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REVIEW

Effects of local cryotherapy for recovery of delayed onset muscle soreness and strength following exercise-induced muscle damage: systematic review and meta-analysis

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Abstract

Purpose The aim of the current study was to evaluate the effects of local cryotherapy on the main symptoms of exercise-induced muscle damage (EIMD) through a systematic literature review.

Methods A search on Cochrane CENTRAL, MEDLINE (*PubMed*), Lilacs and PEDro databases was carried out from inception to March 2018. Studies that performed a protocol of muscle damage induction, and used local cryotherapy as intervention in comparison with control group/placebo were eligible. The studies should evaluate at least one of the outcomes of interest (delayed onset muscle soreness (DOMS) or muscle strength). Studies that did not evaluate any of the variables of interest or applied ice massage or other cooling modalities were excluded.

Results The search identified 221 studies, in which 7 studies met the eligibility criteria and were included. There was a mean PEDro score of 7.28, and all studies were ranked as high methodological quality. Meta-analysis showed local cryotherapy does not seem to be effective to accelerate recovery of DOMS (−0.11; 95% CI −0.8 to 0.57; I^2: 79%) or muscle strength (−0.59; 95% CI −2.89 to 1.71; I^2: 0%) following EIMD.

Conclusion In conclusion, the results showed that local cryotherapy does not seem to contribute for the improvement of DOMS and muscle weakness associated with EIMD.

Keywords Eccentric contraction · Eccentric protocol · Creatine kinase · Cold therapy

Introduction

Muscle damage (DM) can occur in muscular structures—membranes, Z-line, sarcolemma, T-tubules, and myofibrils—as a consequence of the imposition of a mechanical overload [1]. In the literature, the onset of muscle damage associated with an inflammatory process after exercise is well documented [2, 3]. In addition, it is known that, among strength exercises, there is a higher incidence of exercise-induced muscle damage (EIMD) after exercises involving eccentric contraction [4, 5]. Many indirect markers have been used to evaluate muscle damage, but delayed onset muscle soreness (DOMS) and strength are the most remarkable ones.

Currently, cryotherapy modalities are widely used in the treatment of subjective (DOMS) and objective (strength) recovery characteristics [6, 7]. The cooling of the tissue is believed to produce a decrease in blood flow, tissue temperature, and metabolism, leading to a limitation of edema formation and a reduction of cells death by secondary hypoxia, protecting the muscle cells [8]. Cryotherapy can be applied in a variety of ways such as cold-water immersion (CWI) [9], whole-body cryotherapy (WBC) [7], partial-body cryotherapy (PBC) [10] and local cryotherapy [11]. There is a growing body of evidence elucidating the positive effects of CWI [12], WBC [13] and PBC [14]. However, those cooling strategies are more applicable in sports context [15] and have limited insertion in clinical practice. Local cryotherapy, on the other hand, might be a more practical and affordable

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option in a clinical environment, which justifies the need to investigate its potential effects. Furthermore, little is known about the optimal dosage of local cryotherapy. Periods of application between 15 and 20 min are often prescribed, but whether this time is appropriate and sufficient to generate benefits remains unknown.

Although local cryotherapy is more compatible with clinical practice, there is no consensus in scientific research regarding its effectiveness. Review studies that have analyzed the effects of cryotherapy on the symptoms related to EIMD emphasize WBC [6] and CWI [7, 16, 17]. To this date, no review studies have specifically examined the influence of local cryotherapy on subjective and objective markers of EIMD, and it remains uncertain whether local cryotherapy has any potential to accelerate recovery from symptoms of EIMD. Therefore, the aim of the present systematic review and meta-analysis is to verify the effects of local cryotherapy on the treatment of DOMS and muscle weakness related to EIMD. We hypothesized that local cryotherapy would help decrease DOMS and attenuate loss of strength following EIMD.

Methods

The current study utilized PRISMA (Preferred Reporting Items for Systematic Review and Meta-analyses) guidelines for Systematic Reviews and Meta-analysis [18]. The PRISMA is a checklist containing the 27 items that must be included in a systematic review.

Data sources and searches

We searched the following electronic databases (from inception to March 2018): MEDLINE (accessed by PubMed), Physiotherapy Evidence Database (PEDro), The Cochrane Central Register of Controlled Trials (Cochrane CENTRAL), and *Centro Latino-Americano e do Caribe de Informação em Ciências da Saúde* (LILACS). In addition, we searched the references of published studies. The search was performed for the last time in April 2018. The search comprised the following terms: "Cryotherapy", "muscle damage", "delayed onset muscle soreness", "exercise induced muscle damage" combined with a high sensitivity combination of words used in the search for randomized clinical trials [19]. We included publications in English. For the combination of the keywords, we utilized the Boolean terms AND, and OR. The complete search strategy used for the MEDLINE database is shown in Table 1.

Eligibility criteria

We included randomized clinical trials (RCT) and controlled clinical trials (CCT). Studies that applied a muscle damage protocol, performed cryotherapy as a therapy in comparison with a control group, and evaluated DOMS and/or strength were included. The following exclusion criteria were used: (1) samples comprised of people with any disease/dysfunction, (2) samples of people under 18 or over 40 years old; (3) non-application of local cryotherapy; (4) non assessment of some of the outcomes of interest; (5) cross-over designs.

Studies selection and data extraction

Two investigators independently evaluated titles and abstracts of all articles identified by the search strategy. All abstracts that did not provide sufficient information regarding the inclusion and exclusion criteria were selected for full-text evaluation. In the second phase, the same reviewers independently evaluated the full-text articles and made their selection in accordance with the eligibility criteria. Disagreements between reviewers were solved by consensus or through a third person review. Using standardized forms, the same two reviewers independently conducted

Table 1 Search strategy utilized for MEDLINE

#1	("Cryotherapy"[Mesh] OR "cryotherapy" OR "Cryotherapies" OR "Therapy, Cold" OR "Cold Therapies" OR "Cold-Therapies" OR "Cold-Therapie" OR "Therapies, Cold" OR "Cold Therapy" OR "Cold-water therapy" OR "Cold Gel" OR "ice packs" OR "ice towels" OR "ice massage" OR "Ice bag" OR "Crushed-ice packs" OR "Cold packs" OR "Cryocuff" OR "Crushed Ice" OR "Ice" OR "Cold" OR "Body cooling" OR "cooling" OR "cold application" OR "ice therapy" OR "cold-pack" OR "cold pack")
#2	(("delayed onset muscle soreness" OR "DOMS" OR "muscle injury" OR "muscle damage" OR "exercise-induced muscle damage" OR "contraction-induced muscle damage" OR "muscle tenderness" OR "exercise induced muscle damage" OR "muscledamage" OR "delayed onset muscle damage" OR "delayed-onset muscle soreness" OR "delayed-onset muscle damage" OR "skeletal muscle damage" OR "muscle soreness" OR "muscle weakness"))
#3	(randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR ("clinical trial"[tw]) OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) AND (mask*[tw] OR blind*[tw])) OR ("latin square"[tw]) OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh]))
#4	(#1 AND #2 AND #3)

data extraction with regard to the methodological characteristics of the studies, number of participants, age, groups, interventions, outcomes and results. Disagreements were also solved by consensus. DOMS and strength were the outcomes extracted. To improve the clarity of the information provided, the term "strength" is going to be used to refer the muscle ability to produce force.

Quality assessment

The methodological quality of the studies was evaluated using a scale developed by the PEDro database. Based on the Delphi concept, its overall score reliability is sufficient for use in systematic reviews of physical therapy RCTs [20]. The scale contains 11 items and for each criteria defined in the scale, a point (1) is attributed to the presence of quality indicators of the presented evidence, and zero point (0) is attributed to the absence of these indicators. Each satisfied item (except the first) contributes one point to the final score, which is obtained by summing all positive responses. In the present systematic review, the cutoff point of six (6) points was adopted to define the methodological quality of the studies. Thus, the articles were classified as high methodological quality when six or more criteria were positive and of low methodological quality when their score was less than five points.

Data synthesis and analysis

Pooled-effect estimates were obtained by post-intervention values [21]. Calculations were performed using a random-effects method. P value ≤ 0.05 and confidence interval of 95% (95% CI) were considered statistically significant. Statistical heterogeneity of the treatment effects among studies was assessed using Cochran's Q test and the inconsistency I^2 test, in which values above 25% and 50% were considered indicative of moderate and high heterogeneity, respectively [22]. The effect size (ES) between intervention and control groups was calculated using the Cohen's d formula: $\mathrm{ES} = (M_{\mathrm{group1}} - M_{\mathrm{group2}})/\mathrm{SD}_{\mathrm{pooled}}$, where M_{group1} is the mean of the post-values of the intervention group, M_{group2} is the mean of the post-values of the control group, and $\mathrm{SD}_{\mathrm{pooled}}$ is the pooled standard deviation of the intervention and control groups measurements. All analyses were conducted using Review Manager version 5.3. We explored heterogeneity between studies by re-running the meta-analyses removing one paper at a time to check whether some individual study explained heterogeneity. The main outcome used in the meta-analysis was DOMS and strength.

Results

Identification of the studies

The search strategy yielded 221 articles, among which 19 studies were considered as potentially relevant and retrieved for detailed analysis. Seven of these studies met the eligibility criteria and were included in the systematic review ($n = 222$), but only 6 studies had suitable data for the meta-analysis ($n = 182$). Figure 1 shows the flow diagram of the studies included in this review and Table 2 summarizes the characteristics of these studies.

Risk of bias

Regarding the methodological quality of the studies evaluated through the PEDro scale, all included studies were considered of high quality, with scores varying from six to nine points. The mean scores of all studies were 7.28 points. The complete score of each of the studies is described in Table 3. From the analysis of the PEDro scale, it was found that statistical comparisons between groups were reported in all included studies for at least one outcome (criterion 10). In addition, all studies clearly defined criteria 2, 4, 8 and 11, respectively: random assignment of subjects to groups; similarity between groups regarding the most important prognostic indicators; measures of at least one primary endpoint in more than 85% sample; and presence of measures of variability and precision in at least one key result. It is not possible to blind either participants or therapists during local therapy. Therefore, the criteria 5 (blindness of participants) and 6 (blindly of the therapists) were not met by any study. Item 7 (blindness of the evaluators) were filled by four studies.

Description of the studies

From the seven studies selected, six evaluated the effect of cryotherapy on EIMD using application of crushed ice at the site of interest [11, 23–27], and one using a cooling apparatus [28]. The groups for comparison included: control, TENS (transcutaneous electrical nerve stimulation) placebo, TENS, TENS associated with ice, photobiomodulation therapy.

The studies showed a great divergence regarding the protocols of muscle damage induction (series, repetitions, rest time between sets, load, type of contraction and muscle group). Regarding the muscle groups analyzed, three studies induced muscle damage on elbow flexors [24, 25,

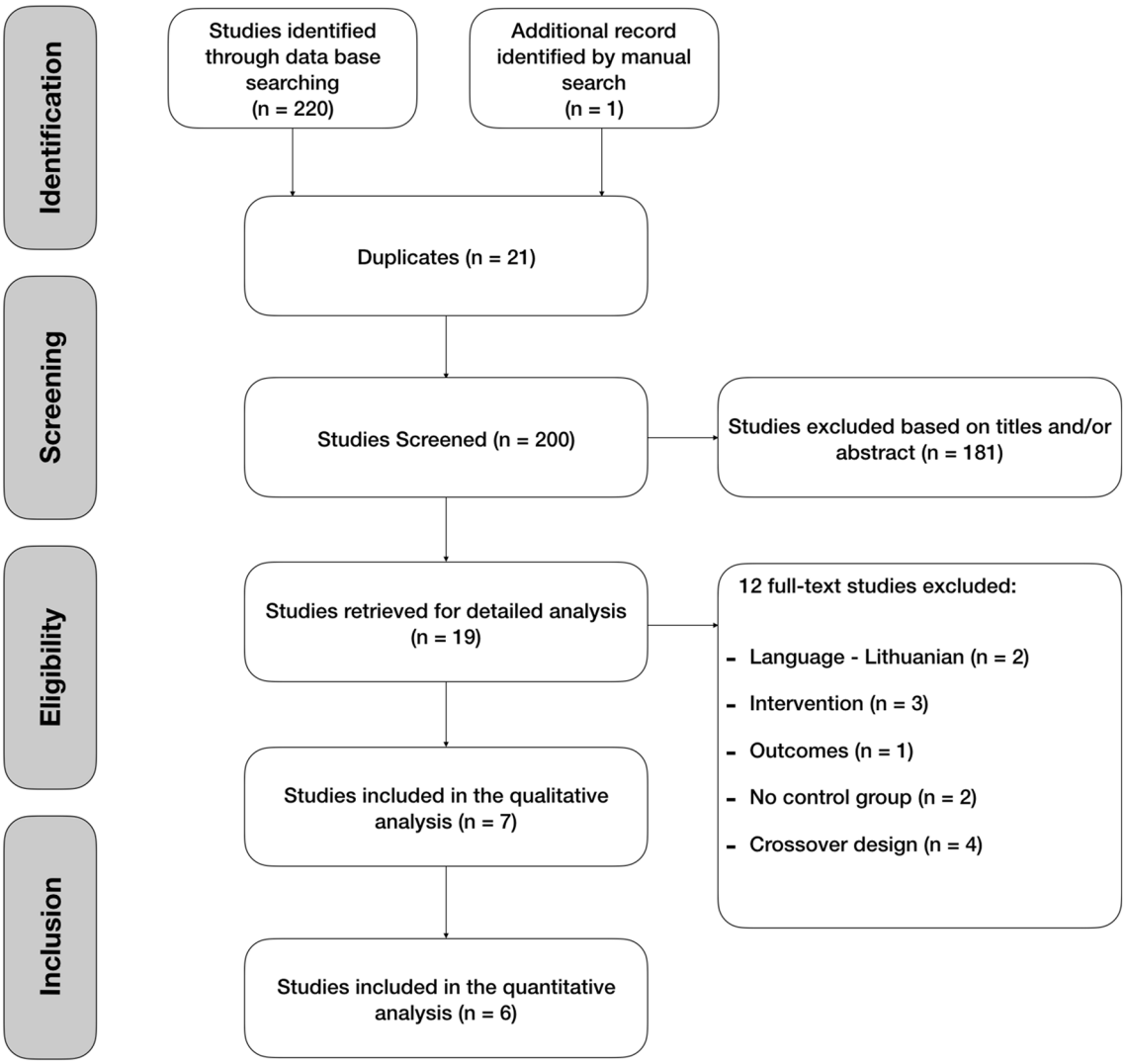

Fig. 1 Flowchart of the studies included in the review

27], one in knee flexors [11], two in knee extensors [26, 28], and one on ankle plantar flexors [23].

As for the intervention protocols, six studies applied cryotherapy in the injured area for 20 min [11, 24–28] and one study [23] calculated the time of the intervention according to the amount of subcutaneous tissue of the subject, ranging from 15 to 60 min. The duration of interventions ranged from immediately after protocol of muscle damage induction up to 96 h after, with a frequency of cryotherapy application ranging from 1 to 3 times per day.

Effects of interventions

Delayed onset muscle soreness

All included studies in the present review evaluated DOMS and used the visual analog pain scale (EVA) to evaluate it. However, only five studies provided suitable data for meta-analysis. The analysis showed that cryotherapy is not effective to improve DOMS at any of the time points evaluated (−0.11; 95% CI −0.8 to 0.57; I^2: 79%; Fig. 2).

Muscle strength

Six studies evaluated muscle strength. Four did so through the maximal voluntary isometric contraction (MVIC) of the muscle group of interest [11, 25–27]; one evaluated the peak of concentric and eccentric peak torque [24], and one evaluated peak power output [28]. However, only two studies had sufficiently homogeneous data for the meta-analysis. The analysis showed that cryotherapy is not effective to accelerate strength recovery at any of the time points evaluated (−0.59; 95% CI −2.89 to 1.71; I^2: 0%; Fig. 3).

Table 2 Characteristics of the included studies

Study (year)	Sample (age)	Groups	Muscle damage induction protocol	Interventions	Outcomes	Results
Denegar and Perrin (1992) [24]	40 untrained women (22 ± 4.3)	G1 = cryotherapy G2 = TENS G3 = cryotherapy + TENS G4 = TENS placebo G5 = control	3 submaximal elbow flexion eccentric-concentric contractions	G1 = local cryotherapy G2 = TENS (pulse rate = 90 pps; phase duration = 90 μs, continuous duty cycle, intensity = tingling sensation G3 = local cryotherapy + TENS G4 = TENS placebo All treatments were applied for 20 min and were carried out 48 h following the muscle damage. All participants performed 4 sets of 30 s of static stretching	DOMS (VAS—Talag Scale); elbow flexion PT Evaluations: pre, 48 h post-muscle damage induction	G1, G2 and G3 decreased DOMS when compared to G4 and G5; no differences between groups were found for PT
De Marchi et al. (2017) [27]	40 active men (19–29 years)	G1 = placebo G2 = cryotherapy G3 = PBMT G4 = cryotherapy + PBMT G5 = PBMT + cryotherapy	5 sets of 10 eccentric/concentric elbow flexors contractions at 90°/s and 180°/s	G1 = placebo G2 = 20 min of cryotherapy (single application) G3 = PBMT (41.7-J) G4 = cryotherapy before PBMT G5 = PBMT before cryotherapy	DOMS (VAS) MVIC CK Evaluations: pre, immediately post-PMDI, post-intervention, 60 min post, 24, 48 and 72 h following the interventions	G3, G4 and G5 reduced DOMS and recovered MVIC 60 min post, 24, 48 and 72 h post-intervention when compared to G1 and G2
Hohenauer et al. (2017) [28]	17 women and 5 men recreationally active (22.6 ± 2)	G1 = cryotherapy G2 = control	3 sets of 30 counter movement jumps	G1 = 20 min of cryotherapy (*Zamar thigh cuff* (8 °C)) G2 = same device at 32 °C	DOMS Peak power output Perceived exertion Vertical jump Evaluations: pre, immediately post, 24, 48 and 72 h post-intervention	No significant differences between groups for any of the variables analyzed
Lima et al. (2017) [25]	19 untrained women (21.6 ± 2.0)	G1 = cryotherapy G2 = control	2 sets of 10 repetitions of maximal isokinetic eccentric elbow flexions at 30°/s with 30 s rest between sets	G1 = 20 min of local cryotherapy twice per day applied immediately post, 24, 48 and 72 h post-PMDI	DOMS (VAS) MVIC Muscle thickness Echo intensity Evaluations: pre, immediately post and 24, 48 and 72 h post-PMDI	No significant differences between groups for any of the variables analyzed

Table 2 (continued)

Study (year)	Sample (age)	Groups	Muscle damage induction protocol	Interventions	Outcomes	Results
Oakley et al. (2013) [11]	17 men and 16 women (24 ± 4.0)	G1 = cryotherapy G2 = control	5 sets of 10 repetitions of isokinetic eccentric knee flexion with 1 min rest between sets	G1 = 20 min of cryotherapy, 3 times per day applied immediately post, 24, 48 and 72 h post-PMDI	DOMS (VAS) MVIC CK Evaluations: Immediately post, and 24, 28 and 72 h post-PMDI	Significant difference between groups for DOMS at 48 h following the PMDI. No other between-group differences were observed
de Paiva et al. (2016) [26]	50 untrained men (18–25 years)	G1 = placebo G2 = PBMT G3 = cryotherapy G4 = cryotherapy + PBMT G5 = PBMT + cryotherapy	5 series of 15 eccentric contractions at 60°/s and 180°/s of knee extensors	G1 = placebo G1 = placebo G2 = 20 min of cryotherapy (single application) G3 = PBMT (41.7-J) G4 = cryotherapy before PBMT G5 = PBMT before cryotherapy	DOMS (VAS) MVIC CK Evaluations: pre, immediately post, post-intervention, 60 min, 24, 48, 72 and 96 h post-interventions	G2, and G5 presented reduced DOMS and improved MVIC 60 min post, 24, 48, 72 and 96 h when compared to G1, G3 and G4
Selkow et al. (2015) [23]	3 healthy men and 15 healthy women (22.2 ± 2.2)	G1 = cryotherapy G2 = control G3 = placebo	100 unilateral concentric-eccentric plantar flexions	G1 = 750 g of crushed ice in the medial gastrocnemius for 15–60 min G3 = 750 g of popcorn Interventions applied immediately post, 10, 24, 34 h post-PMDI	DOMS (VAS) Evaluations: pre-DM, immediately after, 10, 24, 34 and 48 h after a induction of DM	DOMS was lower in G1 when compared to G2 at 34 and 48 h post-PMDI; and lower than G3 at 34 h post-PMDI

TENS transcutaneous electrical nerve stimulation, *MVIC* maximal voluntary isometric contraction, *CK* creatine kinase, *PMDI* protocol of muscle damage induction, *DOMS* delayed onset muscle soreness, *PT* peak torque, *G* group, *VAS* Visual analog scale, *1RM* 1 repetition maximum

Table 3 Evaluation of the methodological quality (PEDro Scale)

Studies	Scores											Total
	1	2	3	4	5	6	7	8	9	10	11	
De Marchi et al. [27]	X	X	X	X	–	–	X	X	X	X	X	9
Denegar and Perrin [24]	X	X	–	X	–	–	–	X	X	X	X	6
Hohenauer et al. [28]	X	X	–	X	–	–	–	X	X	X	X	6
Oakley et al. [11]	X	X	–	X	–	–	–	X	X	X	X	6
de Paiva et al. [26]	X	X	X	X	–	–	X	X	X	X	X	8
Lima et al. [25]	X	X	X	X	–	–	X	X	X	X	X	8
Selkow et al. [23]	X	X	X	X	–	–	X	X	X	X	X	8

Internal validity score of the PEDro scale studies. A point (1) is assigned to the presence and zero point (0) is attributed to the absence of each of the following indicators (with the exception of the first, which is not punctuated): 1—specification of inclusion criteria; 2—random allocation; 3—confidential allocation (blind distribution); 4—similarity between groups; 5—blinding of participants; 6—blinding of therapist; 7—outcome evaluator blinding; 8—measurements of at least 1 primary endpoint in more than 85% sample; 9—intention to treat analysis; 10—comparison between groups at least 1 primary outcome; 11—measures of precision and variability at least one variable

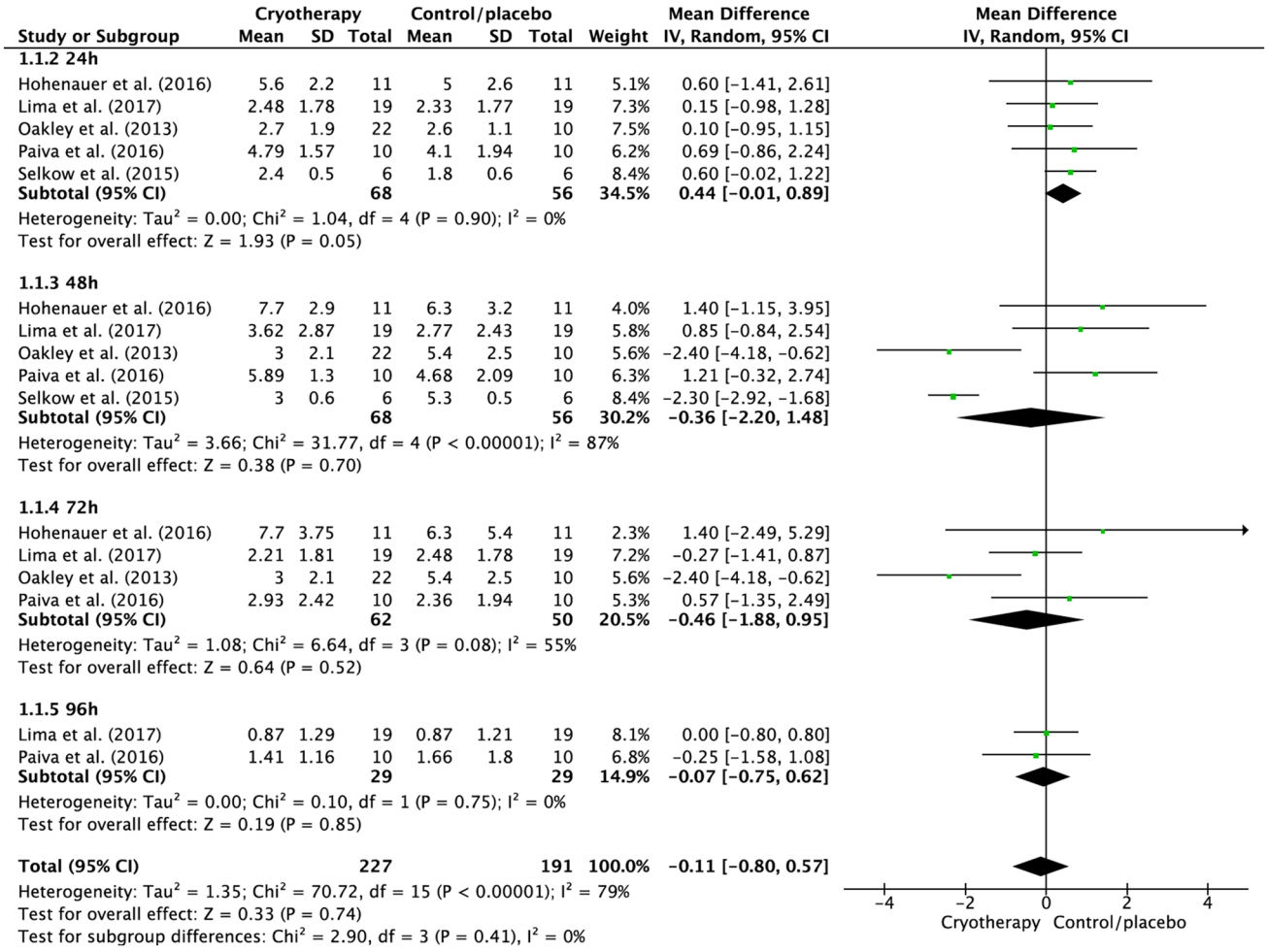

Fig. 2 Analysis of the effects of local cryotherapy on delayed onset muscle soreness compared to a control/placebo group

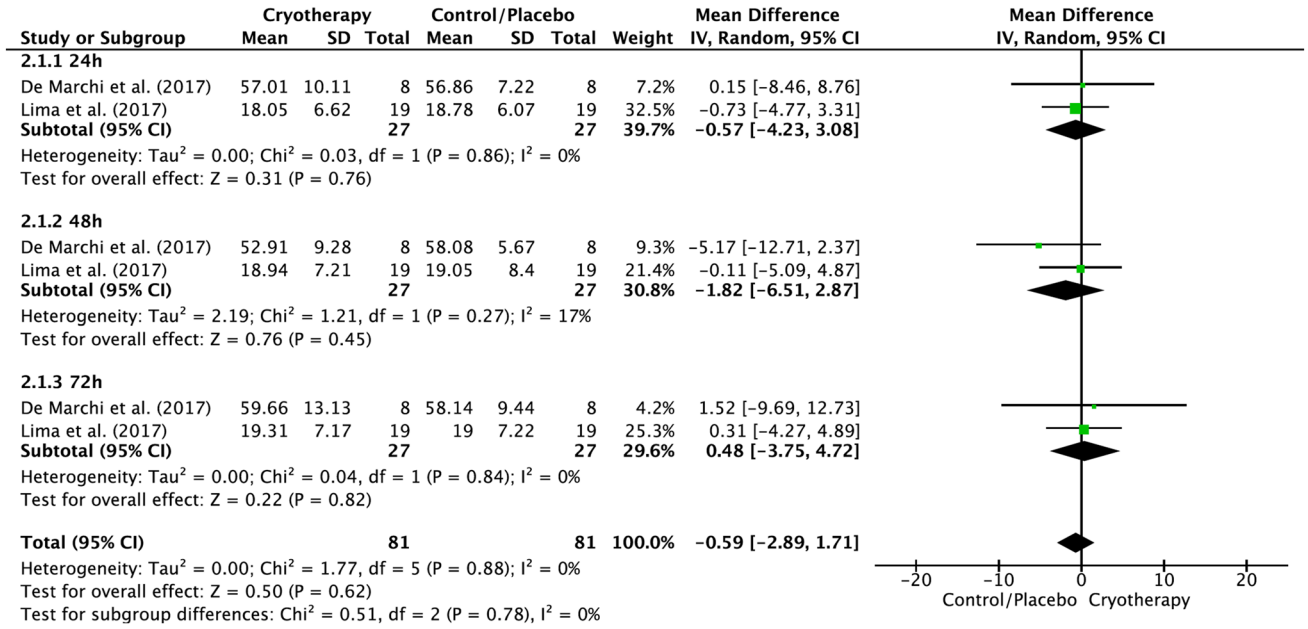

Fig. 3 Analysis of the effects of local cryotherapy on strength compared to a control/placebo group

Discussion

The aim of this systematic review of the literature was to determine the efficacy of local cryotherapy for the treatment of subjective (DOMS) and objective (strength) symptoms associated with EIMD. After a complete analysis of the included articles, seven studies were included in the present review. DOMS and strength were chosen as outcome measures, because they are the variables most commonly investigated. Contrary to our hypothesis, it can be suggested that local cryotherapy is not effective in accelerating recovery of either DOMS or strength.

It is known that the decrease in tissue temperature reduces the oxygen demand, cellular metabolic activity and attenuates the release of vasodilators, reducing the microcirculatory overload by the decrease in circulating blood volume [8]. This, in turn, attenuates the hydrostatic pressure in the endothelial cell, decreasing the formation of edema. Furthermore, the decrease in blood flow causes a reduction in the formation of hematomas and muscle spasm associated with possible pain relief [29]. In addition, there is a decrease in nerve transmission caused by tissue cooling, which would reduce the release of acetylcholine and possibly stimulate inhibitory surface cells to increase the pain threshold [30].

Currently, there are three main common cryotherapy modalities used in sport: cold-water immersion (CWI), whole-body cryotherapy (WBC), partial-body cryotherapy (PBC). During CWI, the water is maintained at temperatures ranging from 5 to 13 °C for 10–24 min [6, 31]. WBC and PBC are more extreme forms of cryotherapy, in the first one the individuals enter two or three closed chambers, where they are exposed to extremely cold air up to 4 min, in temperatures ranging from − 10 to − 130 °C [32, 33], while the latter involves vaporized liquid nitrogen, generating temperatures from − 110 °C down to − 195 °C [10, 34] for 1–3 min. Even though there is a growing body of investigations analyzing the effects of the aforementioned cryotherapy modalities to reduce symptoms of EIMD, there is no consensus in the literature regarding the efficacy of such strategies [12, 13, 35, 36]. Furthermore, they are hardly applicable in a clinical environment, which is the main advantage of local cryotherapy.

Many theories have tried to explain the origin of DOMS [37]. However, whether the initiating stimulus is chemical, thermal, mechanical or a combination of more than one factor remains uncertain [38]. The most accepted theory hypothesize that DOMS is related to the inflammatory response and muscle damage caused by strenuous exercise [37]. Therefore, strategies capable of decreasing inflammatory response might contribute to attenuate symptoms of DOMS. Nevertheless, according to the results found in the present review, local cryotherapy does not seem to provide any benefit to improving symptoms of DOMS. There is a possibility that local cryotherapy does not provide the same physiological benefits seen in other cooling modalities (e.g., CWI and WBC) such as muscle oxygen saturation, cutaneous vascular conductance, and mean arterial pressure [39–41]. Perhaps, the cooling generated by local cryotherapy is just not sufficient to produce significant responses within the tissue. However, it is worth pointing out in this context

that the two studies that found advantages of local cryotherapy over control/sham groups for attenuating symptoms of DOMS used more frequent applications (three times per day) [11] and chose the duration of application according to the amount of subcutaneous tissue [23]. Hence, it is plausible to assume that a single bout of local cryotherapy for a standard period of time (15–20 min) might not be sufficient to generate positive effects on DOMS. It is worth highlighting that even though DOMS is an important variable during muscle recovery it tends to significantly decrease as the activity begins [37]. Force production, on the other hand, seems to be the most remarkable variable to be recovered following strenuous exercises, considering that most sports depend on it.

The diminished ability to produce strength following EIMD is one of the most used and most reproducible objective markers of muscle damage in humans [42, 43]. The reason why muscles are unable to produce maximal force after EIMD remains unclear. However, it is known that contracting skeletal muscles have increased production of reactive oxygen species (ROS) [44], and the increased production of ROS leads to oxidative stress, which might impair force production [45]. The present review demonstrated that local cryotherapy does not seem to be effective to accelerate strength recovery following EIMD. There is no consensus in the literature regarding the effects of cold therapy strategies to accelerate strength recovery following EIMD [9, 35, 36], different methods of application and protocols make it hard to reach a definitive answer. However, it is been suggested that an increase in peripheral catecholamine concentration following CWI might generate an auto-oxidative process, which would perpetuate muscle fatigue [46] and impair force production. This premise was confirmed by a recent investigation that found that CWI seems to delay muscle recovery following EIMD [36]. Furthermore, there is a significant body of evidence suggesting that CWI might impair muscle adaptation during strength training [47–49]. Therefore, the use of cold therapy post-exercise has become questionable, considering that most athletes perform some sort of strength training in their routine. We are unable to state that the rules for CWI and other modalities of cold therapies apply for local cryotherapy. Therefore, the mechanisms underpinning the failure of local cryotherapy to accelerate strength recovery following EIMD remain unclear. Nonetheless, the data found in the present review allow us to suggest that local cryotherapy does not seem to be a worthwhile strategy to be used to accelerate strength recovery following EIMD.

To the best of the authors' knowledge, this is the first review to systematically analyze the influence of local cryotherapy on DOMS and strength. The current review presents relevant methodological strengths such as the analysis of two of the most important variables of EIMD (DOMS and strength). Moreover, a strategy for a sensitive and comprehensive search to assure the location of all studies in this field was held. Another important quality of the present review is the high methodological quality of the included studies; this makes the information provided more reliable. However, the heterogeneity among the included studies prevented more robust meta-analyses, especially for strength, and this should be pointed out as a relevant limitation.

Conclusion

In conclusion, the present review showed that local cryotherapy does not seem to be effective to accelerate recovery from symptoms of EIMD. Even though, local cryotherapy is suitable for clinical practice, the evidence proving its efficacy is limited. It is possible that local cryotherapy might contribute to decrease DOMS if applied more frequently. However, cryotherapy might not be a worthwhile strategy, given the potential harm that it may cause on muscle strength. Considering the current evidence, we discourage physical therapists and conditioning coaches to use local cryotherapy in an attempt to attenuate symptoms of EIMD.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The present study did not require ethical approval.

Informed consent For this type of study, formal consent is not required.

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