JB&JS REVIEWS

Orthopaedic Application of Cryotherapy

A Comprehensive Review of the History, Basic Science, Methods, and Clinical Effectiveness

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Abstract

» Cold therapy, also known as cryotherapy, includes the use of bagged ice, ice packs, compressive cryotherapy devices, or whole-body cryotherapy chambers. Cryotherapy is commonly used in postoperative care for both arthroscopic and open orthopaedic procedures.

» Cryotherapy is associated with an analgesic effect caused by microvasculature alterations that decrease the production of inflammatory mediators, decrease local edema, disrupt the overall inflammatory response, and reduce nerve conduction velocity.

» Postoperative cryotherapy using bagged ice, ice packs, or continuous cryotherapy devices reduced visual analog scale pain scores and analgesic consumption in approximately half of research studies in which these outcomes were compared with no cryotherapy (11 [44%] of 25 studies on pain and 11 [48%] of 23 studies on opioids). However, an effect was less frequently reported for increasing range of motion (3 [19%] of 16) or decreasing swelling (2 [22%] of 9).

» Continuous cryotherapy devices demonstrated the best outcome in orthopaedic patients after knee arthroscopy procedures, compared with all other procedures and body locations, in terms of showing a significant reduction in pain, swelling, and analgesic consumption and increase in range of motion, compared with bagged ice or ice packs.

» There is no consensus as to whether the use of continuous cryotherapy devices leads to superior outcomes when compared with treatment with bagged ice or ice packs. However, complications from cryotherapy, including skin irritation, frostbite, perniosis, and peripheral nerve injuries, can be avoided through patient education and reducing the duration of application.

» Future Level-I or II studies are needed to compare both the clinical and cost benefits of continuous cryotherapy devices to bagged ice or ice pack treatment before continuous cryotherapy devices can be recommended as a standard of care in orthopaedic surgery following injury or surgery.

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Cold therapy, also known as cryotherapy, was utilized by ancient Egyptians as early as 3,000 bce to treat inflammation and infection[1]. By the 1800s, the analgesic and numbing effects of cryotherapy were well recognized and utilized for anesthesia before operations and amputations[2]. Following the Industrial Revolution, pressurized gas (nitrogen) was used to ablatively treat a variety of skin lesions by exposing localized areas of the dermis to temperatures as low as −196°C, ushering in the era of cryosurgery[3]. In 1978, Dr. Gabe Mirkin coined the term "RICE," a mnemonic well known in the sports medicine field for "rest, ice, compression, and elevation."[4] This strategy is still commonly recommended today by orthopaedic surgeons in the postoperative setting and continues to evolve with technological advances.

Cryotherapy is the utilization of the anti-inflammatory and analgesic properties of cold temperatures to facilitate healing, decrease inflammation, and minimize pain after injury or surgery[5-9]. Cryotherapy is commonly recommended following orthopaedic procedures for these desired effects, and despite many advances in postoperative rehabilitation, it remains a mainstay of treatment. For example, a recent systematic review of the joint arthroplasty literature found that 46% of patients undergoing total knee arthroplasty (TKA) received some form of cryotherapy as a treatment modality in the immediate postoperative period[10].

There is conflicting literature regarding the effectiveness of cryotherapy. Currently, there is no consensus on the overall benefit that cryotherapy provides in clinical orthopaedic practice. Additionally, no best practices exist for achieving optimal clinical results while minimizing cost. This article aims to provide a comprehensive review of the currently available literature regarding cryotherapy benefits and clinical outcomes in orthopaedic surgery. Based on this updated review of the literature, we will provide recommendations for the use of cryotherapy in orthopaedic surgery.

Basic-Science Mechanism of Cryotherapy

Cryotherapy is thought to utilize several different cellular and physiological mechanisms that contribute to its overall effect (Fig. 1). These include reduced inflammation, reduced nerve conduction velocity (NCV), and reduced edema. The anti-inflammatory effects of cryotherapy have been confirmed in a variety of studies that demonstrate a reduction in inflammatory markers, such as C-reactive protein (CRP) and neopterin, following the use of various cryotherapy methods[5-7]. The anti-inflammatory effect originates from a variety of biologic pathways, with the overall result being a general shift toward a noninflammatory state that promotes tissue healing rather than tissue destruction.

Several studies identified a notable decrease in pro-inflammatory cytokines such as interleukin-1 beta (IL-1β), IL-2, IL-3, IL-8, and tumor necrosis factor-alpha (TNF-α) with the use of cryotherapy[7,11-15]. This reduction in signaling molecules is accompanied by a similar decrease in production of regulatory proteins such as transcription factors that modulate production of other cytokines such as nuclear factor (NF)-κB, as well as a decrease in the activity of matrix metalloproteinases (MMPs [e.g., MMP-9]), which are responsible for the degradation of extracellular matrix proteins and activation of cytokines[14]. Inflammatory markers are primarily secreted by macrophages, and studies have shown that cryotherapy also successfully reduces macrophage infiltration and activation[5,14]. Histamine, another key inflammatory mediator, was also decreased in patients with rheumatoid arthritis after the administration of whole-body cryotherapy[16]. Furthermore, a reduction in the concentration of the inflammatory mediator prostaglandin E_2 (PGE_2) was found in a rat tendon model and confirmed in a recent clinical study that evaluated patients after knee arthroscopy[17]. Additionally, a positive correlation was found between the temperature in the knee

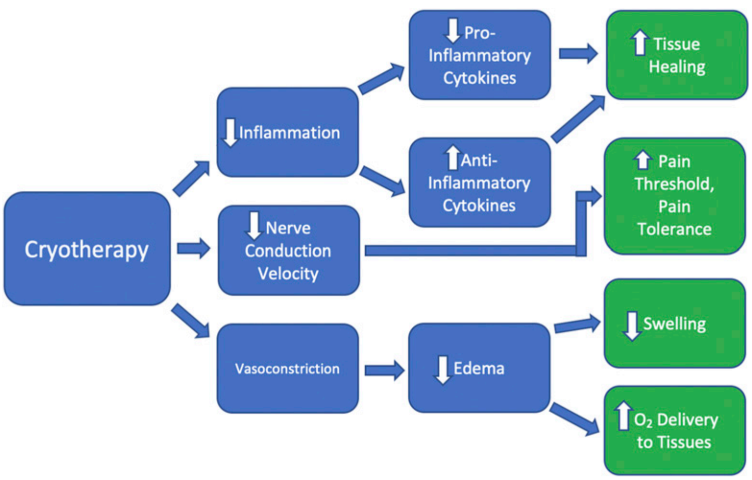

Fig. 1
Flowchart outlining the proposed physiological mechanisms of cryotherapy.

and the concentration of PGE_2 in the clinical study[18].

Just as there is a reduction in pro-inflammatory mediators, there is also an increase in several anti-inflammatory mediators after the use of cryotherapy. Several studies have demonstrated an upregulation of anti-inflammatory cytokines, such as IL-10[11,13,15,19]. This shift to a state of reduced inflammation is accompanied by a marked decrease in the activation of the hypothalamic-pituitary-adrenal (HPA) axis as measured by cortisol in saliva[5]. The HPA axis plays a vital role in the activation of the inflammatory response[20].

The use of cryotherapy is also thought to reduce the overall NCV in the affected area[21]. Algafly and George[8] found that applying ice to the ankle resulted in a substantial decrease in NCV on an electromyogram as well as an increased pain threshold and tolerance as measured by a pressure algometer. This decrease in velocity could be due to delays in the action potential as a result of the low temperature increasing the friction between Ca^{2+} and its cellular gate during the Ca^{2+} and Na^{+} exchange[8,22].

Finally, another cryotherapy mechanism of action is local vasoconstriction caused by a decrease in temperature[9]. This results in a reduction in blood flow to muscles as well as a reduction in hydrostatic pressure within the vessels, which may mitigate the amount of edema at the site of soft-tissue injury[9,23]. Although it may seem counterintuitive, this decrease in perfusion and hydrostatic pressure is thought to be beneficial because increased intramuscular pressure from edema may diminish O_2 delivery[9]. For example, Yeung et al. concluded that a decrease in muscle tissue oxygenation was mitigated after fatiguing exercise through the use of cold water immersion[24].

Cryotherapy Methods

The delivery of cryotherapy following localized injury or surgery has evolved over the past few decades. Despite this evolution, the use of ice bags or packs remains one of the most common and economical cryotherapy methods, with an almost negligible cost. Continuous cryotherapy devices, which feature an external cooling apparatus that circulates chilled water through a joint-specific cuff that the patient wears, can also be used. These devices are capable of cooling at preselected intervals, and some also feature the ability to provide compression to the joint of interest. These devices offer convenience and customizability as an advantage but can cost hundreds of dollars to buy or rent. Several examples of currently available cryotherapy devices can be found in Figure 2.

While not commonly used in the postoperative setting, whole-body cryotherapy has become a popular athletic recovery technique, especially in the field of sports medicine[25]. Whole-body cryotherapy has been achieved traditionally through the use of ice baths, but more recently through the use of cold-air chambers. These chambers have seen a substantial increase in popularity in recent years, and work by briefly exposing the body to chilled gas at temperatures as low as −110°C to −140°C in a temperature-controlled cryochamber for 2 to 3 minutes. These chambers cost tens or even hundreds of thousands of dollars to buy, but single sessions can be purchased individually at fitness centers for \$25 to \$75 per session.

Fig. 2

Examples of currently available cryotherapy devices: Aircast Cryo/Cuff IC Cooler Cooling Unit for delivery of continuous cryotherapy (**Fig. 2-A**, courtesy of DJO Global), Aircast Cryo/Cuff Shoulder, Wrist/Arm, and Knee Cuffs (Fig. 2-B, 2-C, and 2-D, courtesy of DJO Global), and Össur Cold Rush Cold Therapy Unit (**Fig. 2-E**, © Össur).

TABLE I Summary of 25 Studies Comparing Postoperative Pain Scores for Cryotherapy Versus No Cryotherapy*

Study	Sample Size, Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Desteli[45] (2015)	42 vs. 45 (87)	65.4 ± 6.98	65.1 ± 4.06	cTreatment (Waegener)	VAS pain	Day 1	6.1	6.6	>0.05
Gibbons[47] (2001)	30 vs. 30 (60)	70 (11:19)	71 (14:16)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Days 1, 3, 5, 7, and 9	NR	NR	All >0.05
Holm[49] (2012)	10 vs. 10 (20)	66 ± 12 (3:7)	67 ± 12 (7:3)	Bagged ice	VAS pain compared with pre-treatment: at rest	Days 7 and 10	−1.09 ± 1.85	−0.76 ± 1.11	0.48
					VAS pain compared with pre-treatment: on extension	Days 7 and 10	−0.08 ± 1.81	−0.48 ± 1.60	0.42
Holmström[50] (2005)	23 vs. 17 (40)	68 (14:9)	75 (11:6)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain: at motion and at rest	Days 1-7	NR	NR	All >0.05
Kullenberg[53] (2006)	43 vs. 40 (83)	68.1 ± 6 (18: 25)	68.9 ± 6.8 (14: 26)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Day 1	2.1 ± 1.0	2.2 ± 0.8	>0.05
						Day 3	0.8 ± 0.9	1.2 ± 0.7	>0.05
Kuyucu[54] (2015)	27 vs. 33 (60)	67.2 (NR)	68.4 (NR)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Day 1	3.6	2.7	<0.05†
						Day 3	3.3	2.5	<0.05†
						Day 5	3.3	3.0	<0.05†
Levy[58] (1993)	40 vs 40 (80)	74 (7:33)	73 (8:32)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Day 1	7.4 ± 2.7	7.8 ± 2.7	>0.05
						Day 2	5.9 ± 2.4	7.4 ± 1.5	<0.01†
						Day 3	5.6 ± 1.6	6.9 ± 1.9	<0.05†
Morsi[59] (2002)	30 vs. 30 (30 patients total, as all received bilateral TKA)	NR	NR	Custom-made cooling coil device	VAS pain	Hours 1, 2, and 8, days 2, 3, 4, and 6	4.2 ± 0.74 (overall mean of all days)	6.3 ± 1.3 (overall mean of all days)	<0.001†
Radkowski[61] (2007)	28 vs. 36 (64)	63.7 ± 10.4 (15:13)	66.9 ± 10.4 (23:13)	Thermo-Tek Solid State Recirculating Chiller (Thermo-Tek)	VAS pain: worst score of day	Day 1	6.0	5.5	>0.05
						Day 3	7.1	6.3	>0.05
						Day 30	6.2	6.5	>0.05
Smith[29] (2002)	44 vs. 40 (84)	72.1 ± 7.8 (21: 23)	72.0 ± 7.1 (21: 19)	Unspecified cryotherapy pad	VAS pain	Day 1	4.3 ± 1.8	4.2 ± 2	0.32
						Day 2	4.3 ± 2	4.8 ± 1.9	0.72
						Day 3	4.2 ± 1.8	3.5 ± 1.9	0.67
Webb[66] (1998)	24 vs. 25 (49)	69.4 (NR)	70.6 (NR)	Aircast Cryo/ Cuff (DJO Global)	VAS pain	Day 1	4.5	5.8	<0.05†
Wittig-Wells[68] (2015)	29 vs. 29 (29 total patients, due to crossover study design)	64 ± 9.3 (11: 18) for combined groups	64 ± 9.3 (11: 18) for combined groups	Bagged ice	VAS pain	NR	6.9 ± 1.3	6.7 ± 1.5	>0.05
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/ Cuff (DJO Global)	VAS pain	Hour 1	3.71	4.63	
						Hour 2	3.61	3.75	
						Hour 8	4.1	5.22	
						Day 2	5.61	5.88	
						Day 3	5.04	5.37	
						Day 4	4.55	4.63	
						Day 5	4.29	4.65	
						Day 6	4.33	4.39	
						Overall group mean			0.06
Brandsson[43] (1996)	20 vs. 10 (30)	NR	NR	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Hours 1, 2, 4, and 6, days 1 and 2	NR	NR	All <0.05†

continued

TABLE I (continued)

Study	Sample Size, Treatment Vs. Control (Total)	Mean Age (No. Male: Female) Treatment	Mean Age (No. Male: Female) Control	Cryotherapy Method	Outcome Type	Follow-up Time	Results Treatment	Results Control	P Value
Dervin[44] (1998)	40 vs. 38 (78)	30.6 ± 10.2 (27:13)	26.9 ± 6.2 (27: 11)	Cryo/Cuff IC Cooler (DJO Global	VAS pain	Day 1	3.0 ± 1.7	2.5 ± 1.3	>0.05
Edwards[46] (1996)	26 vs. 45 (71)	26 (18:8)	27 (32:13)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Days 1-3	NR	NR	All >0.05
Lessard[57] (1997)	23 vs. 22 (45)	42.0 ± 12.6 (16:7)	44.6 ± 14.9 (15:7)	Cold gel packs	Pain Rating Index Score: total	Days 1-7	8.78 ± 7.08	10.5 ± 6.97	>0.05
					Pain Rating Index Score: Sensory Component	Days 1-7	7.91 ± 6.54	8.59 ± 5.18	>0.05
					Pain Rating Index Score: Affective Component	Days 1-7	0.13 ± 0.34	0.96 ± 1.99	0.03†
					Pain Rating Index Score: Evaluative Dimension	Days 1-7	0.74 ± 0.81	0.91 ± 1.07	>0.05
Ohkoshi[60] (1999)	14 vs. 7 (21)	22.1 ± 6.5 (10: 11) for combined groups	22.1 ± 6.5 (10: 11) for combined groups	Icing System 2000 (Sigmax)	VAS pain	Day 2	76.7 ± 15.1 (5°C group), 34.7 ± 29.8 (10°C group)	6.57 ± 2.05	Significant difference between the 5°C and 10° C groups only†
Whitelaw[67] (1995)	56 vs. 46 (102)	39 (36:20)	36 (36:10)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Hour 6	6.51	6.59	>0.05
						Hour 12	5.85	6.00	>0.05
						Day 1	4.34	4.98	>0.05
						Day 2	3.82	4.19	>0.05
						Day 3	3.15	3.58	>0.05
THA									
Iwakiri[51] (2019)	30 vs. 30 (60)	68.1 ± 9.6 (1: 29)	67.6 ± 8.9 (1: 29)	CF3000 Icing System and Cooling Pad (Sigmax)	VAS pain	Day 4	0.93 ± 1.36	0.12 ± 1.93	0.62
						Day 7	0.71 ± 0.97	1.15 ± 1.73	0.24
						Day 14	0.54 ± 0.94	0.94 ± 1.78	0.29
						Day 28	0.12 ± 0.22	0.33 ± 0.71	0.34
Saito[62] (2004)	23 vs. 23 (46)	59.3 ± 11.4	59.0 ± 11.2	Icing System 2000 (Sigmax)	VAS pain	Days 1-4 and days 4-7	NR	NR	All <0.05†
Hip surgery									
Leegwater[56] (2017)	64 vs. 61 (125)	80.0 ± 10.9 (15:49)	77.2 ± 10.1 (22:39)	Game Ready (CoolSystems)	VAS pain	Day 1	2.39 ± 1.94	2.61 ± 1.94	0.54
						Day 2	1.98 ± 1.90	1.92 ± 1.82	0.84
						Day 3	1.88 ± 1.94	2.15 ± 1.84	0.42
Open shoulder surgery									
Speer[65] (1996)	25 vs. 25 (50)	36.9 (19:6)	39.4 (17:8)	Cryo/Cuff IC Cooler (DJO Global	VAS pain	Day 1	3.13	5.65	0.001†
						Day 10	3.26	4.66	0.03†
Shoulder arthroscopy									
Singh[64] (2001)	32 vs. 37 (69)	NR	NR	Polar Care (Breg)	VAS pain	Day 1	NR	NR	>0.05
						Day 7	NR	NR	>0.05
						Day 14	NR	NR	0.043†
						Day 21	NR	NR	>0.05
Elbow arthrolysis									

continued

TABLE I (continued)

Study	Sample Size, Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Yu[69] (2015)	31 vs. 28 (51)	37.5 ± 13.3 (17:14)	34.9 ± 10.6 (15:13)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain: at rest and with movement	Day 1	2.7 ± 1.7, 6.4 ± 1.8	4.7 ± 2.6, 7.7 ± 2.1	<0.05†
						Day 2	2.5 ± 1.7, 6.0 ± 1.9	4.2 ± 2.1, 7.2 ± 1.2	<0.05†
						Day 3	1.9 ± 1.3, 5.5 ± 2.1	3.5 ± 1.5, 6.9 ± 1.5	<0.05†
						Day 4	1.7 ± 1.2, 5.0 ± 1.9	2.8 ± 1.7, 6.1 ± 1.7	<0.05†
						Day 5	1.4 ± 1.0, 4.5 ± 1.8	2.5 ± 1.5, 5.5 ± 1.8	<0.05†
						Day 6	1.1 ± 1.0, 4.0 ± 1.7	2.0 ± 1.4, 5.0 ± 1.9	<0.05†
						Day 7	1.0 ± 1.0, 3.7 ± 1.7	1.7 ± 1.2, 4.6 ± 2.0	<0.05†
						2 weeks	0.5 ± 0.5, 2.4 ± 1.2	0.8 ± 0.6, 2.8 ± 1.3	>0.05
						3 months	0.1 ± 0.2, 0.3 ± 0.5	0.1 ± 0.2, 0.4 ± 0.5	>0.05

*Visual analog scale (VAS) pain was reported on a 0-10 scale. NR = not reported. †Significant difference in favor of cryotherapy.

The Role of Compression

Compression is commonly applied simultaneously with cryotherapy (bagged ice, ice packs, or continuous cryotherapy devices) as a component of RICE therapy. Compression is thought to help reduce blood flow and edema in the affected area, and therefore works synergistically with cryotherapy to facilitate healing. Most of the studies have not isolated compression as a variable and instead focused on either the effects of cryotherapy or the combined effects of cryotherapy and compression, making it difficult to draw conclusions regarding the effects of compression alone. However, Waterman et al. focused on the effects of compression by comparing compressive cryotherapy to noncompressive cryotherapy and found that compressive cryotherapy yielded better pain scores at both 2 and 6 weeks postoperatively when compared with preoperative pain scores[26]. Additionally, a larger number of patients in the compressive cryotherapy group discontinued all narcotic use by 6 weeks compared with the noncompressive group ($p = 0.0008$). However, there was no significant difference in functional knee scores, edema, or pain scores at 1 week postoperatively ($p > 0.05$). In contrast, 3 other studies that compared compressive and noncompressive cryotherapy treatments found no significant difference between the groups in terms of analgesic consumption, pain, range of motion, blood loss, or swelling ($p > 0.05$)[27-29].

Whole-Body Cryotherapy: Ice Baths

A vast number of randomized controlled trials (RCTs) have evaluated the effect of whole-body cryotherapy using ice baths on a variety of outcomes. These studies have mixed findings, likely on account of variations in the patient population, cryotherapy delivery method, and outcome of interest. A systematic review and meta-analysis performed by Higgins et al. evaluated cold-water bath immersion on the recovery of trained athletes following athletic activity and found that therapy led to improved neuromuscular function with regard to jumping and sprinting at 24 hours after therapy ($p = 0.05$), as well as improved perception of fatigue at 72 hours after therapy ($p = 0.03$)[30]. However, all other time points from a range of 1 hour to >90 hours postintervention showed no significant difference when compared with the control therapy ($p > 0.05$). Additionally, other outcomes of interest, including muscle soreness, range of motion, and biochemical markers, were found to either show no significant difference or have insufficient data to draw conclusions ($p > 0.05$).

A large systematic review by Versey et al. evaluated 53 studies with the goal of providing practical recommendations for the application of cold-water immersion therapy and concluded that immersion for 5 to 15 minutes at a temperature of 10°C to 15°C appeared to be most effective at enhancing recovery[31]. However, that systematic review did not include a meta-analysis because of the overwhelmingly large variety of variables and outcomes of interest in the studies evaluated.

Whole-Body Cryotherapy: Cold Air Chambers

From a basic and translational science perspective, there have been fairly consistent and promising results with regard to disruption of inflammatory signaling and the inflammatory cascade with regimented use of whole-body cryotherapy using cold air chambers following exercise and activity[7,11,15]. Ziemann et al. found improved performance during drills as well as faster recovery in a

TABLE II Summary of 23 Studies Comparing Postoperative Analgesic Consumption with Cryotherapy Versus No Cryotherapy*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Gibbons[47] (2001)	30 vs. 30 (60)	70 (11:19)	71 (14:16)	Cryo/Cuff IC Cooler (DJO Global)	Mean no. of doses of co-dydramol normalized to patient body weight	Day 10	44	40	>0.05
Healy[48] (1994)	50 vs. 55 (105)	NR	NR	Aircast Cryo/Cuff (DJO Global)	Mean narcotic requirements for both unilateral and bilateral procedures (MME)	Days 1-3	96.6, 143.4	100.0, 115.7	>0.05
						Days 4-7	66.3, 52.0	59.5, 79.6	>0.05
Holmström[50] (2005)	23 vs. 17 (40)	68 (14:9)	75 (15:6)	Cryo/Cuff IC Cooler (DJO Global)	Mean morphine usage (mg)	Day 1	13.4	20.8	0.03†
						Days 2-7	NR	NR	> 0.05
Kullenberg[53] (2006)	43 vs. 40 (83)	68.1 ± 6 (18:25)	68.9 ± 6.8 (14:26)	Cryo/Cuff IC Cooler (DJO Global)	Mean morphine usage (mg morphine per kg per 24 hr)	Day 1	0.37 ± 0.11	0.43 ± 0.05	>0.05
Levy[58] (1993)	40 vs 40 (80)	74 (7:33)	73 (8:32)	Cryo/Cuff IC Cooler (DJO Global)	Mean normalized injectable morphine (mg/kg)	Day 2	0.53 ± 0.2	0.69 ± 0.3	<0.05†
Morsi[59] (2002)	30 vs. 30 (30)	NR	NR	Custom-made cooling coil device	Mean analgesic consumption (no. of pills/day)	Day 1-6	1.9 ± 0.73	2.8 ± 0.63	<0.01†
Radkowski[61] (2007)	28 vs. 36 (64)	63.7 ± 10.4 (15:13)	66.9 ± 10.4 (23:13)	Thermo-Tek Solid State Recirculating Chiller (Thermo-Tek)	Postop. opioid consumption (% of patients who did not require additional opioid analgesics)	Day 1	7.1	5.6	0.981
						Day 3	46.4	25	0.111
Scarcella[63] (1995)	12 vs. 12 (24)	69 (NR)	67 (NR)	Hot/Ice Blanket (Thermo Temp)	Mean normalized meperidine usage (mg/kg)	Total through discharge	4.75	4.75	>0.05
Smith[29] (2002)	44 vs. 40 (84)	72.1 ± 7.8 (21:23)	72.0 ± 7.1 (21:19)	Unspecified cryotherapy pad	Mean normalized opioid consumption (mg/kg)	Day 2	0.422 ± 0.31	0.32 ± 0.29	0.245
Webb[66] (1998)	24 vs. 25 (49)	69.4 (NR)	70.6 (NR)	Aircast Cryo/Cuff (DJO Global)	Mean normalized opioid dosage required (mg/kg over 48 hours)	Days 1 and 2	0.57	0.71	<0.01†
Knee arthroscopy									

continued

TABLE II (continued)

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/ Cuff (DJO Global)	Mean Vicodin consumption (no. of pills/day)	Day 1	0.86	1.94	
						Day 2	1.49	2.85	
						Day 3	2.06	2.88	
						Day 4	1.90	3.35	
						Day 5	2.12	3.31	
						Day 6	2.47	2.6	
						Day 7	1.73	1.82	
						Overall group Mean			0.013†
					Mean Percocet consumption (no. of pills/day)	Day 1	1.41	1.94	
						Day 2	3.29	3.22	
						Day 3	3.24	2.43	
						Day 4	1.92	1.37	
						Day 5	1.22	1.00	
						Day 6	0.91	0.97	
						Day 7	1.06	0.51	
						Overall group mean			>0.05
Brandsson[43] (1996)	20 vs. 10 (30)	NR	NR	Cryo/Cuff IC Cooler (DJO Global)	Mean morphine usage (mg)	Days 1 and 2	NR	NR	<0.05*
					Mean codeine usage (mg)	Days 1 and 2	NR	NR	<0.05*
Dervin[44] (1998)	40 vs. 38 (78)	30.6 ± 10.2 (27: 13)	26.9 ± 6.2 (27:11)	Cryo/Cuff IC Cooler (DJO Global	Mean normalized morphine usage (mg/kg)	Total postop.	0.37 ± 0.23	0.35 ± 0.21	>0.05
					Mean codeine usage (no. of 30-mg tablets)	Total postop.	3.86 ± 2.72	3.44 ± 2.1	>0.05
Edwards[46] (1996)	26 vs. 45 (71)	26 (18:8)	27 (32:13)	Cryo/Cuff IC Cooler (DJO Global)	Normalized mean analgesic (morphine, codeine, acetaminophen) usage (mg/kg)	Total through discharge	0.65, 4.14, 73.82	0.60, 3.91, 85.2 (room-temp. cuff)	>0.05
								0.65, 4.31, 70.6 (no cuff)	>0.05
Konrath[52] (1996)	27 vs. 23 (50)	27	25	Polar Care (Breg)	Normalized mean pain medication required (mg/kg)	At discharge	0.59	0.52	>0.05
	23 vs. 27 (50)	26	26	Ice bag	Normalized mean pain medication required (mg/kg)	At discharge	0.60	0.52	>0.05

continued

TABLE II *(continued)*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Ohkoshi[60] (1999)	14 vs. 7 (21)	22.1 ± 6.5 (10:11) for combined groups	22.1 ± 6.5 (10:11) for combined groups	Icing System 2000 (Sigmax)	Mean analgesic required (number of doses)	Days 1 and 2	1.25 ± 0.4 (5°C cuff) 0.7 ± 0.8 (10°C cuff)	1.5 ± 1.0	>0.05 <0.05*
Whitelaw[67] (1995)	56 vs. 46 (102)	39 (36:20)	36 (36:10)	Cryo/Cuff IC Cooler (DJO Global)	Mean pain medication required (doses/day)	Day 1 Day 2 Day 3 Mean	4.23 3.21 2.7	5 4.22 3.12	>0.05 >0.05 >0.05 <0.05*
THA									
Iwakiri[51] (2019)	30 vs. 30 (60)	68.1 ± 9.6 (1:29)	67.6 ± 8.9 (1:29)	CF3000 Icing System and Cooling Pad (Sigmax)	Mean amount of diclofenac sodium suppository (mg)	Through day 21	31.7 ± 60.9	72.2 ± 79.5	0.07
Leegwater[55] (2012)	15 vs. 15 (30)	66 (8:7)	68 (4:11)	Game Ready (CoolSystems)	Mean analgesic usage (MME)	Total postop.	84.7 + 43.6	100 + 73.5	0.593
Saito[62] (2004)	23 vs. 23 (46)	59.3 ± 11.4 (NR)	59.0 ± 11.2 (NR)	Icing System 2000 (Sigmax)	Mean dose of mepivacaine hydrochloride (mg)	Through day 7	295 ± 99	489 ± 160	<0.001*
					Mean dose of diclofenac sodium (mg)	Through day 7	58 ± 54	60 ± 50	0.529
Scarcella[63] (1995)	12 vs. 12 (24)	69 (NR)	67 (NR)	Hot/Ice Blanket (Thermo Temp)	Mean normalized meperidine usage (mg/kg)	Total through discharge	4.14	4.44	>0.05
Hip (multiple procedures)									
Leegwater[56] (2017)	64 vs. 61 (125)	80.0 ± 10.9 (15:49)	77.2 ± 10.1 (22:39)	Game Ready (CoolSystems)	Incidence of analgesic usage (%)	Day 1 Day 2 Day 3	60 32 18	68 26 26	0.35 0.18 0.09
Elbow arthrolysis									
Yu[69] (2015)	31 vs. 28 (51)	37.5 ± 13.3 (17:14)	34.9 ± 10.6 (15:13)	Cryo/Cuff IC Cooler (DJO Global)	Mean dose of sufentanil (μg)	Days 1 and 2	86.5 ± 18.0	93.1 ± 13.2	0.002*

*MME = morphine milligram equivalents, and NR = not reported. †Significant difference in favor of cryotherapy.

population of professional tennis players who received cryotherapy using cold air chambers compared with no cryotherapy[15]. In addition, whole-body cryotherapy has been found to alter bone metabolism in favor of healing by inducing higher levels of osteoprotegerin[32]. A systematic review by Costello et al. evaluated 4 studies to determine the effects of cold air exposure on muscle soreness in exercising adults[33]. The authors found less muscle pain 1 hour after therapy involving cold air exposure compared with controls, but not at any other time points up to 72 hours, and described the evidence from the studies that were evaluated as "very low quality."[33] Another systematic review, by Bleakley et al., evaluated 10 studies to determine the overall effectiveness of cold air exposure and determined that it may improve short-term subjective measures of soreness and recovery, but overall appears to provide little benefit with

TABLE III Summary of 16 Studies Comparing Postoperative Range of Motion with Cryotherapy Versus No Cryotherapy*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Gibbons[47] (2001)	30 vs. 30 (60)	70 (11:19)	71 (14:16)	Cryo/Cuff IC Cooler (DJO Global)	Full knee ROM (°)	Day 10	5 to 82	3 to 78	>0.05
Healy[48] (1994)	50 vs. 55 (105)	NR	NR	Aircast Cryo/Cuff (DJO Global)	Mean max. knee ROM (°)	Days 2-4	80	88	>0.05
						Days 7-14	93	97	>0.05
						Weeks 4-6	111	108	>0.05
Holmström[50] (2005)	23 vs. 17 (40)	68 (14:9)	75 (11:6)	Cryo/Cuff IC Cooler (DJO Global)	Mean active ROM (°)	Week 1	10-84	13-80	>0.05
						Week 6	5-112	9-108	>0.05
					Mean active ROM (°)	Week 1	4-87	6-84	>0.05
						Week 6	2-116	3-111	>0.05
Kullenberg[53] (2006)	43 vs. 40 (83)	68.1 ± 6 (18:25)	68.9 ± 6.8 (14:26)	Cryo/Cuff IC Cooler (DJO Global)	Mean max. knee ROM (°)	Day 1	50.4 ± 8	51.4 ± 11.1	>0.05
						At discharge	75.1 ± 10.5	62.9 ± 12.8	0.0019†
						Week 3	98.9 ± 9.4	87.6 ± 7.8	0.0045†
Levy[58] (1993)	40 vs. 40 (80)	74 (7:33)	73 (8:32)	Cryo/Cuff IC Cooler (DJO Global)	Mean total knee ROM (°)	Day 7	53 ± 13	44 ± 15	<0.05†
						Day 14	77 ± 13	5 ± 14	<0.01†
Morsi[59] (2002)	30 vs. 30 (30)	NR	NR	Custom-made cooling coil device	Mean total knee ROM (°)	Week 1	68 ± 14.8	54 ± 11.04	<0.01†
						Week 6	NR	NR	>0.05
Webb[66] (1998)	24 vs. 25 (49)	69.4 (NR)	70.6 (NR)	Aircast Cryo/Cuff (DJO Global)	Mean total knee ROM (°)	Day 5, week 6, month 3	NR	NR	All >0.05
Scarcella[63] (1995)	12 vs. 12 (24)	69 (NR)	67 (NR)	Hot/Ice Blanket (Thermo Temp)	Mean total knee ROM (°)	At discharge	72.5 ± 15.8	76.8 ± 10.5	>0.05
					Mean gain in knee ROM (°/day)	At discharge	5.5 ± 3.4	4.3 ± 2.8	>0.05
Smith[29] (2002)	44 vs. 40 (84)	72.1 ± 7.8 (21:23)	72.0 ± 7.1 (21:19)	Unspecified cryotherapy pad	Mean max. knee flexion (°)	Day 1	81.3 ± 11.8	83.6 ± 12.9	0.384
						Day 2	84.9 ± 13.4	86.6 ± 12.3	0.95
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/Cuff (DJO Global)	Mean max. knee flexion (°)	Day 7	88	77	0.06
Edwards[46] (1996)	26 vs. 45 (71)	26 (18:8)	27 (32:13)	Cryo/Cuff IC Cooler (DJO Global)	Mean max. knee ROM (°)	Day 2	78	76 (room temp. cuff), 72 (no cuff)	All >0.05
Konrath[52] (1996)	27 vs. 23 (50)	27 (11:8)	25 (13:10)	Polar Care (Breg)	Mean total knee ROM (°)	Before discharge	61 (cuff)	57	>0.05
				Ice bag	Mean total knee ROM (°)	Before discharge	60 (ice bag)	57	>0.05
Ohkoshi[60] (1999)	14 vs. 7 (21)	22.1 ± 6.5 (10:11) for combined groups	22.1 ± 6.5 (10:11) for combined groups	Icing System 2000 (Sigmax)	Days to 120° flexion	NR	12.7 ± 2.2 (5° C cuff)	16.7 ± 5.1	>0.05
							12.9 ± 3.2 (10°C cuff)		>0.05
Whitelaw[67] (1995)	56 vs. 46 (102)	39 (36:20)	36 (36:10)	Cryo/Cuff IC Cooler (DJO Global)	Mean total knee ROM, min. and max. values (°)	NR	5.4 to 121.9	4.2 to 123.6	>0.05
Lessard[57] (1997)	23 vs. 22 (45)	42.0 ± 12.6 (16:7)	44.6 ± 14.9 (15:7)	Cold gel packs	Mean total knee ROM (°)	Day 7	122.1 ± 14.6	114.4 ± 24.4	>0.05
Elbow arthrolysis									
Yu[69] (2015)	31 vs. 28 (51)	37.5 ± 13.3 (17:14)	34.9 ± 10.6 (15:13)	Cryo/Cuff IC Cooler (DJO Global)	Total elbow ROM in flexion-extension (°)	Day 1	103.7 ± 14.6	102.0 ± 15.6	0.341
						Day 3	118.6 ± 14.5	118.0 ± 11.2	0.412
						Day 7	125.0 ± 13.2	123.4 ± 10.8	0.632

*ROM = range of motion, and NR = not reported. †Significant difference in favor of cryotherapy.

TABLE IV Summary of 9 Studies Comparing Postoperative Swelling with Cryotherapy Versus No Cryotherapy*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Healy[48] (1994)	50 vs. 55 (105)	NR	NR	Aircast Cryo/Cuff (DJO Global)	Mean increase from baseline in circumference of thigh at mid-patella and distal aspect of thigh (cm)	Between days 2-4	2.3, 2.2	2.0, 2.0	>0.05
						Between days 7-14	0.3, 0.6	0.7, 0.6	>0.05
						Between weeks 4-6	0.8, 1.0	0.6, 1.0	>0.05
Holmström[50] (2005)	23 vs. 17 (40)	68 (14:9)	75 (15:6)	Cryo/Cuff IC Cooler (DJO Global)	Change in knee diameter compared with baseline (cm)	Day 7	2.0	2.9	>0.05
						Week 6	NR	NR	>0.05
Smith[29] (2002)	44 vs. 40 (84)	72.1 ± 7.8 (21:23)	72.0 ± 7.1 (21:19)	Unspecified cryotherapy pad	Knee swelling (cm)	Hour 24	43.8 ± 3.3	43.9 ± 3.6	0.84
						Hour 48	43.9 ± 2.6	44.5 ± 3.8	0.51
Webb[66] (1998)	24 vs. 25 (49)	69.4 (NR)	70.6 (NR)	Aircast Cryo/Cuff (DJO Global)	Knee circumference 2 cm proximal to patella (cm)	Day 5, week 6, month 3	NR	NR	All >0.05
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/Cuff (DJO Global)	Swelling (unspecified units)	Day 7	NR	NR	0.76
Lessard[57] (1997)	23 vs. 22 (45)	42.0 ± 12.6 (16:7)	44.6 ± 14.9 (15:7)	Cold gel packs	Circumference of knee 3 cm proximal to patellar base (cm)	Day 7	39.2 ± 3.29	40.4 ± 3.37	>0.05
Whitelaw[67] (1995)	56 vs. 46 (102)	39 (36:20)	36 (36:10)	Cryo/Cuff IC Cooler (DJO Global)	Mean circumference of knee at superior pole of patella (cm)	NR	40.5	38.2	>0.05
THA									
Iwakiri[51] (2019)	30 vs. 30 (60)	68.1 ± 9.6 (1:29)	67.6 ± 8.9 (1:29)	CF3000 Icing System and Cooling Pad (Sigmax)	Thigh circumference 5 cm proximal to superior patellar border (ratio of postop.:preop. values)	Day 4	1.04 ± 0.04	1.07 ± 0.06	0.045†
						Day 7	1.06 ± 0.05	1.05 ± 0.06	0.27
						Day 14	1.02 ± 0.05	1.01 ± 0.03	0.16
						Day 28	0.95 ± 0.27	1.01 ± 0.03	0.25
Open shoulder surgery									
Speer[65] (1996)	25 vs. 25 (50)	36.9 (19:6)	39.4 (17:8)	Cryo/Cuff IC Cooler (DJO Global	Visual analog scale asking patients to rate swelling in shoulder (0-10)	Day 10	0.98	2.59	0.002†

*NR = not reported. †Significant difference in favor of cryotherapy.

regard to functional recovery; the authors therefore concluded that athletes can achieve comparable results with cheaper therapies such as a local ice pack[34].

Beyond pain management and acute postoperative care, whole-body cryotherapy using either ice baths or cold air chambers has also been studied extensively as a tool to aid athletes in their recovery. Some studies found neither cold water immersion nor whole-body cryotherapy to be more effective than a placebo intervention at improving functional recovery or muscle soreness after various exercises[33,35-39]. However, other studies found cold water therapy to be more helpful in reducing delayed-onset muscle soreness and enhancing recovery from muscle damage after exercise[5,40,41]. Future high-level studies will be necessary to determine the exact benefits of ice-bath and cryotherapy chamber treatment.

Cryotherapy Outcomes in the Literature

Methodology

A literature search was performed using PubMed. Broad search terms related to cryotherapy were used, including "cryotherapy," "cold therapy," "ice therapy," "continuous cryotherapy," "compressive cryotherapy," and "orthopaedic." After screening for relevant RCTs, 29 studies were identified that directly compared cryotherapy of any form to no cryotherapy following orthopaedic procedures, while 15 studies were identified that compared continuous cryotherapy devices to either bagged ice or ice pack treatment.

Cryotherapy Versus No Cryotherapy

After a review of the current literature, 29 studies were identified that compared

TABLE V Summary of 14 RCTs Comparing Postoperative Pain Scores with Continuous Cryotherapy Devices Versus Bagged Ice or Ice Pack Treatment*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-Up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Bech[73] (2015)	37 vs. 34 (71)	70.4 ± 1.8 (17:20)	71.5 ± 1.8 (19:15)	DonJoy Iceman (DonJoy Canada)	VAS pain	Day 2	3.8 ± 0.25	3.6 ± 0.27	0.67
Demoulin[74] (2012)	22 vs. 22 (44)	Males: 71.7 ± 5.6 (9 total), females: 70.9 ± 8.8 (13 total)	Males: 67.2 ± 11.9 (9 total), females: 68.8 ± 9.5 (13 total)	Aircast Cryo/Cuff (DJO Global)	VAS pain	Day 7	NR	NR	All >0.05
Schinsky[78] (2016)	49 vs. 51 (100)	64.7 (20:29)	65.3 (24:27)	Unspecified continuous cryotherapy device	VAS pain	At discharge	4.82 ± 2.10	4.85 ± 2.14	0.97
						Week 3	2.68 ± 1.68	2.96 ± 2.20	0.82
						Week 6	2.36 ± 2.03	2.26 ± 2.44	0.01‡
Sadoghi[77] (2018)	46 vs. 51 (97)	70.4 (14:32)	71.7 (15:36)	cTreatment (Waegener)	VAS pain	Day 2	3.7 ± 2.1	4.6 ± 2.1	0.03†
						Day 4	NR	NR	>0.05
						Day 6	NR	NR	>0.05
Su[80] (2012)	103 vs. 84 (187)	NR	NR	GameReady (CoolSystems)	VAS pain difference compared with preop. value	Week 2	−0.9	−1.35	>0.05
						Week 6	−2.34	−2.21	>0.05
Thienpont[81] (2014)	50 vs. 50 (100)	67.5 ± 10.5 (15:35)	68.5 ± 10 (10:40)	cTreatment (Waegener)	VAS pain	Day 2	4.0 ± 3.0	3.5 ± 2.5	0.18
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/Cuff (DJO Global)	VAS pain	Hour 1	3.71	4.51	>0.05
						Hour 2	3.61	4.06	>0.05
						Hour 8	4.10	5.49	0.02†
						Day 2	5.61	7.32	0.01†
						Day 3	5.04	5.91	>0.05
						Day 4	4.55	5.03	>0.05
						Day 5	4.29	4.88	>0.05
						Day 6	4.33	4.45	>0.05
Ruffilli[76] (2015)	23 vs. 24 (47)	32.2 ± 6.7 (14:9)	31.4 ± 8.1 (15:9)	Hilotherm (Hilotherm)	VAS pain	Day 1	.0.9 ± 0.8	2.4 ± 1.7	<0.0001†
Schröder[79] (1994)	21 vs. 23 (44)	24.8 ± 5.6 (15:6)	24.2 ± 4.5 (18:5)	Cryo/Cuff IC Cooler (DJO Global)	VAS pain	Day 1	NR	NR	>0.05
						Day 2	NR	NR	>0.05
						Day 3	NR	NR	>0.05
						Day 6	NR	NR	<0.05†
						Week 2	NR	NR	>0.05
						Week 4	NR	NR	>0.05
Waterman[26] (2012)	18 vs. 18 (36)	28.7 (15:3)	30.9 (15:3)	GameReady (CoolSystems)	VAS pain difference compared with preop. score	Week 1	2.22	1.06	0.07
						Week 2	1.57	4.11	0.002†
						Week 6	.47	2.68	<0.001†
Woolf[82] (2008)	24 vs. 29 (53)	NR	NR	Polar Care 500 (Breg)	VAS pain	Day 2	5.28	5.90	>0.05
						Day 5	4.46	4.30	>0.05
						Day 8	4.44	3.80	>0.05
						Day 11	3.32	2.92	>0.05
						Day 14	2.30	3.20	>0.05
Shoulder arthroplasty									

continued

TABLE V *(continued)*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-Up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Noyes[75] (2018)	20 vs. 20 (40)	NR	NR	Polar Care Shoulder Cuff (Breg)	VAS pain	Day 1	4.2 ± 3.0	4.3 ± 3.1	0.989
						Day 3	4.8 ± 2.7	4.7 ± 3.2	0.944
						Week 1	2.9 ± 1.8	3.3 ± 2.5	0.593
						Week 2	2.5 ± 2.1	2.7 ± 1.8	0.742
Shoulder arthroscopy									
Kraeutler[28] (2015)	25 vs. 21 (46)	55.4 (NR)	55.8 (NR)	GameReady Shoulder Wrap (CoolSystems)	VAS pain	Day 0	4.5	4.1	0.67
						Days 1-7	NR	NR	All days >0.05
Wrist arthroscopy									
Meyer-Marcotty[27] (2011)	25 vs. 27 (52)	NR	NR	Cryo/Cuff Wrist Cuff (DJO Global)	VAS pain	Days 1-21	NR	NR	<0.05 for days 1 and 2†, >0.05 for all other days

*Visual analog scale (VAS) pain reported on a 0-10 scale. NR = not reported. †Significant difference in favor of continuous cryotherapy devices. ‡Significant difference in favor of simple ice treatment.

cryotherapy using either bagged ice, ice packs, or continuous cryotherapy devices to no cryotherapy in the postoperative setting (Tables I through IV)[29,42-69]. Postoperative pain scores, analgesic consumption, range of motion, and swelling were summarized from these studies, and the results of the studies included in this review were also stratified by surgical procedure. The majority of studies evaluated the role of postoperative cryotherapy compared with no cryotherapy for knee arthroplasty and knee arthroscopy. The results of these RCTs were generally mixed, but all showed either an equal or superior benefit of cryotherapy use compared with no cryotherapy. Additionally, none of the studies identified any complications that were specifically caused by cryotherapy treatment. Although the available literature is limited in the hip, shoulder, elbow, and wrist, current studies have shown promising results in favor of cryotherapy. However, the limited number of studies in these areas and their heterogenous patient populations and cryotherapy methods make it difficult to draw meaningful conclusions, especially when combined with the small sample sizes used in many of the studies.

The results seen after lower-extremity surgery—for both arthroplasty and arthroscopic procedures—suggest that cryotherapy may be helpful to aid in recovery, depending on the patient population, but the studies offer mixed results. For example, Kullenberg et al. found that compressive cryotherapy tended to improve pain, range of motion, and the length of hospital stay after TKA compared with no cryotherapy, although these results were not statistically significant[53]. Morsi found similar results suggesting that the use of a continuous cryotherapy device after TKA improved range of motion, blood loss, pain scores, and wound-healing and decreased pain medication usage[59]. However, Gibbons et al. compared compressive cryotherapy to a Robert Jones bandage after TKA and found no difference between the 2 groups with the exception of reduced blood loss in the compressive cryotherapy group[47].

The results were similar after hip surgery. Saito et al. concluded that administration of a continuous cryotherapy device after total hip arthroplasty (THA) improved pain and reduced pain medication use, while Iwakiri et al. found that continuous cryotherapy devices significantly reduced local swelling[51,62]. In contrast, Leegwater et al. found that compressive cryotherapy did not contribute any added value in the acute postoperative recovery phase after hip fracture surgery[56].

One pertinent question regarding all forms of cryotherapy is the amount of tissue penetration achieved, and thus whether the reduction in temperature is reaching subcutaneous and deeper tissues. Several studies have sought to answer this question, and while cryotherapy provides an obvious temperature reduction in cutaneous tissues, some studies suggest that this effect may not be reaching subcutaneous tissues. An RCT used temperature probes to determine the reduction in temperature achieved by local cryotherapy using a continuous cryotherapy device in the glenohumeral joint and subacromial space following shoulder arthroscopy[70]. The authors found that surface-applied cryotherapy did not penetrate the glenohumeral joint or the subacromial

TABLE VI Summary of 12 Studies Comparing Postoperative Analgesic Consumption with Continuous Cryotherapy Devices Versus Bagged Ice or Ice Pack Treatment*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Variable	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Bech[73] (2015)	37 vs. 34 (71)	70.4 ± 1.8 (17:20)	71.5 ± 1.8 (19:15)	DonJoy Iceman (DonJoy Canada)	Mean opioid usage (mg)	Between hours 24-48	49.9 ± 5.8	42.3 ± 4.9	0.33
Schinsky[78] (2016)	49 vs. 51 (100)	64.7 (20:29)	65.3 (24:27)	Unspecified continuous cryotherapy device	Doses of analgesic usage in the previous 24 hr (no. of doses)	At discharge	2.54 ± 1.17	2.38 ± 1.03	0.63
						Week 3	2.23 ± 1.51	2.50 ± 1.54	0.83
						Week 6	2.21 ± 1.91	2.23 ± 2.06	0.94
Sadoghi[77] (2018)	46 vs. 51 (97)	70.4 (14:32)	71.7 (15:36)	cTreatment (Waegener)	Total hydromorphone usage (mg)	Day 6	10.23 ± 5.05	12.11 ± 7.97	>0.05
Su[80] (2012)	103 vs. 84 (187)	NR	NR	GameReady (CoolSystems)	MME usage from weeks 0-2 (mg)	Week 2	509	680	<0.05†
					MME usage from weeks 2-6 (mg)	Week 6	NR	NR	>0.05
Thienpont[81] (2014)	50 vs. 50 (100)	67.5 ± 10.5 (15:35)	68.5 ± 10 (10:40)	cTreatment (Waegener)	Morphine usage (mg)	Day 2	38 ± 27	38.5 ± 26	0.925
					Tramadol usage (mg)	Day 2	282 ± 240	317 ± 416	0.61
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/Cuff (DJO Global)	Vicodin usage (mg/day)	Day 1	0.86	2.26	<0.001†
						Day 2	1.49	2.7	0.04†
						Day 3	2.06	2.74	>0.05
						Day 4	1.9	1.51	>0.05
						Day 5	2.12	1.51	>0.05
						Day 6	2.47	1.4	>0.05
Konrath[52] (1996)	27 vs. 23 (50)	27 (11:8)	26 (13:10)	Polar Care (Breg)	Total pain medication usage, normalized to body weight (mg/kg)	At discharge	0.59	0.60	>0.05
Ruffilli[76] (2015)	23 vs. 24 (47)	32.2 ± 6.7 (14:9)	31.4 ± 8.1 (15:9)	Hilotherm (Hilotherm)	Tramadol usage	Day 1	NR	NR	>0.05
Schröder[79] (1994)	21 vs. 23 (44)	24.8 ± 5.6 (15:6)	24.2 ± 4.5 (18:5)	Cryo/Cuff IC Cooler (DJO Global)	Bupivacaine usage (mg/kg)	At discharge	NR	NR	>0.05
					Tramadol (mg/kg)	At discharge	NR	NR	>0.05
					Tilidine (mg/kg)	At discharge	NR	NR	<0.05†
					Pethidine (mg/kg)	At discharge	NR	NR	>0.05
					Pitiramide (mg/kg)	At discharge	NR	NR	<0.05†
Waterman[26] (2012)	18 vs. 18 (36)	28.7 (15:3)	30.9 (15:3)	GameReady (CoolSystems)	No. of patients no longer using analgesics	Week 6	15 of 18	5 of 18	0.0008†
Shoulder arthroplasty									
Noyes[75] (2018)	20 vs. 20 (40)	NR	NR	Polar Care Shoulder Cuff (Breg)	Total MME narcotic consumption	Day 1	43.0 ± 36.7	38.0 ± 42.9	0.382
						Day 3	149.0 ± 106.5	116.3 ± 108.9	0.601
						Day 7	308.1 ± 234.0	228 ± 258.3	0.319
						Day 14	430.8 ± 384.2	347.5 ± 493.4	0.348
Shoulder arthroscopy									
Kraeutler[28] (2015)	25 vs. 21 (46)	55.4	55.8	GameReady Shoulder Wrap (CoolSystems)	MME dose of opioid analgesics	Day 7	201	154	>0.05

*MME = morphine milligram equivalents, and NR = not reported. †Significant difference in favor of continuous cryotherapy devices.

TABLE VII Summary of 11 Studies Comparing Postoperative Range of Motion with Continuous Cryotherapy Devices Versus Bagged Ice or Ice Pack Treatment*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Bech[73] (2015)	37 vs. 34 (71)	70.4 ± 1.8 (17:20)	71.5 ± 1.8 (19:15)	DonJoy Iceman (DonJoy Canada)	Passive ROM (°)	Day 2	54.0 ± 2.4	59.8 ± 3.1	0.14
Demoulin[74] (2012)	22 vs. 22 (44)	Males: 71.7 ± 5.6 (9 total), females: 70.9 ± 8.8 (13 total)	Males: 67.2 ± 11.9 (9 total), females: 68.8 ± 9.5 (13 total)	Aircast Cryo/Cuff (DJO Global)	Mean max. active and passive flexion (°)	Week 1	NR	NR	>0.05
					Mean max. active and passive extension (°)	Week 1	NR	NR	>0.05
Sadoghi[77] (2018)	46 vs. 51 (97)	70.4 (14:32)	71.7 (15:36)	cTreatment (Waegener)	Mean total knee flexion (°)	Day 2 Day 4 Day 6	56 ± 11 NR 86 ± 7	51 ± 16 NR 80 ± 14	0.089 >0.05 0.021†
Schinsky[78] (2016)	49 vs. 51 (100)	64.7 (20:29)	65.3 (24:27)	Unspecified continuous cryotherapy device	Mean ROM in flexion (°)	At discharge	75.9 ± 15.7	79.5 ± 11.7	0.18
					Mean ROM in extension (°)	At discharge	8.32 ± 6.95	6.00 ± 7.94	0.86
Su[80] (2012)	103 vs. 84 (187)	NR	NR	GameReady (CoolSystems)	Difference in max. knee flexion compared with preop. value (°)	Week 2 Week 6	−33 −9.5	−28.7 −8.6	>0.05 >0.05
					Difference in max. knee extension compared with preop. value (°)	Week 2 Week 6	1.5 −1.7	1.6 −1.5	>0.05 >0.05
Thienpont[81] (2014)	50 vs. 50 (100)	67.5 ± 10.5 (15:35)	68.5 ± 10 (10:40)	cTreatment (Waegener)	Mean active flexion (°)	Day 4 Week 6	88.5 ± 12.5 114 ± 12	92 ± 20 120 ± 14	0.30 0.02‡
					Mean active extension (°)	Day 4 Week 6	−1.5 ± 2.5 −0.5 ± 0.7	−1.5 ± 4 −.6 ± 0.8	0.88 0.51
Knee arthroscopy									
Barber[42] (1998)	51 vs. 49 (100)	34 (34:17)	34 (40:9)	Aircast Cryo/Cuff (DJO Global)	Mean max. knee flexion (°)	Day 7	88	77	0.03†
					No. of patients who failed to achieve full knee extension	Day 7	27 of 52	26 of 35	>0.05
Konrath[52] (1996)	27 vs. 23 (50)	27 (11:8)	26 (13:10)	Polar Care (Breg)	Mean total knee ROM (°)	Before discharge	61	60	>0.05

continued

TABLE VII (continued)

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Outcome Type	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Ruffilli[76] (2015)	23 vs. 24 (47)	32.2 ± 6.7 (14:9)	31.4 ± 8.1 (15:9)	Hilotherm (Hilotherm)	Mean max. knee flexion (°)	Day 1	74.8 ± 22.3	43.3 ± 24.7	<0.0001†
Schröder[79] (1994)	21 vs. 23 (44)	24.8 ± 5.6 (15:6)	24.2 ± 4.5 (18:5)	Cryo/Cuff IC Cooler (DJO Global)	Max. knee flexion (°)	Day 1, 2, 3, and 6, weeks 2 and 4	NR	NR	<0.05 for all days†
					Knee extension deficit (°)	Day 1, 2, 3, and 6, weeks 2 and 4	NR	NR	<0.05 for day 28 only†
Wrist arthroscopy									
Meyer-Marcotty[27] (2011)	25 vs. 27 (52)	NR	NR	Cryo/Cuff Wrist Cuff (DJO Global)	Global ROM (°)	Days 1 and 8, week 3	NR	NR	All >0.05

*ROM = range of motion, and NR = not reported. †Significant difference in favor of continuous cryotherapy devices. ‡Significant difference in favor of simple ice treatment.

space. In contrast, Osbahr et al. performed a similar study at the shoulder and found significant decreases in subacromial and glenohumeral temperatures at various time points from 4 to 23 hours after initiation of cryotherapy using a continuous cryotherapy device ($p < 0.05$)[71].

The variation in outcomes that is seen in the literature could be caused by several factors such as the level of tissue penetration, method of cryotherapy, time of application, and types of outcome measures that were used in each study. If the cold temperature does not reach the intended area, then the temperature-dependent mechanisms discussed earlier in the section on basic-science mechanisms would not be relevant. The degree of tissue penetration achieved by cryotherapy as well as the ideal joint temperature to be achieved are areas that will require further study. However, it is important to note that cryotherapy did not result in inferior outcomes in any of studies presented in Tables I through IV when compared with no cryotherapy treatment, and there were also no cryotherapy-specific complications in any of the areas identified.

Continuous Cryotherapy Devices Versus Bagged Ice or Ice Packs

Overall, there were 15 RCTs that directly compared continuous cryotherapy devices to the use of bagged ice or ice packs[26-28,52,72-82]. Once again, the majority of these studies were conducted to evaluate effectiveness in TKA and knee arthroscopy. Results after shoulder arthroplasty, shoulder arthroscopy, and wrist arthroscopy were also evaluated. In the studies evaluated, continuous cryotherapy was found to be superior to bagged ice or ice pack therapy in 6 (43%) of 14 studies in terms of pain scores, 4 (33%) of 12 in terms of analgesic consumption, 4 (36%) of 11 in terms of range of motion, and 2 (22%) of 9 in terms of swelling (Tables V through VIII). In contrast, 2 studies found bagged ice or ice pack treatment to be superior to continuous cryotherapy devices, 1 in terms of pain scores and another in terms of range of motion[78,81].

Out of all procedures studied, continuous cryotherapy after knee arthroscopy appeared to most consistently have favorable results, with the majority of studies demonstrating a significant reduction in pain, swelling, and analgesic consumption and increase in range of motion compared with bagged ice or ice packs (Table IX). Of these studies, only 1 of 6 received funding from an industry partner[42]. The results were more mixed in the knee arthroplasty literature. The majority of studies found no significant reduction in postoperative pain or swelling or improvement in range of motion with continuous cryotherapy compared with bagged ice or ice packs ($p > 0.05$).

Although the studies were limited, continuous cryotherapy does not appear to have a benefit for shoulder surgery compared with bagged ice or ice pack therapy. There was no benefit in any of the postoperative measures in the 2 RCTs that evaluated the shoulder. These results explain why insurance companies often do not cover the costs associated with continuous cryotherapy devices. Continuous cryotherapy may offer convenience as an advantage, with 1 study showing that patients were likely to use continuous cryotherapy devices more often than bagged ice treatment in the postoperative setting[55]. However, based on the results of this review, that may not translate into clinical results. Further Level-I and II studies are needed to better understand the advantage that continuous cryotherapy devices may have in comparison with bagged ice or ice packs according to the surgery type.

Potential Side Effects

Cryotherapy offers a relatively low risk profile within the orthopaedic and athletic community. Many of the

TABLE VIII Summary of 9 Studies Comparing Postoperative Swelling with Continuous Cryotherapy Devices Versus Bagged Ice or Ice Pack Treatment*

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Variable	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
TKA									
Demoulin[74] (2012)	22 vs. 22 (44)	Males: 71.7 ± 5.6 (9 total), females: 70.9 ± 8.8 (13 total)	Males: 67.2 ± 11.9 (9 total), females: 68.8 ± 9.5 (13 total)	Aircast Cryo/ Cuff (DJO Global)	Circumference of knee at joint line, 10 cm above joint line, and 5 cm below joint line (cm)	Day 7	NR	NR	All >0.05
Sadoghi[77] (2018)	46 vs. 51 (97)	70.4 (14:32)	71.7 (15:36)	cTreatment (Waegener)	Mean circumference of knee, mid-patella, 7 cm proximal to patellar base, and 7 cm distal to patellar apex (cm)	Day 6	NR	NR	All >0.05
Schinsky[78] (2016)	49 vs. 51 (100)	64.7 (20:29)	65.3 (24:27)	Unspecified continuous cryotherapy device	Difference in circumference of knee 3 cm above mid-patella compared with baseline (cm)	Postop.	2.56 ± 5.37	2.83 ± 5.28	0.41
						Week 3	1.83 ± 4.70	2.69 ± 5.25	0.22
						Week 6	0.94 ± 4.56	1.56 ± 4.32	0.28
Su[80] (2012)	103 vs. 84 (187)	NR	NR	GameReady (CoolSystems)	Knee girth	Weeks 2 and 6	NR	NR	All >0.05
Thienpont[81] (2014)	50 vs. 50 (100)	67.5 ± 10.5 (15:35)	68.5 ± 10 (10:40)	cTreatment (Waegener)	Knee circumference (cm)	Week 6	45 ± 4.5	45.5 ± 5.1	0.60
Knee arthroscopy									
Ruffilli[76] (2015)	23 vs. 24 (47)	32.2 ± 6.7 (14:9)	31.4 ± 8.1 (15:9)	Hilotherm (Hilotherm)	Circumference of knee at patellar apex, compared with preop. (cm)	Day 1	NR	NR	0.01†
					Circumference of knee 10 cm proximal to the superior patellar pole, compared with preop. (cm)	Day 1	NR	NR	0.001†
					Circumference of knee 15 cm distal to the superior patellar pole, compared with preop. (cm)	Day 1	NR	NR	>0.05
Schröder[79] (1994)	21 vs. 23 (44)	24.8 ± 5.6 (15:6)	24.2 ± 4.5 (18:5)	Cryo/Cuff IC Cooler (DJO Global)	Change in circumference of knee compared with baseline for superior patellar pole, mid-patella, and max. calf girth (cm)	Day 1	NR	NR	>0.05
						Day 2	NR	NR	<0.05 at calf only
						Day 3	NR	NR	<0.05 at superior patella, calf
						Day 6	NR	NR	<0.05 at superior patella, calf
						Day 14	NR	NR	<0.05 at calf only
						Day 28	NR	NR	<0.05 at calf only

continued

TABLE VIII (continued)

Study	Sample Size Treatment Vs. Control (Total)	Mean Age (No. Male: Female)		Cryotherapy Method	Variable	Follow-up Time	Results		P Value
		Treatment	Control				Treatment	Control	
Waterman[26] (2012)	18 vs. 18 (36)	28.7 (15:3)	30.9 (15:3)	GameReady (CoolSystems)	Knee circumference at proximal, central, and distal portions of patella (cm)	Week 1	44.1, 41.4, 38.1	44.0, 41.9, 39.3	>0.05
						Week 2	42.9, 40.3, 37.4	41.8, 40.1, 37.9	>0.05
						Week 6	41.4, 39.7, 36.8	41.3, 40.0, 37.6	>0.05
Wrist arthroscopy									
Meyer-Marcotty[27] (2011)	25 vs. 27 (52)	NR	NR	Cryo/Cuff Wrist Cuff (DJO Global)	Change in wrist volume compared with preop. value (mL)	Day 1	967 ± 24 to 932 ± 34	890 ± 36 to 912 ± 38	>0.05
						Day 21	967 ± 24 to 954 ± 25	890 ± 36 to 905 ± 33	>0.05

*NR = not reported. †Significant difference in favor of continuous cryotherapy devices.

complications related to cryotherapy are secondary to poor patient understanding or prolonged duration of use. Currently, most of the literature pertaining to adverse outcomes involves case reports.

The most publicized and frequently acknowledged complications of cryotherapy are cutaneous reactions. Frostbite damages tissue by direct cellular damage from alterations in osmotic gradient and progressive dermal ischemia[83,84]. Fingers and toes are especially prone to frostbite injuries due to limited blood supply and minimal collateral circulation. Case reports have documented frostbite following an extended duration of cryotherapy to digits following injury or operative procedures[85,86]. In addition to the distal aspects of extremities, the knee is a susceptible region for developing skin complications. Dundon et al. reported on 2 patients who developed skin necrosis over the patella after using cryotherapy for an extended period of time following knee arthroplasty[87]. King et al. described 2 patients who underwent arthroscopic knee surgery and developed perniosis secondary to use of a continuous cryotherapy device in the acute postoperative period[88]. These complications can often be easily prevented by avoiding direct skin contact with the cryotherapy device, limiting the time of usage, and providing appropriate patient counseling.

Cryotherapy has also been linked with peripheral nerve injuries. Malone et al. reported 6 cases of peripheral nerve injuries in athletes following direct cryotherapy. The peripheral nerve injuries included 3 peroneal nerves, 2 lateral femoral cutaneous nerves, and 1 supraclavicular nerve. All athletes returned to baseline neurologic function[89]. This again highlights the importance of appropriate counseling and monitoring of orthopaedic patients receiving cryotherapy.

The greatest risk of complications has been associated with the use of whole-body cryotherapy in nitrogen gas chambers[25]. The extreme temperatures of these chambers place patients at higher risks for complications, and the recommended exposure duration is only 2 to 3 minutes to optimize benefit and minimize risk[90]. There is concern for nitrogen asphyxiation and loss of consciousness secondary to inhalation of the nitrogen gas, and there is 1 documented complication of global amnesia following a whole-body cryotherapy session[90,91].

Cost-Benefit Analysis of Cryotherapy

An extensive review of the literature demonstrated that 44% of studies showed improvement in pain scores with the use of cryotherapy compared with no cryotherapy. In terms of reduction in pain medication consumption, 48% of the studies reported a decrease in pain medication in the cryotherapy group. While the cost reduction in pain medication may or may not justify the additional cost of more advanced methods of cryotherapy application, including continuous flow combined with compression, the reduction in narcotic medication has a societal benefit in helping to curb unwanted diversion into the community. More efficacious and reliable cryotherapy application may make narcotic-free surgery a more realistic goal.

The least expensive cryotherapy method is a single bag of ice for localized pain control, while joint-specific continuous cryotherapy devices represent more expensive options. The cost of these devices can range between $65 and >$250 depending on the hospital contract and on the patient's insurance, which may or may not cover the cost of these devices. The rental cost of units providing continuous cryotherapy with compression can vary substantially between $100 and $700 per week, which may not be covered by insurance. To our knowledge, there is no study in the literature evaluating the cost-

TABLE IX Summary of the Clinical Effectiveness of All Studies Evaluating Postoperative Pain Scores, Analgesic Consumption, Range of Motion, and Swelling

		No. of Studies			
Variable	Joint (Procedure)	Cryotherapy Superior to No Cryotherapy	No Difference	Cryotherapy Inferior to No Cryotherapy	Total
Cryotherapy of any form vs. no cryotherapy				–	
Pain score	Knee (arthroplasty)	4 (33%)	8 (67%)	–	12
	Knee (arthroscopy)	3 (43%)	4 (57%)	–	7
	Hip	1 (33%)	2 (67%)	–	3
	Shoulder	2 (100%)	–	–	2
	Elbow	1 (100%)	–	–	1
	Total	11 (44%)	14 (56%)		25
Analgesic consumption	Knee (arthroplasty)	4 (40%)	6 (60%)	–	10
	Knee (arthroscopy)	4 (57%)	3 (43%)	–	7
	Hip	2 (40%)	3 (60%)	–	5
	Elbow	1 (100%)	–	–	1
	Total	11 (48%)	12 (52%)		23
Range of motion	Knee (arthroplasty)	3 (33%)	6 (67%)	–	9
	Knee (arthroscopy)	–	6 (100%)	–	6
	Elbow	–	1 (100%)	–	1
	Total	3 (19%)	13 (81%)		16
Swelling	Knee (arthroplasty)	–	4 (100%)	–	4
	Knee (arthroscopy)	–	3 (100%)	–	3
	Hip	1 (100%)	–	–	1
	Shoulder	1 (100%)	–	–	1
	Total	2 (22%)	7 (78%)		9
Overall total					29
Continuous cryotherapy devices vs. simple ice treatment					
Pain score	Knee (arthroplasty)	1 (17%)	4 (67%)	1 (17%)	6
	Knee (arthroscopy)	4 (80%)	1 (20%)	–	5
	Shoulder	–	2 (100%)	–	2
	Wrist	1 (100%)	–	–	1
	Total	6 (43%)	7 (50%)	1 (7%)	14
Analgesic consumption	Knee (arthroplasty)	1 (20%)	4 (80%)	–	5
	Knee (arthroscopy)	3 (60%)	2 (40%)	–	5
	Shoulder	–	2 (100%)	–	2
	Total	4 (33%)	8 (67%)		12
Range of motion	Knee (arthroplasty)	1 (17%)	4 (67%)	1 (17%)	6
	Knee (arthroscopy)	3 (75%)	1 (25%)	–	4
	Wrist	–	1 (100%)	–	1
	Total	4 (36%)	6 (55%)	1 (9%)	11
Swelling	Knee (arthroplasty)	–	5 (100%)	–	5
	Knee (arthroscopy)	2 (67%)	1 (33%)	–	3
	Wrist	–	1 (100%)	–	1
	Total	2 (22%)	7 (78%)		9
Overall total					15

effectiveness of using continuous cryotherapy devices with or without compression after surgery. Theoretically, if we can reduce both pain and pain medication consumption after surgery and help to prevent opioid addiction in patients undergoing elective orthopaedic procedures, then that could justify the cost of providing routine continuous cryotherapy treatment for all orthopaedic patients after surgery. However, we do not currently have any evidence to support this statement. Also, if we can reduce postoperative stiffness and physical therapy visits after surgery with cryotherapy, then that could justify the cost as well. In this review of the literature, only 3 (19%) of 16 studies demonstrated improved range of motion after surgery with cryotherapy, whereas the majority of the studies (13 [81%] of 16) showed no difference. Considering the theoretical cost-effectiveness of cryotherapy protocols compared with other strategies, providers may have a value-based incentive to utilize continuous cryotherapy more often for postoperative management, given the reduction in both pain scores (11 [44%] of the 25 studies reviewed) and pain medication consumption (11 [48%] of the 23 studies reviewed). Future high-level prospective studies are needed to reveal the exact cost and benefit of using cryotherapy as a standard of care.

Conclusions

In summary, cryotherapy is commonly used in conjunction with orthopaedic care and includes the use of bagged ice, ice packs, or continuous cryotherapy devices with or without compression. Cryotherapy has been linked with microvasculature alterations that decrease production of inflammatory mediators, disrupt the overall inflammatory response, decrease edema, as well as decrease NCV. The reduction in cytokines as well as the decreased NCV are thought to underly the analgesic effect of cryotherapy. Mixed results from outcome studies provide no clear consensus on the advantages of postoperative continuous cryotherapy devices, with or without compression, compared with bagged ice or ice pack use. However, the risk of complications from cryotherapy, which include skin irritation, frostbite, perniosis, and peripheral nerve injuries, is minimal. Whole-body cryotherapy remains an unproven methodology with higher costs and potentially greater risks. Future high-quality Level-I or II studies are needed to determine the value of continuous cryotherapy devices with and without compression before they can be recommended as a standard of care in orthopaedic surgery following both injury and surgery.

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