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Conservative treatment for repetitive strain injury

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Various conservative treatment options for repetitive strain injury are widely used, despite questionable evidence of their effectiveness. This systematic review evaluates the effectiveness of these treatment options for relieving symptoms of repetitive strain injury and improving activities of daily living. Searches in Medline and Embase, with additional reference checking resulted in 15 eligible trials for this review. Methodological quality was assessed, and data-extraction was performed. With the use of a "best-evidence synthesis", no strong evidence was found for the effectiveness of any of the treatment options. There is limited evidence that multidisciplinary rehabilitation, ergonomic intervention measures, exercises, and spinal manipulation combined with soft tissue therapy are effective in providing symptom relief or improving activities of daily living. There is conflicting evidence for the effectiveness of behavioral therapy. In conclusion, little is known about the effectiveness of conservative treatment options for repetitive strain injury. To establish strong evidence, more high-quality trials are needed.

Key terms controlled clinical trials, cumulative trauma disorders, randomized clinical trials, systematic review, treatment, work-related musculoskeletal disorders.

In the past two decades, repetitive strain injury (RSI) has become a major topic, both socially and scientifically. The prevalence of musculoskeletal disorders reported in the United States has increased steadily, accounting for more than 65% of all occupational illnesses (1). In 1995, 62% of all cases of work-related illness in the private sector, included in a report from the Bureau of Labor Statistics, were due to disorders associated with repeated trauma, such as typing, repetitive tool use, and repetitive grasping or moving of objects other than tools (2). The prevalence of repetitive strain injury in the entire Dutch labor force has been reported to be approximately 19% (3). Repetitive strain injury is not only a major health problem, but also a huge socioeconomic one. The total compensable cost for upper extremity, work-related musculoskeletal disorders in the United States in 1993 was USD 563 million (2).

Musculoskeletal disorders of the upper limbs and neck in association with repetitive or continuous strain in work situations have been described in different countries under various synonyms, such as occupational cervicobrachial disorder (OCD), upper-extremity cumulative trauma disorder (UECTD), work-related upper-limb disorder (WRULD), and occupational overuse syndrome (OOS) (4–6).

In The Netherlands, repetitive strain injury is the most frequently used term for these broad ranges of symptoms and disorders. It is a collective term for syndromes characterized by several complaints, such as pain, tingling, numbness, loss of coordination and loss of force, generally affecting the upper extremities and neck and caused by repetitive or continuous strain.

It is important to keep in mind that terms like repetitive strain injury and upper-extremity cumulative trauma

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disorder are not diagnoses, but merely statements of causation (7). The etiology of repetitive strain injury is usually multifactorial, in many cases the etiology is still obscure (5, 6, 8, 9), and for most cases no specific diagnosis can be made. There are no pathological or radiological characteristics to support the diagnosis, and also there is often no manifestation of neurological signs. In the literature, consistent findings concerning risk factors for repetitive strain injury have been described. Recommendations to prevent these risk factors are logical, but studies on the effectiveness of intervention programs are still awaited. Many patients with repetitive strain injury are treated in primary care. There is a wide variety in the treatment options, ranging from ergonomic advice and workload restrictions to physiotherapy and the prescription of medical aids (10). There is also still little available research on the effectiveness of these types of therapeutic intervention.

This systematic review aims at evaluating the effectiveness of conservative treatment options for repetitive strain injury.

Methods

Selection criteria

Types of studies. Both randomized controlled trials (RCT) and (nonrandomized) controlled clinical trials (CCT) on conservative treatment options for repetitive strain injury were included. The studies had to be published as full reports (no abstracts) written in English, German, Dutch, French or Finnish.

Types of participants. Randomized controlled trials and controlled clinical trials were included if they reported on subjects (male or female) with repetitive strain injury. Repetitive strain injury was defined as any work-related disorder of the upper extremity, neck or thoracic region in work-age adults (18 to 65 years of age), due to repetitive work or continuous strain at work. Complaints were characterized by discomfort, impairment, disability, or persistent pain in joints, muscles, tendons, and other soft tissues, with or without physical manifestations (11). All occupational groups were included. Excluded were studies reporting on patients with acute trauma, neoplasm, metastatic diseases, and fractures. Patients with complaints of the upper limbs, neck, and thoracic region that were not work-related were also excluded.

Types of intervention. Randomized controlled trials and controlled clinical trials in which one form of intervention consisted of conservative therapy (ie, "nonsurgical" therapy) were considered for inclusion. All types of conservative intervention that were prescribed or performed in the treatment of repetitive strain injury were included, such as occupational therapy, physiotherapy, behavioral therapy, multidisciplinary treatment, or medication. Ergonomic measures used in the treatment of repetitive strain injury were also included, for example, specially designed office furniture, computer keyboards, and computer mice.

Types of outcome measures. The primary outcome measures were self-reported pain intensity expressed on a visual analogue scale (VAS) or a numerical rating scale (NRS), a global measure of improvement (overall improvement, percentage of patients recovered, subjective improvement of symptoms), return to work (sickness absence, days off work), and generic functional status (SF-36, Nottingham Health Profile, Sickness Impact Profile). Randomized controlled trials and controlled clinical trials that did not include any type of patient-specific outcome measure were excluded.

Search strategy

In an attempt to identify relevant studies for this review, the following literature search strategy was used: (i) randomized controlled trials and controlled clinical trials were identified through a computer-aided search of Medline (from 1966 to April 2000), Embase (from 1988 to April 2000), and the Cochrane Controlled Trials Register (Issue 2, 2000) and (ii) references given in retrieved articles and other relevant publications and reviews were screened.

The Medline search strategy incorporated the optimal search strategy for randomized and controlled trials by Dickersin (12), combined with the textwords (explode "cumulative trauma disorder") and ("rsi", "repetition strain injury", "repetitive strain injury", "overuse injury", "overuse syndrome", "occupational cervicobrachial disorder", "occupational myalgia", "repeated trauma injury", "musculoskeletal disorder of the neck", "repetitive motion disorder", "work related upper limb trauma injury", "continuous strain injury"). A similar strategy was used in Embase. The complete search strategy is available on request.

Study selection

One reviewer (HK) generated the Medline and Embase search strategies and downloaded the relevant data (author, title, keywords and abstract) of all the identified studies into a computer file. Two reviewers (AG and MvT) independently applied the selection criteria to the studies that were retrieved through the literature search. The abstracts were reviewed or, in case of any doubt,

a copy of the full article was considered. Consensus was achieved to resolve disagreements concerning the selection and inclusion of studies.

Assessment of methodological quality

The methodological quality of the controlled clinical trials and randomized controlled trials was independently assessed by three reviewers (HK, HdV, NdW). Quality assessment was pilot-tested in two trials from a comparable field of research (neck pain) not included in the review. An adjusted version of the criteria list recommended by the Cochrane Back Review Group (13) was used to assess the methodological quality of the randomized controlled trials and controlled clinical trials (appendix). Modifications were made for repetitive strain injury and nonsurgical treatment options regarding prognostic indicators (c) and outcome measures (j). Items could be scored as positive ("yes"), negative ("no"), or unclear ("don't know"). The list consisted of internal validity criteria (items b_1, b_2, c, e, f, g, h, i, l_1, l_2, n, p), descriptive or external validity criteria (items a, d_1, d_2, j, k, m_1, m_2), and two statistical criteria (items o, q).

If the article did not provide sufficient information on one of the methodological quality criteria and the criterion was scored as unclear, the authors were contacted for additional information. This information was used for a final quality assessment made by two reviewers independently. The final scores of the quality assessment were reached in consensus.

Data extraction

Two reviewers (HK and NdW) independently extracted the data, using a standardized form. Information was collected on participants (age, gender), type of repetitive strain injury (criteria on which diagnosis was made, duration of symptoms, location of disorder), interventions (type, duration, treatment schedule), outcome measures, timing of the posttreatment and follow-up measurements, and results (number of patients, point estimates and measures of variability). Although data on all reported outcomes were extracted, outcome measures on subjective symptoms and activities of daily living, including return to work, were considered primary outcomes.

Data analysis

Clinical homogeneity was evaluated by exploring the differences between the studies with regard to study population, types of treatment, and outcome measures. The studies were considered to be heterogeneous with regard to all three criteria. Therefore, it was decided not to pool data from the studies statistically but, instead, to summarize the results according to a rating system for the strength of the scientific evidence, consisting of the following four levels: strong evidence — provided by generally consistent findings in multiple high-quality randomized clinical trials (randomized controlled trials) (level 1), moderate evidence — provided by generally consistent findings in multiple low-quality randomized controlled trials or multiple controlled clinical trials (level 2), limited evidence — only one randomized controlled trial (either high or low quality) or controlled clinical trial (level 3a), conflicting evidence — inconsistent findings in multiple randomized controlled trials or controlled clinical trials (level 3b), and no evidence — no randomized controlled trials or controlled clinical trials (level 4).

Conclusions with regard to the findings of the studies were based on the statistical significance ($P < 0.05$) of the outcome measures on symptoms and activities of daily living, as assessed by the reviewers. Both posttreatment and follow-up results were taken into consideration. Findings were considered to be "generally consistent" if at least 75% of the studies showed similar results.

A study was (arbitrarily) considered to be of high quality if at least 50% (6 out of 12) of the internal validity criteria were fulfilled. A sensitivity analysis was performed to explore the results when high quality was defined as fulfilling 5 and 7 or more of the 12 validity criteria.

Results

Study selection

The literature search resulted in the identification of 986 publications. Fifteen studies in 16 publications met the inclusion criteria, 5 of which were identified in Medline. Searching Embase and the Cochrane database resulted in the identification of 2 additional studies in each (a total of 4 studies). Reference checking resulted in 6 additional studies. In summary, a total of 15 identified trials (12 randomized controlled trials and 3 controlled clinical trials) on conservative treatment for repetitive strain injury met the criteria for inclusion in this review. These studies evaluated the efficacy of physiotherapy (14–17), exercise (18, 19), behavioral therapies (20–24), chiropractic treatment (25), a multidisciplinary rehabilitation program (26), an energized splint (27), and an ergonomic approach (28, 29).

Methodological quality

The results of the methodological quality assessment are shown in table 1. Applying a cut-off point of ≥50%

Table 1. Randomized controlled trials on the effectiveness of conservative treatment options for repetitive strain injury. (RCT = randomized controlled trial, CCT = controlled clinical trial, + = yes, − = no, ? = do not know)

Type of treatment	Scores for methodological criteria																						
	Internal validity [a]												Quality score [b]	External validity [a]							Statistics [a]		Study design
	b_1	b_2	c	e	f	g	h	i	l_1	l_2	n	p		a	d_1	d_2	j	k	m_1	m_2	o	q	
Physiotherapy																							
Vasseljen et al, 1995 (17)	+	+	+	−	?	?	−	−	+	+	+	+	7	+	+	−	+	−	+	+	−	+	RCT
Levoska & Keinänen-Kiukaanniemi, 1993 (15)	+	?	+	−	+	?	−	−	+	+	+	−	6	+	+	+	+	−	+	+	−	+	RCT
Ferguson & Duncan, 1976 (14)	+	?	+	−	?	?	−	+	−	?	+	−	4	−	−	−	+	−	+	+	+	+	RCT
Rundcrantz et al,1991 (16)	−	−	+	−	?	?	−	−	+	−	?	−	2	+	−	+	+	−	+	−	−	+	CCT
Exercise																							
Takala et al, 1994 (18)	+	−	+	−	?	?	−	+	+	+	+	+	6 [c]	−	+	−	+	−	+	−	+	+	RCT
Waling et al, 2000 (19)	?	?	+	−	?	−	−	−	−	−	+	−	2	+	+	+	+	−	+	−	−	+	RCT
Behavioral therapy																							
Moore & Wiesner, 1996 (20)	+	?	+	−	?	?	−	−	−	−	+	−	3	+	+	−	+	+	+	−	−	+	RCT
Spence, 1989 & 1991 (21, 22)	?	?	?	−	−	?	−	?	+	+	+	−	3	+	+	−	+	−	+	+	−	+	RCT
Spence et al, 1995 (23)	?	?	+	−	?	?	−	?	+	−	+	−	3	+	+	−	+	−	+	+	−	+	RCT
Swerissen et al, 1991 (24)	?	?	?	−	?	?	−	−	−	−	+	−	1	+	+	−	+	−	+	−	−	+	CCT
Energized splint																							
Stralka et al,1998 (27)	?	?	?	+	?	?	+	?	−	−	?	−	2	+	+	+	+	−	+	−	+	−	RCT
Chiropractic treatment																							
Leboeuf et al,1987 (25)	?	?	?	−	?	?	−	?	+	−	+	+	3	+	+	+	+	−	+	−	−	−	RCT
Ergonomic approach																							
Rempel et al,1999 (28)	+	?	+	+	+	+	+	+	−	−	+	−	8	+	+	+	+	−	+	−	−	+	RCT
Tittiranonda et al, 1999 (29)	+	?	+	+	?	?	+	+	−	−	+	+	7	+	+	+	+	−	+	−	−	+	RCT
Multidisciplinary rehabilitation																							
Feuerstein et al, 1993 (26)	−	−	+	−	?	?	−	?	?	?	−	?	1	+	+	−	+	−	?	?	−	+	CCT

[a] The definitions for the criteria are specified in appendix 1.
[b] Only internal validity items determined the final quality score.
[c] Intended cross-over design, considered, however, as two separated trials, of which only the first is presented here.

positive items resulted in only five high-quality trials (15, 17, 18, 28, 29). Requests to comment on the quality score attributed to the study and to provide more information were sent to all the authors but one, whose recent address could not be traced. Only 5 out of 14 authors responded (15, 17–19, 28). As a result of their comments and information, we decided to change the assessments of 18 items on the criteria list as follows: 9 from unclear to positive, 5 from unclear to negative, 1 from negative to unclear, and 3 from negative to positive. Table 1 presents the studies for each type of intervention in hierarchical order, according to their internal validity score.

Overall, the methodological quality of the studies was poor, although the scores of the randomized controlled trials were somewhat higher than the scores of the controlled clinical trials. Many studies reported random treatment allocation but failed to describe whether the method of randomization was concealed (b2). Information on co-interventions (f) and blinding of the care-provider (e), patient (h), or outcome assessor (i) was often lacking. Other prevalent shortcomings were that no intention-to-treat analyses (p) were performed and that very few studies stated whether compliance was acceptable (g).

Efficacy of conservative treatment options

Table 2 presents the study characteristics (study design, study population, interventions, and results). Only the outcome measures that were relevant to patients are reported. The outcomes were subjective symptoms [eg, levels of pain (VAS, Pain Beliefs Questionnaire, West Haven-Yale Multidimensional Pain Inventory), numbness or stiffness], and activities of daily living (eg, functional status of the hand, return to work, and interference of symptoms with daily living). Other outcome measures reported in the studies were strength (14, 15, 17, 27), tender points (15, 17, 18, 19), sensibility (27–29), and depression, anxiety, coping strategies or personal harmony (16, 19, 21–24), but they were all considered to be secondary outcomes.

The differences between the groups are presented using 95% confidence intervals when data on exact

Table 2. Characteristics of the (randomized) controlled trials with conservative treatment options for repetitive strain injury (RSI). (RCT = randomized clinical trial, CCT = controlled clinical trial, 95% CI = 95% confidence interval, PNF = proprioceptive neuromuscular facilitation, EMG = electromyographic, WHYMPI = West Haven-Yale Multidimensional Pain Inventory)

Type of treatment	Study design	Study population [a]	Intervention [b]	Reported results
Physiotherapy				
Vasseljen et al, 1995 (17)	RCT, no control group	24 female office workers with shoulder & neck pain; mean age 39.7 years for (1) & 38.1 years for (2)	(1) individual physiotherapy (massage, strength and flexibility exercises, stretching, weight training on apparatus, passive mobilization of cervical spine when indicated); 1 hour per treatment, 2 times a week for a total of 10 treatments (N=12) (2) group exercises (weight training arms, muscle training abdomen & back, practicing correct breathing techniques); 30 minutes/session, 3 sessions/week for a period of 6 weeks (N=12)	Improvement in self-assessment of pain levels in 75% (1) and 17% (2) at the time of posttreatment measurement [difference 58% (95% CI 31–85)], improvement in pain of 50% (1) and 25% (2) after 6 months [difference 25% (95% CI 6–44)]
Levoska & Keinänen-Kiukaanniemi, 1993 (15)	RCT	47 female office workers with neck & shoulder symptoms; mean age 40 years	(1) active treatment group (stretching and dynamic muscle training of neck and shoulder regions), total of 15 visits, 60 minutes/visit, 3 visits/week (N=22) (2) passive treatment group (light stretching and physical exercising of the muscles of the neck & shoulder region, surface heat, massage), total of 15 visits, 60 minutes/visit, 3 visits/week (N=22)	No differences between the groups in patients with RSI for the occurrence of neck-shoulder pain as assessed by the reviewers after the treatment and at the 3-month follow-up; improvement in the occurrence of pain in 18% (1) and 14% (2) in the 1-year follow-up [difference 4% (95% CI -17–+26)]
Ferguson & Duncan, 1976 (14)	RCT with cross-over design; random block design	40 male patients with symptoms of incoordination & aching in one or both upper limbs, from large communication undertaking; age 20–60 years	(1) active exercises for affected hand & forearm combined with application of (subaquatic) ultrasound, 4 weeks (frequency and dosage schedule not presented) (N=28) (2) PNF to whole affected upper limb, preceded by ice pack to hand & forearm, 4 weeks (frequency & dosage schedule not presented) (N=28) (3) massage to affected hand, 4 weeks (frequency & dosage schedule not presented) (N=28)	Improvement in subjective symptoms in 46% (1), 36% (2) and 36% (3) from before to after the trial, but no significant differences between the groups [difference (1) versus (2) and (1) versus (3) 10% (95% CI -2–+24); no difference between (2) & (3)]
Rundcrantz et al, 1991 (16)	CCT, no randomization	18 female & 27 male official dentists with pain & discomfort in neck & shoulders; mean age 41 years	(1) physiotherapeutic treatment based on a psychosomatic approach (to reduce pain & discomfort) & ergonomic instruction; program & number of treatments varied (N=22) (2) ergonomic instruction only, one session during dentist's treatment of 1 or 2 patients (N=22)	No significant differences between (1) & (2) for neck or shoulder pain at the different times of measurement (0800, 1200, 1800) in the posttreatment measurement
Exercises				
Takala et al, 1994 (18)	RCT	45 women with frequent neck symptoms from a security printing company; age 20–55 years, median 43 years for (1) & 45 years for (2)	(1) group gymnastics during workhours, performed for 45 minutes, once a week for 10 weeks (whole body training, consisting of aerobic dynamic exercises, relaxation, muscle stretching) (N=22) (2) control group (not further specified) (N=22)	Overall handicap and interference with work showed a significantly greater reduction in (1) than in (2) after the treatment [c]
Waling et al, 2000 (19)	RCT	103 women reporting work-related neck-shoulder pain recruited on a voluntary basis; mean age 38.2 (range 22–45) years	(1) strength training (individualized & progressive overload on air-machines giving resistance in the concentric part of the movements); 1 hour/session, 3 sessions/week, for 10 weeks (N=29) (2) endurance training (individualized & progressive overload, arm cycling on an arm ergometer); 1 hour/session, 3 sessions/week, for 10 weeks (N=28) (3) coordination training (body awareness training aimed at a better understanding & awareness of the body regarding muscular tension & relaxation in movements); 1 hour/session, 3 sessions/week, for 10 weeks (N=25) (4) control group (studied & discussed stress management); 1 time/week for 2 hours, for a period of 10 weeks (N=21)	Significantly more improvement in current pain and pain at worst in (1), (2) and (3) taken together versus (4) after the treatment; significantly more improvement in pain at worst at the time of the posttreatment measurement in (1) versus (4) and in (2) versus (4); significantly more improvement in myalgia problems during employed work and during household activities in (1) than in (2)
Behavioral therapy				
Moore & Wiesner, 1996 (20)	RCT, with control group, randomization procedure using a list of random numbers	30 females & 2 males, referred from an occupational medicine department, who were diagnosed with upper extremity RSI (carpal tunnel syndrome, wrist tendinitis, de Quervain tenosynovitis or cervical myofascial dysfunction); mean age 35 years	(1) hypnotically induced vasodilatation treatment on an individual basis (basic relaxation & hypnosis techniques, biofeedback, autogenesis, self-hypnosis), 45 minutes/week for 6 weeks (N=15) (2) waiting-list control group (N=15)	Significantly more improvement in pain in (1) than in (2) after 6 weeks [difference 3.6 cm (95% CI 2.0–5.1]

(continued)

Table 2. Continued.

Type of treatment	Study design	Study population [a]	Intervention [b]	Reported results
Behavioral therapy *(continued)*				
Spence, 1989 & 1991 (21, 22)	RCT	44 females & 1 male with medical diagnosis of RSI in which pain condition was due to repetitive work, subjects replied to media publicity or were referred to study by their medical practitioners; no data on (mean) age available	(1) group format cognitive-behavior therapy (major components: goal-setting, cognitive restructuring, relaxation training, cognitive skills for coping with pain, etc); 1 time/week, 1.5 hours for 9 weeks (N=12) (2) individually conducted cognitive-behavior therapy (same components as in group therapy); 1 time/week, 1.5 hours for 9 weeks (N=13) (3) waiting-list control group; maximum of 10 weeks (N=14)	Significantly more improvement in symptoms [pain (McGill)] in (2) than in (3) after the treatment; significantly more improvement in degree of interference of pain in daily living in (2) than in (3) after the treatment; no differences between the groups in the 6-month follow-up; 2-year follow-up results of 19 subjects only showed no differences
Spence et al, 1995 (23)	RCT	40 females & 8 males with history of musculoskeletal pain problems in upper limbs, neck or shoulders in association with repetitive tasks in the workplace; subjects replied to media publicity; mean age 42 years	(1) applied relaxation training (participants were taught a range of relaxation techniques; method relied on subjective awareness of muscular tension and relaxation); 8 sessions of 1.5 hours for 4–6 weeks (N=11) (2) applied EMG biofeedback (auditory feedback concerning muscle tension levels from various sites, no instructions given regarding the relaxation techniques taught); 8 sessions of 1.5 hours for 4–6 weeks (N=12) (3) combined applied EMG biofeedback and relaxation training (auditory signal of biofeedback was available during relaxation practice and exposure to stressor tasks); 8 sessions of 1.5 hours for 4–6 weeks (N=11) (4) waiting-list control group (N=11)	No statistically significant differences found between groups for the measures of WHYMPI, self-monitored pain index or Pain Beliefs Questionnaire posttreatment or in the 6-month follow-up; no significant differences between the groups for interference of pain in daily living in the posttreatment measurement or in the 6-month follow-up
Swerissen et al, 1991 (24)	CCT, no randomization, no blinding	9 females & 3 males recruited by newspaper advertisement (all subjects employed in clerical, administrative or typing positions) with (work-related) injury of muscles, joints or connective tissues of the upper limbs, neck or upper back; mean age 42 years	(1) occupational overuse intervention program (group sessions, given by a clinical psychologist, consisting of movement-oriented relaxation training, muscle & task rotation strategies, training in efficient movement, etc), comprising 8 sessions of 1–1.5 hours over a period of 11 weeks (N=5) (2) waiting-list control group (N=7)	More improvement in number of daily-living activities disrupted by by pain in (1) than in (2) after the treatment and in the 6-month follow-up, but not to a significant extent [difference 10.5 (95% CI -5 – +26)] respectively [difference -4.5 (95% CI -19.9 – +10.9)]; number of daily living activities that subjects engaged in showed no significant differences between (1) and (2) after the treatment measurement [difference -5.3 (95% CI -13.2 – +2.6)] or at the time of the 6-month follow-up [difference -1.7 (95% CI -10.3 – +6.9)]
Energized splint				
Stralka et al, 1998 (27)	RCT, randomization procedure: odd & even number distribution	84 female & 36 male data-processors with symptoms of wrist and hand pain with no specific diagnosis	(1) appropriate-size wrist splint, incorporating energized, high voltage pulsed unit; 30-minute stimulation at worksite during 20 visits over a 35-day period (N=60) (2) identical splint with a nonenergized unit; 30 minutes, 20 visits, 35-day period (N=60)	No intergroup comparisons presented; no data extraction possible
Chiropractic treatment				
Leboeuf et al, 1987 (25)	RCT, no control group	35 females & 3 males with discomfort experienced in upper limb(s) due to repetitive strain or static load stress; subjects replied to a call for volunteers in a local paper; mean age 33 (range 18–63) years	(1) spinal manipulation therapy to hypomobile areas in cervical & thoracic spine, 2 times/week for 5 weeks (N=17) (2) spinal manipulation therapy combined with soft tissue therapy to tender & tight areas of neck, shoulder girdle & upper limbs, 2 times/week for 5 weeks (N=21)	Improvement in frequency of symptoms of 59% in (1) versus 81% in (2) at posttreatment measurement [difference 22% (95% CI -7 – + 51)]; improvement in stages of RSI of 41% (1) and 86% (2) at posttreatment measurement [difference 45% (95% CI 17 – 72)]

(continued)

Table 2. Continued.

Type of treatment	Study design	Study population [a]	Interventions [b]	Reported results
Ergonomic approach				
Tittiranonda et al, 1999 (29)	RCT, random permuted block method	44 females & 34 males diagnosed with possible carpal-tunnel syndrome or wrist or forearm tendonitis as determined by review of the workers' compensation injury and illness database; participants were full-time employed and used a computer keyboard 4 hours/day or 20 hours/week or more; mean age ranged from 40 to 45 years	(1) Apple adjustable keyboard (N=19) (2) Comfort keyboard system (N=11) (3) Microsoft natural keyboard (N=19) (4) placebo (participants' own keyboard was cleaned) (N=20) Participants were asked to use the assigned keyboards in their workplace for 6 months	Significantly more improvement in overall pain severity after 6 months in (3) than in (4); significantly more improvement in overall functional status in (3) than in (4) after 6 months
Rempel et al, 1999 (28)	RCT, no control group	13 females & 7 males who reported to the site occupational medicine clinic and met the criteria for possible carpal-tunnel syndrome; mean age 42 years	(1) keyboard A (Protouch keyboard, Key Tronic Corporation), keys gave greater feeling of looseness when resting fingers on keycaps than did keyboard B, keyboard had greater dampening when key hit bottom than keyboard B (N=10) (2) keyboard B (MacPro Plus keyboard with 2-ounce rubber domes, Key Tronic Corporation) (N=10)	Significantly more improvement in hand pain in (1) than in (2) after 12 weeks [difference 2.4 cm (95%CI 0.2–4.6)]
Multidisciplinary rehabilitation				
Feuerstein et al, 1993 (26)	CCT, no randomization	21 women & 13 men referred to an occupational rehabilitation center with upper-extremity disorders in association with repeated work-related exposure; mean age 37.9 years	(1) multidisciplinary work re-entry rehabilitation program (overall physical conditioning, work conditioning and simulation, pain and stress management ergonomic consultation), daily for 4–6 weeks (N=19) (2) usual care (provided by primary care physician) (N=15)	Return to work rates in 73.7% (1) & 40.0% (2) at an average of 17 (range 3–35) months after treatment for the treatment group, while controls were contacted an average of 18 (range 5–30) months after the evaluation [difference 34% (95% CI 17–50)]; among patients who returned to work, a significantly higher percentage returned to full-time employment, 91% in (1) versus 50% in (2) [difference of 41% (95% CI 19–63)]

[a] The number of patients randomized or included.
[b] The number of patients analyzed.
[c] Since the author of the study presented the cross-over design as two repeated trials, only the first intervention period is presented in this systematic review.

differences or standard deviations or confidence intervals were available. Otherwise (for most continuous outcomes), the differences between the groups have been presented as significant or nonsignificant ($P < 0.05$). It is indicated whether the intervention group was compared with a nontreatment group or to another active intervention group.

Physiotherapy. Four studies evaluating the effectiveness of physiotherapy were identified: two high-quality randomized controlled trials (15, 17), one low-quality randomized controlled trial (14), and one controlled clinical trial (16). Two studies compared exercise therapy (optionally combined with additional physiotherapeutic interventions) with any other type of physiotherapy [eg, massage, ergonomic instruction (14, 16)]. Neither study found significantly more improvement in symptoms in the exercise therapy groups than in the "other physiotherapy" group. There was moderate evidence (level 2) that exercise therapy and other forms of physiotherapeutic intervention are equally effective in providing symptom relief for patients with repetitive strain injury.

Two studies compared group exercises with individually conducted physiotherapeutic exercises (15, 17). One found significantly more improvement in the self-assessment of pain status with individual exercise therapy (17), but the other study (15) found no significant differences between the groups. Therefore, the evidence (level 3b) is conflicting as to whether individually conducted exercise therapy is more effective than group exercise therapy.

Exercises. The effect of exercise (gymnastics) was assessed in one high-quality randomized controlled trial (18) and in one low-quality randomized controlled trial (19). The first study reported significantly more improvement in activities of daily living in the exercise versus the control group at the time of the posttreatment measurement. The other study (19) reported significantly more improvement in "pain at present" and in "pain at worst" when all the exercise groups together were compared with the control group receiving stress management. Both studies reported that exercise had a positive effect. One of these studies was of low methodological

quality, and the other was of high quality. Therefore the evidence is limited that exercise relieves pain and also that exercise improves the daily functioning of patients with repetitive strain injury (level 3a).

One study (19) also reported on comparisons between exercise groups and found significantly more improvement in activities of daily living (both during employed work and during household duties) in the strength exercise group, as compared with the endurance group (limited evidence, level 3a).

Behavioral therapy. Four studies that implemented behavioral therapy were identified: three low-quality randomized controlled trials (20–23) and one controlled clinical trial (24).

Cognitive-behavioral treatment was one of the therapies tried. It is based on a multidimensional model of pain that includes physical, affective, cognitive, and behavioral components (30).

One study (21, 22) assessed the effect of cognitive-behavioral group therapy and individually conducted cognitive-behavioral therapy versus a waiting-list control group. No statistically significant posttreatment or follow-up differences were found for any outcome measure between the cognitive-behavioral therapy groups and the waiting-list controls. In addition, no significant differences were found between the cognitive-behavioral therapy groups and the individually conducted intervention group.

At posttreatment measurement, significantly more improvement in pain was reported in the individually conducted intervention group than in the waiting-list control group. However, of the two outcome measures of pain (McGill and pain-rating scales) reported in this study, only one (McGill Pain Questionnaire) showed statistically significant differences between the groups. For activities of daily living, this study also reported two outcome measures, interference in daily living caused by pain and the Sickness Impact Profile. Again, for only one measure (interference in daily living) was significantly more improvement reported for the individually conducted intervention group than for the waiting-list control group. No statistically significant differences were found in the 6-month follow-up measurements. Another study (24) evaluated an occupational overuse intervention program. The program combined cognitive-behavioral intervention strategies with specific movement-oriented relaxation training, muscle and task rotation techniques, and training in efficient movement. However, no differences in activities were found between the groups after the treatment or at the time of the 6-month follow-up.

Therefore, the evidence (level 3b) is conflicting for the effectiveness of cognitive-behavioral therapy for repetitive strain injury.

Respondent treatment is intended to modify the physiological response system directly, for example, by reducing muscle tension, and it includes providing the patient with a model of the relationship between tension and pain and teaching the patient to replace muscular tension by a tension-incompatible reaction. Electromyographic (EMG) biofeedback, progressive relaxation, and applied relaxation are frequently used (31). One study (23) examined the effectiveness of EMG biofeedback, applied relaxation training, and a combined procedure versus a waiting-list control condition. No statistically significant differences between one of the treatment groups and the waiting-list control group were found after the treatment or at the time of the 6-month follow-up with regard to pain (West Haven-Yale Multidimensional Pain Inventory, Pain Beliefs Questionnaire, self-monitored pain index) or activities of daily living (interference in daily living caused by pain). Another study compared a group receiving hypnotically induced vasodilatation treatment with a waiting-list control group (20) and reported significantly more reduction in pain in the intervention group after 6 weeks of treatment.

There is conflicting evidence (level 3b) that respondent treatment is more effective than a waiting-list control condition in relieving the pain symptoms of patients with repetitive strain injury. The evidence (level 3a) is limited that EMG biofeedback, applied relaxation training, a combined procedure, and a waiting-list control are equally effective in improving activities of daily living among patients with repetitive strain injury.

Energized wrist splint. In one low-quality randomized controlled trial the effect of an energized wrist splint was evaluated (27). Differences in outcomes between the intervention group and the placebo group were reported, but not statistically evaluated.

No evidence (level 4) therefore is available indicating that energized wrist splints are effective in treating repetitive strain injury.

Multidisciplinary rehabilitation. One low-quality controlled clinical trial (26) evaluated the effect of a multicomponent rehabilitation program that included physical conditioning, work conditioning, work-related pain and stress management, ergonomic consultation, and vocational counseling. The intervention group had significantly higher return-to-work rates than the "usual care" group. For patients who returned to work, a significantly higher percentage of the treatment group than of the "usual care" group returned to full-time employment (instead of part-time employment).

Therefore, evidence (level 3a) is limited showing that, for patients with repetitive strain injury, a multi-

component rehabilitation program is more effective in return to work than "usual care" is.

Chiropractic treatment. One low-quality randomized controlled trial evaluated the effect of spinal manipulative therapy, combined with soft-tissue therapy in comparison with spinal manipulative therapy only (25). Significantly more improvement in the frequency of symptoms and improvement in the stages of repetitive strain injury was found in the combined therapy group, and, therefore, the evidence was limited (level 3a) that spinal manipulative therapy combined with soft tissue therapy is more effective than spinal manipulation therapy only in providing short-term symptom relief for patients with repetitive strain injury.

Ergonomic approach. Two high-quality randomized controlled trials that evaluated different ergonomic intervention strategies were identified (28, 29). The first (28) described two keyboards with different force-displacement characteristics. Significantly more improvement in pain was found in the group using keyboard A versus the group using keyboard B. Keyboard A was, among other things, associated with a greater feeling of looseness of the keys when the subjects' fingers rested on the keycaps. In the activities of daily living (hand functional status), no significant differences between the groups were found. This result indicates limited evidence (level 3a) that force-displacement characteristics of keyboard keys can provide symptom relief for patients with repetitive strain injury. The other study (29) evaluated the effects of three alternative geometry keyboards in comparison with a regular keyboard. Only one type of keyboard (Natural Keyboard) showed significantly more improvement than the regular keyboard in both activities of daily living and pain. There is therefore limited evidence (level 3a) that the use of the Natural Keyboard is more effective than a regular keyboard in improving symptoms or activities of daily living.

Sensitivity analysis

Changing the cutoff point of the quality score to ≥ 5 and to ≥ 7 positive internal validity criteria resulted in 5 and 3 high-quality studies, respectively (table 1). However, there were no changes in the strength of the evidence.

Discussion

Study selection

To enhance the validity of this systematic review, an attempt was made to cover the whole range of conservative treatment options for repetitive strain injury as comprehensively as possible. Due to the fact that there is no universal unambiguous definition of repetitive strain injury, some difficulties were expected in identifying all the studies on work-related disorders of the upper extremities and neck. An attempt was made to overcome this difficulty by using all the keywords used in relevant articles concerning repetitive strain injury and by searching various databases (Medline, Embase, Cochrane Controlled Trials Register). The references of all the identified studies were also screened. This procedure resulted in approximately 1000 references to studies, of which only 15 met the inclusion criteria. Despite the extensive search strategy used to identify all relevant studies on the effectiveness of nonsurgical therapy for repetitive strain injury, some studies may have been missed because they were indexed in other databases or published in nonindexed journals.

Although the search included studies published in English, German, Dutch, French, and Finnish, only studies published in English were identified and included in the current review. This approach may have led to publication bias, since studies with significant results are more likely to be published in English (32).

Methodological quality

According to the criteria applied, the methodological quality of the included studies on nonsurgical therapy for repetitive strain injury appeared to be disappointingly low. That was one of the reasons why the evidence of the efficacy of the various treatments was mostly limited. Only 5 studies were considered to be high-quality trials. Studies with lower methodological quality are more likely to be associated with biased findings. The quality of most studies could have been improved if a more-specific description had been given of compliance (g), avoidance or comparability of co-interventions (f), and the (reporting of) concealment of treatment allocation (b2). Blinding of patients (h), care-providers (e), and outcome assessors (i) also formed criteria that were often not met. Since the blinding of care-providers and patients is often very difficult and may have been impossible in some studies in this review (eg, in trials evaluating the effect of physiotherapy, exercise, or behavioral therapy options), it is even more essential to have blinded outcome assessments in trials evaluating these types of treatment.

Efficacy

To date, 12 randomized controlled trials and 3 nonrandomized clinical trials have been performed to evaluate the efficacy of nonsurgical therapies for repetitive strain injury. Because of the generally low methodological

quality of the studies and the heterogeneity of the study populations, outcome measures, and interventions, it was decided not to perform a formal meta-analysis with statistical pooling of the data. Instead, a "best-evidence synthesis" was conducted, taking into account the number, the quality, and the outcome of the studies. No consensus has yet been reached on how to assess the strength of the available evidence, and therefore the levels of evidence used in this review are, to some extent, arbitrary. It was decided to apply this rating system because it has good face validity, it is simple and explicit, and it had already been applied in several reviews on the effectiveness of conservative treatment options for low-back pain (33, 34).

In seven studies the intervention groups were compared with nontreatment control groups (18, 19), waiting-list control groups (20–24), or a kind of placebo intervention group (27, 29). Seven of the 15 tested interventions showed a significant difference in efficacy on at least one outcome measure in a comparison with a control group. In 8 studies, 15 active treatments were compared (14–17, 25, 28, 29). Four intervention trials showed relative efficacy, compared with that of other interventions. However, it remains questionable whether the other interventions were effective indeed.

When the strength of the available evidence for the efficacy of the various nonsurgical treatment options in providing symptom relief and improvement in activities of daily living is summarized, there is no strong evidence for the efficacy of any of the forms of intervention used. This result seems disappointing since many of the interventions are commonly used in daily practice. However, the conclusion that there is no strong evidence of effectiveness does not imply that there is strong evidence that there is no effect. There is definitely a need for higher quality trials with sufficiently large sample sizes that meet the internal validity criteria outlined in this review. Furthermore, future trials should evaluate the effectiveness of interventions for repetitive strain injury using valid, reliable and responsive outcome measures. In this review, it was striking that many studies included a substantial number of different outcome measures. Conceivably, this approach would increase the chance that one of the outcome measures would have a positive outcome by chance. As a consequence, authors should consider including fewer outcome measures. Furthermore, the hierarchy of the outcome measures should be carefully (definition of primary outcomes) considered, and a way must be found to combine multiple end points before data are analyzed (35).

Many studies reported on within-group comparisons. To exclude improvement due to placebo effects or to the natural course of events, it is essential to perform and report between-group comparisons, preferably comparisons between an experimental and a control group.

Presentation of statistical analyses

In some studies the outcomes were not presented consistently in the results section. There was a tendency towards the nonpresentation of insignificant results. Another prevalent shortcoming was that many studies did not present summary data and statistics in sufficient detail. The CONSORT Statement might be of great value in improving the quality of reports on randomized controlled trials (36).

Concluding remarks

In conclusion, little is known about the effectiveness of conservative treatment options for repetitive strain injury. As most studies were of poor methodological quality and did not meet the current standards for the conducting and reporting of randomized controlled trials (36), there certainly is an urgent need for high-quality trials. The development and application of a "gold standard" for the clinical diagnosis of repetitive strain injury could provide more comparable and generalizable results.

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Appendix 1

Criteria list for assessing the methodological quality of randomized controlled trials and controlled clinical trials evaluating the efficacy of conservative treatment options for repetitive strain injury

Patient selection

a Were the eligibility criteria sufficiently specified?
b_1 Was an adequate method of randomization performed?
b_2 Was the treatment allocation concealed?
c Were the groups similar at baseline regarding the most important prognostic indicators?

Intervention

d_1 Was the index intervention explicitly described?
d_2 Was(were) the control intervention(s) explicitly described?
e Was the care-provider blinded to the intervention?
f Were co-interventions avoided or comparable?
g Was the compliance acceptable in all the intervention groups?
h Was the patient blinded to the intervention?

Outcome measurement

i Was the outcome assessor blinded to the intervention?
j Were relevant outcome measures used and presented?
k Were adverse effects adequately described?
l_1 Was the dropout rate acceptable for the posttreatment measurement?
l_2 Was the lost-to-follow-up rate acceptable?
m_1 Was a posttreatment measurement performed?
m_2 Was a follow-up measurement performed?
n Was the timing of the outcome assessments similar in all the groups?

Statistics

o Was the sample size for each group adequate?
p Did the analysis include an intention-to-treat analysis?
q Were point estimates and measures of variability or numbers of people presented for the primary outcome measures?