Cryotherapy and its Correlates to Functional Performance.
A Brief Preview

Márcio Luís Pinto DOMINGUES

Objective: To search the English language literature for original research addressing the effect of cryotherapy on motor performance and recovery. Data Sources: We searched MEDLINE, the Physiotherapy Evidence Database, SPORT Discus, Pubmed, and the Cochrane Reviews database, from 1976 to 2009 to identify randomized clinical trials of cryotherapy, systematic reviews, original articles and methods of cryotherapy. Key words used were cryotherapy, return to participation, cold treatment, ice, injury. Data Synthesis: Brief review including assessment of cryotherapy as a tool of performance and a recovery method. Conclusions: Most studies suggest that a short rewarming time would be beneficial (a couple minutes), which is very reasonable in sports. Also, cooling techniques differ in its result accordingly to the procedures and objectives used. Finally, the type of tissue cooled plays a large role (ie. Joint vs. Muscle).

Keywords: cryotherapy, performance, cold
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Introduction

Athletes consistently work to improve motor performance and delay the onset of fatigue (Amusa, Toriola, 2003; Bompa, 1999). The underlying causes of fatigue and exercise limitation have been extensively studied (Amman, Dempsey, 2008; Hargreaves, 2008; McKenna, Hargreaves, 2008; Noakes, 2000). Skill development, weight training, cardiorespiratory exercises and stretching are just a few of the many activities used to enhance achievement.

A wide range of recovery modalities are now used as integral parts of the training programmes of elite athletes to help attain this balance (Coffey, 2002; Thiriet, Gozal, Wouassi, Oumaru, Gelas & Lacour, 1993; Barnett, 2006; Simjanovic, Hooper, Leveritt, Kellmann, & Rynne, 2008). Achieving an appropriate balance between training and competition stresses and recovery is important in maximising the performance of athletes.

It’s been a while since Grant and Hayden published their classic articles on cryokinetics. Since the work of Kowal (1983), cryotherapy’s depressive effects on the body’s physiological systems have generated concern among many health care practitioners about its effect on motor activity. Since many forms of cryotherapy are used by sports medicine clinicians before or during athletic participation, a more knowledgeable understanding of the immediate and delayed effects of cryotherapy on functional performance is necessary. We will try to determine, within the existing literature, the effects that cryotherapy has on functional performance and also in the recovery as a method of enhancing performance.

Cryotherapy’s physiological action

While humans maintain body core temperature within a strict homeostatic range, skin and peripheral muscle temperature may experience a wide temperature variation. Cryotherapy application is a valuable therapeutic resource, since the cold is a state that compounds less molecular movement which preserves the integrity of the cell. Human body responds to it with a series of systemic and local responses that vary between local reduced metabolic rate and the reduced needs of oxygen to the cell. It is a widely accepted component of treatment for acute injuries due to its hypalgesic effects (Evans, Ingersoll & Worrell, 1995), therefore it has recently re-entered the later stages of rehabilitation as a contributing modality.

However, previous research (Rubley, Denegar, Buckley, Newell, 2003) has suggested that cryotherapy may also reduce muscle strength, nerve conduction...
velocity, and proprioception, all of which are important to function in an athletic environment. It is commonly accepted that it produces physiological answers such as anaesthesia, heat reduction, reduced muscle spasm (Knight, 1995; Bompa, 1999), stimulates relaxation, allows for early mobilization, develops the range of movement, decrease in muscle tension over longer application, reduction of the metabolism (Knight, 1995), breaks the cycle pain-spasm-pain (Bompa, 1999), reduction of circulation and inhibition of inflammation (Knight, 1979; Knight, 1995, Swenson, Swärd & Karlsson, 1996), reduction of post traumatic treatment and reduction in the regeneration phase of rehabilitation.

Results of studies on cold and blood flow vary considerably, however it appears that blood flow increases with superficial cold application and decreases when cold is applied to large skin surface areas. Motor performance is affected by temperature with a critical temperature being around 18 degrees Celsius, above and beneath which muscle performance decreases (Scott, Ducharme, Haman and Kenny, 2004). They examined the effect of prior warming by both active and, to a greater extent, passive warming, may predispose a person to greater heat loss and to experience a larger decline in core temperature when subsequently exposed to cold water. Thus, functional time and possibly survival time could be reduced when cold water immersion is preceded by whole-body passive warming, and to a lesser degree by active warming.

Several studies have aimed to establish if the use of cryotherapy adversely affects various measures which play a role in functional performance. Much has been written about the effects of cryotherapy on individual physiological systems, such as the nervous system (Mecomber & Hermnan, 1971; McMaster, 1977; McMaster, 1982; Kowal, 1983; Buchheit, Peiffer, Abbiss & Laursen, 2008) and the muscular system (Mecomber & Hermnan, 1971; McMaster, 1977; McMaster, 1982; Crowley, Garg, Long, Van Someren & Wade, 1991; Mattacola & Perrin, 1993; Giesbrecht, Wu, White, Johnston & Bristow, 1995; Cross, Wilson & Perrin, 1996; Gatti, Myers & Lephart, 2000; Duck, Kaminski, Horodyski & Bauer, 2000; Atnip & Mcrory, 2004). However, investigators disagree as to whether muscle cooling has an effect on force production (Burke, Holt, Rasmussen MacKinnon, Vossen, Pelham, 2001; Cornwall, 1994; Hatzel and Kaminski, 2000; Kimura, Thompson, 1997); Mattacola & Perrin, 1993; Verducci, 2000), joint position sense (Thieme, Ingersoll, Knight, Ozmun, 1996; Uchio, Ochi, Fujihara, Adachi, Iwasa, Sakai, 2003), or performance (Cross, Wilson & Perrin, 1996; Evans, Ingersoll, Knight & Worrell, 1995).
Cryotherapy has been shown to have no effect on joint position sense or sensory perception and therefore, proprioception appears to be unaffected by the use of cold in the treatment of athletic injuries, namely, sensory perception of the foot and ankle following therapeutic applications of heat and cold (Ingersoll et al., 1992).

Another study was designed to determine the effect of ice immersion on ankle joint position sense. Three different pretest conditions of no ice immersion, 5 min of ice immersion, and 20 min of ice immersion were administered to 31 subjects prior to joint angle replication testing with an electrogoniometer (LaRiviere & Osternig, 1994). Power and isokinetic strength, both appear to be decreased immediately following the application of various cryotherapeutic modalities (Ferretti et al., 1992); ankle strength (Hatzel & Kaminski, 2000); plantar flexor muscle group (Mattacola & Perrin, 1993); sensory and nervous system (Ruiz, Myrer, Durrant & Fellingham, 1993). The performance detriments can be attributed to a loss of electrically evoked force generation and contractile capacities (Davies & Young, 1985), similar results were found with maximal isometric grip strength, when the forearm was immersed in 10°C water for durations between 5 and 20 minutes (Douris, Mckenna, Madigan, Cesarski, Costiera & Lu, 2003).

Knowledge concerning the use of heat and/or cold upon muscular performance would help in the design of exercise programs. However, most research pertaining to strength changes and cryotherapy has primarily been limited to isometric contractions (Mattacola & Perrin, 1993; Cornwall, 1994; Johnson & Bahamonde, 1996; Sanya & Bello, 1999). Conflicting results regarding the effects of cold on isometric strength have been reported by investigators (McGowin, 1967; Coppin, 1978; Bergh & Ekblom, 1979; Barnes & Larson, 1985; Howard, Kraemer, Stanley, Armstrong, & Maresh, 1994). The results of these studies, unfortunately, are equivocal and strength has been shown to increase (Mattacola & Perrin, 1993; Cornwall, 1994; Sanya & Bello, 1999) and decrease (Johnson & Bahamonde, 1996). Also, Knight and Adolp (2003), sustained that while ankle ROM was affected (increased), joint cooling had no affect on lower chain kinetics during a functional, resisted exercise.

Speed and agility, both which are essential to athletic participation have not been studied in great detail (Bergh & Ekblom, 1979; Cross et al, 1996; Evans et al, 1995; Richendollar et al, 2006). A study, however, have demonstrated that following a cold treatment in which muscle was directly cooled, functional performance may be impaired (Cross et al, 1996).
We know that dynamic muscular control mechanism may be altered following cryotherapy. Piedrahita, Oksa, Rintamäki and Malm (2009) designed a study to find out if local leg cooling affects muscle function and trajectories of the upper limb during repetitive light work as well as capability to maintain dynamic balance, they found that local leg cooling did not affect upper limb muscle function or trajectories, but ability to maintain dynamic balance was reduced. Gatti, Myers and Lephart (2000) postulated that cryotherapy negatively affects functional performance specific to the dominant shoulder. In contrast, another study concluded that a 5 min cold water immersion intervention lowered muscle temperature but did not affect isokinetic strength or 1-km cycling performance (Peiffer, Abbiss, Watson, Nosaka & Laursen, 2008); however it is unlikely however to significantly lower the temperature in the deeper articular structures with superficial cryotherapy (Enwemeka, Allen, Avila, Bina, Konrade & Munns, 2002; Merrick, Jutte & Smith, 2003).

Some studies reflect a positive association between cryotherapy and performance (Catlaw, Arnold & Perrin, 1996; Sanya, & Bello, 1999). One study reflected a positive association between the effect of icing the arm and shoulder between weight-pulling sets on work, velocity, and power. Verducci (2000) found that interval cryotherapy between weight-pulling sets is associated with increased work, velocity, and power, similar results were found in baseball pitchers (Verducci, 1997) and Burke, Macneil, Holt, Mackinnon, Rasmussen, (2000) found positive results in maximum isometric force production, velocity and power, between sets. Also the effects of a 20-min focal knee joint cooling intervention on quadriceps central activation ratio (CAR) in healthy volunteers were higher than the control group in weight-bearing explosive strength or power that decreased toward baseline measures (Pietrosimone & Ingersoll, 2009), and a decrease in vertical impulse (Kinzey, Cordova, Gallen, Smith & Moore, 2000), further, joint cryotherapy may provide increased PL activity during the rewarming period following joint cooling (Hopkins, Hunter & McLoda, 2006). Patterson, Udermann, Doberstein, Reineke (2008) suggested functional performance was affected immediately following and for up to 32 minutes after cold whirlpool treatment. It was also evident that there is a gradual performance increase for each measure of functional performance across time. Therefore, the consequences should be carefully considered before returning athletes to activity following cold whirlpool treatment and further work should consider whether joint cooling may affect other areas of sensorimotor control.

Myrer, Measom and Fellingham (2000) developed a study, the first designed specifically to examine the effect of exercise on intramuscular rewarming after a standard crushed-ice-pack treatment, they found that moderate walking significantly enhanced rewarming of the triceps surae. Involuntary activation
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during the rewarming phase following joint cooling is also well documented (Hopkins et al., 2001; Hopkins & Stencil, 2002; Krause et al., 2000).

Whilst there is some evidence that stretching and massage may reduce muscle soreness, there is little evidence indicating any performance benefits. Electrical therapies and cryotherapy offer limited effect in the treatment of Exercise-Induced Muscle Damage (EIMD). However, inconsistencies in the dose and frequency of these and other interventions may account for the lack of consensus regarding their efficacy. Both as a cause and a consequence of this, there are very few evidence-based guidelines for the application of many of these interventions (Howatson & van Someren, 2008), however, one study concludes that cold water immersion after stretch-shortening exercise (SSE) accelerates the disappearance of the majority of indirect indicators of EIMD.

Prior bouts of eccentric exercise provide a protective effect against subsequent bouts of potentially damaging exercise. Further research is warranted to elucidate the most appropriate dose and frequency of interventions to attenuate EIMD and if these interventions attenuate the adaptation process. This will both clarify the efficacy of such strategies and provide guidelines for evidence-based practice. Another study adds that cryotherapy significantly improved immediate range of motion in enhancing supine, extended-leg, hip flexion decreasing pain perception, interfering with muscle spasm, and possibly causing reflex vasodilation (Minton, 1993).

Cooling methods

Different methods of cryotherapy have different effects on muscle tissue. Overall, CWI and contrast water therapy (CWT) were found to be effective in reducing the physiological and functional deficits associated with delayed onset muscle soreness (DOMS), including improved recovery of isometric force and dynamic power and a reduction in localised oedema. While one study says hot water immersion (HWI) was effective in the recovery of isometric force, it was ineffective for recovery of all other markers compared to PAS (Vaile, Halson, Gill, Dawson, 2008a), another research relates no effect at all (Stanley, Kraemer, Howard, Armstrong & Maresh, 1994). These authors in 2008b developed a study where all cold water immersion protocols were effective in reducing thermal strain and were more effective in maintaining subsequent high-intensity cycling performance than active recovery.

Although it isn't the purpose of this research paper, in fact we know DOMS as a particular state of muscular tenderness that can evolve in debilitating pain (Powers & Howley, 2004). Cryotherapy may not have effect on this particular
situation (Yackzan, Adams & Francis, 1984; Weber, Servedio & Woodwall, 1994), instead exercise must be encouraged in order to allow the most affected muscle groups to recover (Cheung, Hume & Maxwell, 2003), particularly eccentric exercises (Weber, Servedio, Woodwall, 1994; Bakhtiary, Safavi-Farokhi & Aminian-Far, 2006). Although a study (Paddon-Jones, 1997) suggests that the use of cryotherapy immediately following damaging eccentric exercise may not provide the same therapeutic benefits commonly attributed to cryotherapy following traumatic muscle injury.

We should also take into account the amount of adipose over the therapy site as a significant factor in the extent of intramuscular temperature change that occurs during and after cryotherapy (Myrer, Myrer, Measom, Fellingham & Evers, 2001). Preliminary evidence suggests that intermittent cryotherapy applications are most effective at reducing tissue temperature to optimal therapeutic levels confirmed by Bleakley, McDonough and MacAuley (2006).

When we talk about core and skin temperature we need to evaluate different cryotherapy modalities. Zemke, Anderson, Guion, McMillan and Joyner (1998) refer that ice massage appears to cool muscle more rapidly than ice bag, whereas during the application of 4 cryotherapy modalities (ice pack, gel pack, frozen peas, mixture of water and alcohol) the ice pack and mixture of water and alcohol was significantly more efficient in reducing skin surface temperature than the gel pack and frozen peas (Kanlayanaphotporn, Janwantanakul, 2005). It has been noticed that ice massage produces a significant drop in intramuscular temperature (Lowdon & Moore, 1975), and to a decrease in core temperature (Palmieri, Garrison, Leonard, Edwards, Weltman & Ingersoll, 2006). A study valuating and comparing the ability of wet ice (WI), dry ice (DI), and cryogenic packs (CGPs) to reduce and maintain the reduction of skin temperature directly under the cooling agent, found no significant differences in mean skin temperature, 15 minutes after removal of the cold modality (time 30) was significant for WI only (Belitsky, Odam & Hubley-Kozey, 1987). On the other hand, cooling rates were nearly identical between ice-water immersion and cold-water immersion, either mode of cooling is recommended for treating the hyperthermic individual (Clements, Casa, Knight, McClung, Blake, Meenen, Gilmer & CaldwellIce, 2002). Armstrong, Crago, Adams, Roberts and Maresh (1996) and McDermott, Casa, Ganio, Lopez, Yeargin, Armstrong and Maresh (2009) refute the theory that ice water immersion is an inefficient cooling modality addressing the efficiency of whole-body cooling modalities in the treatment of exertional hyperthermia.

When the physiological processes produced by cryotherapy are examined in experimental situations, some of these reactions differ from expectations (Meeusen, 1986). Skin, subcutaneous, intramuscular and joint temperature
changes depend on application method, initial temperature and application time. Drinkwater (2008) claims that there isn’t a standard method to investigate the effects of cooling, so protocols range across a variety of temperatures (10-42 °C), temperature assessment methods (skin, intramuscular), cooling mediums (air, water immersion), muscle fibre type (species, fast or slow twitch), contraction type (evoked or voluntary, isometric or dynamic), and isolated versus intact fibres.

Precooling and performance

We need to clarify the effects of pre-cooling on the improvement in exercise performance and the effects of post-exercise cooling on recovery. We know that metabolism remains elevated for several minutes immediately following exercise (Powers & Howley, 2004). While pre-cooling has received much research attention, the mechanisms resulting in enhanced performance remain equivocal and moreover, pre-cooling has previously only been considered effective for endurance performance. Ingram, Dawson, Goodman, Wallman and Beilby, (2009) demonstrated that cold following exhaustive simulated team sports exercise offers greater recovery benefits than Contrast Water Immersion (CWI) or control treatments. There are very few studies that have focused on the effectiveness of hot–cold water immersion for post exercise treatment in a physiological basis, there isn’t enough research (Cochrane, 2004).

Precooling studies (Marino, 2002) confirm that increasing body heat is a limiting factor during exercise. It seems that it is only beneficial for endurance exercise of up to 30–40 minutes with related physiological factors (Olschewski & Bruck, 1988), rather than intermittent or short duration exercise. However, Marsh and Sleivert (1999) concluded that precooling improves short term cycling performance. In the motor co-ordination of the working agonist-antagonist muscle pair of the lower leg there was a dose-dependent response between the degree of cooling and the amount of decrease in muscle performance as well as EMG activity changes. A relatively low level of cooling was sufficient to decrease muscle performance significantly (Oksa, Rintamaki & Rissanen, 1997), and a decreased immediate shuttle run result questions the implications for immediate recovery (Cross et al 1996). Future research is required to determine the physiological basis for the ergogenic effects of precooling on high intensity.

Local leg cooling did not affect upper limb muscle function or trajectories, but ability to maintain dynamic balance was reduced, although other studies claim that whole body cooling impairs muscle performance (Crowley, Garg, Lohn, Van Someren & Wade, 1991; Giesbrecht, Wu, White, Johnston & Bristow, 1995; Cross, Wilson & Perrin, 1996; Gatti, Myers & Lephart, 2000; Duck, Kaminski, Horodyski & Bauer, 2000; At nip & Mcrory, 2004). However, Carman and Knight
(1992) has shown that habituation takes place if cold treatments, consistent in temperature, are applied to the same limb, although some studies report no changes on voluntary motor output (Cornwall, 1994; Evans et al, 1995; Kimura, Thompson & Gulick, 1997).

Although recent research has been useful describing the effects of precooling on exercise performance, little has been conducted on the effects of cooling as a recovery tool from heat stress (Duffield, 2008). Much of the literature investigating cooling on human performance involves cooling of the core (Powers & Howley, 2004), though many performance effects relate to cooling of the periphery (Drinkwater, 2008). The author considers that while most of these effects occur independently of central activation, purposeful core cooling for the purpose of improving athletic performance should be used cautiously to avoid the deleterious effects of peripheral cooling.

On the other side, there are studies that show results depending on the method used precooling via an ice vest (Duffield, Dawson, Bishop, Fitzsimons & Lawrence, 2003), cold water immersion (CWI), and ice packs covering the upper legs (Packs). Castle, Macdonald, Philp, Webborn, Watt and Maxwell (2006) underpin that the method of precooling determines the extent to which heat strain was reduced during intermittent sprint cycling, with leg precooling offering the greater ergogenic effect on peak power output (PPO) than either upper body or whole body cooling. In the same line of results the study of Schniepp, Campbell, Powell and Pincivero (2002) showed that a relatively brief period of cold-water immersion can manifest significant physiological effects that can impair cycling performance, especially by decreasing heart rate. Also, significant decreases in tissue temperature have been shown to decrease nerve conduction velocity, muscle force production, and muscular power (Lee, Warren & Mason, 1978; Sargeant, 1987).

Previous data show that cooling the joint (not cooling muscle) increases surrounding muscle activity, reflex amplitude, and allows for increased force generated around the cooled joint (Krause, Hopkins & Ingersoll, 2000; Hopkins & Stencil, 2002). Conversely, Duck, Kaminski, Horodylski and Bauer, (2000) in their study found that single-leg (SL) vertical jump and 40-yard dash performance were significantly reduced immediately after the application of 10 and 20 minute cryotherapy treatments in a group of female collegiate athletes.

To examine the effects of different thermoregulatory preparation procedures [warm-up (WU), precooling (PC), control (C)] on endurance performance in the heat, Ückert and Joch (2007) concluded that the use of an ice-cooling vest for 20 min before exercising improved running performance, whereas the 20
min WU procedure had a distinctly detrimental effect. Cooling procedures including additional parts of the body such as the head and the neck might further enhance the effectiveness of PC measures. Also, there may be a psychological benefit to athletes with a reduced cessation of fatigue.

Duffield, Dawson, Bishop, Fitzsimons and Lawrence, 2003 conclude that the intermittent use of an ice cooling jacket, both before and during a repeat sprint cycling protocol in warm/humid conditions, did not improve physical performance, although the perception of thermal load was reduced. Longer periods of cooling both before and during exercise (to lower mean skin temperature) may be necessary to produce such a change. Other studies refer improvements in performance (Arngrïmsson, Petitt, Stueck, Jorgensen & Cureton, 2003) reduced thermal and cardiovascular strain and perception of thermal discomfort in the early portion of the run that appear to permit a faster pace later in the run. A practical combined precooling strategy that involves immersion in cool water followed by the use of a cooling jacket can produce decrease in rectal temperature that persist throughout a warm-up and improve laboratory cycling time trial performance in warm conditions (Quod, Martin, Laursen, Gardner, Halson, Marino, Tate, Mainwaring, Gore & Hahn, 2008).

We know that power and functional performance are affected by short-term cryotherapy application. Power and functional performance was impaired immediately and 20 minutes after 10-minute ice bag application to the hamstrings, whereas a shorter duration of ice application had no effect on these tasks. This study examined the immediate and short-term (20 minute) effects of 3- and 10-minute ice bag applications to the hamstrings on functional performance as measured by the cocontraction test, shuttle run, and single-leg vertical jump. A decrease in cocontraction time was observed at 20 minutes post compared with preapplication during the control condition in which no ice bag was applied. (Fischer, Van Lunen, Branch & Pirone, 2009). Other studies didn’t show effects in performance as reported on agility using cold therapy before strenuous exercise (Evans, Ingersoll, Knight & Worrell, 1995); on eccentric peak torque, an athlete can reap the beneficial effects of cryotherapy without compromising eccentric force production or endurance (Kimura, Thompson & Gulick, 1997), on motor control of the digits (Rubley, Denegar, Buckley & Newell, 2003) or on increase hamstring length in healthy subjects (Burke, Holt, Rasmussen MacKinnon, Vossen & Pelham, 2001).

However there has not been great research examining the effects of precooling on high-intensity exercise performance, particularly when combined with strategies to keep the working muscle warm. Sleivert, Cotter and Febbraio
(2001) indicate that pre-cooling does not improve 45-s high-intensity exercise performance, and can impair performance if the working muscles are cooled.

**Joint position sense and neurological effects**

Previous studies have suggested that cryotherapy affects neuromuscular function and therefore might impair dynamic stability. If cryotherapy affects dynamic stability, clinicians might alter their decisions regarding returning athletes to play immediately after treatment. Proprioception and throwing accuracy were decreased after ice pack application to the shoulder. It is important that clinicians understand the deficits that occur after cryotherapy, as this modality is commonly used following acute injury and during rehabilitation. This information should also be considered when attempting to return an athlete to play after treatment (Wassinger, Myers, Gatti, Conley & Lephart, 2007).

Cryotherapy has also been implicated in decreased afferent proprioception information at the knee. Therapeutic programs that involve exercise immediately after a period of cooling should be taken into account because cooling for 15 minutes makes the knee joint stiffer and lessens the sensitivity of the position sense (Uchio, Ochi, Fujihara, Adachi, Iwasa & Sakai, 2003), consistent with Thieme (1992) findings. Significant differences were found for joint position sense (JPS) before and after cold spray application and between JPS scores and pain. In the study, they showed that knee JPS deficits occurred, and postural control was adversely affected, with cryotherapy, and caution should be observed when athletes immediately return to their chosen sport after cryotherapy application (Surenkok, Aytar, Tüzün & Akman, 2008). Moreover, Gardner, Aiken, Robinson, Condra and McGinnis (2000) found that postural sway and balance strategy were not significantly affected following 20 minutes of ankle ice immersion; also lower leg cold-immersion therapy does not impair dynamic stability in healthy women during a jump-landing task (Miniello, Dover, Powers, Tillman & Wikstrom, 2005).

Studies by LaRiviere (1994) in the ankle, knee (Thieme, 1992), and hand (Williams and Rainham, 1980) showed that therapeutic cold treatments did not affect proprioception. Another study says that a 20-minute ice treatment had no effect on joint angle reproduction (Thieme, Ingersoll, Knight & Ozmun, 1996). Despite these studies, the effect of cooling on proprioception of the knee has not been studied extensively.

Thieme et al (1996) refer that one possible explanation for the difference between sectors is that different receptors are active at different points in the knee’s range of motion. They conclude that cooling the knee joint for
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20 minutes does not have an adverse effect on proprioception and Ingersoll, Knight and Merrick (1992) concluded that heat and cold applications can be used prior to therapeutic exercise programs without interfering with normal sensory perception as do other analgesic and anesthetic agents. Similar results were presented in a study of Hopkins and Adolp (2003), ankle and knee joint cryotherapy does not appear to affect normal biomechanics in terms of torque and power of the lower extremity. Joint cryotherapy is an effective treatment that will not inhibit normal motor function that dynamically supports the joint.

It’s been known that cryotherapy has direct physiological effects on contractile tissues, the extent to which joint cooling affects the neuromuscular system is not well understood. Hopkins, Hunter and McLoda (2006). Although some studies have yet to confirm an effect in the joint position sense (Dover & Powers, 2004), others say clinical application of cryotherapy is not deleterious to joint position sense and assuming normal joint integrity patients may resume exercise without increased risk of injury of the ankle (Hopper, Whittington & Davies, 1997). The slowed enzymatic processes and slowed nerve conduction that impair rate of force development also likely reduce local muscular endurance during dynamic contractions and impair manual dexterity (<35 °C). Both the voluntary and evoked force development capacities of muscle is unimpaired until cooling is quite severe (<27 °C). There also exists the hypothesis that the increased viscosity of the synovial fluid is a factor in decreasing finger dexterity in the cold. However, this is not the only factor since cooling of the arm, even when the hands are kept warm, also caused a large decrement in finger dexterity (LeBlanc, 1956).

Also, Hopkins, Hunter and McLoda (2006) with their study tried to detect changes in ankle dynamic restraint (peroneal short latency response and muscle activity amplitude) during inversion perturbation following ankle joint cryotherapy. They concluded that joint cooling does not result in deficiencies in reaction time or immediate muscle activation following inversion perturbation compared to a control.

The extent to which joint cooling affects the neuromuscular system is not well understood. Mecomber and Herman (1971) noted a decrease in the amplitude of action potentials, twitch contraction, and nerve conduction time following maximal tendon taps of precooled Achilles tendons. Consequently, the resultant force development within the muscle and the myotatic reflex’s protective mechanism may be negatively influenced. Also, therapeutic cooling decreases nerve conduction velocity (Halar, DeLisa & Brozovich, 1980). Over this issue, Mac Auley (2001) performed a systematic literature search on ice therapy in injuries, concluding that reflex activity and motor function are impaired following
ice treatment, so patients may be more susceptible to injury for up to 30 minutes following treatment. It is concluded that ice is effective, but should be applied in repeated application of 10 minutes to be most effective, avoid side effects, and prevent possible further injury. Another systematical review considered cryotherapy alone on return-to-participation measures (Hubbard, Aronson & Denegar, 2004) and with optimal results following training (Lievens, 1986).

Results of various studies are consistent on the effects on neuromuscular and pain processes. How can we assess the effect of CWI on postexercise parasympathetic reactivation? A study shows that CWI can significantly restore the impaired vagal-related heart rate variability (HRV) indexes observed after supramaximal exercise. CWI may serve as a simple and effective means to accelerate parasympathetic reactivation during the immediate period following supramaximal exercise (Buchheit, Peiffer, Abbiss & Laursen, 2008).

Experimental models designed to reflect the circumstances of elite athletes are needed to further investigate the efficacy of various recovery modalities for elite athletes. Other potentially important factors associated with recovery, such as the rate of post-exercise glycogen synthesis and the role of inflammation in the recovery and adaptation process also need to be considered in this future assessment.

Conclusion

Most studies suggest that a short rewarming time would be beneficial (a couple minutes), which is very reasonable in sports. Also, cooling techniques differ in its result accordingly to the procedures and objectives used. Finally, the type of tissue cooled plays a large role (i.e. Joint vs. Muscle).

Bibliography


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Márcio DOMINGUES is a finishing PhD Student at the Faculty of Sports Science within the University of Coimbra. He has published national and international articles in sport related themes and made several oral communications internationally. Currently he’s developing two projects related to young sport, migration and talent development.

**Corresponding address:**
Márcio Luís Pinto Domingues
61 Rua Nova
Horta-Velha
3750-862 Borralha
Portugal
Phone: (+351) 910 973 39 06
E-mail: marcio.domingues@live.com.pt