

1 **ABSTRACT**

2 **Aim:** To provide a comprehensive review of the current position in the literature on contemporary  
3 cryo-compression applications for musculoskeletal sports injury management.

4 **Methods:** Eight databases were searched; Sport Discus, Science Direct, CINHAL, Scopus, PubMed,  
5 Cochrane, ProQuest and MEDLINE. Publications restricted to 30-years and English language.  
6 Medical Subject Headings (MeSH), free-text words, and limiting descriptors for concepts related to  
7 cryotherapy and compression for sports injury were applied. Inclusion criteria determined at least  
8 one modality of cryotherapy treatment applied simultaneous to compression or as a comparison,  
9 relevant to sports injury management. Modalities included cryo-compressive devices, gel/ice packs,  
10 in association with concomitant compression. Populations included male or female, healthy or  
11 injured. Two reviewers independently selected eligible articles resulting in twenty-two studies  
12 meeting the inclusion criteria following full-text appraisal.

13 **Findings:** Inconsistent methodologies, low sample sizes and variability in outcome measures  
14 provides uncertainty over optimum protocols. Lack of prior understanding around protocols for  
15 isolated cryotherapy/compression applications prevents understanding on the therapeutic benefits of  
16 combined cryo-compression. No definitive agreement behind optimal cryo-compression applications  
17 were identified collectively from studies other than the consensus that compression aids the  
18 magnitude of cooling.

19 **Conclusions:** Although compression appears a useful adjunct to cooling modalities for the  
20 management of sports injury, no definitive agreement on optimum compression concurrent with  
21 cooling protocols were drawn from the studies. This was consequential of several methodological  
22 gaps in reporting throughout studies highlighting the gap of studies that represent applications within  
23 a sporting context or applied nature.

24 **Key Words:** Modalities, Cooling, Physiological, Musculoskeletal, Cryo-compression.

26

27 **INTRODUCTION**

28 An inflammatory response to musculoskeletal soft tissue trauma presents with characteristics that  
29 include pain, oedema and a proliferation in heat from increased blood flow (Capps, 2009; Rigby and  
30 Dye, 2017). The simultaneous application of cryotherapy and compression is thought to alter the  
31 inflammatory response by initiating therapeutic benefits (Capps, 2009). Current application of  
32 cooling often follows the PRICE (*Protect, Rest, Ice, Compression and Elevation*) guidelines  
33 (Bleakley et al, 2011), recently developed to the acronym of 'POLICE' (*Protection, Optimal Loading,*  
34 *Ice, Compression and Elevation*) management (Bleakley et al, 2012). The purpose of cryotherapy  
35 application is to lower tissue temperatures and occurs through the thermodynamic principles of heat  
36 withdrawal from deeper tissues (Chesterton et al, 2002). For immediate injury applications (Swenson  
37 et al, 1996; Mora et al, 2002; Galiuto, 2016), rehabilitative management (Bleakley and Hopkins,  
38 2013), or post-exercise recovery (Du Pont et al, 2017) the rationale for cryotherapeutic application  
39 varies dependent on the aim (Bleakley et al, 2004). Physiological effects of cooling include analgesia  
40 (Ernst and Fialka, 1994); decline of nerve conduction velocity (Bleakley et al, 2004; Nadler et al,  
41 2004; Algafly and George, 2007) and metabolism (Ho et al, 1995); reduction of inflammation  
42 (Pournot et al, 2011) in association with decreased vascular permeability and vasoconstriction  
43 (Gregson et al, 2011). Although widely accepted for use in sports injury management, cryotherapy  
44 modalities differ extensively and it is unknown as to whether an agreement exists concerning  
45 optimum protocols of cooling, with or without the addition of compression. The effectiveness of  
46 cooling modalities may differ due to several variables surrounding application principles of cooling  
47 (Table 1). In brief these include, efficiency (Merrick et al, 1993), location (Kennet et al, 2007),  
48 dosage, frequency (Jutte et al, 2001), contact area (Janwantanakul, 2009), phase change and enthalpy  
49 of fusion ability of modalities (Merrick et al, 2003; Kwiecien et al, 2020) level of compression  
50 (Alexander et al, 2020), or targeted vs circumferential application (Alexander et al, 2021).

51 Furthermore, the influence of external factors such as; adipose tissue levels, desired target tissue  
52 temperature, and therapeutic responses (Rupp et al, 2012) advocate that protocols should be modified  
53 on an individual basis to achieve greater outcomes and optimisation of response in sporting contexts  
54 (Alexander et al, 2021).

55

56

**\*\*\*Insert Table 1 Here\*\*\***

57

58 Independently compression aims to control oedema, decrease overall blood flow (Kraemer et al,  
59 2004) and predominantly to accelerate injury management through the reduction of clinical symptoms  
60 such as swelling or pain (Song et al, 2016). Principles behind the effects of external compression  
61 include the capacity of influence it has on the lymphatic system, including pressure gradients, gravity,  
62 contraction of skeletal muscle, and reduction of oedema (Kraemer et al, 2004; Ostrowski et al, 2019).  
63 For the management of sports injuries, compression is rationalised through its ability to manipulate  
64 external and internal capillary pressure thus minimising the accumulation of swelling, haematomas  
65 and provide mechanical support (Kraemer et al, 2004). Consequently the facilitation of mechanical  
66 support through compression is important for recovery processes and achievable because of dynamic  
67 immobilisation. The literature suggests that this is due to improved neural input during compression  
68 applications (Kraemer et al, 2004). Pneumatic, static, and intermittent compression in association  
69 with several levels of pressure are described across some of the studies reviewed (Mora et al, 2002;  
70 Knobloch et al, 2007, 2008; Janwantanakul, 2006; Holwerda et al, 2013; Ostrowski et al, 2018;  
71 Kwiecien et al, 2019) with compression as low as  $14\pm 2$  mm Hg reported to affect magnitude of  
72 cooling (Kwiecien et al, 2019). Despite recent publications that investigate simultaneous cryotherapy  
73 and compression applications (Du Pont et al, 2017; Ostrowski et al, 2019; Holwerda et al, 2013;  
74 Kwiecien et al, 2019), a lack of clarity is still evident for single applications of cryotherapy and  
75 compression. Simply for the two modalities of cryotherapy and compression, we do not currently  
76 know optimum dose for either application. Therefore, it is difficult to determine potential combined

77 interaction effects due to the complexity of multiple variables. Unsurprisingly evidence for the  
78 combined application of cryotherapy and compression is lacking through applied studies, and its use  
79 in sport is commonly anecdotal (Kraemer et al, 2004). Methodologies that isolate one of the variables  
80 (cryotherapy) with the other applied simultaneously (compression) may help determine the effect of  
81 simultaneous application through quantification. Therapeutic effects gained from cryotherapy  
82 application combined with compression may play an extensive role in the recovery of tissue injury  
83 though are generally underreported because of the reasons aforementioned. Notably, former research  
84 considers the adjunct of compression with cryotherapy as positive, reporting beneficial outcomes  
85 through further reduction of tissue temperature (Merrick et al, 1993; Tomchuk et al, 2010) or recovery  
86 enhancement (Du Pont et al, 2017). Many recent technological advancements in cryo-compressive  
87 devices are available and allude to the physiological benefits of combining the two. The purpose of  
88 the scoping review therefore was to produce a comprehensive review of the current position in the  
89 literature on contemporary cryo-compression applications for musculoskeletal sports injury  
90 management.

91

## 92 **Research Question**

93 What is the current position in the literature on contemporary applications of cryotherapy and  
94 compression for the management of musculoskeletal sports injuries?

95 In order to determine whether a systematic review would be of value to conduct, a scoping review  
96 was decided on initially, to explore over a broader topic area the available evidence. With the aim to  
97 produce a comprehensive review of the current position in the literature on contemporary cryo-  
98 compression applications for musculoskeletal sports injury management, objectives determined three  
99 key outcomes:

- 100 1. To examine current research and summarise the available evidence base for the applications of  
101 simultaneous cryotherapy and compression modalities typically applied in the management  
102 of musculoskeletal sports injury.
- 103 2. To establish whether agreement exists in the optimal application of simultaneous cryo-  
104 compressive protocols for the management of musculoskeletal sports injuries.
- 105 3. To highlight knowledge gaps in the current evidence base surrounding contemporary cryo-  
106 compression applications for musculoskeletal sports injury management that may help inform  
107 future research in the topic area.

108

## 109 **METHODS**

### 110 *Design and Search Strategy*

111 This scoping review was conducted in accordance with the Preferred Reporting Items for Scoping  
112 Reviews (PRISMA-ScR) guidelines. Directed by the Arksey and O'Malley framework for scoping  
113 reviews (Arksey and O'Malley, 2005) the following steps were completed; *1) identifying the research  
114 question; 2) identifying relevant studies; 3) determine inclusion/exclusion criteria and apply; 4)  
115 charting the data, and finally 5) collating, summarising and reporting the results* (Arksey and  
116 O'Malley, 2005; Levac et al, 2010).

117

118 Two authors (\*\* and \*\*) performed searches to identify relevant studies in the remit of cryotherapy  
119 and compression in the management of musculoskeletal sports injury. In order to guarantee a  
120 comprehensive search of the available literature, sources include electronic databases, reference lists  
121 and the hand searching of key journals. The databases included: Sport Discus, Science Direct,  
122 ProQuest, CINHALL, Scopus, PubMed, Cochrane Library, and MEDLINE (via OVID), searched  
123 between 31<sup>st</sup> March to 1<sup>st</sup> September 2020 and a further search on 25<sup>th</sup> May 2021 to capture any new

124 and relevant articles. A 30-year date restriction representing the development of physiological  
125 justification of cryotherapeutic modalities in sport was applied to the search strategy and captured  
126 contemporary development of cryo-compressive modalities. Grey literature searching followed the  
127 initial database searches utilising ProQuest and Open Grey. Search terms included a mix of Medical  
128 Subject Headings (MeSH), free-text words, and additional limiting descriptors for key concepts  
129 related to cryotherapy and compression for musculoskeletal sports injury. MeSH search terms for  
130 the Cochrane Library Database and Scopus searches did not apply, however conditions of the search  
131 were carried out identically between those databases. A broad range of available literature established  
132 through wide classification of key words follows recommendations for scoping review methods  
133 (Arksey and O'Malley, 2005).

134

#### 135 *Study Inclusion and Exclusion Criteria*

136 In this scoping review, on evaluation of relevant studies, if at least one modality of cryotherapy  
137 treatment was applied simultaneous to compression or as a comparison to compression alone, the  
138 study was included. The application of simultaneous cryotherapy and compression in applicable  
139 studies applied to musculoskeletal sports injury management only and did not consider post-operative  
140 / surgical musculoskeletal management. Cryotherapeutic treatment modalities could include any cold  
141 compression device or gel packs, or ice (wetted/crushed/flaked/cubed), secured with elastic wraps /  
142 bandages that suggested concomitant mild, moderate or high compression reported. Populations  
143 reported in studies could include both male and female subjects, healthy or injured. The consideration  
144 to include studies that represented healthy participants was justified due to the limited availability of  
145 evidence for cryo-compressive applications on injured populations. Several factors acknowledged  
146 earlier may influence the optimisation of ideal cryo-compressive protocols and currently lead to the  
147 poor understanding for optimal protocols in normative populations. Inclusion therefore of both  
148 normative and injured populations within the scoping review commenced to ensure current practice  
149 in the topic area may be defined. Further inclusion criteria comprised articles written in English, all

150 types of research and from the last 30 years. The 30-year period aimed to represent the potential  
151 development of evidence around physiological justification of cryotherapeutic modalities in sport  
152 over time.

153 Exclusion criteria included; articles with applications tested on animal models, the inability to locate  
154 or access full-text articles or any study reporting post-operative application of cryo-compression  
155 modalities. The area of interest for this scoping review was to be based on the application of these  
156 modalities for the acute management of musculoskeletal sports injuries, rather than post-operative  
157 injury care. This was due to the need for clarity on current applications of cryotherapy and  
158 compression in sport; providing a rationale for exclusion of post-operative applications of cryo-  
159 compressive modalities. Table 2 details the full inclusion criteria for this scoping review.

160

161

**\*\*\*Insert Table 2 here\*\*\***

162

163 The search strategy was performed by \*\* and \*\* independently, and any disagreement relating to the  
164 inclusion or exclusion of literature was discussed afterwards. Figure 1 details the full process of  
165 article review. Screening of titles and abstracts indicated the subsequent reviews of full texts initially.  
166 If the title or abstract did not reveal enough information to determine appropriateness for inclusion to  
167 the scoping review, the full article was retrieved for full text review to determine inclusion. Articles  
168 were summarised and charted as per the combined framework by both reviewers independently  
169 (Arksey and O'Malley, 2005; Levac et al, 2010). Manual cross-referencing was performed after all  
170 titles and abstracts from the search were downloaded to Excel to prevent any duplication of studies  
171 or missing literature. Reference lists examined from all articles identified additional potentially  
172 relevant research. Appropriate studies were assessed independently by both reviewers (\*\* and \*\*),  
173 and if articles met the criteria described (Table 2) were included. If any disagreements arose between  
174 reviewers these were resolved by discussion and if any differences remained, a third reviewer (\*\*)

175 settled any arbitration. No disagreements regarding the inclusion or exclusion of any publication  
176 occurred during the review process.

177

178

\*\*\* *Figure 1 Insert Here* \*\*\*

179

### 180 *Data Extraction*

181 Extraction of data was completed by one reviewer (\*\*\*) and to ensure accuracy, data was assessed by  
182 a second reviewer (\*\*). A narrative synthesis was produced following the extraction of data to  
183 provide a summary description for each study which included type of compression, cooling, dose in  
184 terms of cooling and compression (Table 3).

185

## 186 **RESULTS**

187 A yield of 86 articles resulted from the initial searches. After the deduction of duplicate literature  
188 among the database searches and evaluation of the abstracts, 54 potentially eligible studies remained.  
189 Title and abstract review excluded a further 33 articles of which did not meet the inclusion criteria.  
190 Consequently, 22 full text papers were reviewed, all of which met the inclusion criteria (Table 2).  
191 Noteworthy information was extracted from each of the 22 articles and is displayed in Table 3.

192

### 193 *Study Characteristics*

194 The scoping review identified a wide variation in research design alongside several methodological  
195 differences (Table 3). The evidence typically represented observational or randomised control trials  
196 and across the studies several variations in outcomes measures were found. The types of studies  
197 included: x1 systematic review (Bleakley et al, 2004), x14 observational studies (Rigby and Dye,  
198 2017; Du Pont et al, 2017; Janwantanakul, 2009; Ostrowski et al, 2019; Knobloch et al, 2007;  
199 Janwantakakul, 2006; Holwerda et al, 2013; Ostrowski et al, 2018; Kwiecien et al, 2019; Wilkerson  
200 and Horn-Kingery, 1993; Knobloch et al, 2006a; 2006b; Hawkins et al, 2012; Williams et a, 2013),

201 x4 randomised controlled trials (Mora et al, 2002; Merrick et al, 1993; Knobloch et al, 2008;  
202 Tomchuck et al, 2010) and x2 narrative reviews (Capps, 2009; Block, 2010). Largely studies  
203 presented with low sample sizes or no control group, which may have reduced the ability to draw  
204 meaningful conclusions from individual investigations. Although a mix of male (n = 229) and female  
205 (n = 173) participants was evident across studies (age: 26.4±8.5 years), mostly were predominantly  
206 of young male adults and yielded a total population of ~400 participants. This represented an average  
207 number of 22 participants per study reported. From the 22 papers presented, only 11 publications  
208 report compression dose (mm Hg) and 18 reported the length of dose application (minutes). A  
209 summary of characteristics and data extraction for articles included in the scoping review are  
210 represented in Table 3.

211 **\*\*\* Insert Table 3 here\*\*\***

212  
213 Minimal overlap in study findings were noted because of disparity in methodological processes,  
214 protocols investigated and outcomes measures defined. Modalities across the studies included Cryo  
215 Cuff® (n = 5), Game Ready® (n = 5), Koldblue Cryo Bandage (n = 2), Ice bag (*wetted, chipped,*  
216 *crushed, or salted*) (n = 11), Aircast® with Cryo/Strap (n = 1), Squid Go (n = 1), Hyper Ice® (n = 1),  
217 Gel Pack (n = 1), Aquilo Sports® Cryo Compression (n = 1), Power Play™ + Wetted Ice (n = 2) and  
218 Power Play™ + Gel Pack (n = 1). Some studies documented the levels of compression (mm Hg) and  
219 targeted  $T_{sk}$  values within the method protocols, however many failed to successfully report such  
220 details as support to determine efficacy of the modality applied. Those studies that reported pressure  
221 values of compression adjuncts reported values that ranged from 5-75 mm Hg, with consistent /  
222 continuous, pulsatile or intermittent variances in application techniques. With exclusion of the three  
223 review studies, all articles reported the length of cooling exposure. Exposure time varied between  
224 studies however from 15- to 30-minutes. Some articles reported protocols that included a recovery  
225 period and repetition of multiple exposures whilst others reported a single exposure of cryo-  
226 compression. Several different types of wrap were identified across studies, including elastic or

227 plastic wrap to custom designed sleeves held circumferentially with Velcro. The most commonly  
228 investigated protocols reported continuous pressure, at high levels ( $>50$  mm Hg), 30-minute  
229 exposures reporting ice bag applications, however not always the type of ice (i.e. *crushed, wetted,*  
230 *salted*) held in place with elastic or plastic wrap or the GameReady® device. Despite this, collective  
231 findings are not suggestive these components are the most applicable to the management of  
232 musculoskeletal sport injury. Many do not reflect typical half-time or pitchside applications in terms  
233 of dose (time) durations and impact the feasibility of evidence based knowledge into applied practice.  
234 That said, the benefits of simultaneous compression adjuncts were acknowledged in all articles based  
235 on greater magnitudes of cooling ability with compression than without. Consequently, and  
236 collectively these results create a challenge when interpreting the collective stance on the agreement  
237 of cryo-compressive protocols for sports injury management. Clarity of agreement on what may be  
238 the optimal application for cryo-compression was therefore difficult to establish.

239

## 240 **DISCUSSION**

241 To provide a comprehensive review of the current position in the literature on contemporary cryo-  
242 compression applications for musculoskeletal sports injury management was the purpose of this  
243 scoping review. Studies generally indicated that cryotherapeutic modalities are one of the most  
244 commonly applied therapeutic modes used for musculoskeletal trauma management in sport and the  
245 physiological responses of cold applications are well reported (Bleakley et al, 2011; Algafly and  
246 George, 2007; Ho et al, 1995; Gregson et al, 2011; Merrick et al, 1993; Jutte et al, 2001; Ostrowski  
247 et al, 2019). With several studies recognising the traditional principles of PRICE (Bleakley et al,  
248 2011; Galiuto, 2016; Bleakley and Hopkins, 2013; Block, 2010), the adjunct of compression to  
249 cryotherapy appears beneficial across most articles, of which acknowledged the positive effects of  
250 compression on the magnitude of cooling (Capps, 2009; Mora et al, 2002; Du Pont et al, 2017;  
251 Knobloch et al, 2006a; 2008; Janwantanakul, 2006; Tomchuck et al, 2010; Wilkerson and Horn-

252 Kingery, 1993). Differences between the terms ‘mild’, ‘moderate’ and ‘high’ levels of compression  
253 however were poorly defined within the literature with regards to the actual pressure (mm Hg) these  
254 descriptions represented. Additionally, the failure to report skin surface temperature ( $T_{sk}$ ) values in  
255 several studies presented limitations in recognition of whether modalities met therapeutic  $T_{sk}$  ranges  
256 identified in previous literature (Kennet et al, 2007) for physiological effects to take place. Evidently,  
257 the non-reporting of either pressure (mm Hg) or  $T_{sk}$  has repercussions on the ability to define optimal  
258 protocols through objective measures of tissue response. That said, studies published within the last  
259 three years (Rigby and Dye, 2017; Ostrowski et al, 2018; 2019; Kwiecien et al, 2019; Alexander et  
260 al, 2020) all successfully reported measures of pressure (mm Hg),  $T_{sk}$  and in some cases intramuscular  
261 temperature ( $T_{im}$ ), apart from one article (Du Pont et al, 2017), demonstrating progressive  
262 methodological detail and recent popularity in the use of contemporary cryo-compressive modalities.  
263 One consideration making it difficult to assess the quality of studies in this scoping review is the lack  
264 of quality appraisal. This relates to studies that are prone to bias through weak methodologies for  
265 example. The generalisability of publication findings in this scoping review was difficult due to the  
266 heterogeneous nature and flaws across methodologies, however the potential for the use of  
267 contemporary cryo-compressive modalities is indicative across many individual study conclusions.

268  
269 The current scoping review supports earlier work, which highlights that poor agreement across  
270 multiple studies may be due to different combinations of cooling and compression applied and  
271 population groups investigated (Bleakley et al, 2004). Perhaps a limitation across some of the  
272 literature in this scoping review alludes to the inclusion of only healthy non-injured participants  
273 (Knobloch et al, 2006b; Hawkins et al, 2012; Rigby and Dye, 2017; Janwantanakul 2006, 2009;  
274 Holwerda et al, 2013; Kwiecien et al, 2019). It is important to consider that different results may  
275 occur in response to simultaneous cooling and compression between healthy and non-healthy  
276 (injured) tissues. Evidently, findings highlight minimal investigations available on the combination  
277 of treatment (cryotherapy and compression) for acute musculoskeletal sports injury presentations. It

278 is important to note however that until further understanding of protocols are achieved in normative  
279 uninjured populations, metabolic changes associated with injury may be another variable to consider  
280 in the dose/response concept of cryotherapy or that of simultaneous cryo-compressive applications.

281

282 Different applications of compression exist, such as pneumatic or manual, intermittent or static. From  
283 the literature reviewed it appears that both pneumatic and manual approaches may enhance the effect  
284 of local cooling across various cryotherapy modalities. That said, most methods of cryotherapy  
285 cannot be applied in isolation, for example there must always be some level of concomitant  
286 compression. Continuous compared to intermittent compression simultaneously applied with cold  
287 appeared more favourable, albeit weak in the number of papers where this was reported, when  
288 comparing multiple modalities (Holwerda et al, 2013; Ostrowski et al, 2019). Although in one study  
289 equivalent  $T_{im}$  decreases were noted across the comparison of salted ice bag with continuous elastic  
290 wrap compression, with intermittent compression via Game Ready®, or PowerPlay devices  
291 (Ostrowski et al, 2019). Authors highlighted that application is dependent on treatment goals and  
292 stages of rehabilitation (Ostrowski et al, 2019), considered in relation to healing processes and  
293 physiological responses. When choosing between intermittent vs continuous compression  
294 applications, the consideration of such physiological responses, such as oedema formation were noted  
295 (Ostrowski et al, 2019). Although the studies reviewed in this scoping review were favourable of  
296 continuous compression in reducing  $T_{sk}$  compared to intermittent pneumatic this was only conclusive  
297 of two studies (Holwerda et al, 2013; Ostrowski et al, 2019). With distinct differences in outcome  
298 measures between the studies (Holwerda et al, 2013; Ostrowski et al, 2019) definitive conclusions  
299 were unable to be drawn without further investigation, suggestive of multiple modality, compression  
300 (level and mode) and relevant outcomes measures study design, suitable to inform practice. Despite  
301 the availability of former studies that also compared intermittent, pneumatic and static compression  
302 (Capps, 2009; Knobloch et al, 2008), physiological outcomes measures differed (Knobloch et al,  
303 2008; Capps, 2009; Holwerda et al, 2013; Ostrowski et al, 2019), therefore making it difficult for

304 direct comparison of results. As highlighted earlier a key deficiency observed across several study  
305 methods alludes to the lack of pressure (mm Hg) reporting. With only 12 papers out of 22 presenting  
306 this information (Table 3), consequently it is difficult to identify whether differences in compression  
307 dose or application resulted in the variable responses in those papers that failed to report such  
308 information. Therefore, with agreement not easily achieved, optimal cryo-compressive protocols are  
309 non-existent, consequently further research is required in this area through study design and  
310 methodological protocol development.

311

312 From the studies reviewed, literature tends to report on the physiological responses to simultaneous  
313 cryo-compressive applications, however little is known about the effect these applications may have  
314 on biomechanical, perceptual or biochemical responses for example. The only available literature  
315 reported no further decreases in stability or functional performance, comparing simultaneous  
316 cryotherapy and compression to cryotherapy application alone (Williams et al, 2013). With only one  
317 study investigating this it is difficult to provide any generalisability on the effect of variable  
318 compression magnitudes or variations such as constant or intermittent pressure on biomechanical  
319 measures relevant to current practice. Studies that investigate the effects of cryotherapy on  
320 biomechanical parameters report findings in terms of the effect of cooling alone without measure of  
321 accompanying pressure, whether that be intended (cryo-compression modality) or concomitant to the  
322 cooling application. Investigation into simultaneous cryo-compression applications on  
323 biomechanical parameters whereby pressure is quantified alongside temperature would be beneficial  
324 to determine safe thresholds of movement or loading after application once optimal protocols of cryo-  
325 compression for targeted tissue temperature reduction are determined.

326

327 Previous literature has described the research available on the comparison between cooling  
328 with/without compression in sports injury management as having persistent inconsistencies in  
329 methodologies (Bleakley et al, 2004). Sixteen papers reported in this scoping review consider

330 comparisons of cooling with and without compression or compare multiple cryo-compressive  
331 modalities (Merrick et al, 1993; Mora et al, 2002; Bleakley et al, 2004; Knobloch et al, 2008;  
332 Janwantanakul, 2006; 2009; Capps, 2009; Block, 2010; Hawkins et al, 2012; Holwerda et al, 2013;  
333 Williams et al, 2013; Rigby and Dye, 2017; Ostrowski et al, 2019). Most studies agreed the addition  
334 of compression to cooling is beneficial for physiological changes to occur (Merrick et al, 1993;  
335 Janwantanakul, 2009; Knobloch et al, 2008; Capps, 2009; Tomchuck et al, 2010; Bleakley et al, 2012;  
336 Ostrowski et al, 2019). It is still evident however that a gap in the knowledge base represents a lack  
337 of high-quality research available that provides comparisons of variable compressions, contemporary  
338 cryo-compressive applications and outcome measures with sporting relevance. Due to the limited  
339 volume of publications specifically comparing multiple contemporary cryo-compressive devices this  
340 precludes the ability to distinguish comprehensively which application or protocol would provide  
341 optimal therapeutic response for musculoskeletal sports injury management. Further enquiry of  
342 contemporary cryo-compressive modalities for musculoskeletal sports injuries should pursue, to  
343 reduce the gap in knowledge and ensure quality evidence on their efficacy and therapeutic effects that  
344 can be applied in contemporary applied practice. Future studies might consider presenting both group  
345 and individual data for full interpretation of individual response to cryo-compressive interventions,  
346 particularly in athletic populations where positional characteristics or physical traits are known to  
347 influence level of  $T_{sk}$  following local cooling applications, supporting the need for individualisation  
348 of cooling protocols (Alexander et al, 2021). Yet without a clear understanding of the effects of  
349 cryotherapy and compression applied separately, studies that investigate combinations of cooling and  
350 compression may fail to progress the remit of this topic successfully due to the evident gaps  
351 highlighted by the results of this review.

352

### 353 *Limitations*

354 Despite the review offering a current perspective on contemporary applications of simultaneous cryo-  
355 compression for musculoskeletal sport injury management, some limitations exist. The

356 methodological quality of the included papers was not considered following the Arksey and O'Mally  
357 (2005) framework for scoping reviews. We appreciate this limits the appraisal of the available studies  
358 which met the inclusion criteria, and that further critical appraisal for the methodological quality of  
359 papers may be beneficial in terms of a systematic review process in future. Furthermore, our search  
360 criteria excluded studies where cryo-compression was used post-operatively and therefore may have  
361 excluded studies that evaluate simultaneous cryo-compression in this scope. Potential bias to the  
362 selection process of papers in this scoping review may include the exclusion of papers in languages  
363 other than English. The generalisability of findings to injured populations is limited by the lack of  
364 studies that investigate simultaneous cryo-compressive modalities.

365

## 366 **CONCLUSIONS**

367 Available research that investigates simultaneous cryotherapy and compression for the management  
368 of sports injury is limited, diverse and consequently difficult to précis. Methodological differences  
369 surrounding the efficacy of cryo-compressive applications prevents the ability to provide a strong  
370 argument as to what may be optimum protocols in the management of musculoskeletal sports injuries.  
371 Suggestions that compression aids the efficiency of cooling is evident, however studies should report  
372 explicitly compression pressure values (mm Hg) to provide clarity on dose-response findings. There  
373 is no definitive understanding available on individual parameters of optimal cooling temperature,  
374 time, or compression in isolation. Therefore, it is difficult to determine the combination of effects  
375 that may occur from simultaneous applications of cryotherapy and compression. This is due to the  
376 multiple variables that require consideration for cryo-compressive application (Table 1) and the  
377 dynamic interplay that takes place with the body's homeostatic mechanisms. Further enquiry of  
378 contemporary technological advancements in cryo-compressive modalities require significant  
379 investigation. A focus on dose-response through the examination of variable compression pressures  
380 not yet defined in current literature may be beneficial. Defining contemporary protocols of  
381 simultaneous cryotherapy and compression applications is required to enhance understanding in

382 current practice of cryo-compressive modalities. Unless full consideration of multiple variables that  
383 affect the interpretation of outcome measures are deliberated in future studies however, the impact of  
384 findings into current practice will be limited. Furthermore, individual responses were not considered  
385 across studies and future research should observe this to optimise cryo-compressive protocols for  
386 sports injury management.

## 387 **KEY POINTS**

- 388 • Differences in the efficacy of cryo-compressive applications is evident and influenced by  
389 several variables that should be considered when devising optimal cryo-compression  
390 applications.
- 391 • Studies generally agree that compression aids the magnitude of cooling.
- 392 • Definitive practices for the application of simultaneous cooling and compression cannot be  
393 drawn from the current available literature because of inconsistencies in methodological  
394 investigations.
- 395 • Lack of prior understanding around protocols for cryotherapy/compression applied separately  
396 is evident.
- 397 • Further enquiry of contemporary cryo-compressive devices and dose-response is required to  
398 develop optimal protocols for use in sports injury management and should consider multiple  
399 measurable outcomes and individual responses reflective of current applied practices.

400

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403

## 404 **Declaration of interest statement**

405 No conflict of interest declared.

406

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409 application over the anterior thigh across rugby union positions: A crossover randomised  
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530 **Figure Legends**

531 **Figure 1.** PRISMA Flow Diagram of included studies.

532

533 **Table Legends**

534 **Table 1.** Key variables to consider that may influence the optimisation of cryo-compressive  
535 applications.

536 **Table 2.** List of inclusion eligibility criteria utilised for article screening.

537 **Table 3.** Study characteristics and data extraction of included articles.