THE EFFECTIVENESS OF EXERCISE FOR THE MANAGEMENT OF MUSCULOSKELETAL DISORDERS AND INJURIES OF THE ELBOW, FOREARM, WRIST, AND HAND: A SYSTEMATIC REVIEW BY THE ONTARIO PROTOCOL FOR TRAFFIC INJURY MANAGEMENT (OPTIMA) COLLABORATION

Roger Menta, DC, Kristi Randhawa, MPH, Pierre Côté, DC, PhD, Jessica J. Wong, DC, Hainan Yu, MBBS, MSc, Deborah Sutton, MEd, MSc, Sharanya Varatharajan, MSc, Danielle Southerst, DC, Kevin D’Angelo, DC, Jocelyn Cox, DC, Courtney Brown, MSc, DC, Sarah Dion, DC, Silvano Mior, DC, PhD, Maja Stupar, DC, PhD, Heather M. Shearer, DC, MSc, Gail M. Lindsay, RN, PhD, Craig Jacobs, DC, MSc, and Anne Taylor-Vaisey, MLS

ABSTRACT

Objective: The purpose of this systematic review was to evaluate the effectiveness of exercise compared to other interventions, placebo/sham intervention, or no intervention in improving self-rated recovery, functional recovery, clinical, and/or administrative outcomes in individuals with musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand.

Methods: We searched MEDLINE, EMBASE, CINAHL, PsycINFO, and the Cochrane Central Register of Controlled Trials from 1990 to 2015. Paired reviewers independently screened studies for relevance and assessed the risk of bias using the Scottish Intercollegiate Guidelines Network criteria. We synthesized the evidence using the best evidence synthesis methodology.

Results: We identified 5 studies with a low risk of bias. Our review suggests that, for patients with persistent lateral epicondylitis, (1) adding concentric or eccentric strengthening exercises to home stretching exercises provides no additional benefits; (2) a home program of either eccentric or concentric strengthening exercises provides no additional benefits; (3) a home program of either eccentric or concentric strengthening exercises leads to similar outcomes; and (4) a home program of either eccentric or concentric strengthening exercises leads to similar outcomes.
Musculoskeletal disorders and injuries of the upper limb are associated with significant disability in the population. In 2013, arm, wrist, and hand injuries accounted for 12.1% of lost time claims in Canadian workers. Musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand may occur in their supporting and related muscles, ligaments, and capsules. Injuries resulting in neuropathy may involve peripheral entrapment of the median, ulnar, or radial nerve near the elbow or wrist.

The most common conditions affecting the elbow, forearm, wrist, and hand include lateral epicondylitis, medial epicondylitis, and carpal tunnel syndrome. In the general population, the point prevalence of lateral epicondylitis varies from 1% to 3%. Lateral epicondylitis affects as many as 15% of workers who perform tasks involving repetitive hand movements. Medial epicondylitis is less common than lateral epicondylitis and accounts for 10% to 20% of all epicondylitis diagnoses. In the United States, medical care and lost work time associated with epicondylitis are estimated to cost more than US $22 billion annually. Carpal tunnel syndrome is also more common in the general population with a point prevalence ranging from 2.7% to 7.8%. Furthermore, carpal tunnel syndrome is one of the most costly work-related upper extremity disorders, accounting for direct and indirect costs in excess of US $2 billion per year in the United States.

Patient care is dependent on a clinician’s training, beliefs, preferences, and understanding of the evidence. Clinicians often choose to combine various interventions when managing patients; this is also known as multimodal care. Exercise is frequently incorporated into multimodal programs of care; however, it is important to understand if exercise, in isolation, is effective in managing musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand, in addition to determining what types of exercises are effective for these conditions. This will inform which exercise offers benefits to patients when given alone and whether it likely contributes to the effectiveness of multimodal programs of care.

Previous systematic reviews have examined the effectiveness of exercise for the management of lateral epicondylitis and carpal tunnel syndrome. One systematic review found that an eccentric exercise program was effective for the management of lateral epicondylitis. Furthermore, 2 other systematic reviews supported the use of stretching and strengthening for lateral epicondylitis. The last review on lateral epicondylitis found inconclusive evidence to support the use of exercise. In 2007, Piazzini et al suggested that exercise therapy was not effective for carpal tunnel syndrome. However, Page et al in 2012 suggested that neurodynamic mobilization (stretching/nerve flossing exercises) may be beneficial for the management of pain in those with carpal tunnel syndrome. The conclusions of these reviews may have been influenced by methodological limitations. Specifically, all reviews synthesized evidence from all eligible studies regardless of their scientific quality. Second, all reviews included studies with small sample sizes. Studies with small sample sizes may be underpowered and unable to detect differences between groups. Furthermore, small samples increase the likelihood that randomization will fail to equalize baseline characteristics across the intervention arms. Therefore, a systematic review of adequate methodological quality is needed to evaluate the effectiveness of exercise for musculoskeletal disorders and injuries of the elbow, wrist, and hand.

The purpose of this systematic review is to investigate the effectiveness of exercise compared to other interventions, placebo/sham interventions, or no intervention in improving self-rated recovery, functional recovery, or clinical outcomes in adults and children with musculoskeletal disorders and injuries of the elbow, forearm, wrist, or hand regions.

METHODS

Registration

This review protocol was registered with the International Prospective Register of Systematic Reviews on March 12, 2014 (CRD42014008911).

Eligibility Criteria

Population. Our review targeted studies of adults or children with musculoskeletal disorders and injuries of the elbow, forearm, wrist, or hand region. Based on the
infections, malignancies, and systemic diseases.

fractures, complete ruptures, dislocations, osteoarthritis, include but are not limited to grade III sprains/strains, excluded studies of patients with severe injuries, which
time on benefits), and (5) adverse events.

quality of life, or depression), (4) administrative data (eg, school), (3) clinical outcomes (eg, pain, health-related
recovery (eg, disability, return to activities, work, or
following outcomes: (1) self-rated recovery, (2) functional
Exercise for Forearm and Hand Injuries

Centers for Disease Control and Prevention, we defined
musculoskeletal disorders and injuries as injuries or
disorders of the muscles, nerves, tendons, joints, cartilages,
fractures, complete ruptures, dislocations, osteoarthritis,
and supporting structures of the elbow, forearm, wrist, and
hand.17 Musculoskeletal disorders and injuries include but
are not limited to grade I and II sprain/strains, nonspecific
pain, olecranon bursitis, lateral epicondylitis, medial
epicondylitis, cubital tunnel syndrome, carpal tunnel
syndrome, de Quervain tenosynovitis, and other musculo-
skeletal injuries of the elbow, forearm, wrist, or hand region
as informed by available evidence (Tables 1 and 2). We
excluded studies of patients with severe injuries, which
include but are not limited to grade III sprains/strains,
fractures, complete ruptures, dislocations, osteoarthritis,
infections, malignancies, and systemic diseases.

Interventions. We restricted our review to studies that tested
the effectiveness of exercise. We defined exercise as
planned, structured, and repetitive bodily movements
done to improve or maintain 1 or more components of
physical fitness.9 Studies applying exercise in either
supervised or home-based settings to individuals or groups
were included. Exercise may include but is not limited to
strengthening, stretching, and proprioceptive retraining.

Comparison Groups. We included studies that compared one
or more exercise interventions to another one or another
exercise intervention to another intervention, placebo/sham
intervention, wait list, or no intervention.

Outcomes. To be eligible, studies had to include one of the
following outcomes: (1) self-rated recovery, (2) functional
recovery (eg, disability, return to activities, work, or
school), (3) clinical outcomes (eg, pain, health-related
quality of life, or depression), (4) administrative data (eg,
time on benefits), and (5) adverse events.

Study Characteristics. Eligible studies met the following
criteria: (1) English language; (2) studies published
between January 1, 1990, and April 13, 2015; (3) study
designs including randomized controlled trials (RCTs),
cohort studies, and case-control studies; and (4) an
inception cohort of at least 30 subjects per treatment arm
for RCTs or 100 subjects per exposed group for cohort
studies with musculoskeletal disorders and injuries of the
elbow, forearm, wrist, or hand region.

We excluded studies with the following characteristics:
(1) guidelines, letters, editorials, commentaries, unpub-
lished manuscripts, dissertations, government reports,
books and book chapters, conference proceedings, meeting
abstracts, lectures and addresses, consensus development
statements, or guideline statements; (2) study designs
including pilot studies, cross-sectional studies, case reports,
case series, qualitative studies, narrative reviews, system-
atic reviews, clinical practice guidelines, biomechanical
studies, or laboratory studies; (3) cadaveric or animal
studies; and (4) studies on patients with severe injuries (eg,
grade III sprains/strains or fractures and dislocations of the
elbow, wrist, or hand).

Information Sources

We developed our search strategy with a health sciences
librarian (Supplementary data). A second librarian reviewed
the search strategy for completeness and accuracy using the
Peer Review of Electronic Search Strategies Checklist.19,20
We searched the following databases: MEDLINE,
EMBASE, CINAHL, PsycINFO, and the Cochrane Central
Register of Controlled Trials. We searched all bibliographic
databases from January 1, 1990, to April 13, 2015.

The search strategy was first developed in MEDLINE
and subsequently adapted to the other bibliographic
databases. The search terms included subject headings
(eg, MeSH) specific to each database and free text words
relevant to exercise and musculoskeletal disorders and
injuries of the elbow, forearm, wrist, or hand region.

Study Selection

We used a 2-phase screening process to select eligible
studies. In phase 1, random pairs of independent reviewers
screened citation titles and abstracts to determine the
eligibility of studies. Phase 1 screening resulted in studies
being classified as relevant, possibly relevant, or irrelevant.
In phase 2, the same pairs of reviewers independently
screened possibly relevant studies to determine eligibility.
Reviewers met to resolve disagreements and reach
consensus on the eligibility of studies. We involved a
third reviewer if consensus could not be reached.

Assessment of Risk of Bias

Random pairs of trained independent reviewers critically
appraised the internal validity of eligible studies using the

Table 1. Case Definition of Sprains

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Sprain occurs when ligamentous fibers are stretched but remain structurally intact.</td>
</tr>
<tr>
<td>II</td>
<td>Sprain occurs when ligamentous fibers become partially torn. Physical stress reveals increased laxity with a definite end point.</td>
</tr>
<tr>
<td>III*</td>
<td>Sprain occurs when a ligament is completely torn, leading to gross instability.</td>
</tr>
</tbody>
</table>

* Grade III sprains are excluded from this review.

Table 2. Case Definition of Strains

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Strain occurs when &lt;5% of muscle/fibers are disrupted, with fascia remaining intact.</td>
</tr>
<tr>
<td>II</td>
<td>Strain occurs when muscle fibers/tendon discontinuity involves a moderate number of muscle fibers.</td>
</tr>
<tr>
<td>III*</td>
<td>Strain occurs when there is complete discontinuity in the muscle fibers.</td>
</tr>
</tbody>
</table>

* Grade III strains are excluded from this review.
The content of the image is a textual document discussing the methodology and findings of a study on exercise for forearm and hand injuries. The document outlines the process of evidence synthesis, including the use of the Scottish Intercollegiate Guidelines Network (SIGN) criteria to guide the development of evidence-based clinical practice guidelines for the National Health Service in Scotland. It describes the methodology used to assess the risk of bias in studies, the extraction of data, and the synthesis of results. The document mentions the use of the kappa statistic to measure inter-rater agreement and provides details on the screening process, critical appraisal, and the selection of studies for inclusion in the evidence synthesis. The results section highlights the effectiveness of exercise for the management of persistent lateral epicondylitis, and the study characteristics are discussed in detail.
allocation concealment was not adequately described in any studies.\textsuperscript{38-42} Two studies reported differences in baseline characteristics; however, these differences were controlled for in the analyses.\textsuperscript{40,41} Two of the 5 studies did not adequately describe whether there were coninterventions.\textsuperscript{39,41}

The study with a high risk of bias had important methodological limitations. Specifically, there were important differences in baseline characteristics between treatment groups that were not adjusted for in the analysis.\textsuperscript{43} Furthermore, the outcome measures had unknown validity and reliability. Finally, there was no mention of whether an intention-to-treat analysis was carried out.\textsuperscript{43}

**Summary of Evidence**

**Persistent Lateral Epicondylitis (≥3 Months).** Evidence from 1 RCT suggests that adding home eccentric or concentric strengthening exercises to home stretching and advice provides no additional benefit to home stretching exercises and advice alone in patients with persistent lateral epicondylitis\textsuperscript{38} (Table 4). Martinez-Silvestrini et al\textsuperscript{38} randomized patients to 6 weeks of (1) stretching and advice plus eccentric strengthening exercises, (2) stretching and advice plus concentric exercises, or (3) stretching and advice alone. All exercises were performed at home. The stretching and advice group received instruction and advice on stretching exercises for wrist extensors, icing, use of counterforce straps, and how to avoid precipitating and exacerbating activities. Immediately after the 6-week intervention period, those who received eccentric exercises reported statistically significant improvements in pain scores compared to the concentric exercise group (mean difference, 8.0/100 [95% CI, 0.5-15.6]). Furthermore, individuals who received stretching and advice reported statistically significant improvements in pain scores compared to the concentric exercise group (mean difference, -9.0/100 [95% CI, -16.5 to -1.6]). However, neither of these differences were clinically important. No other differences between groups were found.
Table 3. Risk of Bias for Randomized Controlled Trials With a Low Risk of Bias Based on Scottish Intercollegiate Guidelines Network Criteria

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Research Question</th>
<th>Randomization</th>
<th>Concealment</th>
<th>Blinding</th>
<th>Similarity at Baseline</th>
<th>Similarity Between Arms</th>
<th>Outcome Measurement</th>
<th>Percent Dropout</th>
<th>Intention to Treat</th>
<th>Results Comparable Between Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martinez-Silvestrini et al, 2005</td>
<td>Y</td>
<td>CS</td>
<td>N</td>
<td>CS</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>6 wk</td>
<td>Concentric: 4/30, 13.3%; eccentric: 4/31, 12.9%; stretching: 5/33, 15.2%</td>
<td>Y</td>
</tr>
<tr>
<td>Pedersen et al, 2013</td>
<td>Y</td>
<td>Y</td>
<td>CS</td>
<td>CS</td>
<td>CS</td>
<td>CS</td>
<td>Y</td>
<td>No. of dropouts for hand pain cases unknown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peterson et al, 2011</td>
<td>Y</td>
<td>Y</td>
<td>CS</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>1 mo</td>
<td>Exercise: 2/40, 5%; WS: 0/41, 0% 2 mo</td>
<td>Exercise: 2/40, 5%; WS: 0/41, 0% 3 mo</td>
</tr>
<tr>
<td>Peterson et al, 2014</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>CS</td>
<td>Y</td>
<td>Eccentric: 2/60, 3.3%; concentric: 3/60, 5% 6 mo</td>
<td>Eccentric: 3/60, 5%; concentric: 3/60, 5% 12 mo</td>
<td>Eccentric: 3/60, 5%; concentric: 3/60, 5% 24 mo</td>
</tr>
<tr>
<td>Stasinopoulos et al, 2010</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Home exercise program: 0/35, 0% at both 12 and 24 wk</td>
<td>Clinic-based exercise program: 0/35, 0% at both 12 and 24 wk</td>
<td>NA</td>
</tr>
</tbody>
</table>

CS, cannot say; N, no; NA, not applicable; WS, wait and see; Y, yes.

* Non-randomized trial.
<table>
<thead>
<tr>
<th>Author(s), Year</th>
<th>Subjects and Setting; Number (n) Enrolled</th>
<th>Interventions; No. (n) of Subjects</th>
<th>Comparisons; No. (n) of Subjects</th>
<th>Follow-Up</th>
<th>Outcomes</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martinez-Silvestrini et al, 2005&lt;sup&gt;58&lt;/sup&gt;</td>
<td>Adult patients recruited from the Mayo Clinic and in local health clubs in Minnesota. Case definition: Pain and tenderness at lateral elbow &gt;3 mo and pain with 2/3 tests (resisted wrist extension, resisted middle finger extension, and chair lift test); n = 94</td>
<td>CS: (1) Full wrist extension with resistance band (3 sets/10× daily/6 wk); (2) stretching and advice; n = 30</td>
<td>Stretching (S) Stretching and advice: stretches for wrist extensors (3× for 30 s twice daily/6 wk), avoid precipitating and exacerbating activities, use of counterforce strap as needed, information sheet on ice massage; n = 33</td>
<td>Postintervention</td>
<td>Primary outcomes: PFG strength (electronic dynamometer); PRF EQ, DASH, SF-36, pain intensity (100-mm VAS).</td>
<td>Difference in mean change (CS − S) at 6 wk:&lt;sup&gt;4&lt;/sup&gt; PFG (N), −1.0 (95% CI, −5.5 to 3.5); VAS, −9.0 (95% CI, −16.5 to −1.6); total PRF EQ, 0.3 (95% CI, −0.2 to 0.8); DASH, −3.0 (95% CI, −7.4 to 1.4) Difference in mean change (ES − CS) at 6 wk:&lt;sup&gt;4&lt;/sup&gt; PFG (N), −3.0 (95% CI, −1.7 to 7.7); VAS, −1.0 (95% CI, −8.2 to 6.2); total PRF EQ, −0.1 (95% CI, −0.6 to 0.4); DASH, −3.0 (95% CI, −7.5 to 1.5) Difference in mean change (ES − S) at 6 wk:&lt;sup&gt;4&lt;/sup&gt; PFG (N), 4.0 (95% CI, −0.0 to 8.0); VAS, 8.0 (95% CI, 0.5-15.6); total PRF EQ, −0.4 (95% CI, −1.0 to 0.2); DASH, 0.0 (95% CI, −4.5 to 4.5) Between-group mean differences (strength training and advice-advice):&lt;sup&gt;4&lt;/sup&gt; No statistically significant between-group differences in pain intensity and percentage of subjects with pain reductions ≥2</td>
</tr>
<tr>
<td>Pedersen et al, 2013&lt;sup&gt;59&lt;/sup&gt;</td>
<td>Industrial workers (18-67 years old) with repetitive work tasks from Copenhagen, Denmark. Case definition: right hand pain intensity ≥3/9 on the Nordic questionnaire on trouble; n = 95</td>
<td>Supervised progressive strength training (wrist extension with dumbbells) at the workplace provided by staff and students trained in physical education or physiotherapy (20 min/3 times per week for 20 wk). Advice to continue their normal physical activity as usual; n = 40</td>
<td>Advice to continue their normal physical activity as usual; n = 40</td>
<td>20 wk</td>
<td>Primary outcome: pain intensity during the last 7 d (Nordic questionnaire on trouble 0-9)</td>
<td></td>
</tr>
<tr>
<td>Peterson et al, 2011&lt;sup&gt;40&lt;/sup&gt;</td>
<td>Patients (20-75 years old) recruited from general practitioners, physiotherapist, and newspaper advertisements in Uppsala, Sweden, from 2003 to 2006 Case definition: Diagnosis</td>
<td>SE: Progressive loading exercise for extensor muscles at home (3 sets/15 repetitions/daily/3 mo) and some information as comparison group; n = 40</td>
<td>WS with information that condition was painful but harmless and continue ordinary daily activities; n = 41</td>
<td>Immediately postintervention</td>
<td>Primary outcomes: pain on MVC and MME (100-mm VAS); secondary outcomes: muscle strength (hand-held dynamometer); tertiary outcomes: DASH, GQL (well-being score,</td>
<td>Difference in mean change (SE − WS) postintervention:&lt;sup&gt;4&lt;/sup&gt; VAS for MVC (0-100 mm), 15.8 (95% CI, 8.3-23.4); VAS for MME (0-100 mm), 12.9 (95%</td>
</tr>
</tbody>
</table>

(continued on next page)
<table>
<thead>
<tr>
<th>Author(s), Year</th>
<th>Subjects and Setting; Number (n) Enrolled</th>
<th>Interventions; No. (n) of Subjects</th>
<th>Comparisons; No. (n) of Subjects</th>
<th>Follow-Up</th>
<th>Outcomes</th>
<th>Key Findings</th>
</tr>
</thead>
</table>
| Peterson et al, 2014 | Patients (20-75 years old) recruited from general practitioners, physiotherapists, and newspaper advertisements in Uppsala, Sweden. Case definition: Diagnosis of tennis elbow (>3 mo) with pain on palpation, pain on stretching (Mill’s test), pain on loading, and Maudley’s middle finger test; n = 120 | Home-based eccentric exercise group instructed to lower weight by flexing the wrist of the affected arm downwards and to lift back up with unaffected arm (15 repetitions/set and 3 sets daily for 3 mo). Load increased weekly by 1 hectogram; n = 60 | Home-based concentric exercise group instructed to lift the weight by extending the wrist of the affected arm upwards and lower it with unaffected arm (15 repetitions/set and 3 sets daily for 3 mo). Load increased weekly by 1 hectogram; n = 60 | 3, 6, and 12 mo after baseline assessment | Primary outcomes: pain reduction (100-mm VAS) during forearm muscle contraction, pain reduction (100-mm VAS) during forearm muscle elongation; secondary outcomes: muscle strength (N) (hand-held dynamometer); tertiary outcomes: DASH, 0-100: GQL (well-being score, 0-2; activity score, 0-7; complaint score). Adverse events | Difference in mean change (eccentric exercise – concentric exercise):

- 3 mo: VAS for MVC (0-100 mm), 4.3 (95% CI, −1.8 to 10.4); VAS for MME (0-100 mm), 4.8 (95% CI, −1.3 to 10.9); muscle strength (N), 5.9 (95% CI, −4.8 to 16.6); DASH score (0-100), 0.1 (95% CI, −4.0 to 4.2); activity score (0-2), −1.4 (95% CI, −3.0 to 0.2); well-being score (0-7), 0 (95% CI, −0.3 to 0.3); complaint score, 0.4 (95% CI, −0.9 to 1.7) |
- 6 mo: VAS for MVC (0-100 mm), 5.2 (95% CI, −0.7 to 11.1); VAS for MME (0-100 mm), 4.2 (95% CI, −1.8 to 10.2); muscle strength (N), 5.4 (95% CI, −5.4 to 16.2); DASH score (0-100), −0.3 (95% CI, −4.3 to 3.7); activity score (0-2), −0.6 (95% CI, −2.2 to 1.0); well-being score (0-7), −0.1 (95% CI, −0.4 to 0.2); complaint score, −0.2 |

CI, 5.6-20.2; muscular strength (N), 7.5 (95% CI, −5.3 to 20.3); DASH score (0-100), 4.6 (95% CI, 0.6-8.6); well-being score (0-7), 1.0 (95% CI, −0.9 to 2.9); activity score (0-2), 0.2 (95% CI, −0.2 to 0.6); complaint score, 0.0 (95% CI, −1.4 to 1.4) |
| 12 mo: VAS for MVC (0-100 mm), 4.8 (95% CI −1.2 to 10.8); VAS for MME (0-100 mm), 3.7 (95% CI −2.9 to 10.3); muscle strength (N), 4.3 (95% CI, −6.8 to 15.4); DASH score (0-100), 1.3 (95% CI, −2.7 to 5.3); activity score (0-2), −0.9 (95% CI, −2.6 to 0.8); well-being score (0-7), 0.1 (95% CI, −0.2 to 0.4); complaint score, 1 (95% CI, −0.3 to 2.3) |
| No adverse events reported. |

| CS, concentric strengthening; CEP, clinic-based exercise program; ES, eccentric strengthening; GQL, Gothenburg Quality of Life Instrument; HEP, home exercise program; PFG, pain-free grip; PRFEQ, Patient-rated Forearm Evaluation Questionnaire; S, stretching; SE, strengthening exercises; SF-36, Short Form 36; WS, wait and see. |

| a Recalculated data from study. |

| b Data were presented in graphs; differences in mean change and 95% CIs could not be calculated. |

| Stasinopoulos et al, 2010 | Patients (18 years old) from Athens, Greece, referred by physicians and physiotherapists from 2005 to 2007. Case definition: Lateral epicondylitis (≥4 wk): (1) pain on palpation; pain with resisted elbow extension; (3) 2/4 positive tests (Tomsen, resisted middle finger, Mill’s hand grip dynamometer); n = 70 |
| CEP: slow progressive eccentric exercises of the wrist extensors and static stretching exercises of the extensor carpi radialis brevis tendon supervised by a physical therapist (5×/week/12 wk); n = 35 |
| HEP: same exercise protocol as CEP group except performed at home (5×/week/12 wk). Visit with physical therapist 1×/week for further instructions; n = 35 |
| 12 wk postintervention, and 24 wk | Primary outcomes: pain (10-cm VAS); secondary outcomes: elbow function (10-cm VAS); tertiary outcomes: pain-free grip strength (Jamar hand-held dynamometer) |

| Difference in mean change (CEP − HEP): Postintervention (week 12): VAS for pain (0-10 cm), 1.54 (95% CI, 0.54-2.55); VAS for function (0-10 cm), 2.55 (95% CI, 1.72-3.38); pain-free grip strength (lb), 17.05 (95% CI, 16.03-18.07) 3 mo (week 24): VAS for pain (0-10 cm), 1.76 (95% CI, 1.03-2.50); VAS for function (0-10 cm), 2.81 (95% CI, 1.81-3.81); pain-free grip strength (lb), 17.08 (95% CI, 16.14-18.01) |
Similarly, evidence from another RCT suggests that home-based, graded eccentric and concentric exercise programs lead to similar outcomes in patients with persistent lateral epicondylitis. Peterson et al\textsuperscript{41} randomized participants to 3 months of (1) home-based, graded eccentric exercises (15 repetitions/set and 3 sets daily), or (2) home-based, graded concentric exercises (15 repetitions/set and 3 sets daily) (Table 4). There were no statistically significant differences between groups in pain (VAS), muscle strength (dynamometer), disability (DASH), and quality of life (Gothenburg Quality of Life Instrument) at any follow-up. The between-group differences for pain and disability were not clinically important. The clinical importance of the muscle strength and quality-of-life outcomes is unknown because minimal clinically important differences have not been established.

Evidence from a third RCT suggests that a home strengthening exercise program is more effective than “wait and see” in reducing pain in patients with persistent lateral epicondylitis\textsuperscript{40} (Table 4). In their trial, Peterson et al\textsuperscript{40} randomized participants to (1) 3 months of daily home progressive incremental loading exercises for the forearm extensors or (2) “wait and see.” All participants received advice that their condition was painful but harmless and to continue ordinary daily activities. Immediately after the 3 month intervention period, participants in the exercise group reported clinically important improvement in elbow pain (VAS) during maximum voluntary contraction (MVC) (mean difference, 15.8/100 [95\% CI, 8.25-23.35]) compared to individuals in the “wait and see” group. Furthermore, participants in the exercise group reported statistically significant but not clinically important self-reported improvement in elbow pain (VAS) during maximum muscle elongation (MME) (mean difference, 12.9/100 [95\% CI, 5.63-20.17]) compared to individuals in the “wait and see” group. Moreover, the exercise group had statistically significant improvement in disability (DASH) at 3 months when compared to the wait-list group; however, these differences were not clinically important (Table 4).

Evidence from 1 nonrandomized trial suggests that a clinic-based supervised exercise program is more effective than a therapist-monitored home exercise program in reducing self-reported pain, function, and pain-free grip strength in patients with lateral elbow tendinopathy with a mean duration of 5 months (we, therefore, classified this study under persistent duration)\textsuperscript{42} (Table 4). Stasinopoulos et al\textsuperscript{42} compared a clinic-based supervised exercise program to a similar home exercise program. Participants allocated to clinic-based exercise completed a 12-week protocol that included slow progressive eccentric exercises of the wrist extensors and static stretching of the extensor carpi radialis brevis tendon under supervision by a physical therapist 5 times per week. Participants allocated to a home exercise program followed an identical exercise program and received weekly visits from a physical therapist to provide further instructions. At 12 weeks (postintervention) and 24 weeks, participants in the clinic-based exercise program demonstrated statistically and clinically important improvements in self-reported pain (VAS) (mean difference at 12 weeks, 1.54/10 [95\% CI, 0.54-2.55]; 24 weeks, 1.76/10 [95\% CI, 1.03-2.50]). There were also statistically significant differences in function (VAS) (mean difference at 12 weeks, 2.55/10 [95\% CI, 1.72-3.38]; 24 weeks, 2.81/10 [95\% CI, 1.81-3.81]) and pain-free grip strength (mean difference at 12 weeks, 17.05/10 [95\% CI, 16.03-18.07]; 24 weeks, 17.08/10 [95\% CI, 16.14-18.01]). However, the clinical importance of these differences is unknown (Table 4).

**Hand Pain of Variable Duration.** Evidence from 1 RCT suggests that supervised strength training at the workplace does not provide additional benefits to advice to continue normal physical activity to individuals with hand pain (excluding major pathology). In their RCT, Pedersen et al\textsuperscript{39} randomized industrial workers who perform repetitive work tasks and report hand pain to (1) supervised progressive strength training at the workplace (20 minutes/3 times per week/20 weeks) with advice to continue normal physical activity as usual or (2) advice to continue normal physical activity as usual. There were no statistically significant or clinically important between-group differences in pain.

**Adverse Events.** Two trials reported that no adverse events were associated with performing the investigated strengthening or stretching exercises.\textsuperscript{41,42} The other 3 studies did not report on adverse events.\textsuperscript{38-40}

**Discussion**

**Summary of Evidence**

Our systematic review provides an update of the evidence on the effectiveness of exercise for the management of lateral epicondylitis. The role of strengthening exercises for the management of persistent lateral epicondylitis remains unclear. Although a home strengthening exercise program is more effective than “wait and see” for persistent lateral epicondylitis, we found that adding eccentric or concentric strengthening exercises to stretching and advice alone does not improve outcomes of patients with this condition. We also found that clinic-based, supervised eccentric strengthening exercises combined with static stretching were more effective than the same exercises performed at home for patients with persistent lateral epicondylitis. We also found no differences between groups who performed home-based eccentric or concentric exercises for persistent lateral epicondylitis. Moreover, adding supervised progressive strength training does not provide additional benefits to advice to continue normal physical activity as usual for patients with hand pain. We found no studies with a low risk of bias to inform the use of exercise for the management of other musculoskeletal disorders and injuries of the hand, wrist, forearm, and elbow, which include
but are not limited to medial epicondylitis, carpal tunnel syndrome, and de Quervain tenosynovitis.

Previous Systematic Reviews

Some of the findings of our review contradict findings from previous systematic reviews. A review by Cullinane et al.\textsuperscript{13} supported the inclusion of eccentric strengthening exercises as a part of a multimodal therapy program for patients with lateral epicondylitis.\textsuperscript{13} In our review, we found that the addition of an eccentric exercise program to stretching and advice provides no further benefits for patients with persistent lateral epicondylitis. Our conclusions may differ because Cullinane et al. included studies involving multimodal interventions (with exercise as a component of the multimodal program) and studies with a high risk of bias. Furthermore, our review partially agrees with 2 previous systematic reviews\textsuperscript{11,12} suggesting that strengthening exercises are effective for lateral epicondylitis. However, we found 1 recent RCT, published after these reviews, that suggests that the addition of eccentric or concentric strengthening exercises to stretching and advice provides no further benefits for patients with persistent lateral epicondylitis.\textsuperscript{38} We did not find any studies with a low risk of bias that evaluated the effectiveness of stretching alone for lateral epicondylitis. Finally, a review by Bisset et al.\textsuperscript{14} concluded that the evidence for exercise for lateral epicondylitis is inconclusive. Our review suggests that stretching or strengthening exercises may be beneficial for the management of persistent lateral epicondylitis. However, it is not clear which of stretching or strengthening provides more benefit.

We did not find studies with a low risk of bias to inform the discussion on the effectiveness of exercise for other musculoskeletal disorders and injuries of the elbow, forearm, wrist, and hand such as medial epicondylitis, cubital tunnel syndrome, carpal tunnel syndrome, and de Quervain tenosynovitis. Two previous systematic reviews that studied the effectiveness of exercise for carpal tunnel syndrome were found.\textsuperscript{15,16} One review suggested that exercise therapy was not effective for carpal tunnel syndrome,\textsuperscript{15} and 1 review suggested that neurodynamic mobilization (stretching/nerve flossing exercises) may be beneficial for the management of pain in those with carpal tunnel syndrome.\textsuperscript{16} The studies from these reviews were not included in our review because their sample size did not meet our inclusion criteria. Our review found that adding supervised progressive strength training to advice to continue normal physical activity provided no additional benefits for hand pain. However, this study does not specify whether some patients may have carpal tunnel syndrome. As such, the evidence for the effectiveness of exercise for the management of carpal tunnel syndrome can be considered inconclusive.

The conclusions of these reviews may have been influenced by methodological limitations. Conclusions from previous reviews may differ from our results because they synthesized evidence from all eligible studies regardless of their scientific quality.\textsuperscript{11-16} They also included studies with small sample sizes,\textsuperscript{11-16} which reduces the precision of the effect sizes and increases the chance of residual confounding.

Implications of the Research

The findings from this review may help clinicians and health care providers in making evidence-based decisions regarding patient care for the management of musculoskeletal disorders and injuries. It is important to provide evidence-based interventions to limit the personal, financial, and societal burden of disability associated with these conditions.\textsuperscript{7,10} This review suggests that specific exercise interventions may benefit patients; it is, therefore, important for clinicians to prescribe the right type of exercise at the right time during the course of the condition.

Strengths

We implemented a comprehensive and rigorous search strategy that was reviewed by a second librarian to help minimize errors. Second, we defined clear inclusion and exclusion criteria for the selection of relevant studies. Third, we used 2 trained independent reviewers to screen and critically appraise the literature to minimize error and bias. Fourth, the SIGN criteria were used to standardize the critical appraisal process and to inform our scientific judgment. Lastly, our conclusions were based on a best evidence synthesis, omitting studies of low quality to minimize the risk of bias.

Limitations

We limited our search to studies published in the English language, which may have excluded some relevant studies. However, this is an unlikely source of bias because most trials are published in English. The sole inclusion of trials published in English has not previously led to biased results.\textsuperscript{44-47} Second, our search may have missed relevant studies despite our broad search strategy. Third, our review may have missed potentially relevant studies published before 1990. Finally, the critical appraisal process entails scientific judgment that may differ between reviewers. This potential bias was minimized by training reviewers to use a standardized critical appraisal tool and by using a consensus process.

Recommendations for Future Research

High-quality studies to establish the effectiveness of exercise programs are needed to inform for the management of lateral epicondylitis. Similarly, studies are needed to determine the role of exercise for the management of other
common musculoskeletal injuries of the elbow, wrist, and hand (eg, medial epicondylitis, de Quervain tenosynovitis, and carpal tunnel syndrome).

CONCLUSION

This review helps clarify the effectiveness of exercise for the management of musculoskeletal disorders of the elbow, forearm, wrist, and hand. The results suggest that, for persistent lateral epicondylitis, home strengthening exercise is more effective than “wait and see” and that home-based concentric or eccentric exercises lead to similar outcomes. However, adding eccentric or concentric strengthening exercises to stretching and advice provides no additional benefits to stretching and advice alone. This review also found that clinic-based strengthening and static stretching exercises are more effective than monitored home-based strengthening and stretching exercises for persistent lateral epicondylitis. Therefore, the relative effectiveness of stretching vs strengthening the wrist extensors remains unknown for the management of persistent lateral epicondylitis. The review also suggests that supervised progressive strength training added to advice to continue normal physical activity provides no additional benefits for hand pain. No studies with a low risk of bias to inform the use of exercise for the management of other musculoskeletal disorders and injuries of the hand, wrist, forearm, and elbow were found.

ACKNOWLEDGMENT

The authors thank the following people for their contributions to this study: Leslie Verville (administration), Angela Verven (administration), Mike Paulden (critical review), Patrick Loisel (critical review), Richard Bohay (critical review), Carlo Amendolia (critical review), Roger Salhany (critical review), Robert Brison (critical review), J David Cassidy (critical review), John Stapleton (critical review), Margareta Nordin (critical review), Michel Lacerte (critical review), and Murray Krahn (critical review).

FUNDING SOURCES AND POTENTIAL CONFLICTS OF INTEREST

This study was funded by the Ontario Ministry of Finance and the Financial Services Commission of Ontario (RFP no. OSS_00267175). The funding agency was not involved in the collection of data, data analysis, interpretation of data, or drafting of the manuscript. The research was undertaken, in part, thanks to funding from the Canada Research Chairs program. Silvano Mior is a member of the guideline expert panel and consults for the Ontario Chiropractic Association; Pierre Côté received a grant from Ontario Ministry of Finance, travel expenses for teaching reimbursed from the European Spine Society, research chair funding from from the Canada Research Chair Program and Canadian Institutes of Health Research; consulted for the Canadian Chiropractic Protective Association; and had speaking and/or teaching arrangements with the National Judicial Institute and Société des Médecins Experts du Quebec. No other conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Practical Applications

- This review suggests that eccentric or concentric strengthening exercises combined with advice and stretching alone are equivalent for the management of persistent epicondylitis.
- For patients with persistent lateral epicondylitis, home strengthening exercises are more beneficial than “wait and see” for short-term improvements in pain reduction.
- Clinic-based strengthening exercises and static stretching are more effective than monitored home strengthening and stretching exercises.
- The relative effectiveness of stretching vs strengthening the wrist extensors remains unknown for the management of persistent lateral epicondylitis.
- For hand pain of variable duration, supervised progressive strength training added to advice to continue normal physical activity provides no additional benefits.

APPENDIX A SUPPLEMENTARY DATA

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jmpt.2015.06.002.
REFERENCES

38. Martinez-Silvestrini JA, Newcomer KL, Gay RE, Schaefer MP, Kortebein P, Arendt KW. Chronic lateral epicondylitis: comparative effectiveness of a home exercise program including stretching alone versus stretching supplemented...
with eccentric or concentric strengthening. J Hand Ther 2005; 18:411-9 [quiz 20].


