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The efficacy of post-operative devices following knee arthroscopic surgery: a systematic review

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Abstract

Purpose There is a wide array of device modalities available for post-operative treatment following arthroscopic knee surgery; however, it remains unclear which types and duration of modality are the most effective. This systematic review aimed to investigate the efficacy of device modalities used following arthroscopic knee surgery.

Methods A systematic search of the literature was performed on: PubMed; Scopus; MEDLINE; EMBASE; PEDro; SportDiscus; and CINAHL databases (1995–2015) for clinical trials using device modalities following arthroscopic knee surgery: cryotherapy, continuous passive motion (CPM), neuromuscular electrical stimulation (NMES), surface electromyographic (sEMG) biofeedback and shockwave therapy (ESWT). Only level 1 and 2 studies were included and the methodological quality of studies was evaluated using Physiotherapy Evidence Database (PEDro) scores. Outcome measures included: muscle strength, range of motion, swelling, blood loss, pain relief, narcotic use, knee function evaluation and scores, patient satisfaction and length of hospital stay.

Results Twenty-five studies were included in this systematic review, nineteen of which found a significant difference in outcomes. For alleviating pain and decreasing narcotic consumption following arthroscopic knee surgery, cryocompression devices are more effective than traditional icing alone, though not more than compression alone. CPM does not affect post-operative outcomes. sEMG biofeedback and NMES improve quadriceps strength and overall knee functional outcomes following knee surgery. There is limited evidence regarding the effects of ESWT.

Conclusion Cryotherapy, NMES and sEMG are recommended for inclusion into rehabilitation protocols following arthroscopic knee surgery to assist with pain relief, recovery of muscle strength and knee function, which are all essential to accelerate recovery. CPM is not warranted in post-operative protocols following arthroscopic knee surgery because of its limited effectiveness in returning knee range of motion, and additional studies are required to investigate the effects of ESWT.

Level of evidence II.

Keywords Anterior cruciate ligament reconstruction · ACL · Cryotherapy · Continuous passive motion · Surface electromyographic biofeedback · Neuromuscular electrical stimulation · Shockwave therapy

Abbreviations

ACLR Anterior cruciate ligament reconstruction
CCD Cold compression devices
LOHS Length of hospital stay
ROM Range of motion

Introduction

Arthroscopic surgeries are frequently performed to enable patients to return to their pre-operative daily lifestyles [53]. Proper post-operative rehabilitation of the reconstructed knee is essential, especially for a return to active lifestyles

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including running and jumping activities [35]. During post-operative care, a wide array of physical modalities is available. In this review, we attempt to provide a complete evaluation of post-operative physical devices used in rehabilitation by investigating the effect of five different devices following arthroscopic knee surgery, which are all suggested to have healing and recovery benefits for patients: cryotherapy, continuous passive motion (CPM), neuromuscular stimulation (NMES), surface electromyographic (sEMG) biofeedback and shockwave therapy (ESWT) [3, 13, 15, 22, 56].

Cryotherapy is thought to exhibit benefits through vasoconstriction, decreased tissue metabolism, diminished inflammatory release, hypoxia and attenuated nerve conduction, with a resultant decrease in secondary oedema, pain and spasm [26, 46, 52]. While some clinical studies have shown a decrease in narcotic consumption, length of hospital stay, pain, oedema, inflammation, increase in range of motion and/or weight bearing tolerance [3, 24, 27, 36, 59], others have shown no clinical benefit analysing the same outcome metrics [7, 12, 23] with cryotherapy application. CPM uses a motorized device to move the limb through a preset arc of motion. Studies have found CPM to be useful in improving range of motion following knee surgery [4, 21]. However, other studies have reported no additional benefit with CPM use [43, 60]. NMES induces muscle activation through an alternating current, which is transferred through electrodes and adhesive skin pads placed on the target muscle. Previous studies have mitigated voluntary muscle activation deficits and restored quadriceps muscle function with the addition of NMES to rehabilitation protocols [15, 48, 50, 51], while opposing studies have reported no additional benefit with NMES application [38]. sEMG biofeedback is a therapeutic technique whereby sensory or motor stimuli are provided to patients performing voluntary muscle contraction in an attempt to improve voluntary muscle control. This therapy is used to aid patients in developing a greater awareness of an increase in motor unit recruitment that are otherwise involuntary and unfelt [11]. ESWT is defined as pressure waves or transient pressure oscillations that propagate in three dimensions and typically induce a clear increase in pressure within few nanoseconds [42]. ESWT has been more widely used for pain relief and musculoskeletal disorders [55, 57], while there is limited evidence for its effect following arthroscopic surgery.

In the current literature, there is conflicting evidence regarding the aforementioned physical devices following knee surgery. Post-operative therapies can directly impact surgical outcomes and morbidity; therefore, it is useful to consolidate the reports of these randomized controlled trials and provide direction for comprehensive post-operative protocols. To our knowledge, this is the first systematic review to collectively evaluate the effects of physical devices following arthroscopic knee surgery, through level I and II evidence. The objective of this systematic review is to generate evidence-based recommendations as to which physical modalities warrant inclusion into rehabilitation protocols following arthroscopic knee surgery.

Materials and methods

This systematic review was conducted according to the recommendations of the Cochrane Collaboration [18] and the PRISMA reporting guidelines [33]. Physical device modalities were defined as those that require an externally applied device to achieve a physiologically desired therapeutic effect. This study aimed to investigate the results of the most recent studies that were more representative of current post-operative and surgical procedures; thus, studies before 1995 were excluded from this review.

Eligibility criteria

The only studies included in this review were: randomized and quasi-randomized controlled trials, which were defined as those that randomized based on patient record number, date of birth or any information easily accessible to the investigators involved in study completion. The participants must have been subject to minimally invasive arthroscopic surgery, which includes: anterior cruciate ligament reconstruction (ACLR), meniscal repair, patellar chondromalacia, synovitis, loose bodies within the knee complex, or a combination of aforementioned. In addition, patients must have received treatment of cryotherapy, CPM, NMES, sEMG, or ESWT, following an arthroscopic procedure on the knee.

Outcome measures

Primary outcomes included: pain intensity for cryotherapy; knee range of motion for CPM; and quadriceps strength and knee functional outcomes for NMES, sEMG feedback and ESWT. Secondary outcomes included: post-operative analgesic medication, oedema, blood loss, length of hospital stay, quality of life measures and patient satisfaction for each modality. Patient follow-up period was also evaluated for each modality.

Search protocol

Only studies published between January 1995 and December 2015 were included. The following databases were searched: PubMed; CINAHL; EMBASE; PEDro; SportDiscus; and ClinicalTrials.gov. Studies that were not written in the English language or demonstrated industry sponsorship were excluded. Once all randomized control trials were obtained, reference lists of respective articles were evaluated for additional studies. The following search terms were used: "Anterior Cruciate Ligament" AND "Cryotherapy OR Cold Therapy", "Arthroscopic Surgery" AND "Cryotherapy OR Cold Therapy". This search criterion was replicated for all other physical modalities, with the respective modality substituted for cryotherapy.

Study selection

Two reviewers (CTG and AAT) independently screened the titles and abstracts acquired through the database search. The reviewers read any full text that was marked as relevant independently. If full text articles met all factors of inclusion criteria, the studies were included in the review. A third reviewer (JLD) settled any disagreements between the two reviewers.

Assessment of risk of bias in studies

The Physiotherapy Evidence Database (PEDro) scores criteria were used to identify possible biases in the included research studies (Table 1). Ten of the eleven criteria were used to assess internal validity, and eligibility criteria were the sole assessment of external validity for each study [30]. All studies demonstrated level 1 or 2 evidence [5, 61] and received at least five out of the eleven validity items based on the PEDro scores [54].

Search results

The electronic database search revealed 949 unique results (Fig. 1). A total of 882 references were excluded based on titles and abstracts, leaving 67 potentially relevant studies. Thirty-five of these studies were excluded due to out-of-scope material and 7 additional studies were removed due to non-English publication. As a result, 25 studies were included in this systematic review: 12 studies were related to cryotherapy, 2 to CPM, 7 to NMES, 3 to sEMG and 1 to ESWT.

Cryotherapy

Pain relief

Eight studies evaluated the effects of cryotherapy following ACLR. Four studies reported significant differences in pain relief among respective treatment groups, while four studies did not (Table 2). Two [6, 36] out of the four studies reported significantly better pain relief in favour of cold compression device (CCD) compared to no cold controls ($p < 0.05$), while the remaining two studies [45, 58] reported significantly better pain relief in the CCD group compared to the traditional ice group ($p < 0.02$). The four opposing studies found no significant difference in pain relief ranging from the evening of operation through day 6 between treatment and control groups [3, 7, 8, 12]. Examining cryotherapy application after non-ACLR knee arthroscopy, Lessard et al. [27] evaluated pain relief and reported a significant difference in favour of cryotherapy compared to no cold controls, while Whitelaw et al. [59] observed no significant difference in pain relief between CCD and traditional ice.

Secondary outcomes

Eight studies [3, 6, 8, 12, 23, 36, 45, 58] evaluated the effects of cryotherapy on narcotic use following ACLR, and four of eight found a significant decrease in narcotic use [3, 6, 36, 58]. Following non-ACLR knee arthroscopy procedures, Whitelaw et al. [59] and Lessard et al. [27] reported significant decreases in narcotic use in favour of the cryotherapy and CCD group, respectively ($p < 0.04$). In contrast, Zaffagnini et al. [63] demonstrated no significant difference in narcotic use following non-ACLR knee arthroscopy procedures. Six studies [3, 7, 12, 23, 36, 45] evaluated the effect of cryotherapy on range of motion, and Rufilli et al. [45] was the only study that reported a significant improvement post-ACLR ($p < 0.01$). Out of three studies [3, 45, 58] that evaluated oedema post-ACLR, Rufilli et al. [45] was the sole study that reported a significant decrease in knee oedema in favour of the CCD group ($p < 0.01$). Following other arthroscopic surgeries, Whitelaw et al. [59] and Zaffagnini et al. [63] were the only study that evaluated range of motion and oedema, respectively, and reported no significant difference. Finally, five studies [8, 12, 23, 36, 45] evaluated blood loss and one study [36] reported a decrease in mean blood loss ($p < 0.01$) while a second study [45] reported a decrease in suction drainage ($p < 0.01$) post-ACLR. No studies evaluated blood loss following non-ACLR arthroscopic knee surgery.

All four studies [6, 8, 12, 23] that evaluated length of hospital stay found no significant difference between treatment and control groups. Waterman et al. [58] found no difference in quality of life or knee function between CCD and traditional ice following ACLR, nor did Lessard et al. [27] in Likert scale of well-being between cold and no cold. However, Brandsson et al. [6] analysed patient satisfaction and reported an increase with CCD use ($p < 0.05$) compared to no cold, and Whitelaw et al. [59] found an improvement in patient rated difficulty levels in favour of the CCD compared to traditional ice ($p < 0.05$).

Table 1 Methodological assessment of included studies with Physiotherapy Evidence Database (PEDro) score

References	Modality	Randomization	Surgery	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind participants	Blind therapists	Blind assessors	Follow-up	Intention to treat analysis	Group comparisons	Point and variability measures	Cumulative score (Max = 10)
Barber et al. [3]	Cryotherapy	Quasi-RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Brandsson et al. [6]	Cryotherapy	RCT	ACL	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	7
Dambros et al. [7]	Cryotherapy	RCT	ACL	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	7
Dervin et al. [8]	Cryotherapy	Quasi-RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Edwards et al. [12]	Cryotherapy	RCT	ACL	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	8
Konrath et al. [23]	Cryotherapy	RCT	ACL	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	6
Ohkoshi et al. [36]	Cryotherapy	Quasi-RCT	ACL	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5
Rufilli et al. [45]	Cryotherapy	RCT	ACL	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Waterman et al. [58]	Cryotherapy	RCT	ACL	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Lessard et al. [27]	Cryotherapy	RCT	AKS	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	8
Whitelaw et al. [59]	Cryotherapy	Quasi-RCT	AKS	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Zaffagnini et al. [63]	Cryotherapy	RCT	AKS	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	7
Cumulative score				7	12	6	3	0	0	4	12	12	12	12	
Engstrom et al. [13]	CPM	RCT	ACL	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6

Table 1 continued

References	Modality	Randomization	Surgery	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind participants	Blind therapists	Blind assessors	Follow-up	Intention to treat analysis	Group comparisons	Point and variability measures	Cumulative score (Max = 10)
Friemert et al. [16]	CPM	RCT	ACL	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	8
Cumulative score				1	2	1	2	0	0	0	2	2	2	2	
Feil et al. [14]	NMES	RCT	ACL	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9
Fitzgerald et al. [15]	NMES	RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Lieber et al. [29]	NMES	RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Paternostro-Sluga et al. [38]	NMES	RCT	ACL	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Rebai et al. [40]	NMES	RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Ross et al. [44]	NMES	RCT	ACL	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	6
Snyder-Mackler et al. [50]	NMES	RCT	ACL	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	7
Cumulative score				7	7	1	1	1	0	2	7	7	7	7	
Akkaya et al. [1]	EMGB	RCT	AKS	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9
Kirnap et al. [22]	EMGB	RCT	AKS	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Levitt et al. [28]	EMGB	Quasi-RCT	AKS	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	7

Table 1 continued

References	Modality	Randomization	Surgery	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind participants	Blind therapists	Blind assessors	Follow-up	Intention to treat analysis	Group comparisons	Point and variability measures	Cumulative score (Max = 10)
Cumulative score				2	3	1	3	0	0	1	3	3	3	3	
Wang et al. [56]	Shock-wave	Quasi-RCT	ACL	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Cumulative score				1	1	0	1	0	0	0	1	1	1	1	

Continuous passive motion (CPM)

Range of motion

Two studies included in this systematic review evaluated the effects of CPM on range of motion, and both reported no effect [13, 16] (Table 3). Friemert et al. [16] compared continuous active motion (CAM) to CPM and reported no significant difference in range of motion. Engstrom et al. [13] compared active ROM to CPM plus active ROM and reported no significant difference.

Secondary outcomes

Friemert et al. [16] reported no benefit in pain relief with the use of CPM compared to active ROM. Moreover, Friemert et al. [16] evaluated joint position sense (JPS) as a metric to evaluate proprioceptive and sensory motor function and found a significant improvement of 2.2° in range of motion in favour of the CAM group ($p < 0.01$). Engstrom et al. [13] reported no significant difference in muscle atrophy. However, joint swelling measured at the mid-patellar and base of patellar circumference was higher at both positions in the active-motion group compared to the CPM group ($p < 0.05$).

Neuromuscular electrical stimulation (NMES)

Quadriceps strength

Four of the seven studies included in this systematic review found a significant improvement in quadriceps strength with NMES application following ACLR [14, 15, 29, 38, 40, 44, 50] (Table 4). Among the four studies, quadriceps isometric torque [15], quadriceps peak torque [40], isokinetic extension strength [14] and faster recovery of quadriceps strength [50] were all significantly improved with NMES application ($p < 0.05$). Moreover, high intensity NMES resulted in more strength recovery than low intensity, or no application of NMES 6 weeks following surgery ($p < 0.05$) [50].

Functional and self-reported outcomes

Four studies evaluated functional outcomes following NMES, and all four studies demonstrated a benefit [14, 15, 44, 50]. Feil et al. [14] reported improvements in single-leg hop and shuttle run ($p < 0.01$) at 6-weeks post-operation. Fitzgerald et al. [15] found more patients had returned to agility training at 16 weeks ($p < 0.05$). Snyder-Mackler et al. [50] reported better knee flexion excursion ($p < 0.01$). Finally, Ross et al. [44] reported an improvement in knee

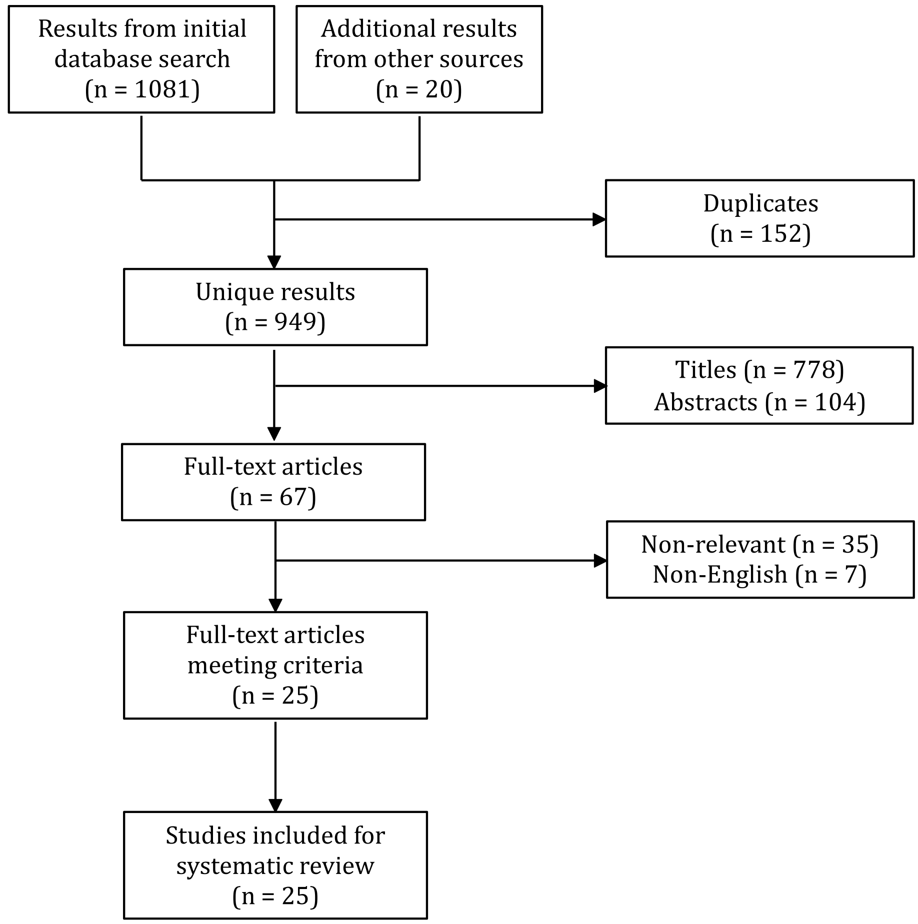

Fig. 1 Workflow of PubMed and Scopus database query

functional outcomes: unilateral squat and lateral step-up test assessed at 6 weeks post-ACLR ($p < 0.05$).

Two studies evaluated self-reported outcomes; both reported improvements in function following NMES treatment [14, 15]. Fitzgerald et al. [15] reported an improvement in achieved daily living scores at 12 weeks ($p < 0.05$). Feil et al. [14] reported an increase in mean improvement on Lysholm score ($p < 0.01$).

Surface electromyographic biofeedback (sEMG)

Quadriceps strength

All three studies that assessed the effect of sEMG following arthroscopic knee surgery reported a benefit in quadriceps strength [1, 22, 28] (Table 5). Among the three studies, the sEMG group had greater vastus medialis and lateralis maximum contraction values [1, 22, 28] compared to NMES or rehabilitation alone ($p < 0.05$).

Functional and self-reported outcomes

Akkaya et al. [1] demonstrated a decrease in time ambulating with an assistive device when using sEMG ($p < 0.02$). Kirnap et al. [22] found greater knee flexion angles in the treatment group ($p < 0.05$). Both Akkaya et al. [1] and Kirnap et al. [22] noted higher Lysholm knee scores in favour of the sEMG groups post-arthroscopic surgery ($p < 0.05$).

Shockwave therapy (EWST)

Only one study reported the effects of shockwave therapy on surgery outcomes. Wang et al. [56] demonstrated improved knee Lysholm functional scores and tendon bone healing, decreased tibial tunnel enlargement and decreased anterior–posterior laxity compared to no-treatment controls 2 years post-ACLR (Table 6).

Table 2 Characteristics and outcomes of twelve studies following cryotherapy application after knee arthroscopic knee surgery

References	Participants	Treatment	Methods	Results
Barber et al. [3]	100 Patients: Group 1: $N = 51$ Group 2: $N = 49$ $\bar{x}$ age: 34 years	Group 1: CCD Group 2: No cold therapy	Outcomes assessed at 1, 2, 8 h and daily evaluations lasting up to 1 week post-operation	1. Pain (VAS and Likert) $p = 0.059$ 2. Narcotic use (total doses (mg/kg) of oxycodone/paracetamol and hydrocodone) $\boldsymbol{p = 0.013}$ 3. Oedema (knee circumference measured using tape) 4) ROM (degrees)
Brandsson et al. [6]	50 Patients: Group 1: $N = 20$ Group 2: $N = 20$ Group 3: $N = 10$ $\bar{x}$ age: 26 years	Group 1: CCD + IA injection of physiological saline Group 2: CCD + IA injection of morphine hydrochloride and bupivacaine Group 3: IA injection of physiological saline	Outcomes assessed at 1, 2, 4, 6, 24 and 48 h post-operation	1. Pain (VAS) $\boldsymbol{p < 0.05}$ 2. Narcotic use (total doses mg/kg of codeine and morphine) 3. LOHS (days) 4. Patient satisfaction $\boldsymbol{p < 0.05}$ *Groups 1 and 2 significantly lower VAS and patient satisfaction than Group 3
Dambros et al. [7]	19 Patients: Group 1: $N = 10$ Group 2: $N = 9$ $\bar{x}$ age: 29.5 years	Group 1: Ice Group 2: No cold therapy	Outcomes assessed at 24 h post-operation	1. Pain (VAS) 2. ROM (degrees) No significant differences between groups
Dervin et al. [8]	78 Patients: Group 1: $N = 40$ $\bar{x}$ age: 30.6 years Group 2: $N = 38$ $\bar{x}$ age: 26.9 years	Group 1: CCD with cold water Group 2: CCD room temp. water	Outcomes assessed at 24 h post-operation	1. Pain (VAS) 2. Narcotic use (total doses mg/kg of morphine and number of codeine tablets) 3. Blood loss (ml) 4. LOHS (days) No significant differences between groups
Edwards et al. [12]	71 Patients: Group 1: $N = 26$ $\bar{x}$ age: 28.7 years Group 2: $N = 21$ $\bar{x}$ age: 26 years Group 3: $N = 24$ $\bar{x}$ age: 28 years	Group 1: CCD cold water Group 2: CCD room temp. water Group 3: No cold therapy	Outcomes assessed at 24 and 48 h post-operation	1. Pain (VAS) 2. Narcotic use (total doses of injectable morphine, oral paracetamol and codeine mg/kg) 3. Blood loss (ml) 4. ROM (degrees) No significant differences between groups
Konrath et al. [23]	100 Patients: Group 1: $N = 27$ $\bar{x}$ age: 27 years Group 2: $N = 23$ $\bar{x}$ age: 25 years Group 3: $N = 23$ $\bar{x}$ age: 26 years Group 4: $N = 27$ $\bar{x}$ age: 26 years	Group 1: CCD cold water Group 2: CCD room temp. water Group 3: Ice Group 4: No cold therapy	Outcomes assessed at discharge	1. Narcotic use (total doses mg/kg of IM meperidine and hydroxyzine; and oral hydrocodone) 2. Blood loss (ml) 3. ROM (degrees) 4. LOHS (days) No significant differences between groups

Table 2 continued

References	Participants	Treatment	Methods	Results
Ohkoshi et al. [36]	21 Patients: Group 1: $N = 7$ Group 2: $N = 7$ Group 3: $N = 7$ $\bar{x}$ age: 22.1 years	Group 1: CCD (5 °C) Group 2: CCD (10 °C) Group 3: No cold therapy	Outcomes assessed at 48 h post-operation	1. Pain (VAS) $\boldsymbol{p < 0.05}$ 2. Narcotic use (total doses of 25 mg of diclofenac sodium consumed via suppository) $\boldsymbol{p < 0.05}$ 3. Blood loss (ml) $\boldsymbol{p < 0.01}$ 4. ROM (degrees) *Group 1 significantly lower blood loss than Group 3 *Group 2 significantly lower VAS and narcotic use than Group 3
Rufilli et al. [45]	47 Patients: Group 1: $N = 23$ Group 2: $N = 24$ $\bar{x}$ age: 31.4 years	Group 1: CCD Group 2: Ice	Outcomes assessed at 24 h post-operation	1. Pain (NRS) $\boldsymbol{p < 0.01}$ 2. Narcotic use (total dose of Tramadol) 3. Blood loss (ml) $\boldsymbol{p < 0.01}$ 4. Oedema (ml) $\boldsymbol{p < 0.01}$ 5. ROM (degrees) $\boldsymbol{p < 0.01}$ 6. Patient satisfaction
Waterman et al. [58]	36 Patients: Group 1: $N = 18$ $\bar{x}$ age: 28.7 years Group 2 $N = 18$ $\bar{x}$ age: 30.9 years	Group 1: CCD Group 2: Ice	Outcomes assessed at 1, 2, 6 weeks post-operation	1. Pain (VAS) $\boldsymbol{p < 0.01}$ 2. Narcotic use (Analgesic use not specified) $\boldsymbol{p < 0.01}$ 3. Oedema (knee circumference) 4. Knee function (Lysholm) 5. Patient quality of life
Lessard et al. [27]	45 Patients: Group 1: $N = 23$ Group 2: $N = 22$ $\bar{x}$ age: 44.6 years	Group 1: Ice Group 2: No cold therapy	Outcomes assessed at 1 week post-operation	1. Pain (McGill pain questionnaire and VAS) $\boldsymbol{p < 0.01}$ 2. Narcotic use (Tylenol 3 and non-prescription medication via home diary) $\boldsymbol{p < 0.03}$ 3. Oedema (Knee girth) 4. ROM (degrees) $\boldsymbol{p < 0.01}$ 5. Quadriceps strength (isometric) $\boldsymbol{p < 0.02}$ 6. Point tenderness $\boldsymbol{p < 0.02}$
Whitelaw et al. [59]	102 Patients: Group 1: $N = 56$ $\bar{x}$ age: 39 years Group 2: $N = 46$ $\bar{x}$ age: 36 years	Group 1: CCD Group 2: Ice	Outcomes assessed at 6, 12, 24, 48 and 72 h post-operation	1. Pain (VAS) 2. Narcotic use (total dosage of acetaminophen/codeine) $\boldsymbol{p = 0.02}$ 3. ROM (degrees) 4. Patient satisfaction $\boldsymbol{p < 0.05}$
Zaffagnini et al. [63]	30 Patients: Group 1: $N = 15$ Group 2: $N = 15$ $\bar{x}$ age: 26.2 years	Group 1: CCD Group 2: No cold therapy	Outcomes assessed at 6 h post-operation	1. Narcotic use (# of patients reached 6 g of non-steroidal anti-inflammatory medication after 6 h) 2. Oedema (not specified) 3. Joint temperature (thermometer probe) No significant differences between groups

Bold ***p*-values** represent significantly better outcomes in the treatment compared to the control group

Table 3 Characteristics and outcomes on two studies following continuous passive motion (CPM) application after arthroscopic knee surgery

References	Participants	Treatment	Methods	Results
Engstrom et al. [13]	34 Patients: Group 1: $N = 17$ Group 2: $N = 17$ $\bar{x}$ age: 27 years	Group 1: Active ROM Group 2: CPM + Active ROM	Outcomes were assessed at 6 weeks post-operation	1. ROM (degrees) 2. Muscle atrophy (thigh circumference) 3. Oedema (knee circumference) ***p* < 0.05**
Friemert et al. [16]	60 Patients: Group 1: $N = 30$ Group 2: $N = 30$ $\bar{x}$ age: 23 years	Group 1: CPM Group 2: CAM	Outcomes were assessed at day 7 post-operation	1. Pain (VAS) 2. ROM (degrees) 3. Joint position sense ***p* < 0.01***

Bold ***p*-values** represent a significantly better outcome in the treatment, compared to the control group

Bold ***p*-values*** represent a significantly better outcome in control group

Discussion

Three out of five physical devices warrant consideration of inclusion in post-operative protocols following arthroscopic knee surgery. Cryotherapy application can effectively mitigate pain and decrease narcotic consumption, while sEMG and NMES can both serve as useful adjuncts to recover quadriceps muscle function and improve knee functional movement tasks. In contrast, CPM does not seem to improve range of motion or other outcome metrics compared with standard rehabilitation alone. There were a limited number of studies on ESWT application; therefore, we cannot recommend the inclusion or exclusion of ESWT into post-operative protocols.

In line with a previous meta-analysis [31], cryotherapy can decrease pain and reduce narcotic consumption following arthroscopic knee surgery, but may not be necessary in all cases. Previous literature fails to address the question of whether or not the cryocompression (CCD) benefits are attributed more to effective cold therapy or the compression component of the device. The two studies that evaluated pain relief by comparing CCD and compression only reported no significant difference in pain relief assessed in the immediate post-operative period (48 h) [8, 12]. Furthermore, the three studies that compared CCD to compression alone reported no difference in narcotic use [8, 12, 23]. Similar results have been found following total knee arthroplasty; there are no significant differences in post-operative narcotic use between CCD and compression alone [17, 49]. These results suggest that proper compression may be just as effective in reducing pain relief and narcotic consumption as CCD. Future studies should investigate the effect of cryotherapy when compared to compression alone.

CPM does not appear to improve outcomes following ACL reconstruction. Both studies included in this review failed to demonstrate a significant improvement in range of motion, pain relief or muscle atrophy following surgery. Oedema was noted as a significant difference between groups; however, there was a significant difference between groups pre-operatively. Thus, the difference cannot definitively be attributed to the intervention. Based on current evidence, CPM use can easily lead to too much time spent in bed, which is contrary to many post-operative protocols [2]. If conducted improperly, it can also induce undesired strain on healing grafts post-ACLR [10] and may increase post-operative blood loss [25, 39]. Although only two studies were included in the evaluation of CPM efficacy, these study results were consistent with randomized studies performed before our inclusion criteria. Prior to 1995, we found no level 1 or 2 study within our remaining inclusion criteria demonstrating a significant difference in blood drainage between CPM and non-CPM, while one study [60] found significantly more blood loss in the CPM group during post-operative day 1 ($p < 0.001$). No study observed a significant difference in knee functional assessment employed through International Knee Documentation Committee tool. Furthermore, only one [62] out of five [13, 16, 41, 43] studies examining ROM and one [32] of four [16, 41, 62] studies observing pain relief found a significant difference in respective outcomes following ACLR. CPM serves as an added expense, lacks evidence and requires additional training of staff for implementation; thus, there does not appear to be an indication for CPM as part of standard rehabilitation protocols.

NMES in conjunction with exercise appears to be more effective in improving quadriceps strength, knee function and self-reported outcome than exercise alone [14, 15]. However, reported improvements in quadriceps strength were only reported in four of the seven studies included in this review. Differences in methodology may explain why two studies failed to produce a significant difference in quadriceps strength following NMES treatment [29, 38]. Paternostro-Sluga et al. [38] used a portable NMES unit and found no significant strength improvement; portable NMES stimulators have previously been shown to produce no measurable benefit [9, 48]. In contrast to other studies

Table 4 Characteristics and outcomes on two studies following NMES application after arthroscopic knee surgery

References	Participants	Treatment	Methods	Results
Feil et al. [14]	96 Patients: Group 1: $N = 29$ $\bar{x}$ age: 34.8 years Group 2: $N = 33$ $\bar{x}$ age: 31.1 years Group 3: $N = 34$ $\bar{x}$ age: 31.6 years	Group 1: Kneehab Group 2: Polystim Group 3: Rehab only	Outcomes were assessed at: Baseline, 6 weeks, 12 weeks and 6 months post-operation	1. Knee extensor strength (**$p < 0.01$**) 2. Single-leg hop (**$p < 0.01$**) 3. Shuttle run tests (**$p < 0.01$**) 4. International Knee Documentation Committee evaluation form 5. Lysholm score (**$p < 0.05$**) 6. Tegner score 7. KT-1000 *Group 1 significantly better than Groups 2 and 3 in all outcome metrics
Fitzgerald et al. [15]	43 Patients: Group 1: $N = 21$ $\bar{x}$ age: 29.2 years Group 2: $N = 22$ $\bar{x}$ age: 31.9 years	Group 1: NMES Group 2: Rehab only	Outcomes were assessed at 12 and 16 weeks post-operation	1. Maximum voluntary isometric torque (**$p < 0.05$**) 2. Activities daily living scale (**$p < 0.05$**) 3. Achievement of clinical milestones (**$p < 0.05$**) 4. Knee pain ratings
Lieber et al. [29]	40 Patients: Group 1: $N = 20$ $\bar{x}$ age: 28 years Group 2: $N = 20$ $\bar{x}$ age: 27.3 years	Group 1: NMES Group 2: Rehab only	Outcomes were assessed at 6, 8, 12, 24 and 52 weeks post-operation	1. Knee extension torque
Paternostro-Sluga et al. [38]	49 Patients: Group 1: $N = 16$ $\bar{x}$ age: 27.8 years Group 2: $N = 14$ $\bar{x}$ age: 22.5 years Group 3: $N = 17$ $\bar{x}$ age: 28.6 years	Group 1: NMES Group 2: TENS Group 3: Rehab only	Outcomes were assessed at 6, 12, 52 weeks post-operation	1. Isokinetic strength knee extensor/flexor 2. Isometric strength (knee extensor/flexor)
Rebai et al. [40]	10 Patients: Group 1: $N = 5$ $\bar{x}$ age: 27 years Group 2: $N = 5$ $\bar{x}$ age: 25.2 years	Group 1: 20 HZ NMES Group 2: 80 HZ NMES	Outcomes were assessed at 12 weeks post-operation	1. Quadriceps peak torque (**$p< 0.05$**) 2. Subcutaneous fat volume (**$p < 0.05$**) 3. Muscle volume
Ross et al. [44]	20 Patients: Group 1: $N = 10$ $\bar{x}$ age: 27.1 years Group 2: $N = 10$ $\bar{x}$ age: 28.4 years	Group 1: NMES Group 2: Rehab only	Outcomes were assessed at 6 weeks post-operation	1. Anterior joint laxity measurement 2. Unilateral squat (**$p < 0.05$**) 3. Lateral step-up test (**$p < 0.05$**) 4. Anterior reach test 5. KT-1000

Table 4 continued

References	Participants	Treatment	Methods	Results
Snyder-Mackler et al. [50]	110 Patients: Group 1: $N = 31$ Group 2: $N = 34$ Group 3: $N = 25$ Group 4: $N = 20$ $\bar{x}$ age: 25 years	Group 1: High intensity NMES Group 2: High/low NMES Group 3: Low intensity NMES Group 4: Rehab only	Outcomes were assessed at 4 weeks post-operation	1. Knee flexion excursion (**$p < 0.05$**) 2. Quadriceps index (**$p < 0.05$**) *Groups 1 and 2 significantly better than Groups 3 and 4 in both outcome metrics

Bold ***p*-values** represent a significantly better outcome in the treatment, compared to the control group

that measure strength benefits [14, 15, 40, 50], Lieber et al. [29] applied shorter contraction and/or lower frequency. Given its relatively low cost and evidence suggesting benefit to patients following arthroscopic surgery, NMES should be considered for rehabilitation protocols following arthroscopic knee surgery.

Based on current evidence, sEMG application is recommended for consideration in post-operative protocols following arthroscopic surgery. All studies included in the review-associated sEMG application with improvements in quadriceps strength measured by muscle force, knee range of motion and functional knee scores compared to standard rehabilitation alone [1, 22, 28]. Unlike electrically induced muscle activations, sEMG biofeedback requires patients to actively contract in response to stimulation, thereby integrating multiple levels of neuronal activity. sEMG provides an immediate incentive, thus producing better outcomes as a result of increased effort [9]. Persistent quadriceps weakness is a major hurdle in arthroscopic knee surgery rehabilitation [19, 37]. The effect of sEMG biofeedback on improved quadriceps strength may be useful in improving post-arthroscopic knee rehabilitation. Independent of mechanism, sEMG biofeedback appears to be an effective complement to standard rehabilitation protocols. Future long-term studies are warranted to assess outcomes following ACLR and long-term benefits, as the current literature does not observe any post-ACLR sEMG application, nor outcomes beyond 6 weeks post-operation.

Only one study investigated the effects of shockwave therapy following arthroscopic surgery; therefore, more studies are required to warrant inclusion into post-operative protocols. It has been suggested that tibial tunnel enlargement might play a pivotal role in the ultimate laxity of autograft [20, 34, 47]. If future studies can confirm results by Wang et al. [56], of tibial tunnel enlargement and ligament laxity, this may have implications for use during post-operative rehabilitation. However, based on the low number of randomized control trials, we cannot adequately determine the efficacy of shockwave therapy following arthroscopic knee surgery.

All studies in this systematic review contained a small group of participants ($n < 110$), which were predominantly comprised of men. Furthermore, fewer than 30 % of the studies included in this systematic review evaluated outcomes longer than 6 weeks; thus, there remains a question of a positive effect on long-term outcomes. Across all modalities there were several inconsistences in methodology that included: type of device, duration of application, type of rehabilitation exercises, follow-up time period and control groups. In addition, many studies lacked objective measures of patient compliance of at-home application and exercises. As a consequence,

Table 5 Characteristics and outcomes on three studies following sEMG application after arthroscopic knee surgery

References	Participants	Treatment	Methods	Results
Akkaya et al. [1]	45 Patients: Group 1: $N = 15$ $\bar{x}$ age: 48.3 years Group 2: $N = 15$ $\bar{x}$ age: 42.7 years Group 3: $N = 15$ $\bar{x}$ age: 49.8 years	Group 1: EMGB Group 2: NMES Group 3: Rehab only	Outcomes were assessed at 2nd and 6th week post-operation	1. Vastus medialis oblique (VMO) contraction values (**$p < 0.02$**) 2. Vastus lateralis (VL) contraction values (**$p < 0.05$**) 3. Lysholm knee function score (**$p < 0.02$**) 4. VAS pain score 5. Gait velocity 6. Time using a walking aid (**$p < 0.02$**) 7. Knee ROM (**$p < 0.02$**) 8. Knee oedema *Group 1 significantly higher VMO and VL contraction values than Groups 2 and 3 *Group 1 significantly better walking aid and Lysholm score than Group 3 *Groups 1 and 2 significantly better knee ROM than Group 3
Kirnap et al. [22]	40 Patients: Group 1: $N = 20$ Group 2: $N = 20$	Group 1: EMGB Group 2: Rehab only	Outcomes assessed at baseline, day 3, 14 and week 6 post-operation	1. ROM (**$p < 0.05$**) 2. Lysholm knee score (**$p < 0.05$**) 3. VMO and VL EMG activity (**$p < 0.05$**)
Levitt et al. [28]	40 Patients: Group 1: $N = 28$ $\bar{x}$ age: 45 years Group 2: $N = 23$ $\bar{x}$ age: 48 years	Group 1: EMGB Group 2: Rehab only	Outcomes assessed at 2 weeks post-operation	1. VMO EMG activity (**$p < 0.03$**)

Bold ***p*-values** represent a significantly better outcome in the treatment, compared to the control group

Table 6 Characteristics and outcomes on one study following shockwave application after arthroscopic knee surgery

References	Participants	Treatment	Methods	Results
Wang et al. [56]	53 Patients: Group 1: $N = 26$ $\bar{x}$ age: 28.3 years Group 2: $N = 27$ $\bar{x}$ age: 27.7 years	Group 1: ESWT Group 2: No EWST	Outcomes were assessed at 6, 12, 24 months post-operation	1. IKDC subjective score (**$p < 0.05$**) 2. Lysholm functional score (**$p < 0.05$**) 3. KT 1000 (**$p < 0.05$**)

Bold ***p*-values** represent a significantly better outcome in the treatment, compared to the control group

notable differences cannot be attributed to any single factor. Another potential limitation of this review is the lack of cost–benefit analysis for the incorporation of each modality into post-operative protocols. Taken together, this collective analysis provides evidence-based recommendations for further evaluations of the physical devices incorporated into current post-operative protocols following arthroscopic knee surgery. Optimal integration of physical devices can provide a standardized method to effectively treat patients following arthroscopic surgery, and aid physicians and physical therapists in developing more objective treatment regimens. Moreover, these enhancements can lead to expedited recovery and improved patient satisfaction.

Conclusion

Of the devices reviewed, cryotherapy most consistently improved pain relief and narcotic use following arthroscopic knee surgery. Cryocompression devices appear more effective than traditional icing alone in alleviating pain and decreasing narcotic consumption following arthroscopic knee surgery. However, cryocompression devices have not been shown to improve outcomes compared to compression alone. Continuous passive motion did not demonstrate a benefit in any outcome metric evaluated, provides an added expense and requires additional training for implementation; thus, there does not appear to be a strong indication for CPM inclusion as part of standard rehabilitation protocols following arthroscopic surgeries. sEMG biofeedback improved muscle strength and function in the post-operative period and should be considered for rehabilitation following arthroscopic surgery. NMES appears to maintain and improve post-operative muscle function and should be considered in post-operative protocols, especially during the period of limb immobilization. There is limited evidence on shockwave therapy, necessitating further investigation. Additional studies will be required to develop optimal post-operative care regimens to maximize outcomes following arthroscopic knee surgery.

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Compliance with ethical standards

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