DRF. Implementation of early strengthening consisted of gentle isometric grip exercises performed as a HEP as well as progressive low-load gripping exercises with putty or exercise grippers during SupT. Based on limited evidence from only these 3 studies, early light strengthening exercises may safely facilitate early functional return to daily activities without significantly increased risk of adverse effects to the surgical repair.

Harms and Benefits

While the evidence is very limited, studies suggest that starting submaximal wrist and hand strengthening exercises as soon as 2 weeks following DRF treatment, even during cast immobilization, may minimally increase the risk for surgical repair stability compromise or potentially a fracture malunion deformity in some subjects. Although the risk is minimal and not significantly different than when you initiate traditional strengthening exercises after 5-6 weeks, physicians and clinicians should weigh the benefits and harms for some patients who are at greater risk for fracture site instability due to their age, bone quality, and fracture severity. It is important to note that studies have included mostly uncomplicated DRF patients with low levels of comorbidities who may benefit from initiating strengthening earlier and safely reaching their ROM, strength, and functional goals sooner.

119

Gaps in Knowledge

The majority of the included studies recruited mostly uncomplicated DRF patients. More studies are needed to compare the effects of early and late wrist therapy initiation times among DRF patients with significant postoperative complications and comorbidities. Further research is also needed to determine whether early strengthening initiation is a safe and effective intervention method for improving short- and long-term outcomes among these DRF subpopulations following non-operative and operative interventions. Future studies should also compare the efficacy of different early or late exercise progression paradigms while providing more clarity on exercise parameters, and attempting to discern the amount of SupT required to attain clinically important short- and long-term functional outcome gains.

Recommendations

A

Clinicians should initiate early therapy that consists of hand, wrist, and shoulder AROM exercises along with light daily activity within the first 3 weeks for patients after operative DRF management to improve short-term (up to 3 months) pain, wrist AROM, grip strength, and functional outcomes, and long-term (≥ 6 months) wrist AROM and grip strength.

B

Clinicians should initiate gradual strengthening, which may consist of light towel and putty isometric squeezing and light-load gripper exercises, at 2 weeks following operative management or during the second week of cast immobilization after a DRF to improve short-term (up to 6 months) pain, wrist AROM, grip strength, and functional outcomes without significant risk to increase of compromising proper fracture healing.

Therapy Supervision and Dosage

The topic of therapy supervision relates to whether rehabilitation is provided in a clinical setting under the direct supervision (SupT) of a clinician [Physical therapist (PT) or Occupational Therapist (OT)] or therapy is performed at home as an unsupervised iHEP under a clinician's instructions. Therapy dosage refers to the applied frequency of supervised sessions. Both therapy supervision and dosage potentially influence clinical outcomes regardless of fracture treatment, operative or non-operative. Several studies have investigated whether the provision of SupT can produce superior outcomes as compared to performing only an iHEP [222, 298, 297, 100, 48, 54, 90, 161]. Some other studies have compared the efficacy of SupT or iHEP to the clinical merits of not utilizing any form of therapy [142, 31, 44]. The dosage of SupT has not been equivalent in all studies. Based on traditional clinical practice patterns, SupT after DRF typically uses 1-3 weekly sessions [222, 298, 297, 100, 90], depending on the therapist's discretion and the extent of post-fracture comorbidities (e.g. advanced age, osteoporosis, diabetes, smoking, high

fall risk, lower socioeconomic level, anxiety, and depression) and complications (e.g. malunion, other concomitant fractures, hand stiffness, nerve compression, carpal ligament injury, and CRPS-1) that may influence therapy outcomes [298], [316]. In several studies [298], [31], [48], [54], [161], the applied SupT dosage had a reduced frequency (average ≤ 1 session biweekly), which under-represents how SupT is typically used in clinical practice, making a valid comparison difficult between SupT and iHEP or no therapy. Optimum therapy mode (SupT, iHEP, or no therapy) and dosage levels following operative and non-operative treatments are not fully agreed among physicians and clinicians. This may be due to the lack of a prognostic-based classification system to guide clinical decision-making. This section presents the currently available literature on the topics of therapy supervision and dosage.

Therapy Supervision

Level I

Two systematic reviews by Valdes et al. and Handoll et al [298], [101], compared the effectiveness of SupT (provided by either PTs or OTs) to an iHEP approach (directed by a therapist or surgeon) following non-operative and operative treatments. Both systematic reviews included the same six RCTs [307], [313], [42], [187], [153], [283]. Studies that were appraised and excluded in these systematic reviews (due to low quality) were also excluded in this CPG. Included in these reviews, Christensen et al. [42] (N=30; 90% female; mean age 66 years) compared SupT to iHEP following non-operative treatment. Both groups were treated by an OT and received the same iHEP instructions. Krischak

122

et al [153] (N=46; 65% female; mean age 54.8 years) compared SupT to iHEP following operative treatment while Maciel et al. [187] (N=41; 75% female; mean age 55.8 years) compared SupT to iHEP following non-operative treatment, and groups in both studies were treated by a PT. Souer et al. [283] (N=94; % females; mean age years) compared SupT to iHEP following operative intervention and SupT was directed by an OT while the iHEP was instructed by the supervising surgeon. One iHEP patient crossed over to SupT due to a lack of progress that was attributed to persistent stiffness. Wakefield et al. [307] (N=96; 90% female; mean age 72 years) compared SupT to iHEP following non-operative treatment with both groups being directed by a PT. Watt et al. [313] (N=18; 94% female; mean age 75.8 years) compared SupT to iHEP following non-operative treatment with SupT being directed by a PT and the iHEP instructed by the supervising surgeon. All these studies showed a moderate to high risk of bias due to several methodological flaws [298], [101]. Outcome measures of pain (VAS), AROM, grip strength, and self-reported functional measures (DASH, and PRWE) were assessed for short- and long-term effects (range 3 - 24 weeks) for the non-operatively (57%) and operatively (43%) treated patients. Forest plots of effect sizes (95% CI) were reported, but effect sizes were not pooled to determine the overall weighted mean difference for all the studies. Reported effect sizes range for function (-0.15 – 1.18; CI: -0.55 – 1.80) favored the iHEP group while effect sizes for wrist motion (-1.56 – 0.58; CI: -2.62 – 0.66), forearm motion (-1.13 – 0.65; CI: -1.13 – 1.07), and grip strength (-0.81 – 0.33; CI: -0.81 – 0.90) favored the SupT group. The magnitudes of the reported effect sizes were not described as clinically meaningful [298]. Both the Valdes et al. and Handoll et al.

123

reviews concluded that both SupT and iHEP treatment approaches may achieve comparable outcomes. Yet, results should be interpreted with caution due to various limitations among the included studies. These limitations included a lack of reporting effect sizes or clinically significant group differences, under-reporting baseline scores, biasing the iHEP group with longer programs, and not reporting sample-size calculations [101]. Sampling selection bias may also have influenced the outcomes of these studies as exclusion criteria were directed to patients with significant post-fracture complications and comorbidities that may adversely influence recovery and require skilled SupT following DRF [101]. These reviews also pointed to the lack of consistency among studies regarding who directed SupT (OT vs. PT) or iHEP (therapist vs. surgeon) [298], [101].

Level I

Soares et al. [278] conducted recent systematic review and meta-analysis to compare the effects of SupT to unsupervised therapy (iHEP or no therapy) following non-operative and operative treatment for DRF. This review included all 6 RCTs from the Valdes et al. [298] and Handoll et al. [101] reviews plus 7 additional studies [297], [31], [100], [48] [54], [90], [161]. Valdes et al. [297] (N=50; 84% female; age range 28-92 years) compared the efficacy of SupT to iHEP following surgery. Both groups were directed by a hand therapist and the SupT group had the same home program instructions as the iHEP group. Groups had equal complication rates (56%) and 4 complicated patients were transferred from the iHEP to SupT group due to poor progression. Bruder et al. [31] (N=33; 75% female; mean age 54 years) compared SupT to no-therapy following non-operative treatment. SupT was

124

directed by a PT, and the no-therapy group received only advise for self-managing daily activities. Guitierrez-Espinoza et al. [100] (N=74; 95% female; mean age 72.1 years) compared SupT to iHEP among older (≥ 60 years) patients following non-operative treatment. Both groups were directed by a PT and SupT had the same home program instructions as the iHEP group. Adherence to the 6-week iHEP group was assessed via phone calls by the therapist. Clementsen et al [48] (N=119; 91% female; mean age 55 years) compared SupT to iHEP after operative treatment. The SupT group performed a progressive exercise program and the same home program instructions as in the iHEP group. Both groups were directed by a PT. Coughlin et al. [54] (N=116; 66% female; mean age 49 years) compared SupT to two modes of iHEP advice (written leaflet vs. video) following non-operative treatment. All three groups were directed by a PT. The leaflet and video iHEP were instructed via 4 clinic visits and consisted of 7 key exercises used in SupT. Complications in the iHEP groups (12.9%) forced 1 video and 6 leaflet patients to cross over to SupT due to poor progress. Lara et al. [161] (N=49; 63% female; age range 46-67 years) compared SupT to video-directed iHEP for 12 weeks following operative treatment. SupT was directed by a hand therapist while the video-based iHEP which consisted of similar exercises to SupT did not require therapist guidance. Two iHEP patients crossed over to SupT due to slow progress. Gamo et al. [90](N=57; 100% female; mean age 68 years) compared SupT to iHEP instructed following operative treatment. The SupT group performed a progressive exercise program and the same home program instructions as in the iHEP group. Both groups were directed by a hand therapist. Common outcome measures were pain, wrist AROM, grip strength, and self-

125

reported function (PRWE). Significant trial heterogeneity limited the ability to perform

meta-analysis effect size summaries to only 6 and 12 weeks with two age-based

subgroups (≤ 40 or > 40 years) analysis. Pain (VAS) was assessed in 8/13 RCTs. At 6

weeks, the younger subgroup showed no significant pain score differences (N=200,

MD=0.17, 95%CI −0.60 to 0.94, P=0.67), but significant pain score difference was

present for the older subgroup (N=178, MD= −1.26, 95%CI −2.13 to −0.04, P=0.00)

favoring SupT. At 12 weeks, no differences in pain existed (N=263, MD= −0.01, 95%CI

−0.25 to 0.24, P = 0.96) regardless of age level. Function (PRWE) was assessed in

7/13 RCTs. At 6 weeks, no significant differences were found for the young (N= 230,

MD = 2.16, 95%CI −8.12 to 12.44, 4 trials, P = 0.68) or older (N= 124, MD= −11.67,

95%CI −24.17 to −0.83, 2 trials, P= 0.07) subgroups. Similarly, no differences in

function existed at 12 weeks (N= 164, MD = 2.09, 95%CI −2.91 to 7.09, 2 trials, P=

0.41) regardless of age level. Wrist flexion and extension AROM was assessed in 6/13

trials. No significant AROM differences existed for flexion at 6 weeks (N= 265, MD =

−0.70, 95%CI −4.06 to 2.65, P = 0.68) or 12 weeks (N= 219, MD = −3.37, 95%CI −9.51

to 2.76, P = 0.28) and for extension at 6 weeks (N= 266, MD = 1.68, 95%CI −1.87 to

5.22, P= 0.35) or 12 weeks (N= 137, MD = 2.61, 95%CI −1.02 to 6.24, P= 0.16). Grip

strength was assessed in 10/13 trials. At 6 weeks, there was no significant grip strength

difference (N= 265, MD = −1.01, 95%CI −4.44 to 2.43, P= 0.57) for the young subgroup

but a significant grip strength difference (P= 94, MD = 4.62, 95%CI −1.51 to 7.73, P=

0.004) existed in the older subgroup favoring iHEP. At 12 weeks, no grip strength

differences existed (N= 268, MD = −1.69, 95%CI −4.46 to 1.08, P= 0.23) regardless of

126

age level. Low methodological quality of the trials and inconclusive results prevented this review from offering sufficient supporting evidence for either intervention.

Level I

Kay et al. [142] compared a 6-week structured iHEP (N=28; 71% females; mean age 55 years) to not performing any therapy (N=28; 68% females; mean age 55.8 years) amongst patients with DRF who were treated via pinning and/or 6-weeks cast immobilization. The iHEP group receive advice by a physical therapist and consisted of edema control; hand, wrist, elbow, and shoulder AROM; wrist passive stretching; and a progressive strengthening exercises initiated at 3 weeks following cast removal. All home exercises were illustrated in a provided booklet to improve compliance. The control group did not receive advice for home exercises. Groups had comparable baseline outcome scores [pain (PRWE subscale), wrist AROM (extension-flexion, ulnar-radial deviation, supination-pronation), thumb opposition, grip strength, and function (Quick DASH, PRWE)] and showed comparable improvements at 3, and 6 weeks following cast removal. Significant group differences existed only at 3 weeks for upper quadrant function (QDASH MD= 13; P=0.008) and 6 weeks for PRWE pain subscale (MD=14; P=0,03) in favor of the iHEP group, which also reported significantly (P = 0.03) greater level of satisfaction. Complication rates in the iHEP and control groups were 46% and 50% respectively. Most common (43%) complication was hand-wrist and shoulder stiffness.

Level III

Oken et al. [222] compared a ST program (N=35; 80% females; mean age 49,8 years) to iHEP (N=20; 60% females; mean age 51.1 years) among uncomplicated patients with non-displaced and stable DRF following 6 weeks cast immobilization. The 3-week ST program (6-7 sessions/week) consisted of PROM and AROM, and stretching exercises and it was directed by a physical therapist. The iHEP group was educated on gentle wrist and hand AROM and passive stretching exercises (hourly during the day, 3 weeks). Groups had equivalent baseline outcome scores following cast immobilization. Significant group differences ($P < 0.05$) in favor of the SupT group existed at 3 weeks in wrist AROM [flexion (MD 10°), wrist extension (19°), supination (MD 30°)], grip strength (MD 12 kg), key pinch strength (MD 3.3 kg), 3-point pinch strength (MD 3.5 kg), and hand edema (MD 20 ml). Outcomes in function were not reported.

Level III

Chung et al. [44] conducted a multicenter low level RCT to determine if any therapy type (SupT, iHEP or both; N=215; 85% females; mean age 71 years) leads to better 12-month outcomes than having no-therapy (N=53, 81% female; mean age 72 years) among older (≥ 60 years) patients following non-operative and operative treatments. Group allocation was not randomized and referral to therapy was based on the surgeons' discretion. In the therapy group 70% of patients had SupT (mean= 9 sessions over 14 weeks) combined with iHEP (mean 17 weeks) in which adherence was not assessed. Both groups were directed by either hand therapists or surgeons. Therapy (SupT or iHEP) was more frequently used following operative (68%) than non-operative

128

treatment (49%). The therapy group showed more complications (69%) than the no-therapy group (60%) but the difference was not significant (P=0.21). No significant group-differences existed for function (MHQ) and wrist AROM outcomes. Significant difference (MD 9 lbs, P=0.03) was found for grip strength in favor of the no-therapy group. A subgroup analysis showed no group-differences in function after adjusting for age and comorbidities. Information on group baseline-equivalency was missing for all outcomes.

Therapy Dosage

As shown in previously reported systematic reviews [298], [101], [278], SupT dosage following DRF is highly variable depending on the surgeon's or therapist's discretion. When SupT is compared to iHEP, 6 trials [42], [153], [222], [297], [100], [90] have applied SupT in a typical clinical practice pattern (≥ 1 weekly sessions) while 6 trials [307], [313], [187], [31], [48], [161] have used a limited SupT dosage (≤ 1 session biweekly) pattern. In two studies [283], [54] the number of SupT sessions was not reported. Of particular importance is the influence of SupT dosage level to therapy outcomes following DRF, especially when is offered to patients with significant complications and comorbidities who should benefit from a typical SupT dosage. No previous studies to date have investigated this concern. This section elucidates the current evidence on outcomes when comparing the typical to limited SupT dosage patterns after non-operative and operative management:

Typical SupT Dosage Pattern

Level I

Guitierrez-Espinoza et al. [100] (N=74; 95% female; mean age 72.1 years) compared SupT (mean 12 sessions over 6 weeks) at a frequency of 2-3 sessions/week to iHEP among older (≥ 60 years) patients following non-operative treatment. Significant differences (P=0.001) existed at 6 weeks for wrist AROM [Extension (MD 20°); flexion (MD 12°)], grip strength (MD 21%), VAS pain levels (MD 1.78); and function (PRWE: MD 17%) as well as at 6 months for wrist extension (MD 19°), flexion (MD 17°), grip strength (MD 26%), and PRWE (MD 17%) in favor of SupT. No complications were reported in either group at 6 months.

Level I

Gamo et al. [90] RCT (N=57; 100% female; mean age 68 years) compared SupT (mean 16.3 sessions over 12 weeks) at a frequency of 1-2 sessions/week to iHEP following operative treatment. Significant group differences (P< 0.05) in favor of SupT were found for pain (VAS) at 4 weeks (MD 8.6 mm) and 6 weeks (MD 7.4 mm), for function (QDASH) at 6 weeks (MD 6.9%), and for wrist AROM (% value relative to the uninjured side) in total flexion/extension (MD 12%) and supination/pronation (MD 7.5%) at 6 weeks. Significant (P< 0.05) wrist AROM differences were present until 8 weeks. No patient complications were reported.

Level I

Valdes et al. [297] RCT (N=50; 84% female; age range 28-92 years) compared SupT (16

sessions over 8 weeks) at a frequency of 2 sessions/week to iHEP following operative treatment. Outcomes on pain, finger and wrist AROM, and grip strength were assessed at 2, 4, 8, and 12 weeks, while function (PRWE) was only assessed at 6 months. No significant group differences existed across all time points. Post-fracture complications in the SupT (N=15) and iHEP (N=13) were comparable, including 4 iHEP patients who were transferred to SupT group due to lack of progress. Intention-to-treat analysis was used in this study.

Level III

Christensen et al. [42](N=30; 90% female; mean age 66 years) compared SupT (mean 37 sessions over 18 weeks) at a frequency of 2 sessions/week to iHEP following non-operative treatment. There was no significant difference in function, which was measured by a non-validated outcome measure (modified Gartlant and Werley score), at 5, and 12 weeks, and 9 months. Comparisons in fracture severity and complication rates between groups was not provided.

Level III

Krischak et al [153](N=46; 65% female; mean age 54.8 years) compared SupT directed by a PT (mean 12 sessions over 6 weeks) at a frequency of 2 sessions/week to an iHEP group following operative treatment. All outcomes were documented as a % value relative to the uninjured side. At 6 weeks, there was a significant difference in function (PRWE; MD 50%, P=0.001), grip strength (MD 22%, P=0.003), and wrist flexion/extension AROM (MD 27%, P=0.001) in favor of the iHEP group. There were no

131

group differences in initial fracture severity levels and post-operative fracture alignment at 6 weeks.

Level III

Oken et al. [222](N=55; 72% females; mean age 50.3 years) compared SupT at a frequency of 6-7 sessions/week over 3 weeks to iHEP which was directed by a hand therapist. Significant group differences in wrist AROM flexion (MD 10°, P=0.004), wrist extension (MD 19°, P=0.001), supination (MD 30°, P=0.002), grip strength (MD 12 kg, P=0.001), key pinch strength (MD 3.3 kg, P=0.001), 3-point pinch strength (MD 3.5 kg, P=0.001), and hand edema (MD 20 ml, P=0.012) were found in favor of SupT at 3 weeks following non-operative treatment. Patients with any post-immobilization complications were excluded from the study.

Limited SupT Dosage Pattern

Level I

Bruder et al. [31] (N=33; 75% female; mean age 54 years) compared SupT (mean 2.9 sessions over 6 weeks) to home advice directed by a physical therapist regarding self-care and daily activity management following non-operative treatment. No significant group differences were found for function (PRWE and QDASH), PRWE pain subscale, wrist AROM (flexion, extension, supination), and grip strength at 7 weeks and 6 months following 6 weeks cast immobilization. No treatment complications were reported for each group.

132

Level I

Clementsen et al. [48]RCT (N=119; 91% female; mean age 55 years) compared SupT at a frequency of 1 session biweekly over 12 weeks to iHEP following operative treatment. The SupT group initiated rehabilitation at 3 days after surgery while the iHEP was immobilized for 2 weeks prior to enacting home exercises. There were no differences in function (QDASH, PRWE), Pain (VAS), wrist AROM, and grip strength at 6, and 12 weeks as well as 1 and 2 years after surgery. Complex intra-articular DRFs were excluded, and post-fracture complication rate was low (10 %) in both groups.

Level II

Maciel et al. [187](N=41; 75% female; mean age 55.8 years) compared a SupT group (mean 4.4 sessions over 6 weeks) to an iHEP group following non-operative treatment. There were no differences in function (PRWE), wrist AROM, and grip strength at 6, and 24 weeks after cast removal. There were no group-differences in fracture severity levels and no complications were reported for each group.

Level II

Wakefield et al. [307](N=96; 90% female; mean age 72 years) compared SupT (mean 3 sessions over 12 weeks) to iHEP following non-operative treatment. Pain (VAS), wrist AROM, and grip strength were assessed at 3 and 6 months following cast removal. Significant group difference existed only for wrist flexion/extension total AROM (MD 12°, P=0.001) in favor of SupT at 6 months. No group-differences were found in fracture severity and displacement levels before or after the 5-week immobilization period.

133

Level III

Watt et al. [313](N=18; 94% female; mean age 75.8 years) compared SupT (mean 5 sessions over 6 weeks) to iHEP group following non-operative treatment. There was a significant group difference for wrist extension AROM (MD 10.3, P=0.010) and grip strength (MD 4.7 kg, P=0.026) in favor of SupT 6 weeks following cast immobilization. There were no group-differences in initial fracture severity levels. No complications were reported for either group.

Level III

Lara et al. [161](N=49; 63% female; age range 46-67 years) compared SupT (mean 5 sessions over 12 weeks) to a video-based iHEP following operative treatment. Videos were created by the study's medical institution and showed their standardized institutional postoperative exercise program. Therapy was initiated 2 weeks after surgery in both groups. No significant differences were found for function (QDASH), Pain (VAS), edema (wrist girth), wrist AROM, and grip strength at 2, 6, and 12 weeks after surgery. A greater number of complex intra-articular DRF were in the SupT (N=16) than the iHEP (N=8) group. Two of them required re-operation. Two iHEP patients crossed over to SupT due to inadequate progress. Intention-to-treat analysis was used in this study.

Evidence Synthesis

Based on limited evidence, this section substantiates the conception that older DRF patients with complications and comorbidities would benefit from weekly SupT services

and an iHEP directed by hand therapists regardless of fracture treatment management, while younger and uncomplicated DRF patient cases may not need SupT services to optimize their short- and long-term functional goals. Three systematic reviews [298], [101], [278] included 12 RCTs that compared SupT to iHEP and a single trial compared SupT to no therapy approach. In 3 other trials, SupT was compared to iHEP [222] and therapy (SupT or iHEP) was compared to no therapy approaches [142], [44]. These trials (4 Level I [297], [100], [48], [90], 3 Level II [307], [313], [187], and 6 Level III [42], [153], [222], [283], [54], [161] produced inconsistent results indicating that both SupT and iHEP may achieve comparable outcomes among patients with DRF following non-operative and operative treatment. Methodological limitations that frequently affected these studies were excluding DRF patients with complications and comorbidities, lacking inadequate power and blinding, having heterogeneous treatment parameters, not assessing function, utilizing non-validated functional measures, lacking baseline equivalency, not adequately reporting treatment details, and not assessing long-term outcomes. Six studies (2 Level I, 2 Level II, and 2 Level III) reported short (3-6 weeks) and long-term (6 months) outcomes in favor of SupT [307], [313], [222], [100], [54], [90]. Two of these studies (Level I and III) [100], [54] recruited patients with post-fracture complications or older patients. These studies results indicated that older patients or patients with more significant post-fracture complications may attain better outcomes (pain, AROM, grip strength, function) from receiving a combination of SupT with iHEP rather than an iHEP alone. Five studies (2 Level I, 1 Level II, 2 Level III) showed comparable outcomes between SupT and iHEP [42], [187], [297], [31], [48], [161]. These studies did not target older patients and they recruited mostly patients

135

with low or no complications. One Level I study [22] which targeted older (≥ 60 years) DRF patients, found SupT to be superior to iHEP. Four studies (2 Level I and 2 Level III) reported the largest rates (10-56%) of patient complications. In these studies, a significant number (up to 30%) of iHEP group patients needed to transfer to SupT due to poor progress indicating that patients with post-fracture comorbidities (i.e., increased hand, wrist, and shoulder stiffness, CRPS-1, OA, CTS) may benefit from SupT provided by a hand therapist for optimum recovery. [307], [313], [222], [100], [54], [90] In one of these studies [307], [313], [222], [100] [54], [90], regression analysis indicated that 35% of the functional deficits were predicted by these co-morbidities at 6 months. Only 2 Level III studies reported outcomes in favor of the iHEP approach [153], [283] but their methodological limitations weakened their potential to support recommendations. Three studies compared therapy to no-therapy. Kay et al. [142] (Level I) strongly supported the short-term (6 weeks) superiority of iHEP as compared to no-therapy following non-operative management. Bruder et al [31] (Level I) showed comparable short- (7 weeks) and long-term (6 months) effects between SupT and advice for only self-care following non-operative management. A critical study limitation was the limited SupT frequency to only 3 sessions over 6 weeks. Chung et al. [44] (Level III) showed inconclusive results when three therapy approaches (SupT, iHEP, or both) were clustered in one group and compared to no therapy. The validity of this study was threatened by lack of randomization, heterogeneity of the therapy group, not monitoring adherence, poor exercise program standardization, and lack of baseline equivalency in the tested outcomes.

136

Regarding therapy dosage, a combination of SupT with iHEP which is directed frequently on a weekly basis (≥ 1 weekly session) by hand therapists (PT or OT) may produce better outcomes (pain, AROM, strength, and function) than limited SupT (≤ 1 session biweekly) following non-operative or operative treatments. Among the 6 trials that applied a typical SupT dosage pattern, three (2 Level I, and 1 Level III) trials reported short- (6 weeks) and longer-term (6 months) outcomes in favor of SupT [222], [100], [90], two (Level I and III) trials showed comparable outcomes [42], [297], and only one (Level III) showed some evidence in favor of the iHEP [153]. In contrast, among the 6 studies that applied a limited SupT dosage pattern, four studies (2 Level I, 1 Level II, 1 Level III) showed comparable outcomes between SupT and iHEP [187], [31], [48], [161] and only two (Level II) studies favored SupT [307], [313]. Collectively, these findings may imply that when SupT has a decreased frequency pattern it tends to produce more comparable short- and long-term clinical outcomes (pain, function, wrist AROM, grip strength) to an iHEP alone approach following non-operative and operative treatments for DRF. This is important because when SupT is provided to patients with significant complications, those patients may need more frequent supervised care by a therapist for proper progression and adequate functional recovery. Among all the 16 reviewed studies, SupT providers were either a PT (N=8), OT (N=2) or a certified hand therapist (N=6), and the iHEP was instructed by the same clinician who directed SupT (N=13) or the supervising surgeon (N=3). Among the 8 studies that favored SupT or iHEP outcomes, the majority (N=7) [307], [222], [100], [54,90] encompassed iHEP training via clinicians (3 Level I, 1 Level II, 3 Level III) and only one study [313] involved a surgeon in iHEP training (Level

137

II) following nonoperative or operative treatments. This provides sufficient evidence to suggest that iHEP provision should be directed and monitored by hand therapists (OT or PT), who are considered upper extremity rehabilitation experts in the healthcare industry. This should be conducted in accordance with the orthopeadic team guidance to ensure ideal multidisciplinary fracture-management standards are followed.

Harms and Benefits

When a decision needs to be made on whether a patient should be referred to SupT services following DRF, risk for harm may be present in terms of over- or under-utilization of healthcare resources. Although an unnecessary referral to SupT may not present additional risks for physical harm to patients who could solely benefit from using an iHEP (i.e., younger and uncomplicated cases), it may lead to an increased burden on the patient's time and financial responsibility while increasing healthcare spending. In contrast, failure to utilize SupT services, especially when therapy is needed (i.e., older patients with comorbidities and complications), may substantially increase the risk of delaying or impairing the full or timely potential of a patient's physical and functional recovery following DRF. This may lead to prolonged rehabilitation times and additional therapy visits that will also substantially increase healthcare costs. Following a DRF, the orthopedic care team should consider both benefits and harms relative to each patient's injury contextual factors individually. More research is needed to better subclassify DRF patients in terms of their therapy dosage needs based on individual factors, injury complexity, and recovery prognosis.

Gaps in Knowledge

Several interdependent elements that may influence outcomes (e.g., age, fracture severity, post-fracture complications, and patient psychosocial factors) should be considered to answer the posed questions of whether SupT is superior to iHEP or no-therapy, and what SupT dosage is optimal. The existing body of literature lacks studies that integrate these contextual factors in a classification system that categorizes patients based on rehabilitation-prognosis. Future high-quality studies are needed to provide answers to these lingering gaps in the research.

Recommendations

B

Clinicians should have older (≥ 60 years) patients or those with complications and comorbidities following operative and/or non-operative management after a DRF attend a SupT program at a frequency of ≥ 1 weekly session and supplemented by an iHEP to improve short- and long-term wrist pain, AROM, grip strength, and function.

A

Clinicians (PTs or OTs) should be the primary instructors of iHEP that are provided to patients following operative and/or non-operative DRF management to improve short- and long-term wrist pain, AROM, grip strength, and function.

139

D

Based on limited or conflicting evidence a recommendation cannot be made regarding whether younger patients without complications and comorbidities following non-operative or operative DRF management should attend a weekly SupT program or perform daily iHEP or no-therapy for optimum short- and long-term outcomes on wrist pain, AROM, grip strength, and function.

Edema Control Methods

Hand and wrist edema control may be important during the early phases of DRF rehabilitation following either non-operative or operative management. Accumulation of hand and digital edema following DRF is considered a significant physical impairment that may negatively impact a patient's recovery. [203] Edema control may consist of several different approaches such as the use of compression garments or gloves, manual lymphatic drainage (MLD) techniques, upper limb elevation, application of intermittent pneumatic compression, and/or other modalities. [106], [7], [203] This section synthesizes the evidence regarding edema control interventions outside of therapeutic modalities following non-operative and operative DRF treatments. Intermittent pneumatic compression units and other modalities will be covered in the therapeutic modalities section of this CPG.

Manual Lymphatic Drainage

Level II

The systematic review and meta-analysis conducted by Gutierrez-Espinosa et al. [99] found evidence to support MLD in the treatment of edema after DRF managed non-operatively or operatively (i.e., external fixator). This systematic review included 2 lower-level RCTs [104], [149] that compared conventional treatment plus massage for edema reduction versus conventional treatment alone. Conventional treatment in both studies included elevation, hand and wrist exercises, compression, functional training, and iHEP instruction (visits: 9-23). The experimental groups in both studies received treatments of MLD which included specific massage techniques aimed at promoting the flow of lymph in the upper extremity (visits: 11-17). In the Knygsand-Roenhoei et al. [149] study (n = 29; 72% female, mean age 63) the experimental group also performed exercises in the segment just massaged along with diaphragmatic breathing, application of low-stretch bandaging and instructions to perform a one-handed massage as part of their iHEP. Knygsand-Roenhoei et al. [149] found no significant difference between groups for edema, AROM, or pain at 1, 3, 6, 9, or 26 weeks. There was a significant difference between groups in favor of MLD for ADLs at 3 weeks (means not reported), but no difference at 6, 9, or 26 weeks. MLD group required significantly fewer treatment sessions (14 vs. 19); after 6 weeks, 21% of MLD group and 60% of conventional treatment group required further treatment for edema. Haren et al. [104] (n=26, 77% female, mean age 61) found a statistically significant difference in median hand volume between groups at 3 days [64 ml in control versus 39ml in MLD group, 95% CI (0.6-49.5)] and 17 days [50 ml

in control versus 27ml in the MLD group, 95%CI (2.2-43.4)]. There were no significant differences between groups at 33 days [35ml in control versus 19ml in MLD (-0.3-31.5)] and 68 days [24ml in control versus 12ml in MLD, 95% CI (-1.0–24.2)].

Level II

In Haren et al. [106] subjects (n = 51, 82% female, mean age = 63) were randomly assigned to receive conventional therapy plus MLD or conventional therapy alone. Treatment for both groups was initiated within 1-6 days after casting or external fixation and included elevation, active and resistive hand/ wrist exercises, compression with an edema glove, and iHEP instruction (7-13 sessions). The MLD group received 40 minutes of MLD in addition to conventional treatment for the first 6 treatment visits. There was a median decrease of 20ml (95% CI = -10 to 45) in the control group and 30ml (95% CI = 10 to 55) in the MLD group (p= 0.005) after 6 sessions. The difference between groups was not significant (5 ml) at 60 days with control having median decrease of 35 ml (95% CI = 15 to 80) in the control group and 40ml (95% CI = 10 to 90) in the MLD group.

Compression Gloves

Level II

Miller-Shahabar et al [203] compared the effects of a custom-made compression glove (20-30 mmHg worn 10 hours/day) plus standard therapy (n = 17, females 82%, mean age = 61.5) to standard therapy only (n = 15, 13 females/2 males, mean age = 68) 2 times per week for 6 weeks. Both groups received AROM exercises for the wrist/fingers,

142

fine motor and daily activities training, and gradual strengthening. Although group means were not provided, the authors reported significantly greater reduction in finger (P < 0.001), hand (P < 0.01), and wrist (P < 0.001) swelling at the 2-week follow-up in subjects who wore the compression glove. While neither group showed further significant improvement in swelling, differences between groups were maintained at the follow-up at 6 weeks. The same pattern of between-group differences over time was reported for AROM with wrist flexion (P < 0.01) and extension (P < 0.001), as well as radial (P < 0.001) and ulnar (P < 0.001) deviation. Improvements in pain and function, as measured using the PRWE, were also significantly (P< 0.05) greater in the glove-wearing group at both 2- and 6-week assessments.

Evidence Synthesis

A conventional approach to management of edema after DRF commonly includes elevation, active and passive exercise, and the application of compression with elastic gloves or wraps. Evidence supporting the addition of other edema control methods to a standard treatment regimen is limited. Evidence from two Level II studies [106], [149] and one Level III study [105] suggests that the addition of specific MLD techniques may have short-term benefits for hand volume [99]. Similarly, one Level II study [203] found that adding a custom-made compression glove improved swelling, AROM, pain and function compared to a standard 6-week protocol. No harm directly related to treatment was reported in any of the studies reviewed.

143

Gaps in Knowledge

Higher level studies are needed to investigate the potential benefits of MLD. No studies have examined the cost effectiveness of treatment and specific parameters of MLD, such as frequency and duration need to be better defined. While one lower level RCT found benefit to adding compression gloves to conventional treatment, further evidence is needed to determine if compression gloves are beneficial without MLD treatment as well as cost effective.

Recommendations

C

Clinicians may perform a combination of edema control techniques that may include MLD and other manual edema mobilization, exercises, elevation, compression gloves, low-stretch bandaging, and iHEP instruction, to induce short-term (2-6 weeks) benefits on hand swelling, AROM, function, and pain following for patients with non-operative and operative DRF management.

Manual Therapy Techniques

Manual therapy is generally considered part of the multimodal rehabilitation approach following DRFs. Joint mobilizations have been advocated to improve pain, joint AROM, and function. [99] Three different approaches to mobilizations have been studied: Kaltenborn sustained translational mobilization, Maitland oscillatory mobilizations, and

144

Mulligan's sustained mobilizations with movement (MWM). Traditionally, mobilizations before tissue resistance have been used for pain relief and edema reduction while mobilizations within or past tissue resistance have been used to improve passive mobility. MWM is typically used to reduce pain with movement, and improve proper arthrokinematics during active movements. Gutierrez-Espinoza et al [99] conducted a systematic review with meta-analysis to examine the effects of manual therapy on functional outcomes in subjects with isolated DRF, however, only one of the included studies compared conventional treatment with manual therapy to conventional treatment alone. Therefore, this systematic review is not included in this review.

Level I

Tomruk et al. [292] studied the effects of early manual therapy on functional outcomes following DRF operative (volar plating) management. Subjects (n=39, mean age= 51, female 53%) were randomized into a standard therapy group or standard therapy plus MWM group with visit frequency of 2 times a week for 12 weeks for both groups. The standard therapy program started at 8 weeks post-op and consisted of hand, forearm, elbow and shoulder active AROM exercises, PROM, stretching, resistance training, and instruction on home exercises. The experimental group also received wrist and forearm MWM sustained glides during AROM. Outcomes were assessed at 3, 6, and 12 weeks. Statistically significant group-differences in favor of the MWM group existed with increased function on PRWE scores ($P< 0.05$, MD range: 14 -19); decreased pain ($P< 0.05$, MD range: 2.7 - 3.2); and increased grip strength ($P< 0.05$, MD range: 4.5 - 8 kg) across all assessment times and DASH scores at 12 weeks ($P< 0.05$, MD: 7.4).

145

Statistically significant group-differences (P< 0.05) also existed in favor of the MWM group for all active wrist AROM (flexion-extension, supination, radial-ulnar deviation) across all assessment times with fair to moderate effect sizes (0.22 – 0.56).

Level I

Reid et al. [242] conducted a multicenter RCT to investigate whether adding MWM to exercise and education improves recovery after non-operative treatment of DRF. A total of 67 (mean age= 60, female 76%) subjects were randomized into 2 groups and attended 4 physical therapy visits over 4 weeks. The control group received standard of care with edema control, skin care, advice for self-care and progression with daily functional activities, and upper limb AROM. The experimental group received the same standard care plus MWM to improve wrist supination and extension. Subjects were trained via instructions and videos to perform the MWM at home 2x/day. Outcomes were assessed at baseline, 4, and 12 weeks. There were statistically and clinically significant differences (based on previously published MCID values) between groups for supination at 4 weeks (MD: 12°, 95% CI= 5 to 20) and 12 weeks (MD: 8°, 95% CI= 1 to 15), and for wrist extension at 4 weeks (MD 14°, 95% CI= 7 to 20) and 12 weeks (MD 14°, 95% CI= 6 to 21). There was a statistically significant group-difference in function in favor of the experimental group (PRWE MD -13, 95% CI= -23 to -4 and Quick DASH MD -11, 95% CI= -18 to -3) at 4 weeks. There was no statistically significant difference between groups for grip strength at any follow-up; 97% improved with MWM at 4 weeks per Global Rating of Change compared to 75% with the control group. No adverse

146

effects were reported other than mild discomfort (pain levels < 3/10) for less than 30 minutes after MWM (27% compared to 15% in the control group).

Level I

Kay et al. [141] investigated the effect of joint mobilizations on pain, AROM, and function in subjects with non-operative and operative DRF management. Subjects (n=39, mean age =53, females 69%) were randomly assigned to a control group (standard multimodal therapy that included advice for edema control, skin care, exercises, functional activities, and iHEP instruction -mean of 3 visits) or mobilization group (same standard therapy plus additional visits of Maitland joint mobilization therapy (mean of 9 visits). Mobilizations consisted of grades I-II accessory (anterior to posterior and posterior to anterior) motions and grades III-IV end-range passive physiologic motions at the wrist and distal radio-ulnar joints. Both groups experienced equivalent outcome improvements and there was no statistically significant difference (p> 0.05) between groups on pain (VAS), grip strength or function at 3 or 6 weeks. There was a statistically significant group-difference in favor of the joint mobilization group at 3 weeks for wrist flexion AROM (MD: 5°, 95% CI: -13.6, 3.6, P = 0.02,). When looking at confidence intervals, this 5° MD may not be clinically important.

Level III

Javaid et al. (2022) [120] compared Maitland and Mulligan's mobilization on hand function and pain after DRF. Subjects (n=60, mean age = 45, number of females unknown) were non-randomly assigned to one of three groups: limited care only (hot pack and PROM),

147

limited care with Maitland Oscillation mobilizations, and limited care with Mulligan Mobilization with movement. Statistically significant improvements were found at 4 weeks and at follow-up for all measures in the Mulligan group (mean improvement of 3.03 points on the VAS, 79.05 on PRWE and 21.56 degrees of wrist extension at 4 weeks, p< 0.0001).

Level III

In a small (n = 8 females; mean age = 64.5) single-subject experimental design study, Coyle et al. [56] compared two mobilization techniques: grade III joint oscillations versus one sustained posterior to anterior glide. Following cast removal at 6-weeks, treatments were performed two times per week for three weeks (total 6 sessions). In general, oscillations led to much greater pain (~44% mean change) and AROM improvement than sustained mobilizations during the first 3 visits (36% mean change in writ extension AROM compared to ~21% for the sustained group) when subjects typically experience higher pain levels. Sustained techniques generally increased pain early on but were more effective for improving wrist extension AROM (30% mean change compared to ~22% for the oscillations) in the last 3 visits.

Evidence Synthesis

Two Level I and one Level III studies suggest that the addition of Mulligan MWM techniques to a standard care program may be more effective than standard care alone to reduce wrist pain and improve AROM and function, at least in the short-term [242], [292], [120]. One Level I study suggests that Maitland oscillation mobilizations may lead to more

148

short-term wrist flexion AROM gains than standard of care [141]. More evidence is needed to determine if grade III oscillations could be superior to Kaltenborn sustained mobilization early in a rehabilitation process for short-term pain control and if sustained mobilizations could be more effective after oscillations are performed to increase wrist AROM amongst subjects with greater amounts of stiffness [56]. While evidence is very limited, studies suggest that adverse reactions related to joint mobilization may include a mild short-lasting (< 30 minutes) post-treatment discomfort in some subjects. No other harms directly related to manual therapy treatment have been reported. It should be noted that all studies included manual therapy as part of a multimodal program and included other therapeutic exercises and edema control interventions within the confines of standard care.

Gaps in Knowledge

The effects of manual therapy after DRF need to be investigated in more high-quality studies with larger samples of subjects, especially those who present with significant stiffness. The optimal parameters (grade, repetitions, frequency, and duration) for joint mobilization techniques are unknown and warrant further investigation. Further research is also needed to determine if self-performed mobilization techniques as part of a iHEP are as effective as those administered by a PT.

Recommendations

B

Clinicians should use manual therapy techniques (MWM, accessory joint mobilizations, oscillations, sustained stretching) as part of a multi-modal management strategy for short-term improvements in wrist pain, AROM, and upper limb function for patients with operative and non-operative DRF management.

Therapeutic Exercises

Therapeutic exercises following DRF are typically implemented regardless of the type of fracture management. Exercises consisting of early AROM with the involved hand and other proximal joints may start during the initial wrist immobilization phase. AROM and PROM exercises with the involved wrist are initiated when proper fracture healing has been attained. Strengthening exercises encompass a variety of isometric and isotonic techniques, which may also involve the unaffected side. Additionally, functional training targeting muscle endurance, coordination, and motor control is integrated [155, 190, 83, 98]. This functional training is a vital component of rehabilitation, often conducted by occupational therapists who frequently collaborate with physical therapists throughout the DRF rehabilitation process [83].

Level I

Gutierrez-Espinoza et al. [98] compared the effects of standard therapy to standard therapy plus a scapular exercise program in 102 subjects (mean age =66, females 80%)

who were treated with closed reduction and cast immobilization post DRF. The subjects in the control group (standard therapy) received 12 visits of AROM in a whirlpool, radiocarpal mobilizations, grip strengthening, and reverse dart throwing exercises. In addition to the above treatment, the scapular exercise group received low intensity scapular positioning exercises below shoulder level. There was a statistically significant and clinically meaningful change in DASH scores between groups at 6 weeks (30.7 for scapular group versus 14 for control, 95% CI for difference between groups 12.6-20.9, p=0.0001) and pain with movement (2.9 cm versus 1.2cm in control group, 95% CI for difference between groups 1.2 to 3.2, p=0.001) favoring the scapular exercise group. There were no differences in PAR or PRWE scores (p>0.05).

Level II

Kuo et al. [155] investigated whether early digit mobilization resulted in better outcomes for hand stiffness and function after external fixation among 22 subjects (mean age = 62, females 68%) with DRF. The early digit mobilization group received massage, PROM/AROM of uninvolved joints, ADLs training, isometric and concentric exercises of the digits, and tendon gliding exercises. The early digit mobilization program started 1 week after external fixation treatment and ended with external fixation removal at 6 weeks. The control group received only standard advice and basic exercises to adjacent joints excluding the hand. Both groups received 12 weeks of regular rehabilitation after removal of the external fixation. No statistically significant differences were found between groups for thumb/finger AROM, grip/pinch strength, and dexterity at any follow-up (1, 3, 6 weeks). A statistically significant difference was found in 'maximal

151

workspace' at 12 weeks in favor of the early digit mobilization group (81.55% vs. 69.54%, P = 0.04 and 89.22% vs. 59.97%, P= 0.03). "Maximum workspace was defined by the authors as "maximal AROM capacity of the thumb and fingers". No adverse effects were reported for either group.

Level II

Magnus et al. [190] evaluated the effects of a home-based strength training of the uninvolved upper extremity on the recovery of muscle strength, AROM, and function among 39 females (mean age =63) subjects with unilateral non-operatively and operatively managed DRFs. The experimental group was prescribed progressive maximum isometric strength training for finger, hand, and forearm muscles of the uninjured upper extremity, 3x/week for 26 weeks. Both the control and experimental group received a standard therapy protocol that included 6 visits of home-program instruction and progression. All outcomes were assessed at 9, 12, and 26 weeks. The only statistically significant differences in favor of the experimental group existed in grip strength (P < 0.01; MD 5.5 kg) and wrist flexion/extension total arc AROM (P < 0.01; MD 20.3°) at 12 weeks. No statistically significant differences existed between groups in function (PRWE) at any of the follow-up points.

Level II

Filipova et al. [83] conducted a RCT to evaluate the efficacy of combined physical and occupational therapy (PT/OT) in comparison with PT alone in 62 subjects (mean age =60, females 77%) with DRF treated conservatively. The subjects in the PT only group

152

received Galvanic bath, AROM exercises, joint mobilizations, and strengthening exercises. The PT/OT group receiving the same treatment as the PT group plus 30 minutes of strengthening, and coordination and endurance training using functional movements. There was a statistically significant difference ($P < .05$) in relative grip strength between groups at discharge and one month after discharge in favor of the PT/OT intervention. There were no between group differences in AROM or DASH at any other follow-up. It is unclear if the additional strength improvement benefits relate to the type of provider, the functional strengthening intervention, or the additional treatment time.

Level II

Picelli et al. [231] evaluated the efficacy of robot-assisted arm training on upper limb impairment in 20 subjects (mean age =62; females 65%) with operatively and non-operatively treated DRF. The robotic arm training group performed 10 sessions (60-minutes each) of robot-assisted AROM and PROM exercises (unilateral, bilateral, mirror-like) 5 days/week for 2 weeks. The control group received conventional AROM, strengthening and functional training exercises. Group outcomes in PROM, AROM, grip/pinch strength, and function (PRWE) were assessed immediately after the 1st session and 4 weeks later. Both groups demonstrated equivalent improvements in all outcomes over 4 weeks with no between group differences. A critical limitation of this study was the very small sample size, which limits estimated statistical power.

Level III

Kaufman-Cohen et al. [140] evaluated the outcomes of standard rehabilitation (control group) compared to a program adding dart-throwing motion plane exercises (experimental) as part of the iHEP to a small sample of 24 subjects (mean age =50, females 42%) treated via ORIF. The control group received edema control, mobilization, wrist strengthening exercises with Theraband for 30 minutes x 12 visits. The subjects in the experimental group received the same as the control group but were also prescribed an iHEP moving the wrist in a dart-throwing motion plane using a modified orthosis. There was no statistically significant difference between groups in AROM, pain, function (PRWE) or grip/pinch strength after 12 sessions (6-8 weeks) although the experimental group had higher satisfaction scores.

Level III

Naqvi et al. [213] evaluated the effect of gamification in 20 subjects with DRF managed with closed reduction. Gamification group (age range 18-65 years, 20% females) played games on Oculus Quest head-mounted display. The control group (age range 18-65 years, 50% females) received standardized rehabilitation. Neither intervention was well described. Both groups showed improvements in pain, AROM, strength, and function but the gamification group showed more improvement in DASH scores at 2 and 4 weeks than the control group. Power calculations not reported.

Level IV

Mitsukane et al. [205] performed a pre and post-test cross-sectional study to evaluate the

154

immediate effect of repetitive wrist extension contractions on grip strength among 28 operatively and non-operatively treated subjects with DRF (mean age =63, females 68%). The subjects in the wrist repetitive extension protocol performed 30 (3 sets of 10) maximum wrist isometric extension repetitions at end-range extension holding a lightweight (5g) rod while the control group rested for 6 minutes. Pain (VAS) and grip strength outcomes were assessed immediately after the experiment. There was a significant post to pre intervention increase in grip strength (P < 0.01; MD 1.4 Kg) and decrease in pain (P < 0.03; MD 7.1 mm) in the experimental group affected side while no statistical improvements were seen in the control group.

Evidence Synthesis

This section has synthesized clinical recommendations based on limited evidence from 8 studies. Only a small number of therapeutic exercises that are commonly utilized following DRFs have been studied to date. Specific rehabilitation guidelines cannot be recommended due to the paucity of experimental studies, limitations in designs, and the variety in therapeutic exercise approach and subgroup of DRF subjects studied. These findings are consistent with the systematic reviews that did not meet the inclusion criteria of this CPG [101], [238]. Evidence seems to support a variety of exercises that include progressive AROM, PROM, tendon gliding exercises, resistive training, motor control and functional training. [83] One Level I study demonstrated short-term improvements in arm function and pain by adding scapular strengthening to standard physical therapy. [98] When exercises are contraindicated or not well tolerated on the

155

involved side, strengthening of the uninvolved side may offer benefits. [190] Exercises to the hand (finger AROM, finger isometric, concentric, and tendon gliding exercises) beginning 1 week after external fixation appear to be safe. [155] The limited evidence and the cost of various technologies prevent recommendations regarding dart-throwing motions using orthosis, gamification, or robot assisted training. [231], [140], [213]

Gaps in Knowledge

While therapeutic exercises post DRF are the mainstay of physical and occupational therapy and are recommended by the CPG team members for improving pain, AROM, strength and function, research studies that examine the efficacy of various commonly utilized therapeutic exercise strategies and progressions in the rehabilitation of DRF are scarce. High-quality studies that examine and compare various modes of therapeutic exercises and their optimal parameters are needed.

Recommendations

B

Clinicians should use properly timed therapeutic exercises including PROM, AROM, tendon gliding, motor control, functional and progressive bilateral resistive exercises that include the scapula, to improve pain, AROM, strength, and function for patients following operative and non-operative DRF management.

Sensorimotor Training

A limited body of research has pointed to the presence of significant wrist sensorimotor (SM) impairment following DRF. [135], [317] This impairment may be associated with a wide range of possible deficits that include decreased hand sensation (i.e., 1- or 2-point touch discrimination, moving touch, stereognosis), diminished proprioception (i.e., wrist joint position sense), decreased wrist and hand strength, and decreased function. [135] Wrist SM impairments are adversely influenced by increased pain levels and may persist for up to 12 weeks following non-operative and operative management for DRF. [135], [136] Several SM intervention methods have been proposed in the literature to address wrist pain and sensibility deficit as well as proprioception and neuromuscular decline following DRF. For early rehabilitation stages graded motor imaging (GMI), mirror therapy, sensory stimulation via vibration, wrist position replication of movement with eyes closed, and wrist isometric exercises have been proposed to help improve pain, sensibility, AROM, and joint position sense (i.e., conscious proprioception.) [134] Among these methods, GMI has been popularized for its three motor-cognitive exercise phases in laterality (i.e., ability to discriminate left vs. right body images), motor imagery (i.e., ability to imagine movement of the affected arm), and mirror therapy (i.e., motion of the unaffected arm in front of a mirror is perceived as motion of the hidden affected arm behind the mirror). [21], [66], [317], [151] For late rehabilitation stages, various strengthening and perturbation exercises towards neuromuscular facilitation and instinctive muscle recruitment (i.e., unconscious proprioception) can be used to restore joint stability. [134]

157

SM training can be provided along with other conventional exercises during SupT or could become integrated in an iHEP.

Level I

Dilek et al. [66] conducted an RCT to compare GMI combined with conventional therapy (N=17, 70% females; mean age 52.5 years) to conventional therapy alone (N=19, 63% females; mean age 47.2 years) 3 weeks after non-operative and operative management for DRF. Patients with complex intra-articular DRFs were excluded from this study. The conventional therapy (16 sessions, 2 sessions/week over 8 weeks) consisted of edema control techniques; AROM and PROM for the hand, wrist, elbow, and shoulder; joint mobilization; proprioception and upper extremity strengthening exercises; and an iHEP. The GMI program progressed through the 3 main elements of lateralization, motor imagery, and mirror therapy. Both treatment groups were directed by a physical therapist. Significant ($P < 0.05$) differences in favor of the GMI group existed at 8 weeks for pain with activity (VAS MD: 6 cm), wrist AROM (flexion MD: 40°, Extension MD: 45°, radial deviation MD: 25°, ulnar deviation MD: 26°, supination MD: 43°), and function (DASH MD: 38% and MHQ MD: 32%). Difference in DASH scores were found to be clinically meaningful (MCID = 10.83). Groups had comparable pre-treatment baselines in all measures as well as fracture severity levels

Level I

Korbus [151] conducted a small RCT among older (≥ 60 years) female patients following operative treatment for DRF to compare groups that performed either mirror therapy

158

(N=12, mean age 75.4 years) or motor imagery (N=8, mean age 73.1 years) to a

control group that performed only relaxation techniques (N=9, mean age 72.4 years). All

three compared interventions were performed for 6 weeks as a home-based training

program (5 times/week for the first 3 weeks, 3 times/week thereafter) in addition to

traditional therapy exercises and an iHEP. Groups were guided by different therapists,

one for the experimental groups and one for the control group. All groups had

comparable baseline characteristics. Significant group difference in function (PRWE)

was shown at 12 weeks for the mirror therapy (MD 8.9%, P< 0.001, Effect size 0.61)

and the motor imagery (MD 5.2%, P< 0.001, Effect size 0.39) as compared to the

control group. Significant wrist AROM (total AROM of flexion, extension, ulnar and radial

deviation) differences as compared to non-affected side were shown at 12 weeks for the

mirror therapy group (MD 10°, P < 0.001, Effect Size 0.36) and the motor imagery (MD

12°, P< 0.001, Effect Size 0.10). Both experimental groups had greater grip strength

improvement rates (ratio to uninjured side) than the control group at 12 weeks, but the

difference was not significant (MD 64.5 - 67.6%, P > 0.05). No adverse effects were

reported, and patients showed a high (≥ 96%) exercise compliance with only 2 drop-

outs.

Level III

Bayon-Calatayud et al.[21] conducted a small trial to compare the efficacy of mirror

therapy combined with conventional therapy (N=11, 72% females, mean age 61 years)

to conventional therapy alone (N=11, 63% females, mean age 55.36 years). Patients

with complex unstable DRF were excluded from this study. Both groups received

equivalent time of therapy via 15 supervised sessions (5 times weekly) over a 3-week period following non-operative and operative treatments. Conventional therapy was directed by an occupational therapist and consisted of physical agents for pain (TENS, Ultrasound, hot pack [HP]/cold pack [CP]), AROM and PROM exercises for the hand and wrist, and strengthening methods. The mirror therapy involved wrist and finger-grasping movements in front of a mirror. No significant group differences (P > 0.05) existed in Pain (VAS; MD 0), wrist extension AROM (MD 4), and self-reported function (Quick DASH; MD 5%) outcomes at 3 weeks following therapy initiation. Groups showed comparable post-fracture complications of 50% (n=11) of patients having sensory loss and hand paresthesia, and 13% (n=6) displaying CRPS-1 symptoms.

Level III

Wollstein et al. [317] conducted a RCT to compare occupational therapy combined with a home-based SM training program (N=29, 85% females, mean age 62.3 years) to only occupational therapy (N=31, 67.7% females, mean age 63.9 years) following operative treatment and 6 weeks immobilization. Occupational therapy (1 session/week over 6 weeks) consisted of edema control, hand and wrist AROM and functional strengthening. The SM home program (3 times/day for 15 minutes) consisted of sensory stimulation via massage or rubbing various textures around the wrist, active hand and wrist motions (eyes open or closed), mirror therapy, motor imagery, and wrist position replications with eyes closed. No significant group differences (P > 0.05) on function (DASH), hand sensation (Semmes-Weinstein Monofilaments, 2-point discrimination, vibration), dexterity (Moberg's pick-up test), wrist proprioception, and wrist AROM existed at 6 and

160

12 weeks. It should be noted that there were significant methodological limitations including a 56-65% loss to follow up rates.

Level IV

Two small prospective quasi-experimental trials by Imai et al. and Imai et al. [119], [118] investigated the efficacy of wrist vibration sensitization therapy to induce kinesthetic illusion of motion and improve pain (VAS), wrist AROM, and function (PRWE) following operative treatment for DRF. In both studies, vibratory stimulation was combined with standard physical therapy (N=24, 91% females, mean age 70.9 years) and compared to a control group of standard therapy only (N=24, 87.5% females, mean age 69.5 years). Both treatment groups initiated physical therapy immediately after surgery for seven consecutive days. Standard therapy consisted of various wrist AROM exercises and cold packs. Vibration therapy was applied via a battery-operated hand-held massager (70-80 Hz) over the distal dorsal forearm (six 30-sec cycles) prior to the start of each physical therapy session. At 7 days, significant (P < 0.05 – 0.001) differences were present in favor of the vibration therapy group in resting pain (MD 31 mm), pain with motion (MD 23 mm), wrist flexion (MD 10.8°), wrist extension (MD 22.4°), supination (MD 13.6°), pronation (MD 10.9°) AROMs, and PRWE (MD 25.5%). Significant differences remained at 4 weeks in resting pain (MD 13 mm), pain with motion (22 mm), wrist flexion (MD 10°), wrist extension (MD 10°), supination (MD 13.3°), pronation (MD 12°) AROMs, PRWE (MD 21.2%) as well as at 8 weeks in resting pain (MD 14 mm), pain with motion (MD 18 mm), wrist flexion (MD 12.8°), extension (MD 10°), supination

161

(MD 12.2°), pronation (MD 14°) AROM, and PRWE (MD 14.1%) in favor of the vibration therapy group. PRWE mean differences were also clinically meaningful.

Evidence Synthesis

A limited amount of information exists with only 6 studies investigating the efficacy of SM training interventions following non-operative or operative DRF management. All analyzed studies compared conventional therapy exercises to a single or multimodal types of SM training interventions when combined with conventional therapy. Three studies (2 Level I and 1 Level III) investigated SM training via either GMI with all its three intervention levels, or they focused on mirror therapy and motor imagery in isolation [21], [66]. Another study (Level III) investigated the efficacy of multimodal SM training that consists of sensory stimulation training (vibration, manual massage and texture re-sensitization), mirror therapy, motor imagery, and other proprioceptive exercises (wrist motion replications with eyes closed, or wrist AROM with eyes closed), and practicing functional activity with both the dominant and non-dominant sides while eyes are closed [317]. Two quasi-experimental studies (Level IV) investigated the efficacy of sensory stimulation via vibration as a way to improve proprioceptive sense of wrist kinesthesia [119], [118]. All of these SM training interventions were provided as either in-clinic supervised activity or part of an iHEP following non-operative or operative treatment. Based on limited evidence, combining GMI or other sensory sensitization or proprioceptive training methods with conventional therapy seems to be a superior approach than conventional therapy alone towards improving wrist and hand pain,

162

AROM, sensation (single-point touch, 2-point discrimination, stereognosis), proprioception (joint position sense), and self-reported anxiety and function. Integration of these SM training interventions in clinical practice should be cost-effective as they don't require expensive instrumentation and they do not present higher risks for adverse effects than conventional therapy. Yet, they may require increased application time and greater supervision or instruction by hand therapists with adequate experience and training. Various methodological weaknesses limited the evidence strength for some of the included studies [21,119, 118, 317]. These limitations consisted of excluding patients with complications; having under-powered sample-sizes; lacking randomization, concealment and blinding; having large loss to follow up; assessing only short-term outcomes; and under-reporting assessment and intervention details, and exercise compliance. No harms were reported from SM training.

Gaps in Knowledge

Stronger high-quality RCTs are needed to determine both the short- and long-term efficacy of the currently proposed SM training methods in isolation or combination with conventional therapy methods after non-operative or operative treatments for DRF. No studies to date have investigated the efficacy of various strengthening and perturbation exercises towards neuromuscular facilitation and instinctive muscle recruitment towards wrist joint proprioceptive stability following a DRF. Future studies need to have stronger methodological designs and maximize the inclusion of complicated DRF patients that would typically benefit from attending SupT.

163

Recommendations

A

Clinicians should integrate all three elements of GMI with conventional therapy to improve short-term outcomes in pain, AROM, and patient-reported function during the early rehabilitation stage (6-8 weeks) for patients following non-operative and operative DRF management.

D

Based on limited evidence a recommendation cannot be made regarding whether a multimodal SM training approach consisting of sensory stimulation techniques (e.g., vibration) and other proprioceptive exercises in conjunction with conventional therapy to improve short-term outcomes in pain, AROM, and function during the initial rehabilitation stage (6-8 weeks) following operative treatment for DRF.

Orthosis Management for Stiffness

Wrist orthosis utilization is a complementary element in the multimodal DRF rehabilitation process [101]. It may be a clinically useful intervention type for select subgroups of complicated patients with DRF who display lack of proper AROM progression using only conventional exercises. Two types of orthotic devices are available following DRF. Their primary aim is to improve physiological motion via inducing permanent viscoelastic elongation of shortened or contracted soft tissues

164

around the wrist joint. Static progressive orthoses are either commercially available or custom-made devices that can apply constant static long-duration stretch at the end-range of available wrist motions [176]. Dynamic orthoses are also commercially available or custom-made devices that can apply constant long-duration stretch at the end-range of wrist motion via spring-loading or elastic mechanisms while allowing intermittent movement [129]. The amount of force applied by static-progressive and dynamic orthoses is adjustable based on a patient's tolerance and is progressed overtime. The disadvantages of orthoses' utilization include their cost, lack of payer reimbursement, and time investment required for patients to apply these devices on a daily basis. Construction of custom-made orthoses require the skilled services of a specialized hand therapist.

Dynamic Orthosis

Level II

Jongs et al. [129] conducted a RCT to investigate whether a dynamic orthosis improves wrist AROM when used in conjunction with standard care. 40 subjects (mean age =62, female 70%) with wrist flexion contractures following operative and non-operative treatment of DRF and 3 weeks immobilization of were recruited. Both groups received routine SupT program for 8 weeks. The experimental group also received stretching via a custom-made dynamic thermoplastic orthosis which was used for 8 weeks (at least 6 hours a day). The splint provided constant low-load wrist extension stretch via an elastic band mechanism and biweekly tension adjustments were performed based on

165

tolerance. Wrist extension PROM, wrist AROM in all directions and function (PRWE and COPM) were assessed at 8 and 12 weeks. A statistically significant but not clinically meaningful group difference was present only for passive extension (MD: 6°, 95% CI: 1-12°) at 12 weeks. No significant or clinically meaningful group differences existed for all other outcomes.

Static Progressive Orthosis

Level V

Lucado et al. [176] retrospectively looked at the effects of static progressive orthosis (Joint Active Systems, Inc) on wrist and forearm AROM, grip strength, and function following operative treatment of DRF. 25 subjects (mean age =46, females 40%) with documented wrist stiffness after DRF and utilizing a static progressive orthosis were included. All participants received hand therapy (mean of 23 visits) in addition to wearing the orthosis 30 minutes daily, which was progressed to 3x30 minutes daily. Statistically significant ($P < 0.05$) pre- to post-treatment differences were seen in all outcomes. Wrist extension increased by 18.6°; flexion increased 11.4°; pronation increased 30°; supination increased 14.5°; grip strength increased 24.5 pounds; DASH improved 24%.

Evidence Synthesis

This section has synthesized clinical recommendation based on limited evidence from only 2 studies that investigated the efficacy of orthosis application following operative

and non-operative DRF treatments. Evidence supporting the addition of orthosis to a standard treatment regimen is limited. One Level II study showed no clinically meaningful improvements in AROM or function at 8 and 12 weeks after wearing a custom-made dynamic orthosis that provided low load stretch [129]. The patient compliance was low, loss to follow up was high (20%), and sample size was underpowered. A second Level V study looked at the effects of a static progressive orthosis, but the lack of control group makes conclusion impossible [176]. The scarcity of evidence poses challenges in formulating definitive recommendations for the utilization of static and dynamic orthoses following DRF. Therefore, guidance in this regard relies largely on expert opinion rather than conclusive empirical evidence.

Gaps in Knowledge

Stronger RCTs are needed to determine the short- and long-term efficacy of both static progressive and dynamic orthoses in improving wrist AROM and function following non-operative and operative DRF management. Future research should identify the preferred orthotic intervention for specific subgroups of DRF patients, particularly those with complications or a less favorable rehabilitation prognosis, while also considering cost-effectiveness. Knowledge gaps exist regarding patient-reported satisfaction and compliance, as well as the impact of orthoses on coordination, strength, and proprioception following DRF.

Recommendations

F

Clinicians may utilize orthoses in conjunction with standard care to improve wrist AROM primarily for certain subgroups of patients who present with difficulty reaching their functional goals due to persistent wrist stiffness after operative or non-operative DRF management.

Therapeutic Modalities

Various therapeutic modalities are available for clinicians to utilize during the DRF rehabilitation process following non-operative or operative treatment. Therapeutic modalities are considered complementary treatment components in a multimodal rehabilitation approach after DRF, encompassing several thermal, electrical, and mechanical modalities [101]. Thermal (i.e., heating and cooling), light-emitting, electrical, and mechanical agents that have been utilized in the rehabilitation of DRF include HP, CP, pulsed electromagnetic field (PEMF) also known as diathermy, cold laser therapy (LT), ultrasound, ultraviolet light therapy (UVLT), warm whirlpool (WWP), transcutaneous electrical nerve stimulation for pain (TENS), intermittent pneumatic compression (IPC), blood flow restriction (BFR), and continuous passive motion (CPM) [38], [188], [286], [287], [33], [326], [271], [256]. Thermal and electrical modalities are known for their biophysical effects on regulating the body's metabolism, influencing the inflammatory healing process, and modulating pain. [204], [191]. Mechanical intermittent compression

168

modalities are known for their usefulness in managing edema [7]. In recent years, BFR

therapy has also gained popularity as a mechanical agent with claimed benefits for

muscle strengthening during resistance training [265]. CPM units are typically electrically

powered devices that can passively apply gradual joint motion at preselected speeds

and ranges for various joints including the wrist. Their postoperative use is generally

directed toward improving joint AROM and pain [271].

Thermal agents (HP, CP, WWP, PEMF)

Level II

Cheing et al. [38] conducted a RCT to investigate the short-term efficacy of CP and PEMF

therapy following non-operative treatment for DRF. They compared 4 groups: Group A

(N=23, 56% females, mean age 65.5 years) had true PEMF and Ice packs, Group B

(N=22, 86% females, mean age 62 years) had sham PEMF and ice packs, Group C

(N=22, 63% females, mean age 63.8 years) had only PEMF, and Group D (N=16, 56%

females, mean age 60.3 years) had only sham PEMF. Conventional therapy combined

with iHEP started three days after 6 weeks cast immobilization for five consecutive days

for all groups. In each session, PEMF therapy was conducted via a U-shaped diathermy

applicator (frequency 50Hz) for 30 minutes around the wrist and hand. Cold packs were

placed over the dorsal forearm and wrist aspects. Post-treatment assessment at day-5

showed that Group A was significantly better on edema (Volumeter: MD range 0.6 -1.1

mm, P = 0.001) than all other groups. For pain at day-5, Group A was better (VAS: MD

range 4.8 – 18.1 mm, P=0.001) than groups C and D. For AROM at day-5, Group A was

169

superior in ulnar deviation (MD range 2.6 – 4.1°, P=0.002) than all other groups, and in pronation (MD range 2.1 – 8.9°, P=0.021) than Group D. All other remaining group comparisons were not significant.

Level III/IV

Krzyzanska et al. [154] and Lazovic et al. [163] conducted studies to investigate the benefit of utilizing PEMF therapy during immobilization following non-operative treatment. The Krzyzanska et al. [154] was a quasi-experimental study (Level IV) which assessed pain, sensation, wrist AROM, grip strength, and function after a 6-week cast immobilization. The experimental group (N=27, 81% females, mean age 58 years) received 22 PEMF therapy sessions addressing the casted arm within a diathermy concentric coil applicator (peak intensity 6-10mT frequency 25-30Hz) for 30 minutes. Patients were treated daily for the first 10 days, and 3 times weekly thereafter. The control group (N=25, 92% females, mean age 63.6 years) did not receive PEMF therapy. The Lazovic et al. [163] study, was a prospective RCT (Level III) which assessed hand edema (figure-of-eight), pain and function (PRWE), and wrist AROM (Flexion-extension, pronation-supination, radial-ulnar deviation) among older (≥ 60 years) women after 4 weeks cast immobilization. The experimental group (N=30, mean age 67.9 years) received 10 sessions of PEMF therapy within a concentric coil (peak intensity 6mT, frequency 25Hz,) for 30 minutes (5 days weekly for 2 weeks), and the control group (N=30, mean age 64.5 years) did not have PEMF therapy. In both studies, all groups followed an iHEP, which consisted of finger, elbow, and shoulder AROM exercises 2-3 times daily.

Upon cast removal, Krzyzanska (2020) et al. [154] found the PEMF group to be significantly better in pain (VAS: MD 2.68 mm, P< 0.0001), sensibility (Monofilaments test MD 0.6 grams, P=0.001; and 2-point discrimination test: MD 0.6 mm, P=0.001), Flexion (MD 10°, P=0.0003) and extension (MD 11°, P=0.0001) AROMs, grip strength (MD 2.3 kg, P=0.001), and function (DASH: MD 30.1%, P=0.0001). Lazovic et al. [163] found significant differences for hand edema (MD 8mm, P=0.001), and wrist flexion, extension, and supination (MDs 8-10°, P=0.01) AROMs in favor of the PEMF group. In this study, no group-differences existed for pain, and function, and a 13% complication rate (hand stiffness and signs of CRPS-1) was reported. Patients in both studies attained full fracture healing with no need to have surgery or extended immobilization time and no adverse effects to PEMF treatments.

Level II

Szekeres et al. and Szekeres et al. [286], [287] conducted two similar trials to investigate the immediate effects of hot pack (HP) and warm whirlpool (WWP) applications on edema and wrist AROM following non-operative or operative treatments for DRF. In both studies, therapy started immediately after cast immobilization (average of 40 days) and patients completed three SupT visits. Each visit started with a 15-minutes treatment of either a HP around the wrist or WWP (40° C) followed by 30-minutes of conventional therapy exercises. The WWP treatment entailed wrist AROM exercises in a semi-dependent position with elbow flexed at 90°. Outcomes were assessed via experienced blinded hand therapists in both studies. In the first study [286], [287] edema was assessed

via a volumeter before and immediately after heat applications as well as 30 minutes after the end of each session, and 3 weeks later. The WWP group (N=30, 86% females, mean age 52.7 years) was found to be superior in edema reduction to the HP group (N=31, 74% females, mean age 54.4 years) immediately after heat applications (P < 0.001, MD 4.9 ml). The WWP treatment presented a tendency for slightly higher edema accumulation at the end of each therapy session or 3 weeks later, but differences were not significant. The second study [286], [287] assessed wrist AROM (flexion/extension, pronation/supination, ulnar/radial deviation) before and after heat applications in each session as well as 3 weeks later. The WWP group (N=30, 86% females, mean age 52.7 years) was found significantly (P < 0.05) better than the HP group (N=30, 76% females, mean age 54.4 years) immediately after heating for wrist extension (MD 2°) and flexion (MD 2.2°). These AROM differences were not clinically meaningful. No AROM differences existed at 3 weeks.

Light-Emitting Agents (LT, UVLT)

Level II

Acosta-Olivo et al. [3] and Sæbø et al. [256] conducted two similar double-blinded RCTs to compare cold LT combined with an iHEP to sham LT with the same iHEP following non-operative and operative treatments for DRF. In the Acosta-Olivo et al.[3] RCT, the LT (N=13, 62% females, mean age 53.2 years) and the sham LT (N=13, 69% females, mean age 59.2 years) groups were recruited after closed reduction/pinning and 6 weeks cast immobilization for DRF. Therapy was initiated within 7 days following cast removal

172

and entailed 10 sessions over 3 weeks. LT (50mW, 980nm,) was applied over 10 acupuncture points at the upper and lower extremity of the involved side. The iHEP (3 times daily) consisted of hand and wrist AROM exercises and advice on self-care with daily activities. In the Sæbø et al. [256] RCT, therapy for the LT (N=23, 82% females, mean age 59 years) and the sham LT (N=27, 88% females, mean age 57 years) groups started immediately following 4-weeks cast immobilization. LT entailed pulsed mode wavelength (60 mW, GaAs, Class 3B) delivered to both dorsal and volar aspects of the wrist with a 64 J total treatment energy over 9 sessions over 3 weeks. The iHEP (5-6 times daily) consisted of hand and wrist AROM exercises and advice on pain management and self-care with daily activities. In the Acosta-Olivo et al. [3] RCT, Pain (VAS), wrist AROM, and function (PRWE) were assessed at the 5th and 10th session, and 1 week after. Significant differences in favor of the LT group existed at the 5th session for pain (MD 1.9mm, P=0.05), wrist AROM [extension (MD 13°, P=0.02), ulnar deviation (MD 6.9°, P=0.01), radial deviation (MD 6.8°, P=0.02)], and PRWE (MD 19.1%, P=0.010). The LT group was significantly better at the final assessment time in pain (MD 1.5 mm, P = 0.02), AROM [flexion (MD 21°, P=0.01), pronation (MD 8.4°, P=0.005), radial deviation (MD 7.7°, P= 0.02)], and PRWE (MD 15%, P=0.04). In the Sæbø et al. [256] RCT, the PRWE pain and disability subscales, and total scores were assessed at 8, 12, and 26 weeks. Statistically significant (P < 0.05) group differences in favor of the LT group existed in pain (MD range 3.38 - 3.38%) subscore throughout all times, and disability (MD range 10.57 - 11.97%) subscore at 8 and 12 weeks. The LT group was significantly (P < 0.05) better in total PRWE (MD range 5.86 - 11.71%) score

173

throughout all times with a clinically meaningful difference at 12 weeks. In both RCTs, groups were equivalent in fracture severity characteristics and baseline measurements, and no adverse effects were reported.

Level II

Sæbø H et al.[256], conducted a double-blinded RCT to compare cold LT (N=27, 70.4% females, mean age 52.4 years) to sham LT (N=26, 76.9% females, mean age 51 years) that were applied during a 4-week cast immobilization among patients with DRF following a non-operative treatment. LT (60 mW, 904 nm GaAs, Class 3B) was initiated within 3 days following injury and entailed 9 sessions over 3 weeks with a 64 J total treatment energy. Treatments were applied through two cast openings over the dorsal and volar aspects of the distal radius. Both groups followed the same iHEP and advice for self-care and avoidance to perform heavy daily activities up to 8 weeks after cast removal. Function (PRWE total score), total wrist AROM (flexion, extension, ulnar and radial deviation, pronation, supination), grip strength, and wrist circumference for edema were assessed at 4 (cast removal), 8, 12, and 26 weeks. Groups had equivalent baselines across all outcomes. No significant differences existed for function and edema across all times. The LT group was significantly better in AROM (MD 43°, P=0.000) and grip strength (MD 6.89 kg, P=0.011) only at 4 weeks. Groups were equivalent in fracture severity characteristics and baseline measurements, and no adverse effects reported.

Level III

Ahmed et al.[5] conducted a small prospective non-blinded RCT to compare a group that received LT (N=20, 75% females, mean age 30.8 years) to a group that received therapeutic ultrasound (N=20, 75% females, mean age 29.6 years) following non-operative treatment for DRF. Both the LT (830 nm, average power 60mW, total dose 9.7 J/cm, 10 minutes) and thermal ultrasound (1.5 w/cm intensity, 3 Mhz, continuous mode, 5 minutes) groups received 16 treatment sessions for 6 weeks immediately after cast immobilization. Information on treatment application sites or whether other traditional exercises were also utilized was not provided. At 6 weeks, the LT group was superior in the PRWE pain (MD 6.4%, P=0.0001), and function (MD 5.73%, P=0.001) subscales. Groups were not significantly (P > 0.05) different on AROM and grip strength, which were assessed via instruments with unknown psychometric properties. Baseline equivalency for all measured outcomes was also not established.

Level III

Zlatkovic-Svenda et al. [326] conducted a prospective non-blinded RCT to compare a group that received NSAIDs pain management, cold packs, and traditional exercises (N=26, mean age 64 years) to a group that received the same protocol along with UVLT (N=26, mean age 62 years) among female patients following non-operative treatment for DRF. Daily therapy was initiated immediately following cast removal. The UVLT was provided via a Bioptron device (95% polarized, low-energy radiation at 480-3400 nm, total energy 360 j/cm^2) on 5 points of the dorsal wrist for 10 minutes/day. Cold packs

175

were applied around the wrist for 5 minutes twice daily. Hand and wrist AROM exercises, and grip exercises with a soft rubber ball were performed for 30 minutes daily. All treatments were provided by a visiting hand therapist at home. Following 15 treatments, the UVLT group was superior in pain (VAS: MD 5.4 cm, P=0.046), and supination AROM (MD 8.8°, P=0.001). At 6-months, a significantly (P< 0.05) lower incidence of CRPS-1 was noted in the UVLT group (0%) as compared to the control group (15%).

Electrotherapy Agents (TENS)

Level II

Lee et al. [164] conducted a small single-blinded prospective RCT to compare the effectiveness of TENS (N=18) and sham TENS (N=18) on pain control among patients with DRF (mean age 55.5 years) who underwent operative management. Demographic information on patients' gender was not provided. Treatment was initiated immediately after surgery in the recovery room. Two electrodes were placed over the Waiguan (TE5) and Quchi (Li11) acupuncture points over the lateral elbow and dorsal wrist, and transmitted conventional sensory (50Hz frequency) TENS once daily for 15 minutes for five consecutive days during hospitalization. The intensity was not turned on for sham TENS treatment. Pain (VAS) outcomes were assessed before and after each treatment. Baseline pain levels were equivalent in both groups. No significant difference in pain (VAS) improvement existed after 5 days. A significant difference (P = 0.002) in post-

treatment pain reduction was noted in after each treatment, indicating only a transient

pain reduction effect. Mean differences were not reported.

Mechanical Agents (CPM, IPC, BFR)

Level I

Shirzadi et al. [271] performed a single-blinded RCT to compare the effect of CPM unit

combined with conventional therapy (N=11, 100 females, mean age 42 years) to

conventional therapy alone (N=10, 81% females, mean age 41 years) following

operative management with 4-6 weeks of immobilization. The majority (72%) of patients

in either group had an external fixator. Both groups received multimodal routine SupT (3

sessions/week over 4 weeks) that consisted of thermal agents, electrical stimulation for

pain, PROM and AROM, and strengthening exercises. In addition, the experimental

group received CPM (2 x 15 minutes per session, 12 sessions) in the clinic for wrist

flexion, extension, supination and pronation and forearm. CPM intensity was adjusted to

patient tolerance using a 5°/minute PROM speed, and 5 sec end-range hold times. Both

groups had significant (P=0.00) improvements in pain (VAS), wrist AROM, and function

(PRWE) at 4, 6, and 12 weeks. A significant (MD 1.29cm, P=0.01) but not clinically

meaningful difference in pain favored the CPM group at 4 weeks. No significant group-

differences existed for all other outcomes across all assessment times.

Level I

Yamazaki et al. [318] conducted a high-quality RCT to compare the efficacy of an IPC (venous perfusion assist) unit (N=50, 76% females, mean age 64 years) to hand elevation (N=52, 81% females, mean age 64 years) on hand edema, pain, AROM, grip strength, and function following operative management. After surgery, the IPC group wore the air-filled compression garment around the affected hand and forearm continuously for 1 day and thereafter 60 minutes daily (3 times for 20 minutes) for 3 weeks. The elevation group wore a sling which kept the affected hand elevated above heart-level for 3 weeks. During this time, both groups were given the same iHEP with AROM exercises and advise for light home-activity while wearing a removable orthosis. Both groups attended SupT between 6 and 12 weeks postoperatively for manual therapy and strengthening. No group differences existed for all outcome measures (edema [fingers and hand girth], pain [VAS], wrist AROM [flexion-extension, supination-pronation] grip strength, and function [DASH, PRWE]) immediately after surgery, and at 1, 3, 6, 12 weeks postoperatively.

Level III

Alkner et al. [7] conducted a RCT to investigate the efficacy of a multimodal edema control program with (N=56, 85% females, mean age 63 years) or without (N=59, 94% females, mean age 63 years) the addition of IPC treatment among older (≥ 50 years) patients following operative management and 4 weeks immobilization for DRF. Both groups were instructed by an OT in an iHEP (4 times daily over 7 weeks) which

178

consisted of hand elevation, hand massage, edema glove, and digital and wrist AROM exercises. The experimental group received IPC supervised treatment (1 hour, 3 times weekly for 7 weeks) via an air-filled bladder unit (AV 6000 Novamedix), applied around the involved wrist with intermittent pressure (60 mmHg, 40 sec on/20 sec off intervals). No significant group differences were found for all outcome measures (pain [VAS], AROM, grip strength, edema [volumetry], and function [COPM]) at baseline, 4, 6, 11 weeks, and one year following surgery.

Level III

Mader et al. [189] conducted a RCT to compare a group that received cold packs, and traditional therapy (N=21, 76% females, mean age 63 years) to a group that received IPC with traditional therapy (N=22, 72% females, mean age 66 years) following operative management via external fixation (74%) or other internal fixation (26%) methods. Both groups were treated for seven days immediately after surgery. Cold packs were applied over the wrist in supine for 20 minutes (10 times/day over 7 days). IPC treatment involved high-velocity impulses (130 mmHg, 2 sec long, 3 times per minute) via the air-filled bladder strapped around the involved hand for one hour (5 times daily over 7 days). In addition, both groups followed the same post-operative exercise (digital joint mobilization and AROM) programs. Hand girth and finger 2-5 total active motion (TAM) were assessed daily for seven consecutive days. By the seventh day, significant group differences existed in favor of the IPC group on edema (MD 3 cm,

179

P=0.01) and digital TAM (P=0.001), which was assessed via a computerized (EVAL software) program of unknown validity and group mean differences were not reported.

Level III

Two small RCTs by Cancio et al. and Sgromolo et al. [33], [265] with similar methodology compared BFR combined with conventional therapy to only conventional therapy during early rehabilitation following non-operative treatment for DRF. Both groups started conventional therapy (2-3 times/week over 8 weeks) following 6-week cast immobilization. The experimental group received BFR at the bicep area during exercise (30 minutes at 50% occlusion rate) in each visit. The Cancio et al.[33] study's BFR group (N=6, 58% females, mean age 51.3 years) and control (N=7, 50% females, mean age 41years) groups were similar in patient-characteristics to the Sgromolo et al. [265] study BFR (N=5, 40% females, mean age 37 years) and control (N=4, 25% females, mean age 43.8 years) groups. No group-differences existed at 4- and 8-week intervals across all outcomes [Pain (VAS), function (PRWE, DASH), wrist AROM, grip strength, and radiographic parameters] in both studies. Based on total change between baseline and 8 weeks, BFR groups were superior on pain with activity (MD 1.5 – 1.7 cm, P= 0.03) and PRWE (MD 17.6 – 27.1%, P=0.01) scores. However, pain (MD 1.4-1.7) and PRWE (MD 19-25%) baseline differences favored the BFR group and confounded the final interpretations in both studies. No radiological or treatment complications were reported in either study.

Level III

Fan et al. [77] conducted a RCT to compare BFR combined with conventional therapy (N=17, 58% females, mean age 44 years) to only conventional therapy (N=18, 44% females, mean age 47 years) following operative treatment for DRF. Both groups started therapy 3-7 days after surgery. Conventional therapy followed a multimodal approach with ice packs, compression therapy, ultrasound, electrical stimulation, PROM and AROM, and submaximal (20% MVC) strengthening exercises for 4 weeks. BFR treatments (5 times/week over 4 weeks) were applied at the bicep area with 40-80% occlusion pressures in 20 minutes sessions during strengthening exercises. Significant differences were shown at 4 weeks for Pain (VAS: MD 1.22 mm, P= 0.01) and isometric wrist strength rate (strength proportion relative to healthy side) was measured via a hand-held dynamometer for flexion (MD 18%, P=0.01) and extension (MD 20%, P=0.01) in favor of the BFR group. At 12 weeks, significant difference in favor of the BFR group existed for function (MD 14%, P=0.01) using the modified Cooney score system, which is a non-validated outcome measure for DRF rehabilitation. No group differences in fracture healing were shown at 4 weeks, and no adverse effects attributable to BFR treatments were reported.

Level III

Yang et al [319] conducted a RCT to compare BFR combined with conventional therapy (N=13, 84% females, mean age 64 years) to only conventional therapy (N=12, 83% females, mean age 64 years) among older (≥ 50 years) patients following non-operative

181

treatment for DRF. Both groups started therapy following a 6-week cast immobilization period. Conventional therapy included wrist PROM and AROM as well as submaximal grip and pinch strengthening exercises twice a week for 6 weeks. BFR treatments (2 times/week over 6 weeks) were applied at the bicep area with 50% occlusion pressures in 8 minutes sessions. Significant differences were shown at 6 weeks for wrist AROM in ulnar deviation [P=0.010, ES (η^2) = 0.25], grip strength [P=0.029, ES (η^2) = 0.19] and function [P=0.002, ES (η^2) = 0.34] in favor of the BFR group but group mean differences were reported. No group differences in fracture radiographic parameters existed at 6 weeks, and no adverse effects attributable to BFR treatments were reported.

Evidence Synthesis

Despite the known biophysical effects of several types of modalities, research evidence on the efficacy of therapeutic modalities following DRF is still limited. This section synthesized clinical recommendations based on 18 available RCTs that have investigated the efficacy of thermal, light-emitting, electrical, and mechanical therapeutic agents in isolation or combined with conventional therapy following non-operative and operative DRF treatments. Among the 5 RCTs on thermal modalities (3 Level II, 1 Level III, 1 Level IV), two trials [286], [287] offered sufficient evidence (Level II) to support the superiority of WWP over HP for improving edema and AROM immediately after application when used along with conventional therapy following non-operative and operative treatments for DRF. The application of WWP did not add greater risk of edema increase by the end of a treatment as compared to HP. One study (Cheing, Wan

182

et al. 2005) offered sufficient evidence (Level II) to support the short-term benefit of PEMF in conjunction with conventional therapy during the first week of rehabilitation on pain, edema, and wrist AROM following non-operative treatment. In this study, the combination of PEMF and CP was superior to using CP or PEMF in isolation. Two lower evidence (Level III-IV) studies [163], [154] found to benefit from applying PEMF treatment during cast immobilization for short-term pain, sensibility, AROM, and functional benefits upon cast removal at 4 weeks. Among the 5 trials on light-emitting agents, 3 studies [3], [255], [256] offered sufficient evidence (Level II) to support a beneficial short-term (3-12 weeks) effect of LT on pain, AROM, grip strength, and function following both non-operative and operative treatment for DRF. One study [326] (Level III) offered weak evidence for the use of UVLT with conventional therapy towards short-term (2 weeks) benefits on wrist pain and AROM after non-operative treatment for DRF. This single study could not support a recommendation on UVLT. The presence of only one study [5] (Level III) on the short-term effects of therapeutic ultrasound as compared to LT could not support any recommendation on ultrasound. There was only one trial [164] (Level II) on electrotherapy (TENS) treatment which indicated that a 15-minute TENS treatment may result in transient postoperative pain reduction. Yet, this could not be maintained for 24 hours, and it was not significantly different than pain reduction induced by a placebo effect. Evidence from this study was insufficient to support a recommendation for TENS application.

Six RCTs on mechanical modalities were of low evidence (Level III). Two of them [189] [7] offered conflicting evidence on the efficacy of IPC therapy. One [189] pointed to IPC short-

183

term (7 days) benefit on postoperative pain, hand AROM, and edema control, while the other [7] found that a multimodal approach of arm elevation, hand massage, AROM, and use of edema glove offers comparable benefits to IPC therapy for short- and long-term (up to 1 years) post-operative improvements on edema, pain, AROM, grip strength, and function. One Level I study [318] indicated that the use of IPC therapy does not offer any additional short-term (up to 12 weeks) benefits on edema, pain, active wrist AROM, grip strength, and function, as compared to only hand elevation when combined with conventional therapy following operative management. The four studies on BFR therapy [3], [265], [77], [319] also offered conflicting evidence. Two of these studies [3], [265] failed to justify that BFR combined with conventional therapy was superior to conventional therapy alone towards short-term (4-8 weeks) benefits in pain, grip strength, wrist AROM, and function following non-operative treatment. Yet, two other studies [77], [319] pointed to the short-term (4-12 weeks) superiority of BFR treatments (2-5 times weekly), which when combined with a multimodal conventional therapy may induce significant pain, wrist AROM, grip and isometric wrist strength, and functional benefits following both non-operative and operative treatments for DRF. All four studies indicated that BFR treatments can be safely applied following DRF without adverse effects. One Level I study [271] refuted the clinical usefulness of CPM to improve wrist pain, AROM, and function 4-12 weeks following operative treatment as compared to conventional therapy. Recommendation for CPM could not be supported based on evidence from only one study. The preponderance of therapeutic modalities studies were affected by various methodological limitations that consisted of small or under-powered samples, significant

184

sampling bias due to lack of concealment or assessor blinding, investigating short-term outcomes among mostly patients with no complications or significant comorbidities, and not always assessing function. A distinct trend in patient characteristics existed in the BFR trials. Three BFR studies [3], [265], [77] recruited younger patients, with near equal male-to-female ratios as compared to most other studies that recruited on average older female patients after a DRF injury. Clinicians should consider both the potential benefits and harms of all these modalities. Although no adverse effects were reported, the projected high cost, clinical application time-demands, safety issues, and lack of reimbursement may be viable concerns for some of these therapeutic agents.

Gaps in Knowledge

More studies with stronger methodological designs are needed to investigate the current or other available thermal and electrical therapeutic agents that are used in hand therapy but have yet to be researched following DRF (e.g., fluidotherapy, electrical stimulation for strengthening). Future higher quality RCTs should investigate both the short- and long-term cost-effectiveness of such therapeutic agents in isolation or combination with conventional therapy amongst patients with various complications and comorbidities following non-operative and operative treatments for DRF. Further research is needed to determine if there are benefits of adding modalities to a multimodal program when subgroups of patients with specific impairments are studied.

Recommendations

B

Clinicians should utilize physical agents including LT, PEMF, WWP, HP, CP in conjunction with conventional therapy to improve short-term outcomes in pain, edema, sensation, wrist AROM, grip strength, and function in patients following non-operative and operative DRF management.

D

Based on conflicting or limited evidence a recommendation cannot be made regarding whether mechanical agents including CPM, IPC, and BFR are more beneficial than conventional therapy alone to improve wrist pain, edema, wrist AROM, grip strength, and function in patients following non-operative and operative DRF mangement.

Interventions Conclusion

In the last 20-plus years, a sizable body of literature has been published to offer evidence for the efficacy of numerous rehabilitation methods following DRFs. Several debated questions and proposed rehabilitation approaches or modalities of varying evidence levels have been investigated and reported. All the intervention recommendations in this CPG have been formulated based on the existing pool of evidence since the late 1990's. Frequent methodological weaknesses that have affected the evidence quality of many included studies consisted of limited enrolment of patients

186

with complications after DRF, underpowered samples, inadequate randomization and concealment, lack of blinding, large loss to follow up, heterogeneity on treatment parameters or therapy providers, lack of baseline equivalency, and use of short-term or not validated outcome measures. Outcomes heterogeneity might have been largely influenced by patient selection criteria variability (e.g., age, fracture severity, treatment approach, and patient comorbidities) across all studies. Lack of controlling this wide-range of contextual factors as well as limited trials availability for several interventions has made the formulation of evidence-based recommendations challenging.

Based on currently evolving evidence, a multimodal rehabilitation approach (i.e., modalities for pain and edema control; AROM exercises at the hand, wrist, and other proximal joints; joint mobilization; strengthening and proprioceptive exercises; functional retraining; advice for self-care and daily activity; and iHEP instructions) may offer the strongest merit towards optimal recovery following DRF. Regardless of fracture-treatment type, an accelerated rehabilitation approach (i.e., shorter immobilization time, immediate implementation of hand AROM and edema control techniques, and wrist AROM initiation within the first 2-3 weeks after surgery) may lead to better outcomes. For the more stable fracture types, the initiation of submaximal hand grip strengthening exercises could be safely implemented around 2-3 weeks post-surgery or even during cast immobilization. Currently, there are no clearly defined guidelines on which subgroups of patients would mostly benefit from one or more of the outlined rehabilitation interventions. More research is needed to determine the efficacy and delineate the benefit-to-harm ratio for all the included rehabilitation interventions.

187

Although conflicting evidence exists on which patients would be best candidates for SupT, the utilization of SupT in a weekly basis should be the preferred approach among older patients or those with significant complications and comorbidities following DRF. Further research is warranted to determine which subgroups of patients would most benefit from only an iHEP or no-therapy approaches, considering the rising cost of health care. Based on best-practice standards, the provision of SupT and iHEP instructions should preferably be directed by a hand therapist for optimum clinical outcomes within the confines of a multidisciplinary team approach.

Decision Tree

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┌─────────────────────────────────────────────────────────────────────┐
│  Component 1. Initial Orthopedic Management - achieving satisfactory  │
│                    alignment and bony union                           │
└─────────────────────────────────────────────────────────────────────┘
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┌────────────────────────────┐      ┌────────────────────────────────────┐
│ Closed reduction with 4-6   │      │ Surgical repair (e.g., percutaneous │
│ weeks cast immobilization   │      │ pinning, external fixator, internal  │
│                             │      │ fixation usually with volar locking  │
│                             │      │ plate)                               │
└────────────────────────────┘      └────────────────────────────────────┘
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┌─────────────────────────────────────────────────────────────┐
│ Early protective mobilization phase - the wrist is immobilized,│
│ self-ROM or fingers, elbows, and shoulders is initiated        │
└─────────────────────────────────────────────────────────────┘
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┌─────────────────────────────────────────────────────────────────────┐
│  Component 2. Outcome measures to assess the level of wrist pain,     │
│  disability, physical impairments to address with treatment, and      │
│                    response to treatment                              │
└─────────────────────────────────────────────────────────────────────┘
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Patient-reported measures

Grade A
- Pain
- PRWE
- DASH/QuickDASH
- MHQ
- NPRS

Performance-based impairments measures

Grade A
- Wrist/forearm/hand ROM
- Grip strength

Grade C
- JTHFT
- Pinch strength
- JPS

```
┌─────────────────────────────────────────────────────────────────────┐
│  Component 3. Prognosis for poor wrist/hand pain and wrist function   │
│                            outcomes                                   │
└─────────────────────────────────────────────────────────────────────┘
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Predictors for Wrist/Hand Function

Grade C
- Age
- High baseline pain/disability
- Psychological health (particularly depression)
- Third-party compensation

Predictors for Chronic Pain/CRPS

Grade C
- Female sex
- High baseline pain
- Psychological health (particularly depression)

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┌─────────────────────────────────────────────────────────────────────┐
│              Component 3. Interventions strategies                    │
└─────────────────────────────────────────────────────────────────────┘
```

No therapy

Grade D
- Younger patients without complications following operative and non-operative management

Instructions for iHEP only

Grade A
- Clinicians (PT or OT) should be the primary instructors of iHEP

Grade D
- Younger patients without complications following operative and non-operative management

SupT ≥ 1 weekly session with an iHEP

Grade B
- Older patients (≥ 60 years)
- Those with complications and comorbidities following operative and non-operative management

Grade A
- Following operative management, initiate SupT and iHEP within the first 3 weeks after surgery

Grade A
- Clinicians (PT or OT) should be the primary instructors of iHEP

Symptom modulation

Grade A
- All 3 GMI elements

Grade B
- MWM
- Joint mobilizations or oscillations before tissue resistance
- Physical agents: LT, PEMF, WWP, HP, CP
- TENS postoperatively

Grade D
- Multimodal SM training (using textures, vibration, or proprioceptive exercises)

Mobility

Grade A
- Wrist ROM postoperatively
- Early initiation of proximal joints, wrist, hand ROM in 3 weeks of surgery
- All 3 GMI elements

Grade B
- MWM
- Joint mobilizations or oscillations into tissue resistance
- AROM in WWP

Grade D
- CPM for PROM

Grade F
- Static/dynamic orthoses

Return to function

Grade B
- Gradual submaximal strengthening (towel or putty, isometric squeezing, light load gripper) starting in 2 weeks of surgery or during immobilization
- Properly timed exercises of ROM, tendon gliding, motor control, functional and progressive bilateral resistive exercises that include the scapula

Grade D
- BFR use for strengthening

Swelling Control

Grade C
- MLD or other manual edema mobilization
- Combination of techniques (exercises, elevation, compression gloves, low-stretch bandaging)

Grade D
- Intermittent Pneumatic compression units

190

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191

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