ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2021;000: 1−18

REVIEW ARTICLE (META-ANALYSIS)

Local Heat Applications as a Treatment of Physical and Functional Parameters in Acute and Chronic Musculoskeletal Disorders or Pain

Ron Clijsen, PhD,[a,b,c,d] Rahel Stoop, MSc,[a] Erich Hohenauer, PhD,[a,b,e] Dirk Aerenhouts, PhD,[c] Peter Clarys, PhD,[c] Carlina Deflorin, MSc,[a] Jan Taeymans, PhD[d]

From the [a]Rehabilitation Research Laboratory 2rLab, Rehabilitation and Exercise Science Group, Department of Business Economics, Health, and Social Care, University of Applied Sciences and Arts of Southern Switzerland, Landquart/Manno, Switzerland; [b]International University of Applied Sciences THIM, Landquart, Switzerland; [c]Faculty of Physical Education and Physiotherapy, Department of Movement and Sport Sciences, Vrije Universiteit Brussel, Brussels, Belgium; [d]Department of Health, Bern University of Applied Sciences, Berne, Switzerland; and [e]School of Sport, Health, and Exercise Science, University of Portsmouth, Portsmouth, United Kingdom.

Abstract

Objectives: The aim of this systematic review and meta-analysis was to evaluate the effectiveness of local heat applications (LHAs) in individuals with acute or chronic musculoskeletal disorders.

Data Sources: An electronic search was conducted on MEDLINE, Cochrane Controlled Register of Trials, Current Nursing and Allied Health Literature, and the Physiotherapy Evidence databases up to December 2019.

Study Selection: Studies incorporating adults with any kind of musculoskeletal issues treated by LHA compared with any treatment other than heat were included.

Data Extraction: Two authors independently performed the methodological quality assessment using the Cochrane Risk of Bias tool.

Data Synthesis: LHA showed beneficial immediate effects to reduce pain vs no treatment ($P<.001$), standard therapy ($P=.020$), pharmacologic therapy ($P<.001$), and placebo/sham ($P=.044$). Physical function was restored after LHA compared with no treatment ($P=.025$) and standard therapy ($P=.006$), whereas disability improved directly after LHA compared with pharmacologic therapy ($P=.003$) and placebo/sham ($P<.028$). Quality of life was improved directly after LHA treatment compared with exercise therapy ($P<.021$). Range of motion increased and stiffness decreased after LHA treatment compared with pharmacologic therapy ($P=.009$, $P<.001$) and placebo/sham ($P<.001$, $P=.023$). The immediate superior effects of LHA on muscular strength could be observed compared with no treatment ($P<.001$), cold ($P<.001$), and placebo/sham ($P=.023$).

Conclusions: Individuals with acute musculoskeletal disorders might benefit from using LHA as an adjunct therapy. However, the studies included in this meta-analysis demonstrated a high heterogeneity and mostly an unclear risk of bias.

Archives of Physical Medicine and Rehabilitation 2021;000:1−18

Musculoskeletal disorders impair physical function and often lead to pain. Those symptoms also appear in healthy individuals or rehabilitation patients after exhaustive or uncommon muscle activity. These activities may cause exercise-induced muscle damage[1] resulting in delayed-onset muscle soreness (DOMS).[2,3] Musculoskeletal pain is often treated with local heat applications (LHAs) in clinical settings or as self-management at home.[4-6]

Superficial LHAs are inexpensive, bearing no negative effects when used correctly. The physiological effects of LHA include increased skin temperature,[7-10] increased intraarticular temperature,[8] increased muscle temperature,[9] and vasodilation,[11] influencing tissue healing through an increased oxygen uptake and faster catalyzed biochemical reactions.[12,13] These physiological changes alter metabolism and elasticity of connective tissue,[13,14] reduce muscle tension, and lead to increased range of motion (ROM).[15,16] Therefore, LHAs have the potential to improve treatment outcomes such as pain, strength, stiffness, ROM, and quality of life

Supported by the Thim van der Laan Foundation.
Disclosures: none

0003-9993/$36 - see front matter © 2021 The Authors. Published by Elsevier Inc. on behalf of The American Congress of Rehabilitation Medicine. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)
https://doi.org/10.1016/j.apmr.2021.06.015

(QOL) in acute and chronic musculoskeletal conditions. However, to date, the use of LHA has not been evaluated using a meta-analysis approach.

Although some studies describe the beneficial effects of LHAs in the treatment of musculoskeletal disorders, there is limited overall evidence to support the use of topical heat in general.[13] Therefore, the aim of this review and meta-analysis was to assess the effects of LHA on pain, muscular strength, ROM, stiffness, physical function, QOL, and disability in individuals with any type of musculoskeletal disorders compared with any treatment other than heat (1) immediately after the intervention (pre to post) and (2) in the follow-up period up to 1 month.

Methods

This work is registered (CRD42019133197) in the International Prospective Register of Systematic Reviews (PROSPERO).

Search strategy and inclusion criteria

A systematic literature search was performed in Medical Literature Analysis and Retrieval System Online (PubMed/MEDLINE), Cochrane Controlled Register of Trials, Current Nursing and Allied Health Literature, and Physiotherapy Evidence databases from the earliest available record to December 2019. Search terms were combined using the Boolean operators "AND"/ "OR" (table 1), and search algorithms were adapted for the different databases. The filters "language" (Dutch, English, French, German, Italian, Spanish) and "human" were used. Reference lists of the selected articles were screened for related articles.

Inclusion criteria served as Population, Intervention, Comparator, Outcomes, and Study Designs scheme and were set a priori according the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement[17]: (1) Participant: individuals aged ≥18 years with any kind of musculoskeletal disorders and/or musculoskeletal pain (including DOMS); (2) Intervention: any type of superficial LHA (eg, wraps); (3) Comparator: no treatment, cold therapy, exercise therapy, standard treatment (eg, information, relaxation), pharmacologic therapy, placebo/sham therapy; (4) Outcomes: pain, physical function, disability, muscular strength, QOL, ROM, or stiffness; and (5) Study design: randomized controlled trials and clinical controlled trials. Studies on patients with tumors, topical (eg, ointments), whole or multiple body (eg, balneotherapy), or radiative heat applications (eg, infrared), and deep-heat methods[16] (eg, diathermy) were excluded. For the purpose of this review, physical function was defined as "patient-reported measures of functional limitations of daily living and activities,"[18] and the term disability was defined as "patient-reported measures of impairment and handicap."[19]

List of abbreviations:

CI	**confidence interval**
DOMS	**delayed-onset muscle soreness**
LHA	**local heat application**
MD	**mean difference**
QOL	**quality of life**
RoB	**risk of bias**
ROM	**range of motion**
SMD	**standardized mean difference**

The searching and selection processes started by screening the retrieved articles based on the title and abstract by 2 independent researchers (R.S., E.H.). The full texts of the selected articles were read independently (R.S., C.D.). In case of disagreement, a third researcher was asked (R.C.) for consensus.

Data extraction and measures of treatment effect

A customized data sheet was used for data extraction. Two independent researchers (R.S., R.C.) performed the data extraction, with a third reviewer (J.T.) consulted in case of disagreement. Musculoskeletal disorders of the studies' populations were classified into acute or chronic as described by the studies. In dubiety, the definition by Treede et al 2015 was followed.[20] Immediate pre- to postintervention and follow-up results measured after 48 hours, 72 hours, and up to 1 month between LHA and control treatment of the outcome variables were extracted. Mean and SD were extracted or calculated if adequate variability measures were presented. Reported interquartile ranges were transformed into SD.[21] Whenever central tendencies and variations were not reported numerically, data were extracted manually from figures.

Methodological quality of the included studies

All included studies were rated using the Cochrane Risk of Bias (RoB) tool.[22] Each domain was graded as "low" (+) if RoB was low, as "high" (−) if RoB was high, and as "unclear" (?) if data were insufficient to state a clear rating. All ratings were independently performed by 2 reviewers (R.S., D.A.). In case of disagreement, a third reviewer (R.C.) was asked for consensus.

Data analysis

The meta-analysis calculations and preparation of the forest plots were conducted using the Comprehensive Meta-Analysis software.[a] A random-effects model was used to account for the heterogeneous nature of the included studies. Weighting factors were calculated based on the DerSimonian and Laird inversed-variance method.[23] Standardized mean difference (SMD) was calculated to describe the individual studies' effect size (ES). The corresponding 95% confidence intervals (CIs) around individual studies' ES and around the overall weighted mean ES estimate were calculated. Results are graphically presented as forest plots. ES interpretation was performed following Cohen's benchmarking: SMD<0.20 (negligible effect), SMD between 0.20-0.49 (small effect), SMD between 0.50-0.79 (moderate effect), and SMD≥0.80 (large effect).[24]

Cochran Q test was applied to test the null hypothesis of no heterogeneity (ie, that all studies have a common ES). The Q value, the corresponding degrees of freedom, and the corresponding exact P value were reported. Higgins' I^2 value was computed to interpret the amount of the total observed variance that can be explained by the true between studies variance (rather than random sampling error). For the interpretation of the observed between-studies heterogeneity, Higgins' benchmarking values were followed: I^2 around 25% (low), I^2 around 50% (moderate), and I^2 around 75% or more (high).[25]

If adequate, subgroup analysis was performed to specify the effects of LHA on patients with acute and chronic musculoskeletal disorders. Further, a subgroup analysis was also performed to examine the ES extracted from studies on individuals without musculoskeletal disorders (with DOMS) with ES from studies

Table 1 Overview on search terms and combinations

1. Term		2. Term		3. Term		4. Term
Local	AND	Heating*	AND	Application	AND	Musculoskeletal pain*
OR		OR		OR		OR
Partial body		Hyperthermia, induced*		Treatment		Musculoskeletal diseases*
OR		OR		OR		OR
Superficial		Thermal		Physical therapy modalities*		Cardiovascular diseases*
		OR				OR
		Thermotherapy				Nervous system diseases*
		OR				OR
		Temperature*				Psychophysiological disorders*
						OR
						Athletic performance*
						OR
						Muscle damage
						OR
						Delayed onset of muscle soreness
						OR
						Muscle fatigue*
						OR
						Hypertrophy
						OR
						Inflammation*
						OR
						Recovery of function*
						OR
						Regeneration*
						OR
						Muscle soreness*
						OR
						Rehabilitation*
						OR
						Atrophy*

* Medical Subject Headings of the National Library of Medicine—proven.

investigating individuals with a musculoskeletal disorder (eg, knee osteoarthritis). Whenever 2 or more studies per outcome parameter was available, a subgroup follow up analysis on acute and chronic conditions was performed for 48 hours,72 hours, and 1 month after the last treatment in an attempt to explain the observed heterogeneity. Subgroup analyses were conducted assuming a common variance, because of the low numbers of studies within the subgroups. Thus, T^2 was pooled and used as the common (more accurate) between-studies variance across all subgroups.[26]

Sensitivity analysis was conducted to test the robustness of the overall weighted mean ES against extreme individual studies' ES by excluding the corresponding study or studies from the meta-analysis. In this event, results were mentioned before and after the sensitivity analysis.

Results

Included studies and methodological quality

In this systematic review and meta-analysis, a total of n=25 studies fulfilled the a priori set inclusion criteria. From the total of N=1352 participants, n=849 were in the LHA group and n=803 were in the control group. Figure 1 displays the search and selection process.

Six studies[27-32] presented multiarm analyses (31 direct head-to-head comparisons). Eight studies[29,33-39] investigated individuals with acute conditions (neck or back pain), and 6 studies[31,40-44] focused on individuals without musculoskeletal disorders experiencing DOMS. Chronic conditions comprised individuals with osteoarthritis in 6 studies,[27,28,30,45-47] nonspecific neck or back pain in 3 studies,[32,44,48] and 1 study each for fibromyalgia[49] and frozen shoulder.[50]

In the meta-analyses the effects of LHA were compared with other treatment modalities. In the comparison LHA vs no treatment, 9 studies[27,28,31,34,41,42,44,45,48] reported the effect on pain, 5 were studies on DOMS,[31,34,41,42,44] 4 were studies on physical function,[27,28,45,48] 2 were studies on muscular strength,[42,44] and 2 studies each investigated the effects on QOL[27,28] and ROM on joint stiffness.[28,45] In the comparison LHA vs cold application, 6 studies[27,28,31,33,40,43] reported on pain and 2 studies reported on QOL.[27,28] The analysis LHA vs exercise evaluated 3 studies each on the effect on pain[29,32,47] and physical function[29,32,47] and 2 studies each on disability[29,32] and QOL.[32,47] The effects of LHA vs standard care was evaluated in 6 studies on pain relief,[29,32,38,39,49,51] in 5 studies[29,32,39,49,51] on restoring physical function, and in 2 studies on disability.[29,32] In the comparison LHA vs pharmacologic therapy, 2 studies each investigated the

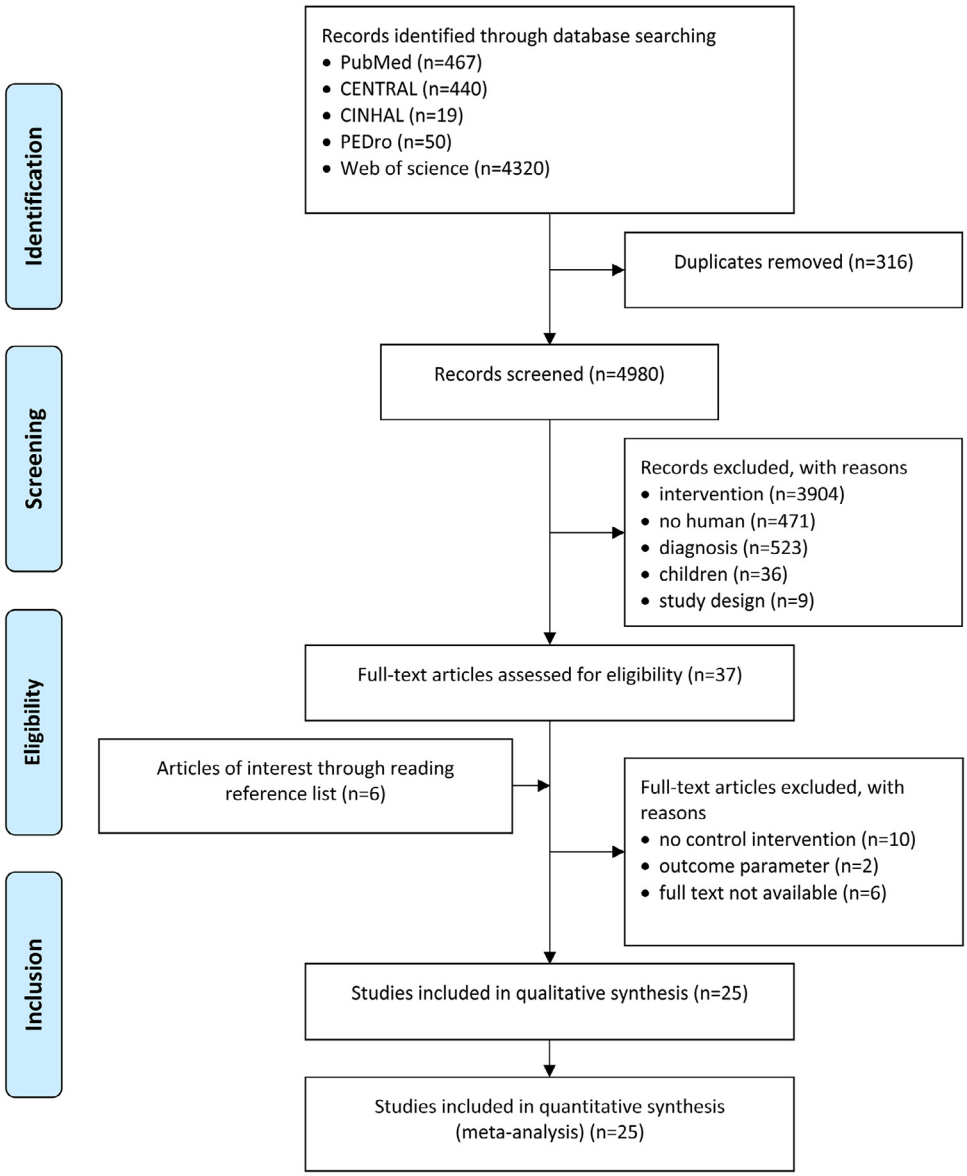

Fig 1 Flowchart of study selection process. CENTRAL, Cochrane Controlled Register of Trials; CINAHL, Cumulative Index to Nursing and Allied Health; PEDro, Physiotherapy Evidence Database.

outcomes on parameter pain,[35,46] disability,[35,46] and stiffness.[35,46] In the analysis LHA vs placebo or sham therapy, 3 studies (4 comparisons) reported the effect on pain relief,[30,36,37] 3 studies (4 comparisons) reported on disability, 1 study (2 comparisons) reported on muscular strength,[30] 2 studies reported on ROM,[36,37] and 3 studies (4 comparisons) reported on stiffness.

Table 2 depicts detailed information on the included studies.

The RoB analysis (fig 2, fig 3) indicated a low (14/25 studies) and unclear selection bias (11/25 studies) for random sequence generation. Insufficient data reporting led to an unclear RoB for allocation concealment (19/25 studies). The difficulties of blinding in LHA studies are reflected in the high risk of performance (17/25 studies) and detection bias (14/25 studies). Similarly, insufficient data reporting induced an unclear risk of detection bias (11/25 studies). Most of the included studies had a low risk of attrition bias (21/25 studies). Reporting and other bias were rated in all studies as unclear on account of data reporting or lack of published study protocols.

Figure 3 displays the classified RoB of all analyzed studies separately.

LHA vs no treatment

Pain and DOMS

The effect of LHA vs no treatment on pain revealed an overall, large effect favoring LHA (SMD=−0.802 [95% CI, −1.0 to −0.5]) with a high and significant heterogeneity (Q_8=36.4; P<.001; I^2=78.0%) (fig 4). The sensitivity analysis, excluding 1 outlier[44] (demonstrate an extremely high ES in favor of LHA) (see fig 4), showed that LHA remained significant compared with no treatment to decrease pain (SMD=−0.664 [95% CI, −0.9 to −0.3]).

The immediate effects of LHA compared with no treatment on DOMS[31,34,41,42,44] favored LHA treatments (SMD=−1.474 [95% CI, −2.6 to −0.3]). The single study[34] that examined low back

Table 2 Overview on studies' characteristics

Author Study Type Comparison	Diagnosis (Acute, Chronic) Total Sample Size (Sex, Age [y])	Intervention Duration No. of Participants (Sex, Age [y])	Control Intervention Duration No. of Participants (Sex, Age [y])	Outcome Variables Assessments Used (Follow-up Periods)
Aciksoz et al[26] RCT Heat vs cold treatment Heat vs no treatment	Primary knee OA (chronic) N=96	Hot application (°C NM) 20 min 2 × /d for 3 wk n=32 (M: 5, F: 27) (age 61.56±7.94)	Cold application (°C NM) 20 min 2 × /d for 3 wk n=32 (M: 6, F: 26) (age 64.31±8.37) No treatment n=32 (M: 7, F: 25) (age 63.50±9.12)	Disability: WOMAC (FU 1mo) Pain: VAS (FU 1mo) QOL: NHP (no FU) Stiffness: WOMAC (no FU)
Denegar et al[25] RCT crossover Hot vs cold treatment Hot vs no treatment	Knee OA (chronic) N=34 (M: 11) (age 54.6±19.91) (F: 23) (age 64.87±10.67)	Hot water, hot pad (°C NM) 20 min 2 × /d for 5 d	Cold water (°C NM) 20 min 2 × /d for 5 d No treatment (comfortable sitting) 20 min/d for 5 d	Pain: VAS (no FU) PFU: KOOS (no FU) QOL: KOOS (no FU)
Fioravanti et al[45] RCT Heat vs exercise therapy	Primary knee OA (chronic) N=60	Mud pack (43°C) and bath tub (38°C) 35 min for 12 d Analgesic drugs 500 mg and NSAIDs 1120 mg/d for 12 d n=30 (M: 2, F: 28) (age 72.48±8.26)	Standard exercises Analgesic drugs 500 mg and NSAIDs 1120 mg/d for 12 d n=30 (M: 6, F: 24) (age 69.23±9.91)	Disability: FIHOA (no FU) Pain: VAS (no FU) QOL: SF-36 mental component (no FU)
Garra et al[31] RCT Heat vs cold treatment	Neck or back pain (acute) N=60	Heating pad (mean skin temperature 55.5°C) 30 min 400 mg ibuprofen orally n=31 (M: 15, F: 16) (age 38±15)	Cold pad (mean skin temperature 1.83°C) 30 min 400 mg ibuprofen orally n=29 (M: 18, F: 11) (age 36±11)	Pain: VAS (no FU)
Giannitti et al[43] RCT Heat vs no treatment	Knee OA (chronic) N=32	Mud pack (42°C), bath tub (37°C) 35 min/d for 2 wk 12 applications in total Standard treatment (exercise, symptomatic drugs, SYSADOA, intra-articular hyaluronic acid) n=21 (M: 10, F: 11) (age 69.36±11.29)	Standard treatment (exercise, symptomatic drugs, SYSADOA, intra-articular hyaluronic acid) n=11 (M: 5, F: 6) (age 69.52±7.17)	Pain: VAS (no FU) PFU: WOMAC (FU 48h) Stiffness: WOMAC (no FU)

(*continued on next page*)

Table 2 (*Continued*)

Author Study Type Comparison	Diagnosis (Acute, Chronic) Total Sample Size (Sex, Age [y])	Intervention Duration No. of Participants (Sex, Age [y])	Control Intervention Duration No. of Participants (Sex, Age [y])	Outcome Variables Assessments Used (Follow-up Periods)
Kettenmann et al[32] RCT Heat vs no treatment	Low back pain (acute) N=30	Heat wrap (40˚C) 4-8h/d for 4 d NSAIDs if needed n=15 (M: 7, F: 8) (age 56.2±14.9)	NSAIDs if needed n=15 (M: 3, F: 12) (age 57.9±11.7)	Pain: VAS (no FU)
Lauche et al[30] RCT Heat vs exercise therapy Heat vs relaxation	Nonspecific neck pain (chronic) N=63 (M/F: NM) (age NM)	Grain-filled heated pillow 15-20 min, relaxing music 1 × /wk for 5 wk n=19	Alexander Technique 45 min 1 × /wk for 5 wk n=21 Guided imagery 45 min 1 × /wk for 5 wk n=24	Disability: Neck disability Index (no FU) Pain: VAS (no FU) PFU: SF-36 (FU 48h) QOL: SF-36 mental component (no FU)
Leung et al[48] RCT Heat vs no treatment	Frozen shoulder (chronic) N=20	Hot pack (63˚C) 3 × /wk for 4 wk followed by 4 stretching exercises for 30 s n=10 (M: 2, F: 8) (age 62.5±12.13)	4 stretching exercises of each 30 s 3 × /wk for 4 wk n=10 (M: 2, F: 8) (age 57.3±13.10)	ROM: shoulder index (no FU)
Lewis et al[46] Crossover Heat vs no treatment	Low back pain (chronic) N=15 (M: 6, F: 9) (age 47.6±8.3)	Heat wrap (40˚C) 8 h Analgesics if needed	No treatment Analgesics if needed	Disability: RMQ (FU 48h) Pain: NRS (no FU) PFU: Likert scale (no FU) Anxiety: HADS (no FU)
Löfgren and Norrbrink[47] Crossover Heat vs standard treatment	Fibromyalgia (chronic) N=57 (F: 57) (age 41±8.3)	Thermal stimulator (40˚C) 45-120 min/d for 3 wk n=28	TENS 45-120 min/d for 3 wk n=29	Pain: NRS (no FU) PFU: subscore FIQ (no FU) Stiffness: subscore FIQ (no FU) Anxiety: subscore FIQ (no FU)
Mayer et al[27] RCT Heat vs exercise therapy Heat vs standard treatment	Low back pain (acute) N=67 (M/F: NM) (age NM)	Heat wrap (40˚C) 8 h/d for 5 d n=22	Full ROM flexion and extension exercises 3 × 1-2 sets of 15-20 reps under supervision plus daily at home 1 × /h when awake for 5 d n=24 Acute low back pain guide booklet n=21	Disability: RMQ (FU 48h) Pain: VAS (FU 48h) PFU: rating of perceived capacity (FU 48h)
Mayer et al[38] RCT Heat vs cold treatment	DOMS (acute) induced by 2 sets of 25 reps at 100% peak isometric lumbar extension strength, 2-min rest between sets N=32	Heat wrap (40˚C) 2 × 8 h between 18-42 h post exercise n=16 (M: 7, F: 9) (age 25.5±7.2)	Gel-filled cold pack (˚C NM) 15-20 min every 4 h between 18-42 hours post exercise n=16 (M: 7, F: 9) (age 24.3±6.0)	Pain: VAS (FU 48h)

(*continued on next page*)

Table 2 (*Continued*)

Author Study Type Comparison	Diagnosis (Acute, Chronic) Total Sample Size (Sex, Age [y])	Intervention Duration No. of Participants (Sex, Age [y])	Control Intervention Duration No. of Participants (Sex, Age [y])	Outcome Variables Assessments Used (Follow-up Periods)
Michlovitz et al[28] RCT Heat vs placebo medication	Wrist pain (chronic): hand OA, tendinosis, strain, and sprains N=56 Carpal tunnel syndrome N=24	Heat wrap (40˚C) 8 h for 3 d	Oral placebo medication 2 tables, 4 × /d	Disability: patient rated wrist evaluation (no FU) Pain: NRS (FU 48h) Stiffness: NRS (FU 48h) Grip strength: dynamometry (FU 48h)
Nadler et al[33] RCT Heat vs drug therapy	Low back pain (acute) N=213 (M/F: NM) (age 18-55)	Heat wrap (40˚C) 8 h for 2 d n=111	Oral ibuprofen 1200 mg/d for 2 d n=102	Disability: RMQ (FU 48h) Pain: NRS (FU 48h) Stiffness: numeric rating scale (FU 48h) ROM: distance to floor (no FU)
Nadler et al[34] RCT Heat vs placebo medication	Nonspecific low back pain (acute) N=180 (M/F: NM) (age NM)	Heat wrap (40˚C) 8 h for 3 d n=92	Oral placebo medication 2 tablets, 3 × /d n=88	Disability: RMQ (FU 48h) Pain: NRS (FU 48h) Stiffness: numeric rating scale (FU 48h) ROM: distance to floor (no FU)
Nadler et al[35] RCT Heat vs placebo medication	Nonspecific low back pain (acute) N=63 (M/F: NM) (age NM)	Heat wrap (40˚C) 8 h for 3 nights n=31	Oral placebo medication 2 tablets n=32	Disability: RMQ (FU 48h) Pain: NRS (FU 48h) Stiffness: numeric rating scale (FU 48h) ROM: distance to floor (no FU)
Nuhr et al[36] RCT Heat vs standard treatment	Low back pain (acute) N=90 (M/F: NM) (age NM)	Heated blanket (42˚C) 24.8±8.1 min n=47	Woolen blanket (˚C NM) 26.2±9.3 min n=43	Anxiety: NRS (no FU) Pain: VAS (no FU)
Petrofsky et al[39] CCT Heat vs no treatment	DOMS (acute) induced by 4 sets of 25 biceps curls against resistance until failure N=10 (M/F: NM)	Heat wrap (40˚C) 8 h n=5 (age 25.80±3.11)	No treatment n=5 (age 16.51±13.32)	Pain: VAS (FU 48h, 72h)
Petrofsky et al[40] RCT Heat vs no treatment	DOMS (acute) induced by 3 sets of 5-min squats at 90˚ or below with 3-min rest between each set N=40 (M/F: NM)	Heat wrap (40˚C) 8 h n=20 (age 25.3±3.0)	No treatment n=20 (age 26.1±2.6)	Pain: VAS (FU 48h, 72h) Strength: MVIC (FU 48h)

(*continued on next page*)

Table 2 (*Continued*)

Author Study Type Comparison	Diagnosis (Acute, Chronic) Total Sample Size (Sex, Age [y])	Intervention Duration No. of Participants (Sex, Age [y])	Control Intervention Duration No. of Participants (Sex, Age [y])	Outcome Variables Assessments Used (Follow-up Periods)
Petrofsky et al[41] RCT Heat vs cold treatment	DOMS (acute) induced by 3 sets of 5-min squats at 110° hip bent with a 3-min rest between each set N=40	Heat wrap (40°C) 20 min n=20 (M: 10, F: 10) (age 26.1±2.6)	Cold wrap (°C NM) 20 min n=20 (M: 10, F: 10) (age 25.5±2.7)	Pain: VAS (FU 48h, 72h) Strength: MVIC (FU 48h)
Petrofsky et al[42] RCT Heat vs no treatment	DOMS (acute) induced by 3 sets of 5-min squats at 110° hip bent with a 3-min rest between each set N=40 (M/F: NM)	Heat wrap (40°C) 8 h n=20 (age 26±2.6)	No treatment n=20 (age 25.3±3.0)	Pain: VAS (FU 48h, 72h) ROM: goniometer (no FU) Strength: MVIC (FU 48h)
Petrofsky et al[50] RCT Heat vs standard treatment	Nonspecific neck pain (chronic) N=37	Heat wrap (40°C) 6 h n=26 (M: 8, F: 18) (age 52.8±13.5)	Standard therapy n=11 (M: 3, F: 8) (age 52.6±18.3)	Disability: NDI (no FU) Pain: VAS (no FU)
Sumida et al[29] RCT Heat vs cold treatment Heat vs no treatment	DOMS (acute) induced by eccentric elbow flexion at a rate of 30°/s, range 110° to 10°, 2 sets of 35 reps, 5-min rest between sets N=53 (age NM)	Hot gel pack (43.3°C) 20 min n=17 (M: 7, F: 10)	Cold gel pack (1.7°C) 20 min n=18 (M: 9, F: 9) No treatment n=18 (M: 4, F: 14)	Pain: VAS (no FU)
Tao et al[37] RCT Heat vs standard treatment	Low back pain (acute) N=43 (M/F: NM)	Heat wrap (40°C) 8 h/d for 3 d n=25 (age 35)	Educational written material n=18 (age 36.2)	Disability: RMQ (FU 1mo) Pain: VAS (FU 1mo)
Yildirim et al[44] RCT Heat vs drug therapy	Knee OA (chronic) N=46	Moist heating pad (40-46°C) 20 min/d for 4 wk, total 15 applications n=23 (M: 3, F: 20) (age 58.78±10.56)	Routine Medication n=23 (M: 4, F: 19) (age 58.78±9.55)	Disability: WOMAC (no FU) Pain: WOMAC (no FU) PFU: SF-36 physical component (no FU) QOL: SF-36 mental component (no FU) Stiffness: WOMAC (no FU)

Abbreviations: CCT, clinical controlled trial; F, female; FIHOA, Functional Index for Hand Osteoarthritis; FIQ, Fibromyalgia Impact Questionnaire; FU, follow-up; HADS, Hospital Anxiety and Depression Scale; KOOS, Knee Osteoarthritis Outcome Score; M, male; MVIC, maximal voluntary isometric contraction; NDI, Neck Disability Index; NHP, Nottingham Health Profile; NM, not mentioned; NRS, numeric rating scale; NSAID, nonsteroidal anti-inflammatory drug; OA, osteoarthritis; PFU, physical function; RCT, randomized controlled trial; RMQ, Roland-Morris Questionnaire; SF-36, Short Form-36 Health Survey; SYSADOA, symptomatic slow acting drugs for osteoarthritis; TENS, transcutaneous electrical nerve stimulation; VAS, visual analog scale; WOMAC, Western Ontario MacMaster Questionnaire.

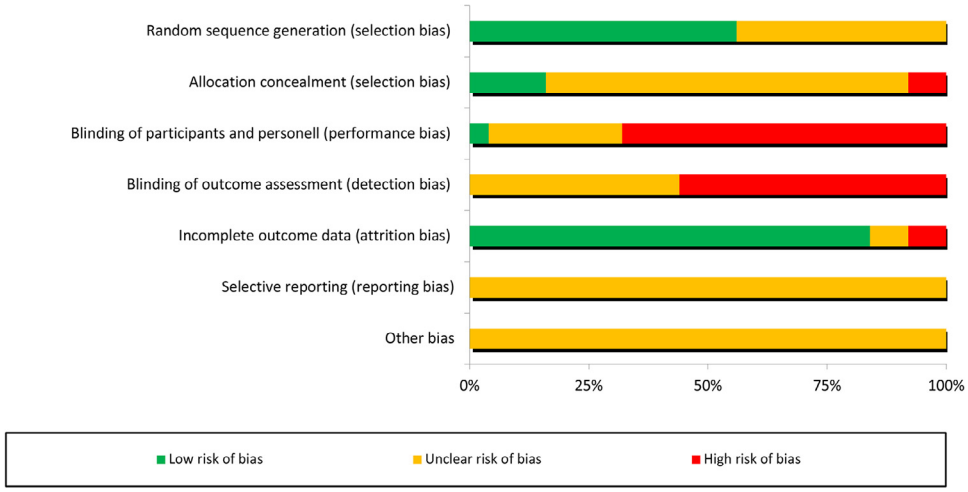

Fig 2 Risk of bias analysis of each included study.

Author	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Aciksoz et al. 2017	-	-	+	?	?	?	?
Denegar et al. 2010	-	?	+	+	-	?	?
Fioravanti et al. 2014	-	?	+	+	-	?	?
Garra et al. 2010	-	+	+	+	-	?	?
Giannitti et al. 2017	-	?	+	+	-	?	?
Kettenmann et al. 2007	-	+	+	?	-	?	?
Lauche et al. 2016	-	-	+	+	-	?	?
Leung et al. 2008	-	?	+	+	-	?	?
Lewis et al. 2012	?	?	+	+	+	?	?
Löfgren et al. 2009	?	?	+	?	-	?	?
Mayer et al. 2005	-	?	+	+	-	?	?
Mayer et al. 2006	-	-	+	+	-	?	?
Michlovitz et al. 2004	?	?	+	+	-	?	?
Nadler et al. 2002	-	?	+	+	-	?	?
Nadler et al. 2003a	-	?	+	+	-	?	?
Nadler et al. 2003b	-	?	+	+	-	?	?
Nuhr et al. 2004	-	-	+	+	-	?	?
Petrofsky et al. 2012	?	?	?	?	?	?	?
Petrofsky et al. 2013	?	?	?	?	-	?	?
Petrofsky et al. 2015	?	?	?	?	-	?	?
Petrofsky et al. 2016	?	?	?	?	+	?	?
Petrofsky et al. 2017	?	?	?	?	-	?	?
Sumida et al. 2003	?	?	?	?	-	?	?
Tao et al. 2005	?	?	-	?	-	?	?
Yildirim et al. 2009	?	?	?	?	-	?	?

Fig 3 Risk of bias analysis summary of all included studies.

pain observed that LHA was more beneficial compared with no treatment (P=.017). Contrary to these observations, LHA was not superior compared with no treatment in reducing pain in chronic conditions[27,28,45,48] (SMD=−0.457 [95% CI, −0.9 to 0.03]).

Only 2 studies, both investigating the effects of LHA compared with no treatment on DOMS, performed a follow-up measurement after 48 hours.[42,44] The results indicate that LHA is more beneficial to reduce pain after 48 hours than no treatment (SMD=−2.330 [95% CI, −3.0 to −1.5]).

Follow-up measurements after 72 hours revealed that LHA was still more effective than no treatment to reduce pain symptoms received from DOMS[41,42,44] (SMD=−1.134 [95% CI, −2.0 to −0.1]).

After 1 month, 1 study investiaged the effects of LHA vs no treatment on pain in chronic conditions[28] and found no differences between LHA and no treatment.

Physical function and disability

LHA resulted in improved physical function compared with no treatment in chronic conditions[27,28,45,48,50] (SMD=−0.522 [95% CI, −0.9 to −0.06]; Q_3=2.439; P=.486; I^2=0.0%) (see fig 4).

One study[28] demonstrated no difference in disability compared with baseline values immediately after LHA (SMD=−0.310 [95% CI, −0.9 to 0.2]).

Physical function remained higher after LHA vs no treatment after 48 hours (SMD=−0.554 [95% CI, −1.0 to −0.05]).[45,48,50]

Effects on muscular strength

Two studies[42,44] from the same research group investigated the effects on DOMS immediately after LHA and favored LHA to restore muscular strength compared with no treatment (SMD=−1.737 [95% CI, −2.4 to −1.02]), demonstrating a low heterogeneity (Q_1=0.001; P=.969; I^2=0.0%) (see fig 4).

Pooled results from the 2 studies[42,44] revealed that muscle strenght values remained higher 48 hours after LHA (SMD=−1.479 [95% CI, −2.1 to −0.8]).

Quality of life

The studies[27,28] investigating chronic musculoskeletal conditions found no differences between LHA and control treatment on QOL (SMD=−0.492 [95% CI, −1.0 to 0.02]; Q_1=0.02; P=.882; I^2=0.0%) (see fig 4).

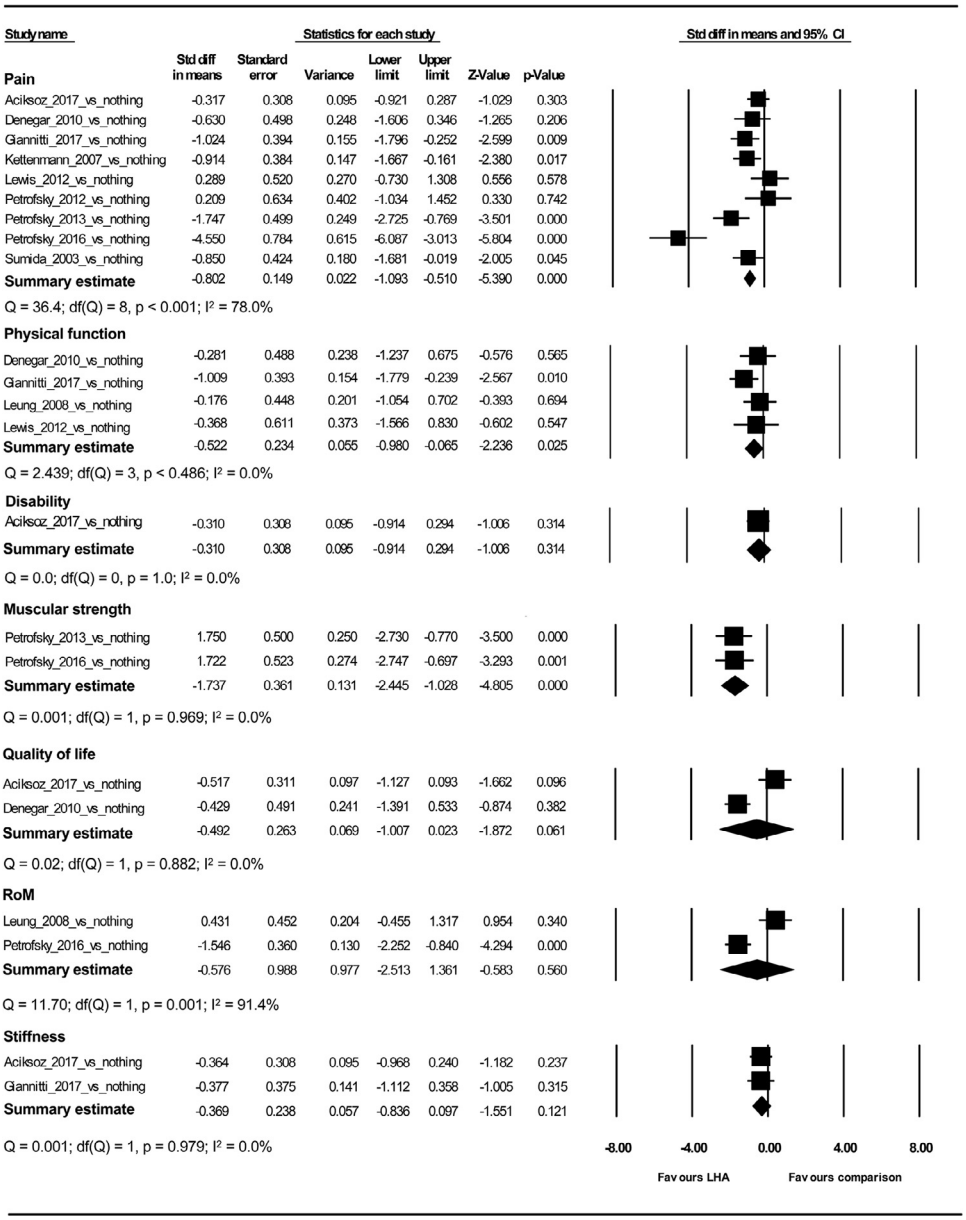

Fig 4 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs no treatment. The diamonds represent the overall weighted mean ES.

Range of motion

LHA did not alter ROM immediately after treatment (SMD=−0.576 [95% CI, −2.5 to 1.3]; Q_1=11.70; P=.001; I^2=91.4%) (see fig 4) in acute[44] and chronic[50] conditions.

Stiffness

No benefical effects of LHA vs no treatment were found for joint stiffness (SMD=−0.369 [95% CI, −0.8 to 0.09]; Q_1=0.001; P=.979; I^2=0.0%) (see fig 4).[28,45]

LHA vs cold

Effects on pain

The effect between LHA and cold therapy resulted in a nonsignificant difference (SMD=−0.184 [95% CI, −0.6 to 0.3]) with a moderate heterogeneity (Q_5=14.2; P=.014; I^2=64.9%) (fig 5).

The effects of LHA remained nonsignificant compared with cold for the subgroup analyses in acute conditions[31,33,40,43] (SMD=−0.130 [95% CI, −0.9 to 0.6]) and chronic conditions[27,28] (SMD=−0.271 [95% CI, −0.7 to 0.2]).

The sensitivity analysis excluding all studies on individuals without musculoskeletal disorders (experiencing DOMS)[31,40,43] demonstrated that LHA was also not superior to cold in reducing pain (SMD=−0.176 [95% CI, −0.5 to 0.1]).

No differences between LHA and cold treatments were observed after 48 hours (SMD=−2.101 [95% CI, −4.9 to 0.7]).[40,43]

Controversially after 72 hours, the effects of LHA vs cold therapy demonstrated that LHA was superior to cold in reducing pain in acute conditions (SMD=−1.743 [95% CI, −3.0 to −0.3]).[41-44]

One study conducted a 1-month follow up measurement to evaluate the potential effects of LHA and cold on pain and found no (P=.85) significant difference between the 2 interventions.[28]

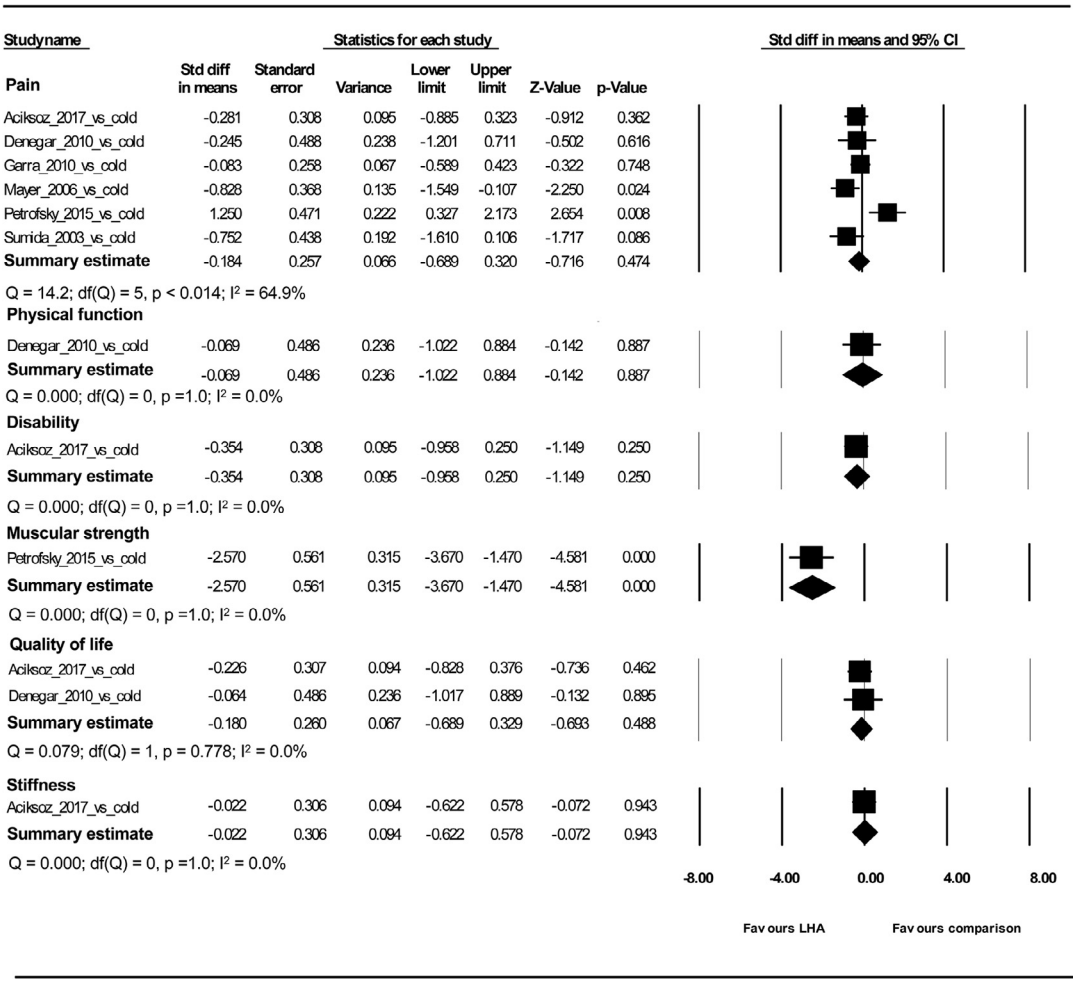

Fig 5 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs cold therapy. The diamonds represent the overall weighted mean ES.

Effects on physical function and disability

Our analyses revealed that LHA had no immediate effect on physical function[27] (mean difference [MD]=−0.069 [95% CI, −1.0 to 0.8]; Q_0=0.0; P>.99; I^2=0.0%) or disability[28] (MD=−0.354 [95% CI, −0.7 to 0.2]; Q_0=0.0; P>.99; I^2=0.0%) compared with cold in chronic conditions (see fig 5).

After 48 hours, no effects for LHA compared with cold could be observed for disability[28] (MD=−0.354 [95% CI, −0.9 to 0.2]) or physical function[27] (MD=−0.069 [95% CI, −1.0 to 0.8]).

Effects on muscular strength

The study of Petrofsky et al showed, that LHA has a positive effect on restoring muscular function immediately after LHA treatment (P<.001; Q_0=0.000; P>.99; I^2=0.0%)[43] and remained significant up to 48 hours after the intervention (P=.001) (see fig 5).

Effects on QOL

No immediate effect in favor for LHA compared with cold was found to improve QOL (SMD=−0.180 [95% CI, −0.6 to 0.3]; Q_1=0.079; P=.778; I^2=0.0%).[27,28]

Effects on stiffness

One study[28] result showed that LHA is ineffective to immediately affect tissue stiffness compared with cold therapy (P=.943; Q_0=0.000; P>.99; I^2=0.0%) (see fig 5).

LHA vs exercise

Effects on pain

Compared with exercise, LHA was not beneficial to reduce pain immediately after the treatment (SMD=−0.415 [95% CI, −1.0 to 0.1]; Q_2=4.966; P=.083; I^2=59.7%) (fig 6).[29,32,47]

Subgroup analysis showed that LHA was not superior to exercise in acute[29] (P=.504) and chronic[32,47] (P=.338) conditions.

Effects on physical function or disability

In a comparison of the immediate effects between LHA and exercise therapy on physical function and disability, LHA had no effect on physical function compared with exercise (SMD=−0.478 [95% CI, −1.4 to 0.4]; Q_2=7.027; P=.03; I^2=71.5%) (see fig 6).[29,32,47]

Our analysis based on 2 studies[29,32] showed that LHA was also not superior to exercise to positively influence disability

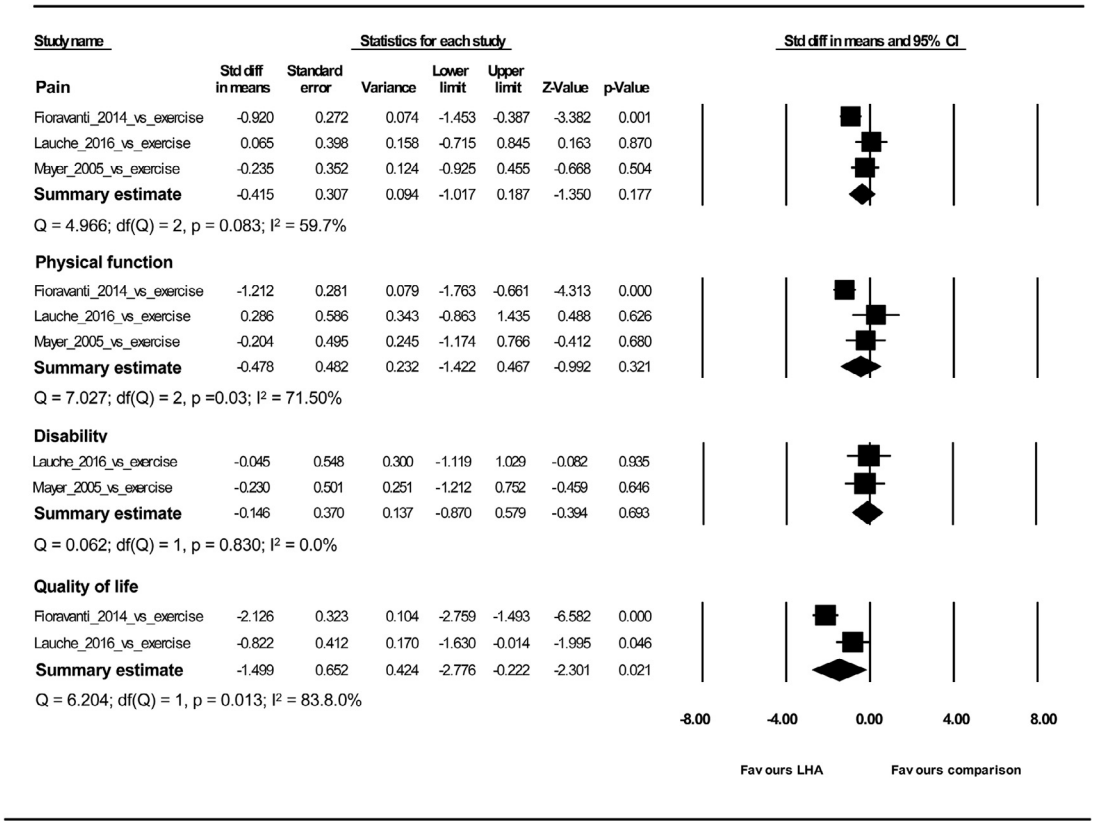

Fig 6 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs exercise therapy. The diamonds represent the overall weighted mean ES.

(SMD=−0.146 [95% CI, −0.8 to 0.5]; Q_1=0.062; P=.830; I^2=0.0%) (see fig 6).

In acute[29] and chronic conditions[32,47] no effects were found (acute: SMD=−0.230 [95% CI, −1.2 to 0.7; chronic: SMD=−0.551 [95% CI, −2.0 to 0.9]).

After a 48-hour follow-up period, LHA was also not significantly different from exercise in acute[29] and chronic[32] conditions (SMD=−0.132 [95% CI, −0.7 to 0.4].

Effects on QOL

The results of our analysis revealed that LHA has an immediate positive effect compared with exercise on QOL, using the Short Form-36 Health Survey[32,47] (SMD=−1.499 [95% CI, −2.7 to −0.2]) with a high and significant heterogeneity (Q_1=6.204; P=.013; I^2=83.8%) (see fig 6).

LHA vs standard therapy

Effects on pain

LHA was found to be beneficial compared with standard therapy in reducing pain (SMD=−0.784 [95% CI, −1.4 to −0.1]). However, the included studies showed a high and significant heterogeneity (Q_5=33.753; P<.001; I^2=85.1%) (fig 7).[29,32,38,39,49,51]

Analyzing acute[29,38,39] and chronic[32,49,51] conditions separately from each other, our analysis revealed that LHA is effective in acute (SMD=−1.265 [95% CI, −2.0 to −0.4]) but not chronic (SMD=−0.227 [95% CI, −0.5 to 0.1]) conditions.

Only 1 study[29] investigated the effects after 48 hours and found a positive effect in favor for LHA (MD=−2.330 [95% CI, −3.1 to −1.4]) compared with standard therapy. After 1 month, LHA was still superior to standard therapy to decrease pain[39] (MD=−0.693 [95% CI, −1.3 to −0.07]).

Effects on physical function or disability

Compared with standard therapy, LHA had an immediate positive effect on restoring physical function (SMD=−0.444 [95% CI, −0.7 to −0.1]),[29,32,39,49,51] with a low heterogeneity between studies (Q_4=2.064; P=.724; I^2=0.0%) (see fig 7).

The effect in acute conditions[29,39] was not in favor of LHA (SMD=−0.393 [95% CI, −0.9 to 0.1]), whereas in chronic conditions[32,49,51] LHA was beneficial compared with standard therapy (SMD=−0.476 [95% CI, −0.8 to −0.06]).

Disability was evaluated in 2 studies,[29,32] resulting in a nonsignificant difference between LHA and standard therapy (SMD=−0.496 [95% CI, −1.1 to 0.2]; Q_1=0.143; P=.705; I^2=0.0%) (see fig 7).

Two studies[29,32] performed follow-up measurements after 48 hours and observed that LHA was not superior to standard therapy to restore disability (SMD=0.090 [95% CI, −0.5 to 0.7]).

After 1 month, LHA was effective to restore disability compared with standard therapy (MD=−0.664 [95% CI, −1.2 to −0.04] in 1 study.[39]

Effects on QOL

The effects between LHA and standard therapy on QOL showed no significant differences between LHA and standard therapy (MD=−0.527 [95% CI, −1.2 to 0.2]; Q_0=0.0; P>.99; I^2=0.0%) (see fig 7).[32]

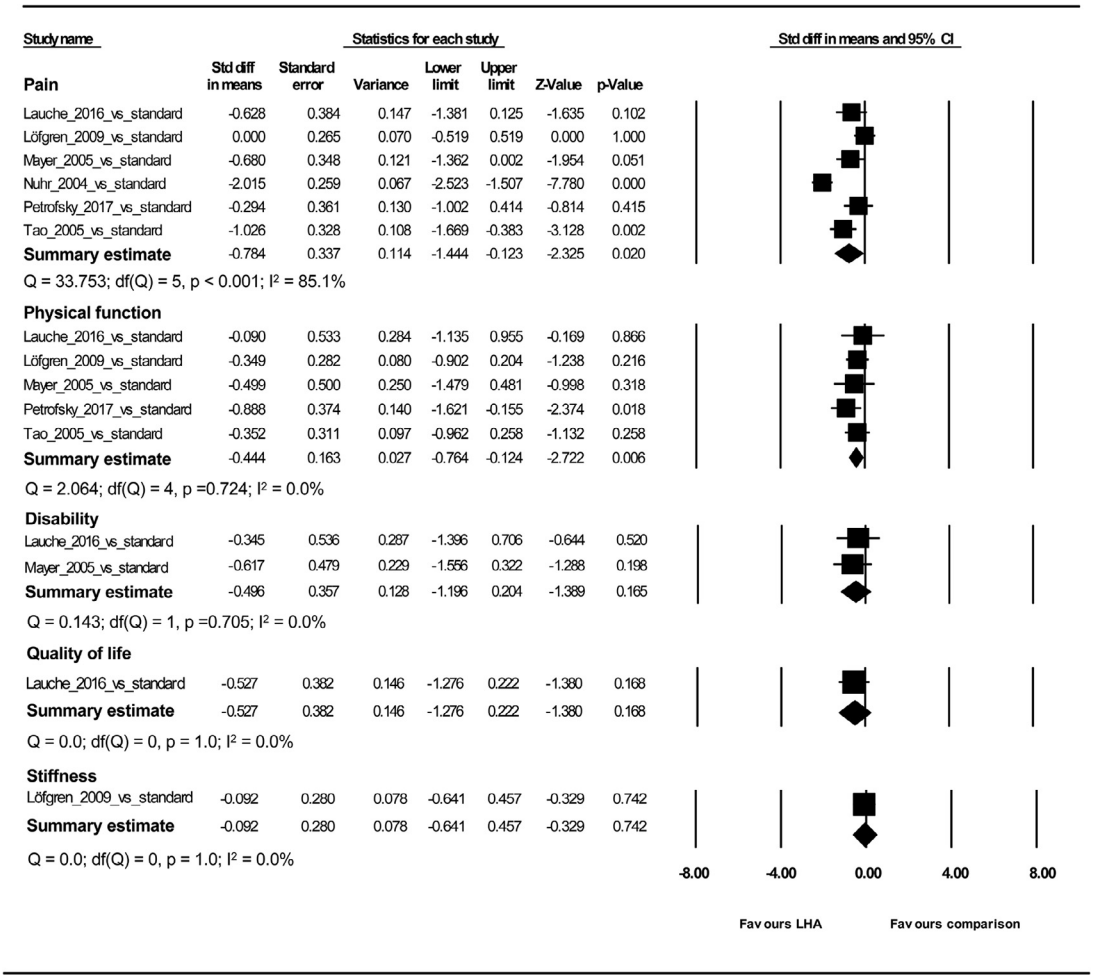

Fig 7 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs standard therapy. The diamond represents the overall weighted mean ES.

Effects on stiffness

No beneficial effects were found for LHA compared with standard therapy in affecting stiffness[49] (MD=−0.092 [95% CI, −0.6 to 0.4]; Q_0=0.0; P>.99; I^2=0.0%) (see fig 7).

LHA vs pharmacologic therapy

Effects on pain

LHA had a pain relieving effect immediately after the intervention compared with pharmacologic therapy in acute[35] and chronic[46] conditions (SMD=−0.555 [95% CI, −0.8 to −0.3], Q_1=0.034; P=.855; I^2=0.0%) (fig 8).

At 48-hour follow-up the results from Nadler et al showed that compared with pharmacologic therapy, LHA was effective to reduce pain (SMD=−0.462 [95% CI, −0.7 to −0.1]).[35]

Effects on physical function and disability

Only 1 study[46] compared LHA and pharmacologic therapy on physical function and found no effect between the interventions (SMD=−0.810 [95% CI, −1.6 to 0.04]; Q_0=0.0; P>.99; I^2=0.0%) (see fig 8).

However, the pooled results revealed that LHA had a positive effect on disability compared with pharmacologic therapy (SMD=−0.396 [95% CI, −0.6 to −0.1]; Q_1=0.668; P=.414; I^2=0.0%) (see fig 8).[35,46]

After 48-hour follow-up, the results demonstrated that LHA is more beneficial than pharmacologic therapy to positively affect disability (SMD=−0.472 [95% CI, −0.7 to −0.2]). However, this observation is based on only 1 study.[35]

Effects on QOL

Based on the results from 1 study,[46] QOL was not affected from LHA nor from pharmacologic therapy (MD=−0.187 [95% CI, −0.7 to 0.3]; Q_0=0.0; P>.99; I^2=0.0%) (see fig 8).

Effects on ROM

Only 1 study[35] demonstrated that LHA is more effective than pharmacologic therapy to increase ROM after the intervention (SMD=−0.354 [95% CI, −0.6 to −0.08]; Q_0=0.0; P>.99; I^2=0.0%) (see fig 8).

Effects on stiffness

The pooled results indicated that LHA has a positive effect on stiffness compared with pharmacologic therapy (SMD=−0.408 [95% CI, −0.6 to −0.1]; Q_1=0.045; P=.833; I^2=0.0%) (see fig 8) in acute[35] and chronic[46] conditions.

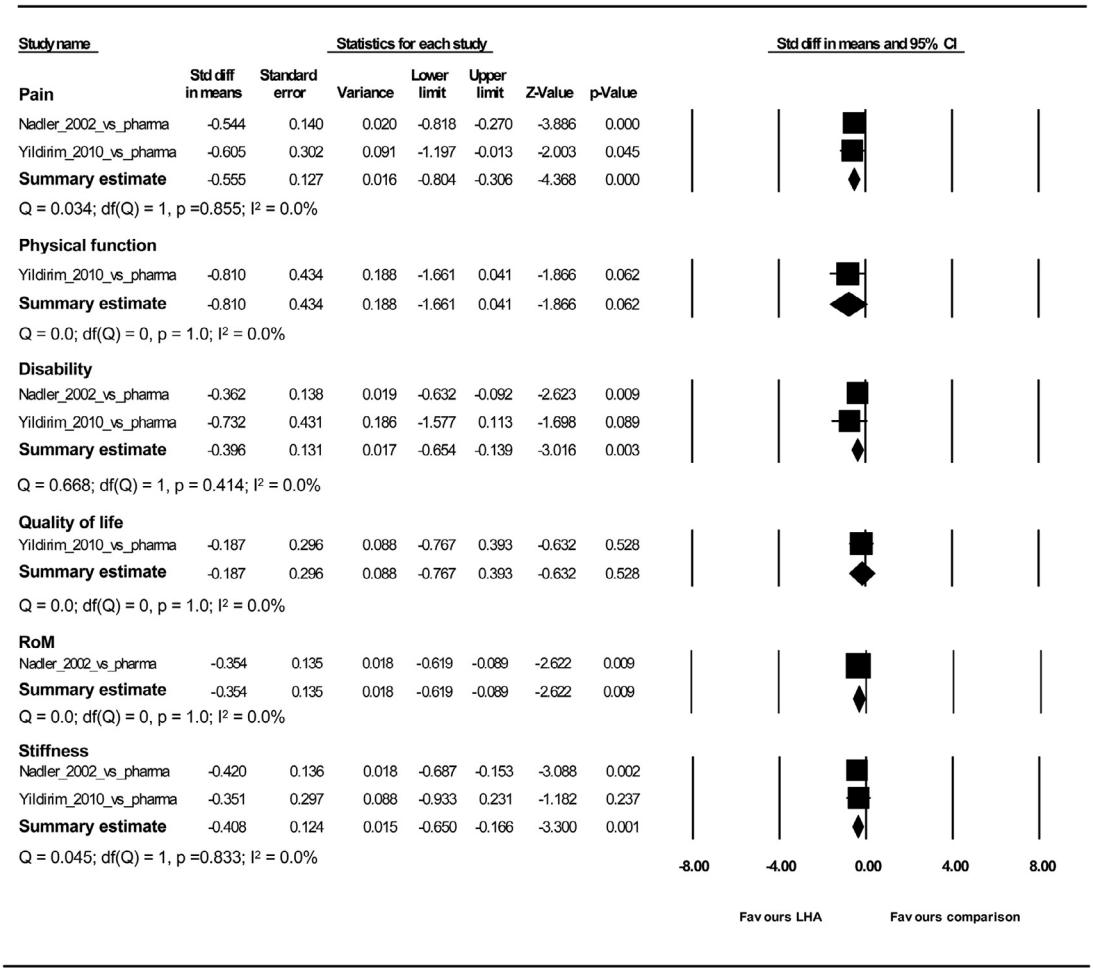

Fig 8 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs pharmacologic therapy. The diamonds represent the overall weighted mean ES.

After 48 hours, the effect remained significant (MD=−0.448 [95% CI, −0.6 to −0.1] in favor of LHA.[35]

LHA vs placebo or sham therapy

Effects on pain

Three studies[30,36,37] resulting in 4 head-to-head comparisons investigated the difference between LHA and placebo/sham therapy on pain. The overall weighted mean effect showed that LHA has an positive effect compared with the control group on immediate pain reductions (SMD=−3.002 [95% CI, −5.9 to −0.07]; Q_3=195.98; P<.001; I^2=98.4%) (fig 9).

The effect remained significant in favor of LHA in acute[36,37] conditions (SMD=−5.153 [95% CI, −8.3 to −1.9]) but not in chronic[30] conditions (MD=−0.768 [95% CI, −1.5 to 0.02]). However, the sensitivity analysis, excluding 1 outlier study,[37] showed that LHA is not more beneficial than placebo or sham to decrease pain (SMD=−1.741 [95% CI, −3.6 to 0.1])

The effect remained significant in favor of LHA at 2 follow-ups recorded 48 hours after initial LHA (SMD=−5.250 [95% CI, −5.7 to −4.7]).[36,37]

Effects on disability

Our analysis revealed that LHA has a positive immediate effect on disability compared with the control group (SMD=−1.278 [95% CI, −2.4 to −0.1]) with a high heterogeneity (Q_3=50.665; P<.001; I^2=94.0%) (see fig 9).[30,36,37]

However, after 48 hours, no difference could be observed anymore (SMD=−1.991 [95% CI, −4.8 to 0.8]).[36,37]

Effects on muscular strength

Muscular strength was investigated from 1 study[30] and showed that directly after LHA, muscular strength was positively affected (MD=−0.847 [95% CI, −1.6 to −0.08]; Q_1=2.170; P=.141; I^2=53.9%) (see fig 9).

Effects on ROM

LHA was effective compared with placebo or sham therapy to increase ROM after the intervention in 2 studies[36,37] (SMD=−4.156 [95% CI, −5.3 to −2.9]) with a high heterogeneity (Q_1=5.774; P=.016; I^2=82.6%) (see fig 9).

Effects on stiffness

The pooled results from 3 studies[30,36,37] including 4 comparisons demonstrated that LHA is superior to placebo or sham therapy to

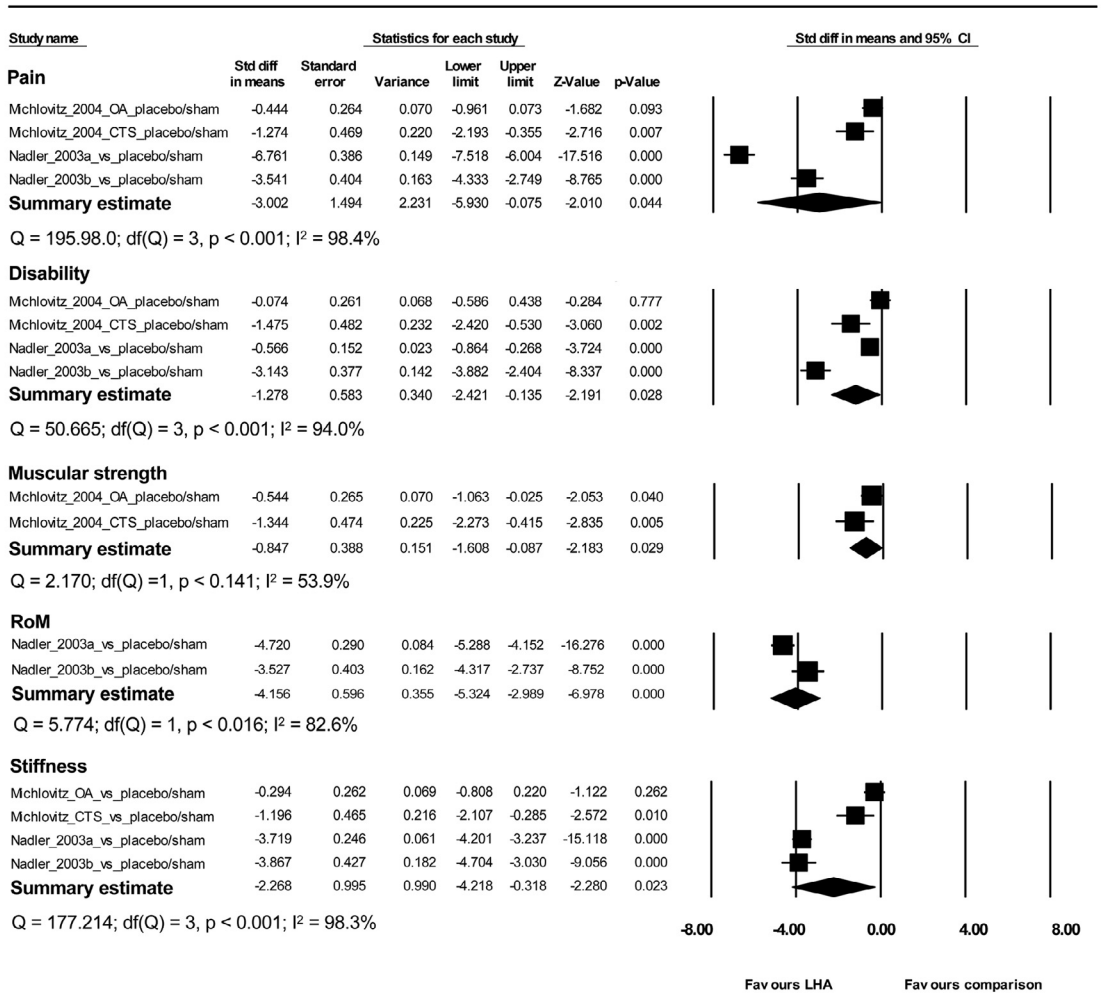

Fig 9 Forest plot of the meta-analysis illustrating the overall weighted effect of heat application vs placebo or sham therapy. The diamonds represent the overall weighted mean ES.

positively affect stiffness (SMD=−2.268 [95% CI, −4.2 to −0.3]; Q_3=177.214; P<.001; I^2=98.3%) (see fig 9).

After 48 hours, the positive effect in favor of LHA remained significant (SMD=−2.906 [95% CI, −5.6 to −0.1]) for tissure stiffness.[30,36,37]

Treatment dose

The included studies show a large heterogeneity regarding the treatment dose, ranging from 15-20 minutes once a week to 8 hours per day for 5 days[14,32]. LHA was applied at temperatures of 40°C[29,30,35-37,39-44,48,49,51] or 63°C[50] or was not reported.[27,32]

Discussion

Summary of findings

This systematic review and meta-analysis sought to investigate the effects of superficial LHA on physical and functional outcomes in individuals with any kind of musculoskeletal disorders or pain.

The main findings of the review are (1) compared with no treatment, LHA had moderate to large beneficial effects on pain relief and improved physical function immediately after application; (2) LHA resulted in significantly greater pain relief and physical function improvement compared with a standard treatment; and (3) compared with placebo or sham application there is marginal evidence that LHAs have a beneficial effect on pain relief, improving disability, and tissue stiffness.

LHA vs no treatment

LHA was effective to relieve pain in musculoskeletal disorders. The largest beneficial effects of LHA were observed in 2 studies on participants without musculoskeletal disorders, treated with local heat wraps (40°C) for 8 hours, experiencing DOMS after exercise. The studies used chemical heat wraps (using exothermic iron oxidation reaction), which are believed to act on the peripheral nervous system, whereas applications of short duration are presumed to induce pain reduction through the gate control theory in the central nervous system.[9,52] However, in an earlier published study[41] from these authors, no effects were found regarding pain relief in participants without musculoskeletal disorders with DOMS. A possible explanation for the differences between these studies might be, that in 1 pilot study[41] the elbow flexors were exercised, whereas in the other 2 studies[14,44] the legs were

exercised, leading possible to a different presentation of DOMS.[53] The observed beneficial effects in pain relief remained significant in favor of LHA in follow-up measurements up to 48 hours. Interestingly, the studies[14,41,43,44] all investigating DOMS on healthy participants with a high treatment dose (40˚C for 8 hours) show an overall beneficial effect for pain reductions after follow-ups of 72 hours. However, these analyses and findings are limited by the brevity of studies.

Four studies[2,27,45,46] found a significant improvement in physical function after LHA compared with no treatment in patients with chronical musculoskeletal conditions. The investigated pathologies included knee osteoarthritis,[27,28,45] low back pain,[2] and frozen shoulder.[50] Three studies[2,45,50] performed follow-up assessments at 48 hours where LHA continued to show a beneficial effect on physical function. These results suggest that LHA is effective in improving physical function. Further beneficial effects of LHA vs no treatment were found for muscular strength but not for QOL, ROM, or stiffness. However, the pooled results from the meta-analyses were obtained from a limited number of studies (n=2 for each outcome), which might have led to an over- or underestimation of the standardized weighted mean.

LHA vs cold

No differences were found between the effect of LHA compared with cold application in reducing pain or improving QOL. Cold gel packs (1.7˚C) on the biceps,[31 31] applied as an adequate cooling strategy,[54] resulted similar effects as LHA, whereas cold wraps applied to the thighs[43] (temperature not reported) reduced pain more effectively than LHA. In the study of Petrofsky et al,[43] LHA was effective in improving muscular strength. It is well established that[55] tissue temperatures can affect conduction velocity, which might explain the immediate improved muscle function. Based on the current state of research, no conclusive results for LHA being superior to cold application were found.

LHA vs exercise

LHA compared with exercise therapy shows only beneficial effect in the studies[32,47] investigating QOL. Interestingly, compared with the other included studies, the study of Fioravanti et al[47] shows strong immediate effects in pain reduction and improved physical function (see fig 6). Only the study from Mayer et al[29] has a significant follow-up effect after 48 hours for pain.

LHA vs standard therapy

Immediate significant effects were found for LHAs vs standard therapy for pain reduction and improvement of physical function. A subgroup analyses for pain showed that LHA is more effective in acute compared with chronic conditions to decrease this subjective outcome. The studies[29,38,39] investigating LHA in acute conditions, treating patients with acute low back pain patients, showed high significant results in pain relief vs standard treatment. A comparison between acute and chronic conditions revealed that LHA is more effective in improving physical function in chronic than in acute conditions compared with standard therapy. However, these analyzed results are based on a limited number of included studies. Therefore, patients with acute nonspecific low back pain should follow the recommendations of the guidelines[56] and remain physically active.[57]

LHA vs pharmacologic therapy

Our study revealed limited findings on the effect of LHA vs pharmacologic treatment because the number of included studies was in most comparisons too low to make solid interpretations on the findings.

Nevertheless, positive effects were seen in favor for LHA on pain relief, disability, ROM, and tissue stiffness (see fig 8). Apparently, thermal treatment seems to induce changes in the mechanical characteristics of soft tissue, which might explain partially the abovementioned positive effects.[58] Although the results of the present study are limited, LHAs can be applied from patients by themselves, are cost-effective, and are a relatively safe or adjunct therapy form. Although some treatment guidelines do not support the use of LHA in the treatment of acute and chronic musculoskeletal disorders or pain conditions, health care providers (eg, physiotherapists) should be able to decide individually whether or not the use of LHA can be beneficial for their patients.

LHA vs placebo or sham therapy

More profound results are found in the comparison of LHA vs a placebo or sham treatment for pain relief, disability, muscular strength, ROM, and tissue stiffness (see fig 9). Regarding pain relief, the strongest results were found in the study results from Nadler et al[37] and Nadler,[36] treating patients with acute, nonspecific low back pain with heat wraps (40˚C for 8 hours for 3 days) vs an oral placebo medication. Both studies led to results favoring LHA vs placebo treatment (see fig 9). Interestingly, the effect of the LHA was higher when the treatment was conducted during the day. Although the authors[36,37] state that impaired sleep plays a strong role during recovery from illness and injury. LHA during the day seems to have a larger pain-relieving effect. LHA in combination with daily activity seems to be superior in pain relief compared with passive LHA during the night.[37]

Evaluation of methodological quality

There were large limitations within the current evidence base on the effectiveness of LHA. The overall study quality of the review was low, and we were unable to meaningfully subgroup the included studies into high and low quality. The included studies demonstrated a moderate to high heterogeneity, and most studies had an unclear or high RoB in terms of allocation concealment, blinding of participants and personnel, blinding of outcome assessment, and selective reporting. From a limited number of studies, central tendencies and variations were extracted manually from figures. Although this was undertaken by 2 independent researchers with inconsistencies checked by a third reviewer to achieve consensus, it still serves as an estimation of treatment effect. Overall, the limited number of outcomes, especially in the subgroup analyses and the poor quality of evidence, means that results should be interpreted with caution.

Summary of the evidence

The present study focusses on topical LHA as a treatment for impaired physical function parameters of acute and chronic musculoskeletal disorders or pain.

Our results implicate that LHAs have in general a positive immediate effect on pain compared with no treatment, standard therapy, pharmacologic therapy, and placebo/sham therapy. LHA

immediately increased physical function compared with no treatment and standard care, and improvements in disability were higher in the LHA group vs the groups receiving pharmacologic therapy or placebo/sham therapy. Based on the results of 2 studies, an immediate effect in favor of LHA on QOL was found compared with exercise therapy.

LHA was in general beneficial to immediately restore ROM and stiffness compared with pharmacologic therapy and placebo/sham therapy. Marginal evidence for restored muscular strength after LHA treatments compared with no treatment, cold treatments, and pharmacologic treatments was found.

Study limitations

Despite the abovementioned positive effects of LHA, the included studies demonstrate a high heterogeneity regarding included population, outcome assessment, and treated pathologies. For the included studies, insufficient data reporting was a major issue, not only for the methodological quality assessment but also for data extraction when results were presented graphically only. Further, numeric rating scales and self-reporting questionnaires were widely applied to evaluate physical and functional outcome parameters, which may have led to potential under- or overestimation of the outcome results. Another limitation is that the results of this meta-analysis are mostly based on a low number of included studies with a high risk of performance and detection bias, especially in the follow-up analyses.

Nevertheless, LHA can be applied from patients by themselves, are cost-effective, and are a relatively safe or adjunct therapy form to reduce pain and improve physical function, ROM, and tissue stiffness. Although some treatment guidelines do not support the use of LHA in the treatment of acute and chronic musculoskeletal disorders or pain conditions, health care providers (eg, physiotherapists) should be able to decide individually whether or not the use of LHA can be beneficial for their patients.

Therefore, the results cannot be transferred to other heat application methods. Duration, frequency, and temperature range of LHA treatment might also have affected the studies' outcomes. Future high-quality randomized controlled trial studies should focus on data reporting and variation of application types and frequencies of LHA in the management of musculoskeletal disorders.

Conclusions

In conclusion, LHA is a commonly used treatment modality to reduce the symptoms of various musculoskeletal disorders. The current evidence base suggests that LHA is more beneficial than no treatment and standard care to reduce pain and to improve physical function. Some evidence is available that LHA is more effective to restore ROM and stiffness than pharmacologic therapy and placebo/sham therapy. These results could be of interest for physiotherapists, health care practitioners, and exercise physiologists alike. The effects favoring LHA seem to be most likely present in acute conditions compared with chronic conditions.

Regarding follow up effects, the findings are based on a limited number of studies, which makes a meaningful interpretation difficult. Because of heterogeneity of methodologies used and unclear risk of bias the included studies, the effectiveness of LHA remains relatively unclear. In this research area high-quality well-reported research is required.

Supplier

a. CMA II; Biostat Inc.

Keywords

Hot temperature; Meta-analysis; Musculoskeletal diseases; Pain; Physical therapy modalities; Quality of life; Rehabilitation; Review

Corresponding author

Ron Clijsen, PhD, Weststrasse 8, Landquart 7302, Switzerland. *E-mail address:* ron.clijsen@supsi.ch.

References

1. Lavender AP, Nosaka K. Changes in fluctuation of isometric force following eccentric and concentric exercise of the elbow flexors. Eur J Appl Physiol 2006;96:235–40.
2. Lewis PB, Ruby D, Bush-Joseph CA. Muscle soreness and delayed-onset muscle soreness. Clin Sports Med 2012;31:255–62.
3. Valle X, Til L, Drobnic F, et al. Compression garments to prevent delayed onset muscle soreness in soccer players. Muscles Ligaments Tendons J 2013;3:295.
4. French SD, Cameron M, Walker BF, Reggars JW, Esterman AJ. A Cochrane review of superficial heat or cold for low back pain. Spine (Phila Pa 1976) 2006;31:998–1006.
5. Crowe M, Whitehead L, Jo Gagan M, Baxter D, Panckhurst A. Self-management and chronic low back pain: a qualitative study. J Adv Nurs 2010;66:1478–86.
6. Furlan RM, Giovanardi RS, Britto AT, Oliveira e Britto DB. The use of superficial heat for treatment of temporomandibular disorders: an integrative review. Codas 2015;27:207–12.
7. Clijsen R, Taeymans J, Duquet W, Barel A, Clarys P. Changes of skin characteristics during and after local Parafango therapy as used in physiotherapy. Skin Res Technol 2008;14:237–42.
8. Oosterveld FGJ, Rasker JJ. Effects of local heat and cold treatment on surface and articular temperature of arthritic knee. Arthritis Rheum 1994;37:1578–82.
9. Trowbridge CA, Draper DO, Feland JB, Jutte LS, Eggett DL. Paraspinal musculature and skin temperature changes: comparing the ThermaCare HeatWrap, the Johnson & Johnson back plaster, and the ABC Wärme-Pflaster. J Orthop Sports Phys Ther 2004;34:549–58.
10. Lohman EB, Bains GS, Lohman T, DeLeon M, Petrofsky JS. A comparison of the effect of a variety of thermal and vibratory modalities on skin temperature and blood flow in healthy volunteers. Med Sci Monit 2011;17:72–81.
11. Charkoudian N. Mechanisms and modifiers of reflex induced cutaneous vasodilation and vasoconstriction in humans. J Appl Physiol 2010;109:1221–8.
12. Heinrichs K. Superficial heat modalities. Superficial Therm Modalities 2003;16:277–88.
13. Malanga GA, Yan N, Stark J. Mechanisms and efficacy of heat and cold therapies for musculoskeletal injury. Postgrad Med 2015;127:57–65.
14. Petrofsky JS, Laymon M, Lee H. Effect of heat and cold on tendon flexibility and force to flex the human knee. Med Sci Monit 2013;19:661–7.
15. Bleakley CM, Costello JT. Do thermal agents affect range of movement and mechanical properties in soft tissues? A systematic review. Arch Phys Med Rehabil 2013;94:149–63.

16. Nadler SF, Weingand K, Kruse RJ. The physiologic basis and clinical applications of cryotherapy and thermotherapy for the pain practitioner. Pain Physician 2004;7:395–400.
17. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339:b2700.
18. Garber CE, Greaney ML, Riebe D, et al. Physical and mental health-related correlates of physical function in community dwelling older adults: a cross sectional study. BMC Geriatr 2010;10:6. https://doi.org/10.1186/1471-2318-10-6.
19. Perenboom RJ, Wijlhuizen GJ, Garre FG, Heerkens YF, van Meeteren NL. An empirical exploration of the relations between the health components of the International Classification of Functioning, Disability and Health (ICF). Disabil Rehabil 2012;34:1556–61. https://doi.org/10.3109/09638288.2011.647233.
20. Treede RD, Rief W, Barke A, et al. A classification of chronic pain for ICD-11. J Pain 2015;156:1003–7.
21. Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions. Hoboken: John Wiley & Sons; 2011.
22. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:1–9.
23. Veroniki AA, Jackson D, Viechtbauer W, et al. Methods to estimate the between-study variance and its uncertainty in meta-analysis. Res Synth Methods 2016;7:55–79.
24. primer Cohen JA power. Psychol Bull 1992;112:155–9.
25. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–60.
26. Borenstein M, Hedges L, Rothstein H. Meta-analysis: fixed effect vs. random effects. 2007. Available at: https://www.Meta-Analysis.com. Accessed September 6, 2021.
27. Denegar C, Dougherty D, Friedman J, et al. Preferences for heat, cold, or contrast in patients with knee osteoarthritis affect treatment response. Clin Interv Aging 2010;5:199–206.
28. Aciksoz S, Akyuz A, Tunay S. The effect of self-administered superficial local hot and cold application methods on pain, functional status and quality of life in primary knee osteoarthritis patients. J Clin Nurs 2017;26:5179–90.
29. Mayer JM, Ralph L, Look M, et al. Treating acute low back pain with continuous low-level heat wrap therapy and/or exercise: a randomized controlled trial. Spine J 2005;5:395–403.
30. Michlovitz S, Hun L, Erasala GN, Hengehold DA, Weingand KW. Continuous low-level heat wrap therapy is effective for treating wrist pain. Arch Phys Med Rehabil 2004;85:1409–16.
31. Sumida KD, Greenberg MB, Hill JM. Hot gel packs and reduction of delayed-onset muscle soreness 30 minutes after treatment. J Sport Rehabil 2003;12:221–8.
32. Lauche R, Schuth M, Schwickert M, et al. Efficacy of the Alexander Technique in treating chronic non-specific neck pain: a randomized controlled trial. Clin Rehabil 2016;30:247–58.
33. Garra G, Singer AJ, Leno R, et al. Heat or cold packs for neck and back strain: a randomized controlled trial of efficacy. Acad Emerg Med 2010;17:484–9.
34. Kettenmann B, Wille C, Lurie-Luke E, Walter D, Kobal G. Impact of continuous low level heatwrap therapy in acute low back pain patients: subjective and objective measurements. Clin J Pain 2007;23:663–8.
35. Nadler SF, Steiner DJ, Erasala GN, et al. Continuous low-heat wrap provides more efficacy than ibuprofen and acetaminophen for acute low back pain. Spine (Phila Pa 1976) 2002;27:1012–7.
36. Nadler SF, Steiner DJ, Petty SR, Erasala GN, Hengehold DA, Weingand KW. Overnight use of continuous low-level heatwrap therapy for relief of low back pain. Arch Phys Med Rehabil 2003;84:335–42.
37. Nadler SF, Steiner DJ, Erasala GN, Hengehold DA, Abeln SB, Weingand KW. Continuous low-level heatwrap therapy for treating acute nonspecific low back pain. Arch Phys Med Rehabil 2003;84:329–34.
38. Nuhr M, Hoerauf K, Bertalanffy A, et al. Active warming during emergency transport relieves acute low back pain. Spine (Phila Pa 1976) 2004;29:1499–503.
39. Tao X, Bernacki EJ. A randomized clinical trial of continuous low-level heat therapy for acute muscular low back pain in the workplace. Int J Occup Environ Med 2005;47:1298–306.
40. Mayer JM, Mooney V, Matheson LN, et al. Continuous low-level heat wrap therapy for the prevention and early phase treatment of delayed-onset muscle soreness of the low back: a randomized controlled trial. Arch Phys Med Rehabil 2006;87:1310–7.
41. Petrofsky J, Laymon M, Berk L, et al. A pilot study using blood biomarkers and physiological parameters to assess ThermaCare heat wraps for efficacy and timing of application of reduce DOMS from exercise. J Appl Res 2012;11:84–96.
42. Petrofsky J, Berk L, Bains G, et al. Moist heat or dry heat for delayed onset muscle soreness. J Clin Med Res 2013;5:416–25.
43. Petrofsky JS, Khowailed IA, Lee H, et al. Cold vs. heat after exercise —is there a clear winner for muscle soreness. J Strength Cond Res 2015;29:3245–52.
44. Petrofsky JS, Berk L, Bains G, Khowailed IA, Lee H, Laymon M. The efficacy of sustained heat treatment on delayed-onset muscle soreness. Clin J Sport Med 2017;27:329–37.
45. Giannitti C, De Palma A, Pascarelli NA, et al. Can balneotherapy modify microRNA expression levels in osteoarthritis? A comparative study in patients with knee osteoarthritis. Int J Biometeorol 2017;61:2153–8.
46. Yildirim N, Filiz Ulusoy M, Bodur H. The effect of heat application on pain, stiffness, physical function and quality of life in patients with knee osteoarthritis. J Clin Nurs 2010;19:1113–20.
47. Fioravanti A, Tenti S, Giannitti C, Fortunati NA, Galeazzi M. Short- and long-term effects of mud-bath treatment on hand osteoarthritis: a randomized clinical trial. Int J Biometeorol 2014;58:79–86.
48. Lewis SE, Holmes PS, Woby SR, Hindle J, Fowler NE. Short-term effect of superficial heat treatment on paraspinal muscle activity, stature recovery, and psychological factors in patients with chronic low back pain. Arch Phys Med Rehabil 2012;93:367–72.
49. Löfgren M, Norrbrink C. Pain relief in women with fibromyalgia: a cross-over study of superficial warmth stimulation and transcutaneous electrical nerve stimulation. J Rehabil Med 2009;41:557–62.
50. Leung MS, Cheing GL. Effects of deep and superficial heating in the management of frozen shoulder. J Rehabil Med 2008;40:145–50.
51. Petrofsky JS, Laymon M, Alshammari F, Khowailed IA, Lee H. Use of low level of continuous heat and Ibuprofen as an adjunct to physical therapy improves pain relief, range of motion and the compliance for home exercise in patients with nonspecific neck pain: a randomized controlled trial. J Back Musculoskelet Rehabil 2017;30:889–96.
52. Draper DO, Hopkins TJ. Increased intramuscular and intracapsular temperature via ThermaCare Knee Wrap application. Med Sci Monit 2008;14:PI7–11.
53. Saka T, Akova B, Yazici Z, Sekir U, Gur H, Ozarda Y. Difference in the magnitude of muscle damage between elbow flexors and knee extensors eccentric exercises. J Sports Sci Med 2009;8:107–15.
54. Schinsky MF, McCune C, Bonomi J. Multifaceted comparison of two cryotherapy devices used after total knee arthroplasty: cryotherapy device comparison. Orthop Nurs 2016;35:309–16.
55. Nadler SF, Feinberg JH, Reisman S, et al. Effect of topical heat on electromyographic power density spectrum in subjects with myofascial pain and normal controls: a pilot study. Am J Phys Med Rehabil 2001;80:809–15.
56. Oliveira CB, Maher CG, Pinto RZ, et al. Clinical practice guidelines for the management of non-specific low back pain in primary care: an updated overview. Eur Spine J 2018;27:2791–803.
57. Luna EG, Hanney WJ, Rothschild CE, Kolber MJ, Liu X, Masaracchio M. The influence of an active treatment approach in patients with low back pain: a systematic review. Am J Lifestyle Med 2019;13:190–203.
58. Benech N, Negreira CA. Monitoring heat-induced changes in soft tissues with 1D transient elastography. Phys Med Biol 2010;55:1753.