Cryotherapy duration is critical in short-term recovery of athletes: a systematic review

Alexander H Jinnah,1 Tianyi David Luo,1 Christopher Mendias,2 Michael Freehill3

ABSTRACT

Importance Cryotherapy is one of the simplest and oldest therapeutic methods used to alleviate acute soft tissue trauma and muscle soreness. However, inconsistent outcomes have been reported due to inconsistent protocols.

Objective To determine if various cryotherapy methods lead to enhanced recovery in athletes and identify optimal methods and protocol for short-term recovery in athletes.

Evidence review PubMed/MEDLINE and SPORTDiscus databases were searched from 1 April 1950 to 31 December 2018. The search algorithm used was: (Icing OR Ice Therapy OR Cryotherapy) AND (Athlete OR Sports) NOT (Case Reports). Inclusion criteria was human clinical studies with level 1–4 evidence, a cohort of at least 20 athletes, who were followed to determine the effect cryotherapy had on performance, pain and/or recovery were included. Abstracts, reviews, case reports and conference proceedings were excluded. Seven studies investigating the effect cryotherapy recovery were included. Manual extraction and compilation of demographic, methodology, functional and biochemical outcomes from the studies were completed. Non-randomised trials were assessed using the Methodological Index for Non-Randomised Studies and the randomised were assessed using Oxford quality scoring system.

Findings Decreased pain or muscle soreness was seen with cold water immersion(CWI) when compared with passive recovery. Other outcome variables assessed (biomarkers, functional tests) did not reveal consistent findings. Longer icing times (>10 min) were associated with detrimental effects in muscle power and activity.

Conclusions and relevance Duration is the critical variable in conventional cryotherapy, with prolonged icing leading to immediate detriment in muscle power and activity. Thus, we recommend using ice cryotherapy following exercise for no longer than 10 min for pure hypoalgesia. CWI had a greater benefit on recovery than passive cryotherapy. Furthermore, CWI has a more beneficial effect on recovery in the first 24 hours following exercise versus immediately postrecovery. We recommend using a protocol to include immersion times of 11–15 min in 11°C–15°C (52°F–59°F) water.

Level of evidence Level III.

INTRODUCTION

Cryotherapy (CT) is one of the simplest and oldest therapeutic methods used to alleviate acute soft tissue trauma, pain and muscle soreness.1 2 It has been used to accelerate recovery in athletes following exercise for decades.1 3–6 The scientific reasoning behind CT is to decrease tissue surface temperature to minimise hypoxic cell death, oedema formation and muscle spasms, all of which ultimately reduce pain and inflammation.7–13 CT is a broad term encompassing the use of cold temperatures as a medical therapy. Under this broad umbrella, therapies have ranged from simple ice packs and cold water immersion (CWI) to more sophisticated methods of whole body cryotherapy (WBC).2 14–19

Conventional iced of long durations (>10 min) is detrimental to immediate muscle power and activity, and should only be used for hypoalgesia.

Cold water immersion cryotherapy for 11–15 min at 11–15°C has a beneficial effect on recovery that is greatest 24 hours after the cryotherapy.

What is already known

► Cryotherapy leads to a reduction in pain and inflammation by decreasing metabolite concentrations within soft tissues.

What are the new findings

► Conventional icing of long durations (>10 min) is detrimental to immediate muscle power and activity, and should only be used for hypoalgesia.

► Cold water immersion cryotherapy for 11–15 min at 11.5°C has a beneficial effect on recovery that is greatest 24 hours after the cryotherapy.
Systematic review

authors have questioned the efficacy of CT on exercise recovery in athletes.28–30

Due to variations in the type and duration of CT and the lack of consistent recommendations for its use in the existing literature, we conducted a qualitative systematic review to determine the existing therapeutic protocols and their effectiveness in athletes. Specifically, we sought to answer the following questions:

1. Does conventional ice therapy performed within 1 hour of exercise aid in recovery to baseline performance immediately post-therapy and at 24 hours post-therapy?

2. Does any alternative CT performed within 1 hour of exercise aid in recovery to baseline performance immediately post-therapy and at 24 hours post-therapy?

Answers to these questions will allow recommendations to be made for postgame exercise competition CT and for the optimal CT for athletes that need to perform competition on a daily basis (baseball position players, hockey players, etc).

METHODS

Literature search

A systematic review was conducted according to Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines using a PRISMA checklist.31 A review of the published English language literature assessing the short-term recovery in athletes was performed using PubMed/MEDLINE and SPORTDiscus databases. The search algorithm used was as follows: (Icing OR Ice Therapy OR Cryotherapy) AND (Athlete OR Sports) NOT (Case Reports). Inclusion criteria was human clinical studies from 1 April 1950 to 31 December 2018 with level 1 through 4 evidence,32 a cohort of athletes (amateur, high school, collegiate or professional), who were followed to determine the effect CT had on performance, pain and/or recovery. Exclusion criteria included abstracts, reviews, case reports, conference proceedings, animal studies, investigation not in English and use of a non-athlete population. Studies were then divided into two categories: conventional ice CT and alternative CT programmes. Studies which assessed the athlete immediately following (within 1 hour) and/or 24 hours after CT were included for analysis. Non-randomised trials were assessed using the Methodological Index for Non-Randomised Studies (MINORS)33 and the randomised were assessed using the Oxford quality scoring system.34

Alternative CT methods included CWI and WBC. CWI consists of a specific region of the body being submerged in temperature controlled water (usually 5°C–15°C (41°F–59°F)) for a predetermined time (usually 5–20 min). WBC entails an exposure of the entire body to extremely cold temperatures (≤−100°C (−148°F)) for 2–4 min.

Data collection

Two reviewers (AHJ and TDL) independently extracted suitable data from the studies meeting inclusion criteria. Appropriate data included any physical or biochemical outcome which assessed the efficacy of the cooling modality immediately and/or 24 hours after cooling. Sample size and demographic data were also extracted from each study. The two reviewers then compared their findings and any variation was settled by the senior author (MTF).

RESULTS

Literature search

Seven studies met the inclusion and exclusion criteria for review (figure 1). The included studies involved a total of 180 athletes with a mean age of 22.2 years (range 15–32).

Conventional ice cryotherapy

Three of the seven studies with level 1 and 2 evidence assessed the efficacy of conventional ice CT on recovery in 93 subjects with a mean age of 22.9 years (table 1).35–41

All of these studies investigated the immediate effect icing had on biomarkers, soreness, or athletic performance. The duration of icing application among these studies ranged from 3 to 30 min.

Subjective muscle soreness and pain were assessed by Behringer et al42 (table 2). It was noted that there was no difference in delayed onset muscle soreness (DOMS), despite the known hypoalgesic properties associated with conventional CT.1–43

Functional performance was assessed by the remaining investigations.39,44 Fischer et al found that 10 min of local CT impaired power and functional performance immediately following CT, but that shorter durations (3 min) had no effect. Similarly, Lee et al44 observed a decrease in countermovement jump height following local CT for 20 min. A summary of the findings in these studies can be found in table 2.39–42 44

Data obtained from these trials varied in its reliability as judged by the MINORS criteria or the Oxford quality scoring system. Fischer et al39 was the only non-randomised trial included and can be determined to have a MINORS criteria score of 20/24, indicating a low risk of bias. However, Behringer et al42 and Lee et al44 had a Oxford quality score of 1/5 and 2/5, respectively. This indicates that the randomised studies were of poor quality.

Alternative cryotherapy

Four studies of level 1 or 2 evidence evaluated 87 subjects with a mean age of 21.3 years with respect to physical recovery following alternative CT methods (table 3).45–48

Of the four studies, three assessed the effect of CT immediately and 24 hours following therapy,46–49 and one assessed the recovery at 24 hours only.45

Cold water immersion

Ascensão et al46 and Doeringer et al45 directly compared the effects of CWI with passive recovery, while Elias et al and Webb et al compared CWI with contrast water therapy (CWT).47 48

Our review demonstrated that CWI had a general positive effect on physical performance and biomarkers. DOMS was assessed in two studies,34,46 while perception of muscle soreness/exertion was assessed in the remaining two.39 44 Despite the differing protocols, all investigations concluded that soreness was decreased in the CT groups when compared with their control group.

Biochemical markers representing muscle damage, for example, creatine kinase (CK), myoglobin and C reactive protein were investigated in two of the studies.46 48 Both of these demonstrated a significant improvement following CWI. Furthermore, varying functional tests were commonly used as outcome variables. Elias et al47 found an improvement in functional tests with CT, however, Ascensão et al46 and Doeringer et al45 observed mixed results.

Assessment of quality of the randomised studies done using the Oxford quality scoring system demonstrated that these investigations were all of poor quality with scores of 1/5 in all cases except for Doeringer et al (score of 2/5).

DISCUSSION

The present study reviewed the existing literature regarding different methods of CT in athletes following exercise to evaluate the evidence and make recommendations regarding protocols to maximise recovery. Our results demonstrated a variety of CT protocols and an array of outcome variables used to
assess the efficacy of CT following exercise. Outcome variables assessed demonstrated that CWI had the greatest positive impact on recovery.

**Conventional ice cryotherapy**

Overall, the current literature investigating the effect of conventional CT on recovery in athletes demonstrated no impact or a negative one on an athlete’s performance. However, it is important to note that these studies all had varying methodologies and protocols used for CT. Furthermore, in order to maintain consistency within the studies, the athletes were required to strictly adhere to their recovery modalities with no adjunctive measures. This may not be reproducible, because in reality athletes may choose to use additional recovery methods as adjuncts to improve performance and recovery.

The reason for conventional CT demonstrating negative impacts on recovery may be due to CT duration. All of the investigations included in our review used CT times of at least 10 minutes, except for one cohort within the study by Fischer et al. Interestingly in this cohort, the authors found a change from a detrimental impact on recovery to having no effect. Short-term, intermittent icing is a method of CT that has been implemented by several authors for in-game use for baseball pitchers. The authors demonstrated a positive effect on innings pitched, velocity, and accuracy. Recovery after 24 hours was assessed by Yanagisawa et al. following implementation of a light

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**Table 1 Conventional icing times and demographics**

<table>
<thead>
<tr>
<th>Study</th>
<th>Year published</th>
<th>Level of evidence</th>
<th>Participants</th>
<th>Mean age (years)</th>
<th>Icing time (min)</th>
<th>Primary/secondary outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fischer et al</td>
<td>2009</td>
<td>2</td>
<td>42</td>
<td>22.2</td>
<td>3 or 10</td>
<td>Shuttle run, co-contraction test and vertical jump</td>
</tr>
<tr>
<td>Lee et al</td>
<td>2017</td>
<td>1</td>
<td>21</td>
<td>21</td>
<td>20</td>
<td>CMJ or SJ height</td>
</tr>
<tr>
<td>Behringer et al</td>
<td>2018</td>
<td>1</td>
<td>30</td>
<td>25.7</td>
<td>30</td>
<td>CK, h-FABP, DOMS</td>
</tr>
</tbody>
</table>

*CK, creatine kinase; CMJ, countermovement jump; DOMS, delayed onset muscle soreness; h-FABP, fatty acid binding protein; SJ, squat jump.*
Table 2 Conventional icing studies outcome variables and results

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcome variables</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fischer et al</td>
<td>Shuttle run, co-contraction test and vertical jump</td>
<td>Power (vertical jump) was impaired immediately and 20 min after 10 min ice bag application to the hamstrings, whereas a shorter duration of ice application had no effect on these tasks.</td>
</tr>
<tr>
<td>Lee et al</td>
<td>CMJ or SJ height</td>
<td>CMJ height decreased immediately after ankle and knee cryotherapy, no change was seen in the rest group. CMJ height returned to baseline 10 min after CT.</td>
</tr>
<tr>
<td>Behringer et al</td>
<td>CK, h-FABP, DOMS</td>
<td>No difference in DOMS was observed between MLD, icing or rest. No changes in SJ height were noted in CT or rest group.</td>
</tr>
</tbody>
</table>

CWI, cold water immersion; CK, creatine kinase; CMJ, countermovement jump; CT, cryotherapy; DOMS, delayed onset muscle soreness; h-FABP, fatty acid binding protein; MLD, manual lymphatic drainage; SJ, squat jump.

Table 3 Alternative cryotherapy times and demographics

<table>
<thead>
<tr>
<th>Study</th>
<th>Year published</th>
<th>Level of evidence</th>
<th>Participants</th>
<th>Mean age (years)</th>
<th>Therapy</th>
<th>Cryotherapy time (min)</th>
<th>Primary/secondary outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascensão et al</td>
<td>2011</td>
<td>1</td>
<td>20</td>
<td>Not listed</td>
<td>Cold water immersion</td>
<td>10</td>
<td>DOMS, biochemical markers, performance tests</td>
</tr>
<tr>
<td>Elias et al</td>
<td>2013</td>
<td>1</td>
<td>24</td>
<td>19.9</td>
<td>Cold water immersion</td>
<td>14</td>
<td>Perceived measures, jump performance, repeat sprint testing</td>
</tr>
<tr>
<td>Webb et al</td>
<td>2013</td>
<td>2</td>
<td>21</td>
<td>23.5</td>
<td>Cold water immersion</td>
<td>5</td>
<td>PMS, CMJ, CK</td>
</tr>
<tr>
<td>Doeringer et al</td>
<td>2018</td>
<td>1</td>
<td>22</td>
<td>20.6</td>
<td>Cold water immersion</td>
<td>25</td>
<td>DOMS, flexibility, CMJ, shuttle, 10 m dash</td>
</tr>
</tbody>
</table>

CMJ, countermovement jump height; CK, creatine kinase; DOMS, delayed onset muscle soreness; PMS, perceptual muscle soreness.
benefits of CWT derives from decreased oedema and metabolite production from the cold, with the reduction in pain and muscle spasm with promotion of soft tissue healing with heat.56 57 This is often thought of as a flushing of the soft tissues of the affected region. Two of the articles included in this review compared CWT with CWT57 48; however, the protocols used varied. This variation in protocols used is most likely responsible for the variation in results seen.47 48 58 It can be postulated that these differences are due to the difference in time of CWI; however, this conclusion cannot be made due to the lack of a consistent protocol in the literature. Contrast water therapy remains an intriguing alternative form of recovery in athletes that should continue to be studied, but due to the negating effects of heat it is beyond the scope of this review.

Whole body cryotherapy

No articles involving WBC were included in this review due to the lack of literature with a large enough cohort. Due to this, no conclusion can be made in this review to advocate for or against this method of CT after exercise. Accordingly, a recent Cochrane review by Costello et al14 stated that based on the available evidence they could not advocate for WBC as a recovery method. However, it is important to note that there is no evidence of adverse events with WBC, therefore, we cannot recommend against its use. Future studies should focus on large cohorts in order to obtain good evidence in regard to this method of CT.

Limitations

As with all systematic reviews, this study was limited by the available literature. Despite the high levels of evidence (1 and 2) of the published studies involving CT in athletes following exercise, there was no homogeneous method of evaluating recovery following exercise. This led to an inability to statistically compare outcome variables. Furthermore, the quality of evidence obtained was shown to be of low quality, despite it being level 1 or 2 evidence. Another limitation is the variability in exercise protocols, which prevented direct comparison of the included studies because each protocol may have prompted differing amounts of exercise-induced soft tissue damage.

CONCLUSION

To our knowledge, this is the first systematic review to evaluate the effect of all different types of CT on recovery in athletes immediately following and 24 hours after CT. Unfortunately, the literature consists of outcomes and protocols that vary widely, therefore, definitive conclusions are not easily made. We can conclude that the duration of ice CT has a direct impact on recovery, and therefore recommend using prolonged icing (>10 min) for pure hypoalgesia. CWI therapy may facilitate recovery and alleviate muscle soreness within the first 24 hours following activity, and we advocate for a protocol of immersion time of 11–15 min in 1°C–15°C (52°F–59°F) water. However, athletes who do not have to compete on a daily basis could see more benefit.

Future research

Further research in this area should focus on establishing a protocol and fixed outcome variables that allow the assessment of recovery immediately following exercise and after 24 hours. Additionally, the large variety of protocols should be subdivided to evaluate specific activities. This will allow evaluation of the soft tissue damage that occurs with varying exercises. Furthermore, future research in this area should consist of high-quality randomised controlled trials of parallel groups with group concealment and sufficient sample sizes to obtain satisfactory power.

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