

Postoperative Cryotherapy in Joints Other Than the Knee

A Systematic Review of Pain, Edema, Analgesic Use, and Blood Loss in the Shoulder, Hand, Hip, and Ankle Joints

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Background: Cryotherapy has proven effective for pain reduction in the knee joint. However, its efficacy in other joints is less clear.

Purpose: To explore the benefits of cryotherapy in joints excluding the knee.

Study Design: Systematic review; Level of evidence, 4.

Methods: In June 2023, a review of EMBASE, PubMed MEDLINE, PROSPERO, ClinicalTrials.org, and the Cochrane Library was performed following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines. Search terms were “cryotherapy,” “cold application,” “postoperative,” and “postoperative period.” Studies that assessed postoperative cryotherapy in joints excluding the knee were included. Spine, tumor, and pediatric studies were excluded. Outcomes evaluated were postoperative pain status, analgesic use, edema, and blood loss.

Results: Out of 6749 studies, 22 studies (1424 patients) were ultimately included. Postoperative pain was evaluated in 20 studies, analgesic consumption in 14 studies, edema in 8 studies, and blood loss in 6 studies. Cryotherapy showed significant benefits in pain reduction in 9 studies, decreased analgesic use in 7 studies, edema reduction in 4 studies, and decreased blood loss in 2 studies. The hip showed the most consistent benefits from cryotherapy, across all studied parameters. However, increased haloperidol consumption was noted in hip fractures. Cryotherapy benefits after wrist surgery (4 studies; 211 patients) varied by procedure. Particularly for carpal tunnel procedures, continuous cryotherapy showed significant reductions in pain, analgesic use, and postoperative edema. For ankle surgeries (4 studies; 301 patients), cryotherapy was beneficial for pain and analgesic consumption, but it was not the optimal edema-resolving method. Benefits in elbow surgery (1 study; 59 patients) were limited to pain and analgesia consumption. For shoulder surgery (6 studies; 311 patients), the evidence was not consistent regarding the benefits of cryotherapy on postoperative pain despite a general trend toward amelioration, with compression cryotherapy and continuous cryotherapy showing the best results.

Conclusion: The effectiveness of cryotherapy appeared dependent on the specific surgical context and the protocol used. Pairing cryotherapy with compression led to better outcomes than cryotherapy alone. Special consideration should be given when implementing cryotherapy after hip fractures.

Keywords: review; cryotherapy; postoperative; joints; orthopaedic surgery

inflammation and edema, as well as the metabolic rate of cells.⁵ It affects pain by decreasing free nerve-ending sensitivity, slowing synaptic activity, and increasing firing thresholds.⁵ It also reduces edema by leading to local vasoconstriction for longer than simply the duration of application.^{9,45,47}

Orthopaedic surgeons routinely use cryotherapy as a postoperative treatment modality.^{6,31} Reports on this practice have been increasing.^{38,42} The application of cold on the knee joint specifically has been greatly described in the literature, in the setting of both joint replacement and sports-related surgery.^{45,47} Recent studies also suggest dynamic compression is more efficient than static compression.²⁶ The body of knowledge pertaining to other joints remains smaller by comparison, and results are inconsistent. Postoperative patient satisfaction and rehabilitation may depend on type of modality administered, the presence of other analgesic treatments such as nerve blocks, and the temperature range used.^{43,48} These have a potential effect on reducing muscle atrophy and increasing speed of recovery after rehabilitation.⁹

The goal of this systematic review was to define the effect of cryotherapy on the postoperative management of joint pathologies excluding the knee as evaluated by its impact on postoperative pain, analgesic consumption, edema, and blood loss. We hypothesized that the effectiveness of postoperative cryotherapy varies significantly across different joints and surgical procedures, with certain joints possibly demonstrating more pronounced benefits.

METHODS

Eligibility Criteria

The structure of this systematic review was set in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines of 2020.³⁰ The literature was searched to find studies based on the following criteria.

- **Study design:** The studies were prospective randomized controlled trials (RCTs), nonrandomized trials, or retrospective comparative studies. Initial inclusion criteria were all articles that report on the use of cryotherapy in postoperative management of all joints excluding the knee.
- **Comparison:** The individual studies had to involve a comparison between different cryotherapy types or between a cryotherapy and a noncryotherapy modality.

Outcome Measures

The primary outcome measures were postoperative pain levels as evaluated by standardized tools such as the visual analog scale (VAS) for pain or Numeric Pain Rating Scale (NRS), as well as analgesic consumption. Secondary outcome measures assessed postoperative joint edema and blood loss.

Information Sources and Search Strategy

A thorough literature search was conducted on June 5, 2023, utilizing prominent databases such as PubMed MEDLINE, EMBASE, PROSPERO, ClinicalTrials.org, and the Cochrane Library to ensure comprehensive coverage of the topic. An advanced search strategy was employed, using a combination of Medical Subject Headings (MeSH) terms and keywords. The primary search string was ("Cryotherapy" [MeSH Terms] OR "Cryotherapy" [All Fields] OR "Cold application" [All Fields]) AND ("Postoperative Period" [MeSH Terms] OR "Postoperative" [All Fields]).

References of included studies were also manually screened to identify potential studies missed during the initial search.

Study Selection and Quality Assessment

Two authors (A.H. and K.M.K.) independently performed the study selection based on titles and abstracts. Studies were excluded if they did not meet eligibility criteria. After the first round of exclusions, another screening using the entire content of the remaining articles was performed. The 2 authors reviewed all articles before a final decision was made. Reviewers were not blinded to any study characteristics including journal, authors, and study institution. Study quality was first assessed using sample size, study design, follow-up consistency, and variability of results. Overall level of evidence applicable to orthopaedic surgery was also assessed.⁴⁶

Data Collection and Analysis

The data extracted included outcomes such as pain, edema, blood loss, and use of analgesics. Also included was the information on affected joints, type of surgery, and timing of outcome measurement. General characteristics of the studies were also noted. The type of cryotherapy used as well as, control were also recorded. These studies were grouped together into predefined categories, based on the

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joint type: hip, ankle, shoulder, elbow, and wrist. Whenever possible and necessary, information was taken through direct contact with the study authors.

Using Review Manager 5.4 software, a meta-analysis of the data was attempted. However, due to heterogeneity and incomplete information, this could not be performed appropriately.

The risk of bias was assessed using the Revised Cochrane risk-of-bias tool for randomized trials short version (RoB 2).

RESULTS

Included Studies

A total of 6749 studies were identified and screened. Of those, 6633 were excluded after evaluation of title and abstract because they were duplicates, irrelevant to the topic, pertained to the knee joint, did not have an available abstract, had an inappropriate study design, were case reports, or studied pediatric populations. A total of 116 records were sought for retrieval. Three records could not be retrieved. A full-text analysis was done for 113 records. In the end, 22 studies[§] with a total of 1424 patients were included in the review. Reasons for exclusion were again lack of relevance to the topic and inappropriate studies, including non-English language articles.

The flowchart in Figure 1 details the search and selection process.

Study Characteristics and Quality

The included studies varied in design, with levels of evidence ranging from 1 to 4. The characteristics of each study are shown in Table 1. Overall, 11 studies^{||} evaluated the upper extremity. The shoulder was the most commonly studied joint of the upper limb (6 studies^{2,15,19,28,39,48}; 311 patients). The remaining upper extremity studies assessed wrist and hand procedures (4 studies^{12,25,32,33}; 211 patients). One study (Yu et al⁴⁸; 59 patients) evaluated cryotherapy in elbow arthrolysis. Eleven studies[¶] involved the lower extremity, and the hip was the most commonly studied in the lower limb (7 studies^{1,13,17,21,22,29,37}; 542 patients). The remaining 4 studies^{7,23,35,41} (301 patients) evaluated the foot and ankle joints.

The results of the risk-of-bias assessment are displayed in Figure 2. The results of the assessment can be due to the fact that few studies were truly randomized; they did not follow a predetermined plan or failed to state that they were; and patients could not be blinded to the type of intervention undergone, as the use of cryotherapy would have been noticed.

[§]References 1, 2, 7, 12, 13, 15, 17, 19, 21-23, 25, 28, 29, 32, 33, 35, 37, 39-41, 48.

^{||}References 2, 12, 15, 19, 25, 28, 32, 33, 39, 40, 48.

[¶]References 1, 7, 13, 17, 21-23, 29, 35, 37, 41.

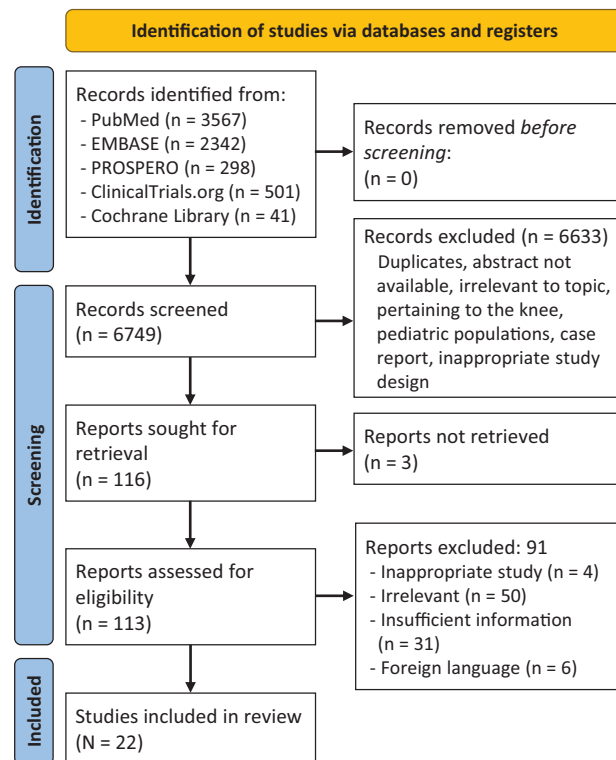


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 flow diagram for the systematic reviews.

Effect of Cryotherapy on VAS/NRS Pain Scores and Analgesia Dosage

Pain was evaluated in all but 2 studies^{33,41} (Table 2). Time intervals ranged from preoperative to 3 months postoperative. Of these, 9 studies^{1,12,17,23,29,37,39,40,48} demonstrated a significant decrease in pain scores in the cryotherapy group at ≥ 1 postoperative time point. Fourteen studies[#] evaluated the use of oral analgesics; among these, 7 studies^{1,7,12,29,32,37,48} showed that analgesic use was significantly decreased in patients using cryotherapy.

Hip Surgery. Albrecht et al¹ evaluated patients with and without cryotherapy after total hip arthroplasty (THA) and found that patients with continuous cryotherapy had a significantly lower pain level compared with control ($P < .001$). In another study, Saito et al³⁷ assessed pain severity in patients after THA. The patients were randomized into either a control group or a cryotherapy group. The latter received cryotherapy treatment for 4 days. During those first 4 days, there was significantly more pain in the control group ($P < .050$).³⁷ Similar trends were shown by Leegwater et al,²² Iwakiri et al,¹³ and Okoro et al,²⁹ without reaching statistical significance. Meanwhile, Okoro et al revealed significant reduction in codeine, paracetamol, nonsteroidal anti-inflammatory drugs, and tramadol doses in the cryotherapy group.

[#]References 1, 7, 12, 15, 17, 19, 21, 22, 28, 29, 32, 35, 37, 48.

TABLE 1
Summary of Studies on Cryotherapy Interventions for Various Joint Procedures^a

Lead Author (Year)	Study Design; LOE	Joint/Surgery Type	Control Group		Experimental Group 1		Experimental Group 2		Outcomes Reported		
			n	Intervention ^b	n	Intervention	n	Intervention ^c	Pain	Edema	Analgesic Use
Hip (7 studies, 542 patients)											
Albrecht (1997) ¹	Clinical trial; 2	Hip/THA	70	None	72	Cold pump therapy	72	Cold	X		X
Saito (2004) ³⁷	RCT; 1	Hip/THA	23	None	22	Computer - controlled cryotherapy		—	X		X
Leegwater (2012) ²²	RCT; 1	Hip/THA	15	None	15	Compressive cryotherapy		—	X		X
Leegwater (2017) ²¹	RCT; 1	Hip/fracture	61	None	64	(Continuous flow) compressive cryotherapy		—	X		X
Okoro (2019) ²⁹	Prosp cohort study; 2	Hip/THA	15	None	13	Continuous cryotherapy		—	X		X
Klaber (2019) ¹⁷	Prosp cohort study; 2	Hip/arthrosc FAI		—	20	Compressive cryotherapy	20	Standard cold	X		X
Iwakiri (2019) ¹³	Retrospective case- control; 3	Hip/THA	30	None	30	Controlled cold therapy		—	X	X	
Foot and Ankle (4 studies, 301 patients)											
Stöckle (1997) ⁴¹	RCT; 1	Foot and ankle/ fracture	20	Cool packs	20	Continuous cryotherapy	20	Impulse compression		X	
Rohner-Spengler (2014) ³⁵	RCT; 1	Foot and ankle/ fracture	23	Ice	21	Bandage	14	Impulse compression	X	X	X
Lin (2018) ²³	Retrospective case- control; 4	Calcaneus/ fracture	49	None	51	Periop cryotherapy	48	Preop cryotherapy	X		
De Boer (2021) ⁷	Retrospective case- control; 3	Foot and ankle/ fracture	17	None	18	Cold compression		—	X		X
Shoulder (6 studies, 311 patients)											
Singh (2001) ³⁹	RCT; 1	Shoulder/open and arthrosc	32	None	32	Continuous cryotherapy		—	X		
Speer (1996) ⁴⁰	RCT; 1	Shoulder/ stabilization, RCR, TSA	25	None	25	Cryotherapy		—	X		
Kraeutler (2015) ¹⁹	RCT; 2	Shoulder/RCT		—	25	Compressive cryotherapy	21	Ice water	X		X
Alfuth (2016) ²	RCT; 2	Shoulder/RCR, SAD, instability surgery		—	26	Cold compression	26	Cold	X	X	
Noyes (2018) ²⁸	RCT; 1	Shoulder/TSA		—	20	Compressive cryotherapy	20	Ice water	X		X
Kara (2020) ¹⁵	Retrospective observ; 4	Shoulder/RCT	16	None	20	Ice wrap	23	Subacromial injection	X	X	X
Elbow (1 study, 59 patients)											
Yu (2015) ⁴⁸	RCT; 1	Elbow/arthrolysis	28	None	31	Cryotherapy		—	X		X
Wrist and Hand (4 studies, 211 patients)											
Rembe (1970) ³³	RCT; 1	Hand/not reported	15	None	15	Cryotherapy		—		X	
Hochberg (2001) ¹²	RCT; 1	Wrist/carpal tunnel		—	33	Controlled cold therapy	35	Ice therapy	X	X	X
Meyer-Marcotty (2011) ²⁵	RCT; 1	Wrist/arthrosc		—	25	Compressive cryotherapy	28	Standard cryotherapy	X	X	

(continued)

TABLE 1
(continued)

Lead Author (Year)	Study Design; LOE	Joint/Surgery Type	Control Group		Experimental Group 1		Experimental Group 2		Outcomes Reported		
			n	Intervention ^b	n	Intervention	n	Intervention ^c	Pain	Edema	Analgesic Use
Pouedras (2021) ³²	Prosp case-control; 2	Wrist and thumb/ trapeziectomy with or without interposition of pyrocarbon implant or 4-corner fusion	30	None	30	Cryotherapy splint	—	—	X		X
Total			469		628		327		20	8	14

^aarthrosc, arthroscopic; FAI, femoroacetabular impingement; LOE, level of evidence; observ, observational; periop, perioperative; preop, preoperative; prosp, prospective; RCR, rotator cuff repair; RCT, randomized controlled trial; retros, retrospective; SAD, subacromial decompression; THA, total hip arthroplasty; TSA, total shoulder arthroplasty.

^bDashes in this column indicate no noncryotherapy controls were included in these studies.

^cDashes in this column indicate areas not applicable.

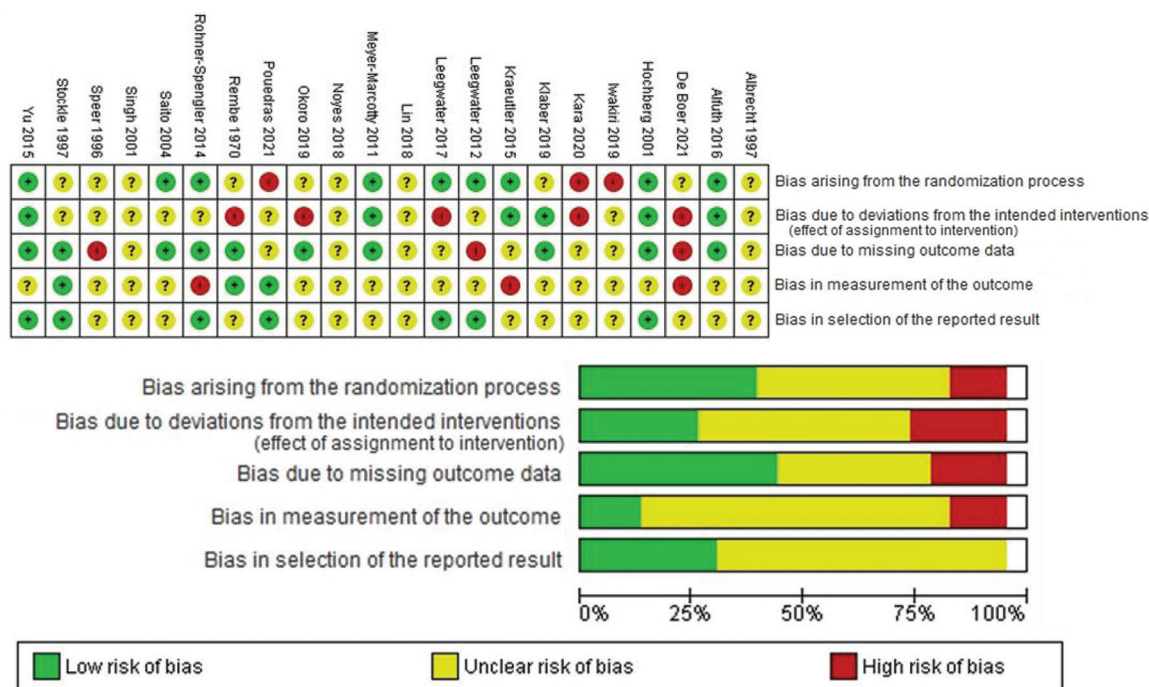


Figure 2. Results of the risk-of-bias assessment.

Regarding other hip surgeries, Klaber et al¹⁷ studied patients after hip arthroscopy and found overall lower VAS scores in the cryotherapy group ($P = .003$). The 2017 Leegwater et al²¹ study revealed significantly reduced hip fracture pain on postoperative day 3 when using continuous flow compression cryotherapy as compared with control, with comparable results for the other studied time points. However, this was associated with an increased need for haloperidol medication in the cryotherapy group.

Foot and Ankle Surgery. Regarding the ankle, a clear reduction in VAS scores was demonstrated in 1 study,²³ while in the other study the decreased use of analgesics was the only indicator of improved pain within that population.⁷ This study⁷ was limited by its sample size, level of evidence, and high risk of bias. Interestingly, both studies addressed ankle fracture surgeries.

Lin et al²³ studied postoperative pain and wound complications after calcaneal fracture repair. Patients were

randomized into 3 groups: a control group, a group receiving postoperative cryotherapy, and a group receiving perioperative cryotherapy. By day 3, both cryotherapy groups had significantly lower VAS scores than controls. However, there was no difference between the cryotherapy groups.²³ Meanwhile, De Boer et al⁷ found that cold therapy in patients with ankle and hindfoot fractures did not significantly affect pain while significantly decreasing the analgesia needs.

Shoulder Surgery. When considering all shoulder procedures, 2 RCTs (Singh et al³⁹ and Speer et al⁴⁰) reported a significant reduction in pain between patients who received either continuous cryotherapy³⁹ or compression cryotherapy⁴⁰ compared with control. Conversely, Kara et al¹⁵ and Noyes et al²⁸ failed to achieve statistically significant pain reductions when using cryotherapy in total shoulder arthroplasty and rotator cuff repair, respectively.

Elbow Surgery. In the only study evaluating elbow surgery, Yu et al⁴⁸ found that when applied 3 times daily for 1 week after elbow arthrolysis, cryotherapy led to significantly less pain for the duration of the treatment, while both at rest and in motion ($P < .050$). This difference disappeared after cryotherapy was discontinued.

Wrist Surgery. Wrist surgery studies yielded mixed results, with inconclusive benefits on VAS pain after wrist arthroscopy and trapeziectomy/4-corner fusion surgery.^{25,32} Meanwhile, Pouedras et al³² demonstrated significant reduction of analgesia consumption during the in-hospital postoperative period. Hochberg¹² found that 3 days after carpal tunnel release, patients treated with controlled cold therapy had a better pain score than those treated with standard ice therapy (4.5 ± 3.2 vs 7.3 ± 2.5 , respectively; $P < .001$). In contrast, studies involving non-cryotherapy control failed to find significant improvement of postoperative VAS pain while demonstrating significant decrease in analgesic doses.^{13,32}

Effect of Cryotherapy on Postoperative Edema

Edema was evaluated in 8 studies,^{2,12,13,15,25,33,35,41} and it was measured differently for each joint (Table 3). In the case of the shoulder joint, methods used included measurement of circumference² or distance between 2 points.¹⁵ Other methods included water displacement after submerging the affected limb in water.^{25,33} For the lower limb studies, circumference at the ankle (figure-of-8-20 measurement method as described by Rohner-Spengler et al³⁶) or thigh (at specific landmarks) was used.^{13,35,41} There were no included studies on edema after elbow surgery.

Hip Surgery. After a postoperative cryotherapy management for 72 hours, Iwakiri et al¹³ reported significantly lower thigh circumference at day 4 in the cryotherapy group compared with the control group with respective ratios, 1.041 ± 0.038 versus 1.067 ± 0.055 ($P = .045$).

Ankle Surgery. There were notable controversies surrounding the most effective method for reducing

postoperative edema. A 1997 study by Stöckle et al⁴¹ demonstrated that continuous cryotherapy and intermittent impulse compression were markedly superior to standard cool pack therapy, with reductions in edema ranging from 32% to 74% in the intervention groups compared with a modest 10% to 45% reduction in the control group (cool pack therapy). The differences were in favor of intermittent impulse compression when compared with continuous cryotherapy. However, this assertion was later challenged by Rohner-Spengler et al³⁵ in 2014, who found that intermittent compression was not better than cold therapy, unless used with additional stockinette or bandage compression and elevation. They also found that use of layered bandages, while reducing swelling more quickly, actually caused less ankle movement by the third day after surgery compared with the control group.³⁵

Shoulder Surgery. Two studies involving the shoulder failed to reveal a statistically significant difference in edema level between cryotherapy and control.^{2,15} In the study by Alfuth et al² involving shoulder surgeries, 2 interventions were compared. The first showed an edema range of 32.4 to 35.5 cm from 0 to 24 hours postoperatively, and the second showed a slightly higher range of 34.4 to 36 cm. Compared with the control group, edema was lower in the intervention groups, but the difference was not statistically significant.

Wrist and Hand Surgery. Two studies^{25,33} compared cryotherapy with a noncryotherapy control: the first one was the RCT by Meyer-Marcotty et al²⁵ after wrist arthroscopy. The authors observed a trend toward less edema in the control group, but this difference did not reach statistical significance.²⁵ Conversely, Rembe³³ reported a smaller postoperative hand volume increase (indicating less edema) in the cryotherapy group for patients treated for rheumatoid arthritis, but this did not reach statistical significance. Similarly, Hochberg¹² reported a significantly greater decrease in edema after a carpal tunnel procedure in the continuous cold therapy group compared with the standard ice pack group, with a percentage change of $-1.9\% \pm 2.8\%$ versus $4.1\% \pm 2.7\%$ respectively ($P < .001$).

Effect of Cryotherapy on Postoperative Blood Loss

Six studies^{1,21,22,29,37,48} discussed blood loss (5 studies for hip surgery^{1,21,22,29,36} and 1 study for elbow surgery⁴⁷) (Table 4). Several means were used for the evaluation of blood loss. These included difference in hemoglobin in mmol/L,^{21,22} mg/dL¹ as well as g/L,²⁹ incidence of blood transfusions,²¹ and volume lost in milliliters.^{22,37,48} In all studies, blood loss and change in hemoglobin were higher in patients in the control group compared with patients who underwent cryotherapy; however, the result was only statistically significant in 2 studies involving THA.^{22,29}

DISCUSSION

The main finding of the current review was that the effectiveness of cryotherapy, in spite of its benefits in the knee

TABLE 2
Effect of Cryotherapy on Pain Control^a

Study	Group	VAS/NRS Pain			Analgesia Dosage	
		Score ^b	Overall VAS Trend	Significance	Overall Analgesia Trend	Significance
Hip						
Albrecht ¹ (1997)	• 72 cold pump therapy • 72 cold alone • 70 control	1-2 days postop • Cold pump: 2-2.05 • Cold alone: 4-4.07 • Control: 3.83-4	Lower with cold pump therapy	Significant	Lower piritramide/kg with cold pump therapy	Significant
Saito ³⁷ (2004)	• 22 computer-controlled cooling • 23 control	• Intervention: 1.8-0.2 • Control: 4.1-0.6	Lower with Intervention	Significant	Lower analgesic in intervention	Significant
Leegwater ²² (2012)	• 15 compressive cryotherapy • 15 control	• Intervention: 1-1.4 • Control: 2-2.4	Lower with Intervention	NS	Lower Oramorph (liquid morphine) in intervention	NS
Iwakiri ¹³ (2019)	• 30 cold therapy • 30 control	4-28 days postop • Intervention: 0.93-0.1 • Control: 1.15-0.3	Lower with Intervention	NS	Lower NSAID in intervention	NS
Okoro ²⁹ (2019)	• 13 cryotherapy • 15 control	1 day postop • Intervention: 5.68 ± 1.94 • Control: 3.72 ± 2.46	Lower with Intervention	NS	Lower codeine, paracetamol, NSAID, tramadol in intervention	Significant for paracetamol
Leegwater ²¹ (2017)	• 64 continuous-flow cryotherapy compression • 61 control	Preop to 2-3 days postop • Intervention: 2.7-1.88 • Control: 2.61-1.92	Lower with Intervention	Significant only on day 3	Lower paracetamol and NSAID in intervention, lower haloperidol in control	NS for paracetamol and NSAID, significant for haloperidol
Klaber ¹⁷ (2019) ^c	• 20 compressive cryotherapy • 20 standard cryotherapy	• Compressive cryotherapy: 1-2 (0-5) • Standard cryotherapy: 2-3 (1-6)	Lower with compressive cryotherapy	Significant	Lower analgesia doses in compressive cryotherapy group	NS
Foot and Ankle						
Lin ²³ (2018)	• 51 periop cryotherapy • 48 preop cryotherapy • 49 control	3 days postop • Periop cryotherapy: 3.1 ± 1.2 • Preop cryotherapy: 3.3 ± 1.1 • Control: 6.8 ± 2.7	Lower with intervention	Significant	Not reported	Not reported
De Boer ⁷ (2021)	• 18 cold therapy • 17 control	7 days postop • Intervention: 1 • Control: 3.5	Lower with intervention	NS	Lower analgesic and NSAID in intervention	Significant
Shoulder						
Speer ⁴⁰ (1996)	• 25 compression cryotherapy • 25 control	• Intervention: 3.133-3.258 • Control: 5.649-4.664	Lower with Intervention	Significant	Not reported	Not reported
Singh ³⁹ (2001)	32 continuous cryotherapy: • 15 open • 17 arthrosc 32 control: • 15 open • 17 arthrosc	Intervention: • Open: 4.9 • Arthrosc: 4.6 Control: • Open: 7.3 • Arthrosc 6.7	Lower with Intervention	Significant	Not reported	Not reported

(continued)

TABLE 2
(continued)

Study	Group	VAS/NRS Pain			Analgesia Dosage	
		Score ^b	Overall VAS Trend	Significance	Overall Analgesia Trend	Significance
Noyes ²⁸ (2018) ^c	20 continuous cryotherapy 20 plain ice	0-14 days postop - Continuous cryotherapy: 5.9-2.5 - Plain ice: 6.8-2.7	Lower with continuous cryotherapy	NS	Lower morphine in plain ice group	NS
Kara ¹⁵ (2020)	23 ice wrap 20 subacromial injection 16 control	Preop–23 days postop - Ice wrap: 5.95-2.4 - Subacromial injection: 6.2-2.2 - Control: 7.56-3.2	Lower with intervention (both)	NS	Lower in intervention (both)	NS
Alfuth ² (2016) ^c	26 cold compression 26 cold alone	1 day postop - Cold compression: 2.3 - Cold alone: 2.4	Comparable	NS	Not reported	Not reported
Kraeutler ¹⁹ (2015) ^c	25 compressive cryotherapy 21 standard cryotherapy	2-10 days postop - Compressive cryotherapy: 3.9-2.3 - Standard cryotherapy: 4.7-2.3	Comparable	NS	Lower morphine in standard cryotherapy group	NS
Elbow						
Yu ⁴⁸ (2015)	31 cryotherapy: - At rest - In motion 28 control: - At rest - In motion	Intervention (1-90 days postop) - At rest: 2.7-0.1 - In motion: 6.4-0.3 Control (1-90 days postop) - At rest: 4.7-0.1 - In motion: 7.7-0.4	Lower with Intervention	Significant	Less sufentanil in intervention	Significant
Wrist						
Meyer-Marcotty ²⁵ (2011)	25 compression cryotherapy 28 control	1-21 days postop - Intervention: 4.2-1.8 - Control: 6.1-3	Lower with Intervention	NS	Not reported	Not reported
Pouedras ³² (2021)	30 cryotherapy (cold pack) 30 control	0-6 days postop - Intervention: 0.23-2.19 - Control: 0.18-2.04	Similar	NS	Lower morphine at day 0, and NSAIDs at days 1-7 in intervention	Significant
Hochberg ¹² (2001) ^c	35 ice therapy 33 controlled cold therapy	3 days postop - Cryotherapy: 4.7 - Controlled cold therapy: 6.6	Lower with controlled cold therapy	Significant	Lower pills in controlled cold therapy group	Significant

^aarthrosc, arthroscopy; NRS, Numeric Pain Rating Scale; NS, not significant; NSAID, nonsteroidal anti-inflammatory drug; periop, perioperative; postop, postoperative; preop, preoperative; VAS, visual analog scale.

^b The data in this column are either VAS or NRS values, which are comparable pain assessment scales.

^cThe control group consisted of patients who used a different cryotherapy modality.

TABLE 3
Effect of Cryotherapy on Postoperative Edema^a

Study	Edema Measurement Technique	Edema Range	Conclusion	Significance
Hip				
Iwakiri ¹³ (2019)	Ratio, postop/preop of thigh circumference measured at 5 cm proximal to the patellar superior border	4-28 days postop • Cold therapy: 1.041-0.946 • Control: 1.067-1.007	Lower edema in intervention group	Significant at day 4
Ankle				
Stöckle ⁴¹ (1997)	Percentage reduction	24 hours–6 days postop • Continuous cryotherapy: 32%-70% reduction • Intermittent impulse compression, 53%-74% • Cool pack (control): 10%-45%	• All procedures decreased edema • Order of efficiency of edema-resolving methods: postop intermittent impulse compression > continuous cryotherapy > cool pack therapy	Significant
Rohner-Spengler ³⁵ (2014)	Changes in mm	Effect of 2-day preop application: change in measurement • Multilayered bandages, –11.0 mm (–23%) • Intermittent impulse compression, –0.3 mm (0%) • Ice pack control: –2.0 mm (–5%) Effect of 2-day postop application: • Bandage, –7.3 mm (–22%) • Intermittent impulse compression, + 5 mm (+ 46%) • Ice pack (control): + 3.5 mm (17%)	• Order of efficiency of edema-resolving methods: multilayered bandages > intermittent impulse compression = ice pack therapy • The use of multilayered bandages resulted in quicker edema resorption but was associated with less ankle dorsiflexion on postop day 3 than the control group • Intermittent compression was not better than cold therapy, unless used with additional stockinette or bandage compression and elevation	Significant
Shoulder				
Alfuth ² (2016)	Circumference	Cold compression (0-24 hours postop) • Circumf 15 lat, 32.4-35.5 cm • Circumf 20 lat, 34.4-36 cm Cold alone (0-24 hours postop) • Circumf 15 lat, 34-35.3 • Circumf 20 lat, 36-37.8	Lower edema in intervention group	NS
Kara ¹⁵ (2020)	Distance between 2 points	24 hours–21 days postop • Ice wrap: 24.56-22.04 cm • Subacromial injection: 24.6-22.05 cm • Control: 24.06-21.12	Comparable	NS
Wrist				
Rembe ³³ (1970)	Postop percentage increase	48-96 hours postop • Cold submerging twice daily: 16.3%-17% • Control: 22.1%-17.8%	Lower in intervention	NS
Hochberg ¹² (2001)	Circumference	Preop–3 days postop • Cryotherapy: 17.9-17.5 cm • Controlled cold therapy: 17.2-17.9 cm	Lower edema with controlled cold therapy	Significant
Meyer-Marcotty ²⁵ (2011)	Volume (mL): water displacement after submerging affected limb in water	1-21 days postop • Cryotherapy: 967-932 mL • Control: 912-890 mL	Lower in control	NS

^aCircumf 15 lat, circumference 15 cm proximal of the lateral epicondyle; Circumf 20 lat, circumference 20 cm proximal of the lateral epicondyle; NS, not significant; postop, postoperative; preop, preoperative.

TABLE 4
Effect of Cryotherapy on Postoperative Blood Loss^a

Study	Group	Overall	Significance
Albrecht ¹ (1997)	• 72 cold pump therapy • 72 cold alone • 70 control	Hb-diff, mg/dL • Cold pump therapy: 1.73 • Cold alone: 1.45 • Control: 2.14	NS
Leegwater ²² (2012)	• 15 compressive cryotherapy • 15 control	Hb-diff, mg/dL • Intervention: -1.79 ($\Delta_{d1\text{-preop}}$); -2.16 ($\Delta_{d3\text{-preop}}$); -0.38 ($\Delta_{d3\text{-d1}}$) • Control: -2.34 ($\Delta_{d1\text{-preop}}$); -2.63 ($\Delta_{d3\text{-preop}}$); -0.29 ($\Delta_{d3\text{-d1}}$)	Significant
Leegwater ²¹ (2017)	• 64 continuous flow cryocompression • 61 control	Hb-diff, mmol/L • Intervention: -0.29 • Control: -0.51	NS
Okoro ²⁹ (2019)	• 13 cryotherapy • 15 control	Hb-diff, g/L, mean $\pm$ SD • Intervention: 22.38 $\pm$ 5.71 • Control: 29.13 $\pm$ 10.22	Significant
Saito ³⁷ (2004)	• 22 computer-controlled cooling • 23 control	Blood loss, mL, mean $\pm$ SD • Intervention: 1110 $\pm$ 685 • Control: 1123 $\pm$ 436	NS
Yu ⁴⁸ (2015)	• 31 cryotherapy • 28 control	Blood loss, mL, mean $\pm$ SD • Intervention: 304.4 $\pm$ 134.4 • Control: 341.0 $\pm$ 166.6	NS

^a_d, day; NS, not significant; preop, preoperative.

joint, cannot be reliably deduced based on the current body of evidence. Many variables, such as the morphology of the joint, the design of the cryotherapy modality, the type of procedure, and the lack of standardization of protocols, prevent such conclusions. There was, however, a general trend toward improvement when cryotherapy was used.

Cryotherapy demonstrated considerable benefits in pain reduction after hip, ankle, elbow, and carpal tunnel surgeries, although findings were less consistent for shoulder and other wrist procedures. Additionally, cryotherapy notably reduced postoperative edema, specifically for hip and carpal tunnel surgeries, but was not the best option for resolving edema in ankle surgeries. Furthermore, cryotherapy significantly reduced blood loss after hip surgeries.

Effect of Cryotherapy on Pain Control as Measured by VAS/NRS and Analgesic Dose

Pain was measured in different ways in the included studies. Those that were selected included the use of the VAS/NRS scores as well as the use of analgesics, which were assessed separately in this review. Differences in pain reduction were not consistent, with some studies showing a significant reduction in pain compared with others. Continuous cryotherapy, as well as differences in the application of cryotherapy, may be responsible for such results. Furthermore, the type of analgesic used at home after discharge was generally of a different class and potency than that used in the hospital setting before discharge. Although postoperative pain scores were generally lower in cryotherapy groups across most studies, the absence of statistical significance in many instances precludes

a definitive statement on the effectiveness of cryotherapy after surgery. This is true even though it would seem only natural to employ this noninvasive modality to improve patients' postoperative experience. In fact, cooling reduces the metabolic rate of cells as well as oxygen demand in an already oxygen-depleted environment. It also reduces free nerve-ending sensitivity and increases firing thresholds, thus directly acting on the advent of postoperative pain.^{5,24,27}

One drawback of cryotherapy after hip surgery is that it increases haloperidol consumption in patients with hip fracture.²¹ This scenario can be explained given the advanced age of most hip fracture patients, who are consequently more prone to postoperative delirium.⁴⁴ The cold sensations produced by cryotherapy, while effective for pain and edema reduction, might induce added discomfort or confusion, thereby exacerbating delirium. Furthermore, suboptimal ergonomics requiring immobilization of geriatric patients to keep cryotherapy applied may also add to the requirement of haloperidol after hip fractures. That being said, haloperidol has been found to decrease duration of hospitalization, as well as severity and duration of postoperative delirium, and therefore may be beneficial to patients, regardless of the use of cryotherapy.¹⁴

In the context of shoulder surgery, the 2 studies^{38,39} that found significant decreases in VAS pain scores encompassed a heterogeneous patient population undergoing diverse shoulder surgeries (rotator cuff repair, arthroplasty, and instability surgery), yet exhibited an unclear risk profile based on the RoB 2. With the more recent studies unable to achieve significant improvement, the question of the effectiveness of the postoperative protocols may be raised, both in terms of analgesic use and

cryotherapy application, including compression cryotherapy, continuous ice wrap cryotherapy, and cold therapy alone.

The single high-evidence elbow surgery study with pain outcomes,⁴⁸ which also had a low level of bias, showed reduced pain with cryotherapy, but the significant pain decrease was only apparent in the early postoperative days. The lack of significance beyond the second week might be due to the overall pain reduction in both study groups, minimizing observable differences. This perhaps indicated that there is a limit to the effectiveness of postoperative cryotherapy.

There were inconclusive benefits on VAS pain scores after wrist arthroscopy and trapeziectomy/4-corner fusion surgery.^{25,32} However, carpal tunnel syndrome patients appeared to benefit more from continuous cryotherapy than standard cold therapy, although these findings lacked a comparison with a noncryotherapy control group.¹² Although only patients undergoing carpal tunnel were found to improve in this review, few studies exist to draw definitive conclusions regarding the type of wrist procedure that would benefit from cryotherapy, and further investigations are required.

Effect of Cryotherapy on Postoperative Edema

At this level, cryotherapy appears to be particularly beneficial in the context of hip surgery.¹³ Moreover, there seems to be a potential advantage of using cryotherapy after carpal tunnel procedures.²⁵ While the study by Hochberg¹² did not include a noncryotherapy control, it did demonstrate that continuous cryotherapy provides better control of edema than standard cold therapy. However, the clinical relevance of their finding can be debated, as they reported only a 0.7-cm decrease in wrist circumference in favor of continuous cryotherapy. In the context of ankle surgeries, while cryotherapy appears beneficial, it may not be the most effective method for postoperative edema management. The studies by Stöckle et al⁴¹ and Rohner-Spengler et al³⁵ both highlight the superior benefits of intermittent compression and layered bandages, respectively. This underscores the complexity of managing postoperative edema in ankle surgeries, where a multimodal approach including cryotherapy, compression, and elevation may be most effective.

On the other hand, our review did not show significant benefit of cryotherapy in terms of edema after shoulder and elbow surgery. Differences in measurements and paucity of studies may be responsible for this, and further studies are therefore required, with standardization of edema measurement methods for each joint. Although conclusions cannot be made regarding edema, a stiffness-prone joint such as the elbow would require further studies evaluating if cryotherapy would lead to a reduction in edema, which in turn would lead to an improvement in mobility

Effect of Cryotherapy on Postoperative Blood Loss

The beneficial effect of cryotherapy on blood loss was only found in 1 study on the hip.²⁹ This is likely associated with

its vasoconstrictive effect, and therefore extensive use of this modality is justified in the postoperative setting in order to limit blood loss.^{9,16} Notably, this aspect was not investigated for other joints, except for the elbow, which typically involves low-bleeding surgeries. Furthermore, blood loss is measured based on the use of a postoperative drain, and studies show no difference in follow-up between patients who have a drain placed and those who do not.^{10,11} It is therefore not considered a standard of care. In this review, the paucity of studies that included the use of drains and the difference in duration, in addition to the different locations and cryotherapy modality, did not allow for a meta-analysis to be performed. If the practice of postoperative surgical-site drainage declines, difficulty in reaching definitive conclusions may be encountered.

Overall, the inconsistency in results compared with cryotherapy in the postoperative setting in knee surgery may be due to inconsistency in the use of dedicated hardware or instruments to promote the cold effect on the affected joint, specifically in terms of ergonomics. In fact, cylindrical and snug-fit cryotherapy devices on the knee cannot be properly applied on other joints. Furthermore, the studies reported often describe makeshift cryotherapy applications that are not as ergonomic as those used on the knee joint. This, and the depth of the joint being treated, as well as different joint size, different machine settings to accommodate size, and range of motion of joints may play a role in the inconsistency in the results reported in the literature.

Cryotherapy is associated with some risks, which are not widely reported in the literature nor in the studies analyzed. These include cardiovascular strain, which is found to increase while applying cryotherapy modalities. Other complications include skin irritation and even peripheral neuropathy when patient education is not enforced, according to Kunkle et al,²⁰ who also found that knee arthroscopy procedures benefited the most from postoperative cryotherapy, in spite of benefits in other joints. These authors added a provision that further studies are required for other joints.

Limitations

Inevitably, some heterogeneity arose within the studies, and it was sufficient to prevent a meta-analysis from being completed. Also, in addition to the difference in assessment tools used for each outcome, the time points at which they were evaluated varied from one study to another. Further outcomes were sparsely evaluated, such as blood loss,^{1,22,29,37,48} the need for reoperation,⁷ patient satisfaction,^{7,28,35,39} complication rate,^{7,23} and range of motion.^{25,33,35,48} When comparisons were possible, some data, such as standard deviations pertaining to the outcome results, were insufficient to extract or were minimal enough to add excessive weight to one study compared with the rest. Some studies looked for a significant difference between different cryotherapy modalities^{2,12,17,19,25,28} and found none.^{25,28} Although randomization is possible in such studies, the requirement of informed consent meant

that even if part of the personnel team was blinded to the treatment arm, the patients were not. This invariably leads to a bias that may have affected the results of the studies performed and subsequently reported. Furthermore, the studies that were included did not specify if the limbs were elevated in the postoperative setting, which may have caused bias in the outcomes.³ Finally, available articles pertaining to this topic often assessed multiple variables within a study, potentially leading to bias in the results due to unidentified correlations, such as the role of pain medications in decreasing VAS pain scores, or the degree of swelling on pain, or the timing of various treatments in the perioperative setting.^{3,4,8,34}

CONCLUSION

The findings of this systematic review indicated that the advances in knowledge and protocols pertaining to the knee joint have not yet been standardized for other joints. Further research is warranted to obtain more uniform postoperative treatment of joints other than the knee, including whether a compression component should be added to the cold component during cryotherapy, determining which joint exhibits clear benefits, and which joint-related procedures benefit the most from cryotherapy. Work in close contact with industry consultants may help in identifying, designing, and standardizing practices for specific joints and surgical procedures.

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