Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

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Comments	Section
	Title and Abstract (5%) Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review (25%) To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
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CARDIFF METROPOLITAN UNIVERSITY
Prifysgol Fetropolitan Caerdydd

CARDIFF SCHOOL OF SPORT

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COMPARATIVE EFFECTS OF ICE BATHS ON PHYSIOLOGICAL RESTORATION, PERCEIVED RECOVERY AND REPEATED SPORTS PERFORMANCE IN UNIVERSITY HOCKEY PLAYERS

Dissertation submitted under the discipline of SCRAM

ROSS MATTHEWS

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TABLE OF CONTENTS

CHAPTER 4: RESULTS

CHAPTER 5: DISCUSSION

CHAPTER 6: CONCLUSION

APPENDICES

LIST OF TABLES

LIST OF FIGURES

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ABSTRACT

The intention of this investigation was to determine the effect of ice baths on recovery from delayed onset muscle soreness. This study is one of few studies to incorporate measurements of performance, physiological restoration and perceived muscle soreness, while examining the effects of ice baths on the alleviation from DOMS. The study observes the impact an ice bath has on these aspects of recovery, in search of evidence to support the utilisation of this recovery strategy in university field hockey.

Quantitative methods were employed in search of results predetermined by the aims of the study. 12 participants were involved in the testing process, which was carried out over two weeks. The study utilised a crossover design where participants experience the ice bath intervention in one of the weeks while receiving no intervention during the other week. The non-intervention week was treated as a control, against which data collected during the ice bath intervention week could be compared. The participants underwent performance (drop jumps), physiological status (creatine kinase) and perceived muscle soreness testing prior to undergoing a predetermined eccentric exercise plan to induce the effects of delayed onset muscle soreness. Participants then either experienced the ice bath intervention immediately post exercise under precise protocol or received no recovery intervention. They were retested 24 and 48 hours post exercise.

Following data collection, statistical analysis commenced to recognize trends in the data. Statistical significance *($p<0.05$)* was evident throughout the results, however on a practical basis, these results should not be considered entirely reliable. Further research is required in the field to substantiate the evidence behind the use of ice baths as a recovery intervention and prevent anecdotal recommendation. Future research should also focus on establishing set protocol for optimised us of ice baths, as this is still highly contradictory and inconclusive.

CHAPTER 1

INTRODUCTION

A comprehensive review of past literature has produced limited investigation into the impact of ice baths as a recovery strategy with regards to reproducing high quality performance in bouts of exercise a few days apart, and the practise of ice baths appears to be recommended anecdotally and without scientific evidence (Wilcock, Cronin & Hing, 2006). A recent survey performed in South Africa among the support staff of elite rugby teams, highlighted ice baths as the most popular form of post match recovery, with 83% of the staff/teams adopting this strategy, even though there is limited scientific evidence demonstrating the effectiveness of ice baths from an adaptation perspective (Van Wyk & Lambert, 2009).

A recent study executed by Bleakley and Davidson (2010) provided equivocal evidence that ice baths are effective, while a study conducted by Yamane et al. (2006) concluded that ice baths had a negative effect on an athlete's performance. This kind of logic is common in the practice of recovery interventions. Another example of this nature is the extensive use of anti-inflammatory drugs for combating muscular injury with the practice of this being divergent from scientific evidence and recommendation (Paoloni, Milne, Orchard & Hamilton, 2009). This dilemma brings to question the quality of the research that is being conducted in this area. It seems as though practitioners have their own agenda in the subject of recovery, one that occurs independently and in disregard for what scientific evidence suggests (Van Wyk & Lambert, 2009). In order for the athlete to benefit from the most advantageous recovery treatment available, the gap between actual practice and the recommendations suggested by scientific evidence needs to be addressed. The most beneficial strategy for recovery will not be established until this is achieved.

This investigation aims to contribute to knowledge in this area by reducing the gap between scientific evidence and anecdotal practice. The objective is to adopt a sports specific approach and perform the study on a population of university level field hockey players. This particular population of field hockey players is required to repeat, highly competitive bouts of exercise with little recovery time. The intention behind focusing on this specific population is to reduce the difference between laboratory-based research and reality, and perhaps benefit the specific population for future prescription of ice baths as a recovery approach.

The recovery effect from delayed onset muscle soreness (DOMS) following an ice bath intervention strategy will be closely scrutinised in a selection of variables, such as performance, physiological restoration and perceived recovery. These factors are considered important when focusing on recovery enhancement (Wilcock et al., 2006; Rowsell, Coutts, Reaburn, & Hill, 2009; Eston, Byrne & Twist, 2003). The analysed data will report on whether there is any evidence to support the use of ice baths as a recovery strategy, with any form of advantage gained, considered as support for the use of ice baths as a recovery intervention.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section aims to provide a detailed, critical review of recent and relevant literature surrounding the topics contained within the study. Contradicting views and conclusions discovered through previous research will be analysed and considered, allowing for more specific direction when forming a hypothesis for this particular investigation. Furthermore, previous methods used in the examination of whether ice baths are an effective recovery strategy will be taken into account in anticipation for the methodology adopted in this research. A summary of the rationale and aims of the study will also be included.

2.2 University Field Hockey

Field hockey is a high intensity, physically demanding and competitive team invasion game. It requires a high degree of athletic ability, specifically in the form of cardiovascular endurance, speed and muscular strength in order to be successful at university standard (Reilly & Borrie, 1992). Match play includes periods of low intensity jogging and walking, diversified with sprinting, changes of direction and high-acceleration/deceleration movement demands (Gabbett, 2010). A typical university field hockey season demands constant high volume, frequency and intensity in competition and in training. Repeated competition and training puts strain on the physiological, neurological, psychological and nutritional function of the players (Calder, 2003). University players are habitually required to participate in two matches a week, interspersed with multiple training sessions and physical conditioning, for several consecutive months. These frequent, repeated bouts of exercise might not allow adequate time for the players to fully recover before the next bout. This imposes severe physiological stress on players, resulting in high levels of fatigue and the requirement of having to compete and train while their muscles are in a condition of disrepair (Halson & Jeukendrup, 2004).

2.3 Delayed Onset Muscle Soreness (DOMS)

For many years, lactic acid was credited as a primary contributor to DOMS, but contrary to popular belief this is not the case. In fact, it has been proven in a study conducted by Szymanski (2001), that during intensive exercise, lactate levels increase, but within 30-60 minutes post exercise return to their original state. DOMS generally develops within 24 hours of the exercise being performed, peaking between 24-72 hours post exercise and subsiding up to several days later depending on the severity (Armstrong 1990; Cleak & Eston, 1992; Ebbeling & Clarkson, 1989; Nosaka & Clarkson, 1995). Studies have discovered that it can take as long as five days for the acute pain to disperse and even longer for muscles to be fully recovered and regain optimal function (Cheung et al, 2003). The studies above by Armstrong (1990), Cleak and Eston (1992) and Szymanski (2001) clearly demonstrate that the peak effect of DOMS and peak lactate levels do not coincide. Therefore a conclusion can be made that there is no relationship between lactate and DOMS.

It has been confirmed in previous research that following an unfamiliar activity or intensive, eccentrically challenging exercise, muscular damage is a result, and an athlete might be susceptible to the effects of DOMS. The likely cause of muscle damage occurs during the ‘loading profile’ of an eccentric exercise (contraction during muscle fibre lengthening) where a great amount of stress is placed on the associated tissue (Enoka, 1996).

DOMS is still not yet fully understood by researchers, as common ground has yet to be found cross-study, this being clear as several diverse theories have previously been presented (Polwmans & Smith, 2008). Theories surrounding the cause of DOMS relate to damaged muscle fibres, a breakdown of proteins contained in the muscle causing an inflammatory response, cell inflammation, connective tissue damage and muscle spasm, while cellular degradation and enzyme efflux are also considered to be causes (Armstrong, 1984; Byrd, 1992; Cheung et al., 2003; Clarkson & Sayers, 1999; Friden & Lieber, 1992; Smith, 1991). It was suggested by Smith (1991) that several theories are responsible for athletes suffering from DOMS. Subsequent research has drawn a more accurate hypothesis, deciding that several factors comprising of cellular, neural and connective mechanisms, combine to cause the symptoms experienced with DOMS (McHugh, Connolly, Eston, & Gleim, 1999). Given the literature supporting the role of cell inflammation and muscle damage in DOMS (Szymanski, 2001), it would seem pertinent that future studies should focus on measures of these two physiological markers. There are clear links between the these markers, and cryotherapy being administered as the recovery modality. It is generally agreed that cryotherapy reduces swelling and inflammation and has been utilised in the management of acute injuries for many years (Enwemeka et al., 2002).

Damage is caused at cellular level in the form of a disturbance to the sarcolemma, disintegration of the sarcoplasmic reticulum, lesions of the plasma membrane, cytoskeletal harm and swollen mitochondria (Armstrong, 1990; Friden & Leiber, 1992; Stauber, 1989). This being said, damage is restricted to only a relatively nominal amount of fibres in comparative terms to the affected muscle. Feelings of pain, a dull muscular ache, tenderness, swelling and stiffness are some of the symptoms associated with DOMS, coupled with effects such as restricted range of movement and inhibited force production (Cleak & Eston, 1992b; Friden, Seger & Ekblom, 1988; Hill & Richardson, 1989; Howell, Chlebourn & Conatser, 1993; Nosaka & Clarkson, 1997). DOMS is among other things, a consequence of poor recovery and may result in the athlete being unable to perform at the desired intensity when next required (Szymanski, 2001). The stressful components of competition and training may cause temporary muscular impairment and in turn cause a decline in an athlete's usual level of performance (Barnett, 2006). Accompanying a decreased standard of performance, there is an increased risk of injury (Barnett, 2006). Specific to hockey, a study carried out by Thompson et al. (2009) confirmed that the repetitive, eccentric movements required by intermittent running/sprinting during hockey training and matches can cause the muscular damage that contributes to DOMS.

2.4 Eccentric Exercise

A common movement in sport consists of muscles being required to produce cycles of eccentric and concentric movement, also known as the stretch-shortening cycle (SSC), for example running. Greater muscle damage occurs during eccentric loading compared to concentric loading due to higher forces acting on the muscles; the muscle is forced to lengthen whilst producing a contraction (Cash, 1996; Clarkson & Sayers, 1999). Fibrous adhesions contained within the muscle involved in the movement are broken due to the tension and sheer force the muscles are subjected to (Cash, 1996). Assuming that mechanical damage to the muscle is a contributing factor to the cause of fatigue, greater fatigue might be induced by similar eccentric-concentric muscle actions such as jumping and running. Studies have found that there is a apparent prolonged (48-72 h) reduction in jumping height when fatigue is achieved from high volume, eccentric loading exercises such as barbell squats and plyometric jumps, and this might also be recognized as a cause of muscle damage (Byrne & Eston, 2002a; Friden & Lieber, 2001; Vaile & Gill, 2003; Viitasalo et al., 1995).

These movements have been proposed as responsible for damaging the connective tissue and muscular fibres, therefore inducing DOMS; but the athlete would still be required to perform the exercise for a sufficient duration, at an adequate intensity for this to occur (Armstrong, Warren & Warren, 1991). Greater perceived muscle soreness and mechanical damage to the muscle is credited to eccentric exercise due to it being linked to high peak forces (Talag, 1973), when compared to concentric and isometric exercise which presented lower perceived levels of muscle soreness in a study by Clarkson, Byrnes, McCormick, Turcotte and White (1986).

2.5 Creatine Kinase

Creatine kinase (CK) is a metabolite that is commonly used as a measure of muscle damage according to the level contained in the blood (Rawson, Gunn & Clarkson, 2001). Cell permeability is thought to increase as a reaction to exercise-induced injury, which causes increased diffusion of CK and other myoproteins into the interstitial space (Enwemeka et al., 2001; Eston & Peters, 1999; Warren, Lowe & Armstrong, 1999). With cryotherapy being the recovery intervention being researched in this study, and the effects associated of this strategy; CK is the ideal indicator of muscle damage in this instance. It is known that cooler temperatures stimulate vasoconstriction, which in turn decreases lymphatic, capillary and cellular permeability, ultimately resulting in a decrease in CK levels (Enwemeka et al., 2001; Eston & Peters, 1999; Howatson, 2003). CK levels are an established measure of muscle damage and this method of measurement has been utilised in a similar manner in numerous studies. It has been stated that measuring CK is the most specific biochemical test that can be utilised to measure muscle damage (Henson & Rao, 1966).

2.6 Recovery

Recovery is popularly defined as muscle being restored back to a state similar to that experienced pre-exercise (Tomlin & Wenger, 2001). The importance of recovery from training effect or competition should not be underestimated, when repeated activity is required by an athlete, as temporary performance decrements will otherwise ensue (Barnett, 2006). Athletes must balance competition and training load with appropriate recovery if optimal performance is required (Kuipers, 1998). If the speed of recovery can be enhanced, this would give the athlete a competitive advantage. It has been proven that recovery should begin immediately post exercise, continuing for up to 24 hours, and is considered equally vital to an athlete’s routine, as a warm up is immediately pre-performance (Barnett, 2006). The process of recovery can last up to five days or longer for the muscles to completely return all aspects to full previous function (Cheung et al, 2003). Athletes seek to utilise any effective modality to facilitate the recovery process in an endeavour to restore and adapt physiologically and psychologically, in preparation for the next competition or training session (Barnett, 2006). Athletes will usually adopt a modality that is relevant to their specific sport but also one that is easily accessible/administered, suited to personal preference and most effectively influences the athletes perceived enhancement towards recovery.

There are many various strategies that athletes adopt for accelerated recovery. A study performed on rugby players highlighted popular examples ranging from: stretching, active recovery, sleep and nutrition; to massage, cryotherapy, ultrasound, compression garments and non-steroidal anti-inflammatories (NSAID's); even though there is little or no evidence to support the effectiveness of any of these techniques (Barnett, 2006). Regardless of the chosen recovery modality, the fundamental aim is to reduce the effects of fatigue, speed up the injury process and minimise the ephemeral impairment to an athletes performance; keeping in mind that positive adaptation should be encouraged simultaneously (Barnett, 2006). Competitive advantage is gained through any positive effect that the modality gives the athlete. This can even refer to the athletes perceived effect of the modality and the extent by which a positive psychological effect influences recovery enhancement. In a previous study by Rowsell et al. (2009) in which participants were exposed to cold water immersion, perceived exertion questionnaires reported significantly lower levels of muscle soreness, even though direct and indirect measures reported no difference. This example demonstrates how possible gains from recovery strategies can be purely psychological and future research should explore this possibility further. Research in this area of recovery and the search for the most optimal recovery strategy that can be subjected to scientific examination, is ongoing.

To enhance recovery and improve subsequent performance, players and coaches use many different recovery strategies. A strategy gaining popularity and increasingly being recommended anecdotally amongst numerous athletes, professional sporting bodies and support teams is cold-water immersion (Calder, 2000; Cochrane, 2004). Currently according to Van Wyk & Lambert (2009), ice baths/cold water immersion and stretching are the most widely used and established recovery strategies. Slightly less popular modalities include massage and active recovery. This information was gathered from reputable sources in the sporting world.

2.7 Cryotherapy

There are four fundamental modes of water immersion, each involving differences in the water temperature. These modes include: warm immersion, contrast bathing, neutral bathing (water temperature is equal to body temperature) and cryotherapy (ice bathes), the selected modality for this study. Cryotherapy is a treatment modality commonly used in the management of acute sports-related injury and can be defined as “cold therapy” (Bleakley, McDonough, & MacAuley, 2004). Ice is a frequently used cryotherapy tool, used in a clinical setting as a therapeutic approach with the aim to utilise low temperatures to provide treatment or medical therapy to reduce acute pain and inflammation of soft tissue damage (Saito, Soshi, Tanaka, & Fujii, 2004). Cryotherapy is proposed to reduce tissue inflammation, oedema, the formation of haematoma and pain, therefore in theory, this modality should transfer to the recovery of DOMS if we assume cell inflammation and muscle damage are primary causes of the effect (Smith, 1991; Swenson, Sward, & Karlsson, 1996). However, the success of cryotherapy is unclear due to the limited research to substantiate its effectiveness and it is uncertain whether any benefit to recovery should be credited to water temperature or hydrostatic pressure. It is commonly known that pressure over the submerged surface of the body is higher under water than in air (at sea level). This hydrostatic pressure causes gases and fluids to migrate from extracellular space to the vascular compartment, enabling an enhancement in recovery due to the removal of swelling (Wilcock, Cronin & Hing, 2006). A study by Vaile, Halson, Gill and Dawson (2008) provided conclusive evidence that hydrostatic pressure created physiological changes which were the cause of significantly reduced muscle swelling.

Cryotherapy has been shown to be a more useful intervention in terms of recovery enhancement when compared to other strategies, specifically sports massage, supporting the recent increase in popularity (Delextrat, Calleja-Gonzalez, Hippocrate & Clarke, 2013). While research conduced by Cheung et al, (2003) revealed that there is little benefit from ice baths, when the aim of application is to treat and prevent the effects of DOMS. These examples demonstrate the inconclusive nature of the research on offer and it remains principally anecdotal, but this has undoubtedly had little effect on cold-water immersion or ice baths as an increasingly popular recovery method (Calder, 2000; Cochrane, 2004).

According to Wilcock et al. (2006), ice baths instigate other physiological effects such as a reduction in heart rate, cardiac output and oedema as well as analgesic treatment. These physiological effects are suggested to aid the reduction of cell death (Wilcock et al., 2006), tying in with the theory of cell inflammation being an associated cause of DOMS and how this can be treated. Merrick, Rankin, Andres and Hinman (1999) concluded that ice baths are successful in accelerating recovery post competition/training if it is assumed that decreasing inflammation, muscle damage, blood flow, metabolic rate and intra-articular temperatures are the resultant effects. Further to the effects previously described, there are other responses that are associated with the use of ice baths as a recovery strategy. The usual firing rate of muscle spindle afferents is slowed down due to the effect the cold has on the conduction of nerve impulses. Reflex response is also inhibited to an extent. These physiological reactions to the cold in turn reduce pain and muscle spasm (de Jesus et al., 1973; Prentice, 1999).

2.8 Ice Bath Protocol

There is currently no consensus with regards to protocol for the application of cryotherapy in relation to duration of treatment, temperature of the water and frequency of application (Quinn, 2008), although several studies have attempted to provide guidance. It is common practice in many sports for athletes to use ice baths as a strategy to enhance recovery from performance (Van Wyk & Lambert, 2009), even though literature around the subject is inconclusive and some studies even suggest that it could produce an adverse effect. Van Wyk and Lambert (2009) stress the importance of quality research in this field to develop and establish set parameters for ice bath application. Certain factors need to be considered and controlled when designing ice bath procedure, such as temperature of the water, duration of exposure, timing of the application, the type of exercise causing fatigue and the body area to be immersed. Previous studies have been carefully considered in the development of the application protocol used for this study.

A study executed by Sramek et al. (2000) showed that exposure to low temperatures for at least 10 minutes after intense exercise was vital in allowing any physiological or vasomotor changes to become stable. Simulateously, subcutaneous and intramuscular temperatures have shown to lower by 7-10°C (Meeusen & Lievens, 1986). It is also worth noting that Sramek et al. (2000) recommend a water temperature of 14°C because the study found that this temperature encouraged optimal physiological responses, for example metabolic rate was increased by 350% compared to water temperatures of 20°C and 32°C.

Numerous studies have investigated cryotherapy as a recovery strategy, uncertainly providing a number of possible positive effects as reason to adopt this strategy, with few relating these effects particularly to performance. Previous literature has made it common knowledge that applying cold to an area will decrease muscle, subcutaneous, skin and core temperature (Enwemeka et al., 2002; Hartvickson, 1962; Johnson et al., 1979; Lowden and Moore, 1975; Myrer et al., 1997). This should warrant the use of ice baths as a post-exercise intervention as exercise has been proven to increase body temperature and cause inflammation of the muscles (Smith, 1991). The decrease in internal temperature causes the blood vessels in the area to constrict. The extent of injury is restricted because of this vasoconstriction, and a reduction in inflammation and swelling is promoted due to blood being redirected from the cold and a decrease in metabolic rate (Enwemeka et al., 2002).

Practitioners are in little doubt, based on anecdotal evidence, about the efficacy of ice baths as an immediate care treatment, treatment for muscle damage and as a rehabilitation tool. Insufficient data has been collected in evidential research to substantiate the use of cryotherapy or to explain the associated mechanisms by which it works. It is not possible to provide a conclusive explanation of the effects of cryotherapy on sport-induced inflammation at this stage. Future research should strive to examine and refine current protocols and provide an explanation on the working mechanism. Further research will determine whether this strategy should be adopted as a recovery intervention or if it should be avoided.

2.9 Review Summary and Aims

Many teams in sport have programmed physical conditioning sessions, training sessions and a multitude of competitive matches with little emphasis on recovery (Barnett, 2006). University level field hockey teams rarely facilitate this need for implemented recovery, regardless of the players being required to compete and perform at a high standard in at least two matches a week for several months. Considering that the effects of DOMS can take up to seven days to disperse, and the high competitive demand of the season; this highlights how little time the players have to recover, and the importance of incorporating recovery into regular routine to promote optimal performance (Szymanski, 2001).

Ice baths are believed to enhance recovery in a multifaceted manner, affecting elements of performance, physiological restoration and psychology (Wilcock et al., 2006; Rowsell et al., 2009; Eston, Byrne et al., 2003). This increases the importance of securing scientific evidence in support of the strategy. They are also considered to be an easily administered recovery strategy, which is perhaps another reason why many professional teams around the world utilise the approach, although on the basis of anecdotal prescription (Van Wyk & Lambert, 2009). Due to ice baths being practiced anecdotally and with scientific evidence around the topic remaining scarce and contradictory, further quality research is necessary to conclude whether ice baths have any effect on recovery enhancement from DOMS (Lateef, 2010). Studies should consider investigation into ice bath application protocols, to establish the most optimal method for accelerated recovery (Van Wyk & Lambert, 2009).

This research attempts to examine elements of a university level field hockey player that are affected by DOMS (performance, physiological restoration and perceived muscle soreness), and determine whether ice baths provide any benefit to recovery. Positive results could potentially direct future research down a worthwhile avenue.

2.10 Hypothesis

The general hypothesis after considering past experience and literature, supports ice baths in providing beneficial effects aimed at recovery from DOMS. The areas where the greatest effects are most likely to be expected are within the drop jump performance variable and the participant’s perceived effect, when the intervention is implemented.

CHAPTER 3

METHODOLOGY

3.1 Introduction

A number of concerns need to be accounted for when implementing the appropriate methods required when any research is undertaken. Theoretical, ethical and practical considerations need to be explored and addressed. Guidance in this domain was sourced from Patton (2002) who recommends that dependable methodological choices should be made regarding the question being researched, the rationale for the investigation and the resources available. After reviewing recent literature concerning recovery strategies, and in particular literature associated with ice baths and the effect ice baths have on DOMS, it was decided that quantitative methods would provide the appropriate numerical measurement and statistical analysis required in this study (Gratton & Jones, 2004).

This section will discuss each of the above areas in detail. The primary focus of the research will however be on the comparison of passive recovery and ice baths as recovery interventions and their effect on DOMS, with relation to perceived recovery, physiological restoration and performance.

3.2 Participants

The aim of the study was to produce information that might be considered valuable by a specific group. For this reason, the sample for this study was selected from the Cardiff Metropolitan University Men's First XI field hockey team. 15 male field hockey players (Mean ± SD; age 21 ± 1.9 years, stature 178.0 ± 5.0 cm, body mass 76.7 ± 8.1 kg) volunteered for the study, all of which met the required selection criteria. Selection criteria for this study required all participants to be focus group members, suggesting that the participants are of a similar playing ability, train and compete a similar volume throughout a typical week, and are familiar and competent in the movement patterns that were demanded by the resistance exercise challenge (REC). Previous studies by Baechle and Earle (2008) and Verheijen (1998) advise that training status and experience are important factors to take into account when subjecting participants to strenuous activity. Participants with less experience and training status might not be able to cope.

3.3 Screening, Information Sheets and Informed Consent

Participants were screened and deemed healthy and able to partake in the study prior to commencement. This was ensured through the completion of a Physical Activity Readiness Questionaire (PAR-Q) by each of the volunteers (see Appendix D). The results from the PAR-Q were analysed prior to the commencement of testing, as a positive response to any of the questions in the PAR-Q meant that the participant was not considered suitable for testing. The participants also had to be free from known illness and injury and not consume any nutritional supplements or anti-inflammatory medication. The participants were informed of the procedures and commitments required by the investigation through information sheets (see Appendix C), and an informed consent document was signed in order to take part (see Appendix B). These documents gave clear detail as to what the study included and what was required, highlighting the fact that participants had the right to withdraw from the study at any time, without explanation (Jackson, 2012). The Cardiff School of Sport Ethics Committee approved this study prior to commencement (see Appendix A). Permission from the focus group coach and the team coach regarding the inclusion of the athletes in the study was sought after before experimental trial began.

3.4 Participant Guidelines

Once selected for the study, participants were given strict guidelines to adhere to. Participants were asked to refrain from exercise, alcohol and caffeine for at least 48 hours prior to the commencement of the study, and for the duration of the testing. It was also requested that participants remained well hydrated and ate sensibly throughout this period. Due to the purpose of the study being to assess whether ice baths are effective as a recovery strategy, all other forms of recovery should be eliminated. This includes foam rolling, recovery supplements such as protein, stretching, massage and compression garments. Obedience to these set guidelines was monitored through self-reported compliance. This simply involved basic questioning of what activities the participant had partaken in and an estimation of fluid and nutritional intake. However, with the participants being university students and with the testing being carried out mid season, it was not possible to ensure the guidelines were completely adhered to due to commitments the participants might have had and failed to report.

3.5 Experimental Design

This study was designed to investigate whether ice baths affect the rate of recovery following a REC that has induced DOMS and whether this recovery intervention has an effect on the time it takes for an individual to be "ready" to perform at a high level.

These aims were achieved using a two period, crossover design where the trials were separated by two weeks. In week one, participants were randomly assigned into two recovery trials. Groups would complete an identical REC to encourage DOMS after warming up. Immediately following the REC, one group would experience a recovery intervention in the form of an ice bath and the other group would receive no intervention. Physiological, psychological and performance tests were collectively carried out at specific intervals over 48 hours, to gauge levels of recovery in each variable. The testing was performed minutes prior to the REC, repeated 24 hours later and again 48 hours post-REC. A minimum of one-week gap separated the variables to allow participants to recovery fully and be found in the same physical condition as they were prior to the first variable. The passive recovery week acted as a baseline score to allow a comparison to be made between ice bath intervention and a non-intervention recovery strategy.

Results collected from these tests were statistically analysed to decipher a difference between passive recovery and an ice bath intervention variable on each individual participant (Field, 2009). This would give an indication as to whether ice baths as a recovery strategy have any effect on DOMS, with regards to any of the variables measured.

3.6 Familiarisation Session

A familiarisation session was conducted with the ultimate aim to ensure the researcher and participants were familiar with all the equipment being used and the protocol of the study. The session allowed the researcher chance to identify any potential faults with the procedure and reduce the risk of errors that could occur due to inexperience. A mistake with protocol could put the study at risk by affecting the validity and quality of the findings (Blessing & Chakrabarti, 2009). Participants performed a set of the REC and several drop jumps to avoid any confusion with the movement patterns required on the days of testing.

3.7 Warm-Up

The participants were taught a five-minute warm up protocol specific to the squat movement pattern, which would be standardised throughout the testing. This protocol would be initiated immediately prior to the REC and any performance test. The warm-up consisted of a low intensity aerobic “pulse raiser” followed by a series of squat activation, mobilisation and potentiation drills (See Appendix F).

3.8 Testing Facility

The National Indoor Athletic Centre (NIAC) based on the Cardiff Metropolitan University, Cyncoed Campus, was the site for testing. The facility houses a diagnostics gymnasium containing a Keiser squat machine, a 200-meter running track and a dedicated ice bath room with several fixed baths and an ice machine. Baechle and Earle, (2008) among others suggest that when administering tests, consideration should be made for environmental factors such as temperature, wind and rain. This could be controlled to a greater extent due to the facility being indoors.

3.9 Anthropometric Measuring Equipment

Height and weight measurements were recorded using a portable SECA 321 stadiometer (Vogel & Halke, Hamburg, Germany) and SECA 770 electronic scales (Vogel & Halke, Hamburg, Germany) respectively. This equipment has been used in many studies due to the reliability and accuracy of measurements produced (Rowsell et al., 2009).

3.10 Testing Protocols

Participants were required to complete a battery of tests throughout the study. Three tests were utilised as markers to clearly display the level of recovery achieved at each stage of the study with regards to either receiving the ice bath intervention or simply the passive recovery control/non-intervention. The stages of the study refer to pre-REC, 24 hours post-REC and 48 hours post-REC, demonstrated below in Figure 1. These three tests included capillary blood samples (physiological), a visual analogue scale (VAS) (psychological) and a performance test.

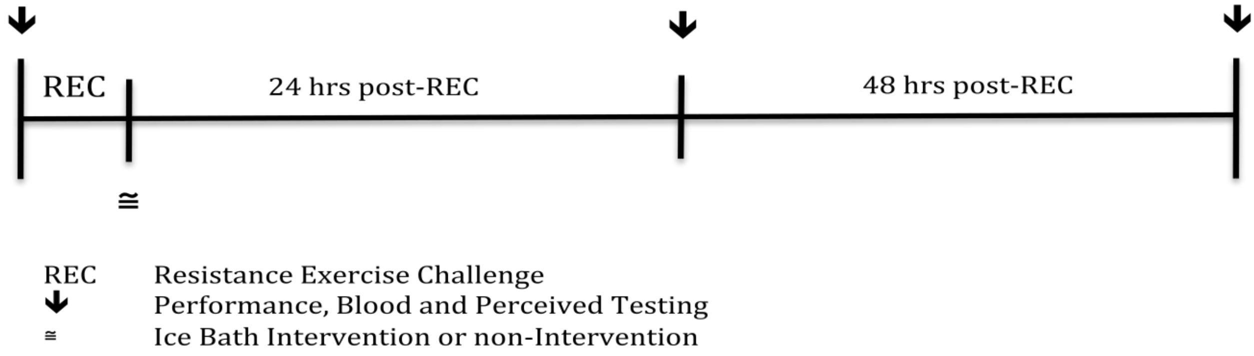

Figure 1. The time scale for performance testing, blood sampling, and perceived muscle soreness evaluation during the trial as well as the time point for the ice bath intervention has been displayed

It was decided that the physiological (CK), psychological (VAS) and performance baseline tests would be performed prior to the REC and identical tests would be repeated at the different stages (24 and 48 hours post-REC) post implementation of the recovery intervention. This indirect method of testing is considered to be a reliable method of measuring recovery (Starkey & Johnson, 2006).

3.11 Physiological Test

Physiological restoration was determined through the use of a blood sample and reflotron, and displayed in a quantifiable amount. The result from this test gave insight into the baseline CK values pre-REC, the damaged caused by the REC displayed in the post-REC testing stages and the level to which the participants recovered at each stage. Plasma CK activity was determined from a circulatory blood sample. A warm fingertip was cleaned with a sterile alcohol swab and allowed to dry. Capillary puncture was made with an Autoclix lancette and a sample of whole blood (32 ml) was pipetted from a capillary tube onto the test strip and analysed for CK activity using a reflotron Plus System that performed a colorometric assay procedure (Reflotron, Roche Diagnostics, Lewes, East Essex, UK). This system uses a plasma separation principle, which is incorporated in the reagent carrier on the test strip. The numerical reading produced by the test allowed the recovery status of the participant to be observed on a physiological level.

3.12 Psychological Test

Psychology plays a vital role in higher standard sports. Any advantage that is gained by the team or individual should be appreciated. The study required participants to evaluate their own perceived level of muscle soreness, specifically of the lower limb extensor muscles, through the completion of a 10-centimeter (cm) VAS questionnaire (Lenn et al, 2002), shown in Figure 2 below. The rating ranged between 0 cm (no pain) and 10 cm (very severe pain). Participants positioned a mark on the scale during leg extension to indicate the severity of perceived muscle soreness they were experiencing. A measurement (in cm) was calculated from the zero to the participants mark. This scale presents a personal representation as to the level of perceived soreness the participant was experiencing at each stage. If the participant perceives that they have recovered to a greater degree when compared to physiological recovery, this should still be regarded as a positive outcome.

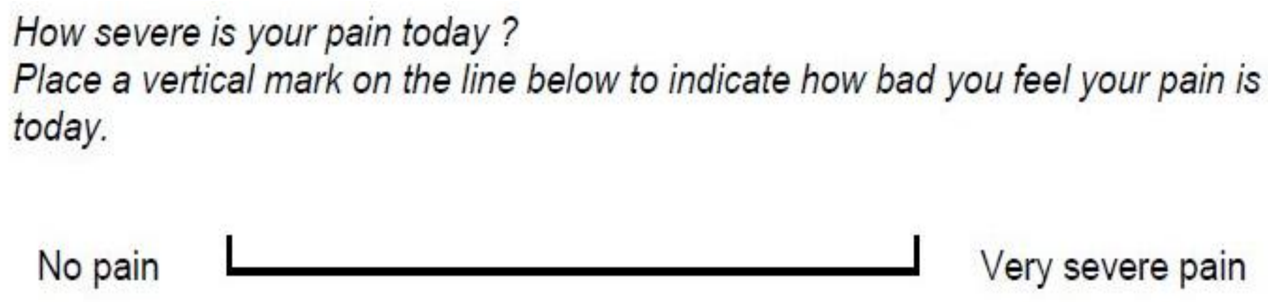

Figure 2. Visual analogue scale for perception of lower limb muscle soreness

3.13 Performance Test

Research conducted by Viitasalo et al, (1995) where drop jumps were utilised as a performance measure to illustrate the effects of water immersion on fatigue, inspired the performance assessment method for this study. Participants were allowed three attempts to produce the highest drop jump possible. Participants stepped off a 30-centimeter box onto a contact mat (SmartJump, Fusion Sport, Brisbane, Australia) where they attempted to leave the mat as quickly as possible, while still producing a maximal jump. Sufficient rest was given between each jump, allowing enough time for the participant to recover and avoid any effects of fatigue. This ensured a maximal effort was produced and the most accurate results were generated. Reactive strength index (RSI) was the focus measure collected from the testing due to it being directly relevant to plyometric ability and a representative of fatigue if the effort produced was lower in the post-tests compared to the pre-test. Young (1995) defined reactive strength as the ability to quickly change from an eccentric contraction to a concentric contraction. The value of RSI is derived from the height jumped, divided by the time in contact with the ground prior to take-off (height jumped/contact time). RSI is construed as the ability to endure the stretch loads through the muscles and quickly apply force in the opposite direction (McClymont & Hore, 2003). RSI includes the use of the stretch-shortening cycle (SSC) and in this respect can be classified as fast (contact time $<$ 0.25 s) or slow (contact time $>$ 0.25 s) contraction times (Schmidtbleicher, 1992). This particular research is concerned with the fast SSC movement as this relates to sprint speed and agility, requirements of field hockey (Schmidtbleicher, 1992). Performance was measured using SmartJump (Fusion Sport, Brisbane, Australia) equipment due to the accuracy of the results this equipment generates and the practicality of setting up and operating it in a field environment (Carling, Reilly & Williams, 2009).

3.14 Resistance Exercise Challenge Protocol

The objective of the REC design was to standardise the movement pattern being performed and the amount of exercise being executed by the participants. This was achieved by a predetermined quantity of sets and repetitions. These were important factors to consider, however the primary purpose of the REC was to induce DOMS. The lower limb was the target for the effects of DOMS; therefore the movement pattern prescribed for the REC was the squat jump. This movement was selected, as a high amount of eccentric load is demanded from the squat jump, especially in the landing/deceleration phase. In order to produce a significant DOMS effect, a high number of set and repetitions were prescribed. Participants were therefore required to complete 8 sets of 15 full squat jumps transitioned with 20 half squat jumps. A twenty kilogram weighted barbell was the standard resistance applied and a two-minute rest period was allowed between sets. The REC was adapted from a previous study that examined the effect of DOMS (Nie & Lin, 2004). The REC was delivered using a Keiser Squat machine (Keiser Inc., Fresno, CA) and it was ensured that the participants were supervised at all times. The Keiser Squat machine with its digital display allowed the researcher to observe the power produced on the first squat jump of the set, and monitor the power percentage each jump thereafter achieved in relation to the first jump. This allowed close monitoring of performance, motivation to be given to the participants when there was a significant decrease in power output and it also guaranteed maximal effort from the participants, thus inducing maximal effects of DOMS. To further ensure that maximal effort was sustained throughout the REC, participants were asked to give a rating of perceived exertion (RPE) from 6-20 (Borg, 1998) once they had completed the challenge (see Appendix E). The RPE scale was used to demonstrate the level of physiological strain participants experienced upon completion (Lythe & Kilding, 2011).

3.15 Ice Bath Protocol

There is currently no standard protocol concerning ice bath temperature or immersion duration (Quinn, 2008). After extensively reviewing existing research, it was deduced that on average, for every degree of water temperature, the participant should spend roughly the equivalent amount of time immersed in the water. Past research has employed immersion durations ranging from three to 20 minutes (Crowe, O'Connor & Rudd, 2007; Hamlin & Sheen, 2004; Vaile & Gill, 2003). A ten-minute immersion duration strategy was utilised in this study as Sramek, Simeckova, Jansky, Savlikova and Vybrial (2000) stated that physiological stabilisation was achieved after ten minutes of immersion, and in particular, changes of the vasomotor become stable in this time period. The ten-minute immersion period began once the participant's lower limb was fully submerged up to the iliac crest. The duration was timed using an EA Combs 510 stopwatch (EA Combs Ltd, Wanstead, London) and the water temperature was periodically measured with a standard mercury thermometer (Rowsell, Coutts, Reaburn & Hill, 2009). The water temperature adopted in many studies is between 10-15°C. The water in this study began at 10°C, and remained between 10-15°C throughout, as White (2011) suggested this temperature range was optimum. The water temperature was regulated during each immersion with crushed ice and it was periodically agitated to prevent a warm insulation layer forming around the participant. Many previous studies have employed this temperature strategy, supported by Sramek et al. (2000) where the greatest physiological response was reported at 14°C. Results from a study conducted by Williams, Landers and Wallman (2011) showed that immersion immediately following exercise has beneficial effects on performance the following day, thus was included in protocol of this research. The single treatment ice bath protocol was similar to that used in a previous study by Yanagisawa et al (2003a,b).

3.16 Data Analysis

The data collected from the 12 participants was then analysed using IBM SPSS Statistics (version 20), which is a statistical data analysis package. The program ran a two-way repeated measures ANOVA test to analyse the data and determine whether there was a significant difference between the ice bath and passive recovery strategies on the enhancement of recovery from DOMS, across a series of variables. The test was repeated for the performance, physiological and psychological variables. Significance was accepted at $p < 0.05$.

CHAPTER 4

RESULTS

4.1 Introduction

The data collected during the testing process from the tested variables will be demonstrated in this chapter as statistical results. The aim of the study was to provide further information demonstrating whether ice baths are an effective recovery intervention for alleviating the effects of DOMS by comparing these results to the data collected during a passive recovery strategy (control/non-intervention). Graphs and tables will be utilised to depict the information clearly.

4.2 Intervention Data Analysis

4.2.1 The Mean and Standard Deviations

Table 1. Mean values of participants for performance, physiological and psychological scores in pre REC, post 24 hour REC and post 48 hour REC for ice baths and passive recovery (mean ± SD)

Strategy	Time Scale	Performance ($mm.ms^{-1}$)	Physiological (IU/L)	Psychological (cm)
Ice Bath	Pre REC	2.01 ± 0.48	413 ± 249	3.16 ± 2.01
	Post 24 REC	1.84 ± 0.37	481 ± 300	5.48 ± 2
	Post 48 REC	1.96 ± 0.41	283 ± 149	5.14 ± 1.24
Passive	Pre REC	2 ± 0.45	280 ± 159	3.25 ± 2.25
	Post 24 REC	2.03 ± 0.29	252 ± 109	4.22 ± 1.53
	Post 48 REC	2.03 ± 0.37	224 ± 81	3.56 ± 2.23

4.2.2 Performance Variable

A two-way repeated measures ANOVA was run to determine a significant difference in performance between ice baths and passive recovery. The results showed no significant difference *($p>0.05$)* in performance between ice bath and passive recovery. However, the Bonferroni adjusted post hoc tests revealed a significant decrease *($p<0.011$)* in performance 24 hours post-REC during the ice bath intervention, demonstrated in Figure 3.

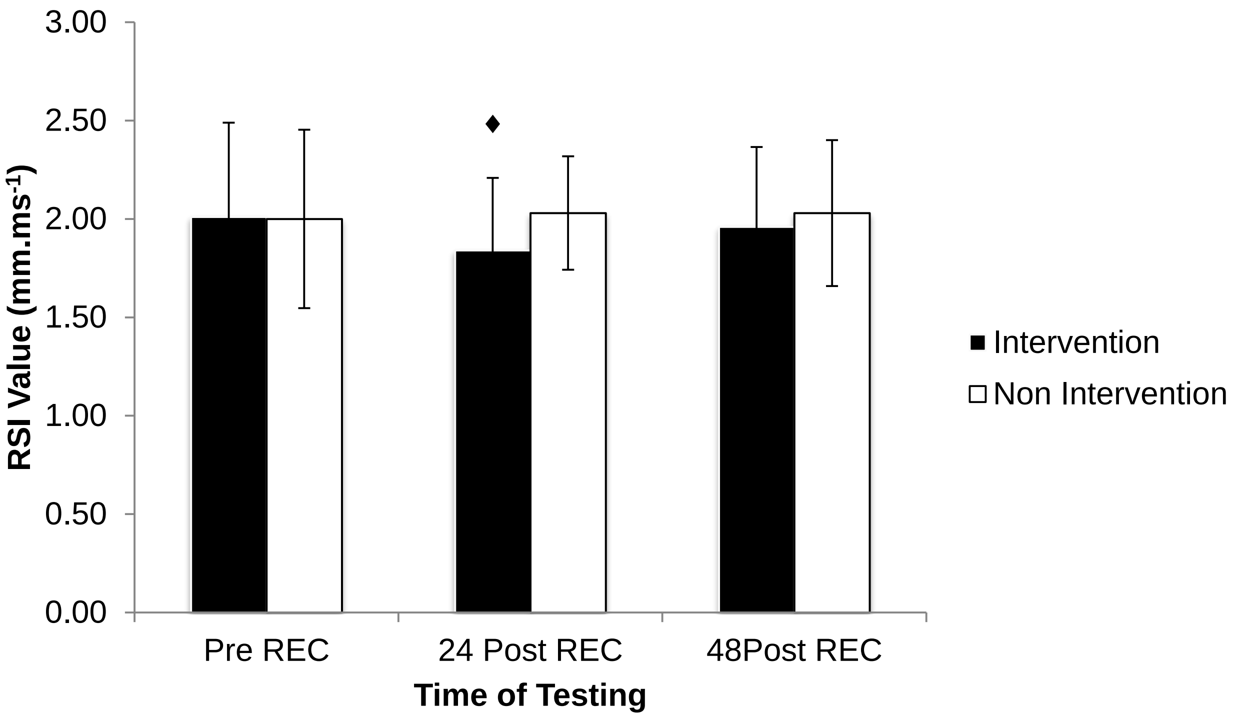

Figure 3. Mean values for RSI performance variable at each of the testing intervals for ice baths and passive recovery (♦significant decrease in RSI 24 hour post-REC)

4.2.3 Physiological Restoration (CK) Variable

A two-way repeated measures ANOVA was run to determine a significant difference in CK levels between ice baths and passive recovery. The results showed a significant difference in CK levels *($F=7.0$, $p<0.023$)* between ice bath intervention and passive recovery, with Bonferroni adjusted post hoc tests revealing there was generally significantly higher mean CK levels *($p<0.023$)* throughout the ice bath intervention compared to passive recovery. Results also highlighted a significant difference in mean CK levels *($F=4.7$, $p<0.020$)*, with Bonferroni adjusted post hoc tests showing significantly decreased CK levels *($p < 0.015$)* between 24 hours post-REC and 48 hours post-REC. Although there was no significant difference between the ice bath and passive recovery at 24 hours post-REC *($F=2.7$, $p>0.092$)*, the Bonferroni adjusted post hoc tests revealed significantly higher CK levels during the ice bath week at this test interval. There was no significant interaction between the intervention and CK levels at the time intervals *($F=2.7$, $p>0.092$)*, however Bonferroni adjusted post hoc tests exposed significantly reduced CK levels *($p<0.021$)* between 24 hours post-REC and 48 hours post-REC, specifically during the ice bath week. These differences can be observed clearly in Figure 4.

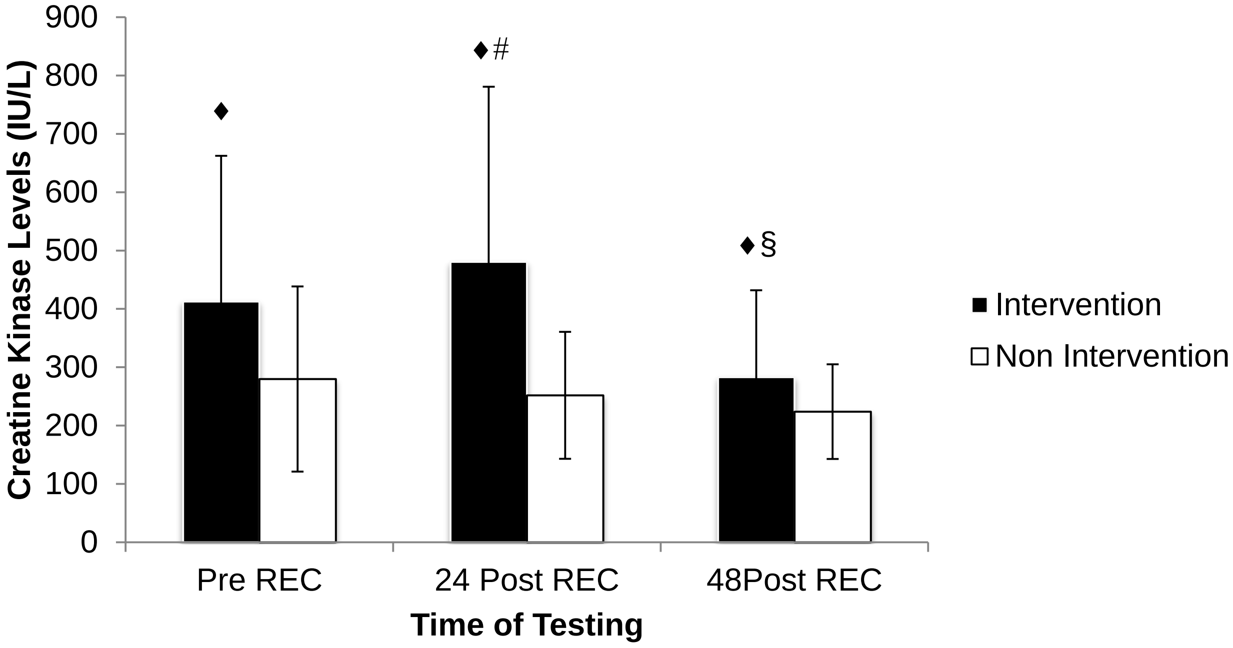

Figure 4. Mean values for CK levels at each of the testing intervals for ice baths and passive recovery (♦significantly higher mean compared to control; #significantly higher 24 hour post-REC compared to control; §significant decrease from 24 hour to 48 hour post-REC)

4.2.4 Perceived Effect Variable

A two-way repeated measures ANOVA was run to determine a significant difference in perception of recovery between ice baths and passive recovery. The results showed a significant difference *(F=6.3, p<0.007)* in perception of muscle soreness between the testing intervals, with Bonferroni adjusted post hoc tests revealing a significantly higher *(p<0.016)* VAS score between pre-REC and 24 hour post-REC regardless of the intervention strategy. There was no significant interaction between the intervention and VAS score at the time intervals *(F=2.2, p>0.135)*, however Bonferroni adjusted post hoc tests showed a significantly higher VAS score *(p<0.038)* during the ice bath week at the 48 hour post-REC time interval. The Bonferroni adjusted post hoc test also revealed a significantly higher VAS score during the ice bath week when comparing pre-REC to 24 hour post-REC *(p<0.003)* and pre-REC to 48 hour post-REC *(p<0.026).* These results have been displayed in Figure 5.

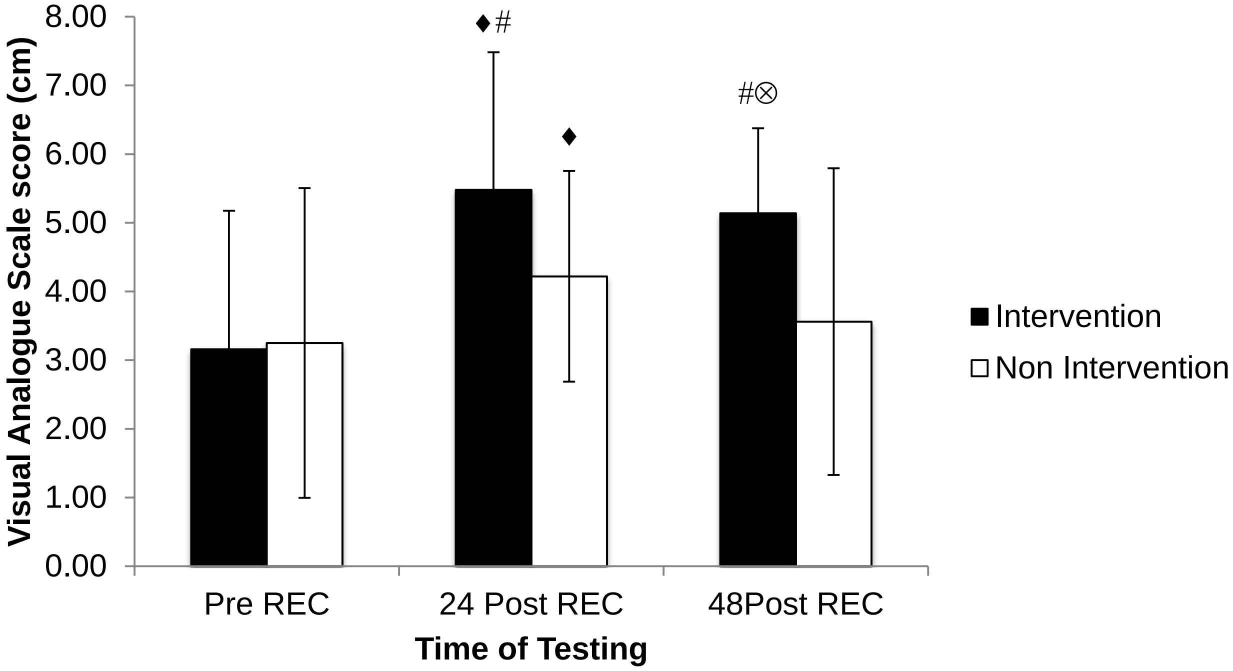

Figure 5. Mean values for VAS score of perceived muscle soreness at each of the testing intervals for ice baths and passive recovery (♦significantly higher than pre-REC; #significantly higher compared to pre-REC in ice bath week; ⊗significantly higher compared to 48 hour post-REC in control)

4.3 Variables Separated by Week

After looking at the intended results for the study, another trend has been noticed. Due to unforeseen circumstances, mainly due to participant availability and the availability of the facilities, the majority of the participants performed the ice bath intervention in the first of their two weeks of testing. This has brought to light further investigation into the order in which the variables were performed, looking at the variables on a week-by-week basis. The results that follow show results that were recorded in week one and week two, and a comparison between the two weeks has been made.

4.3.1 The Mean and Standard Deviations

Table 2. Mean values of participants for performance, physiological and psychological scores in pre REC, post 24 hour REC and post 48 hour REC in week one and week two of testing, regardless of intervention (mean ± SD)

Strategy	Time Scale	Performance ($mm.ms^{-1}$)	Physiological (IU/L)	Psychological (cm)
Week 1	Pre REC	1.92 ± 0.43	459 ± 216	3.07 ± 1.58
	Post 24 REC	1.87 ± 0.37	457 ± 198	5.32 ± 1.85
	Post 48 REC	1.97 ± 0.42	285 ± 82	5.06 ± 1.78
Week 2	Pre REC	2.08 ± 0.48	234 ± 152	3.35 ± 2.56
	Post 24 REC	2.01 ± 0.31	276 ± 271	4.38 ± 1.83
	Post 48 REC	2.02 ± 0.36	249 ± 155	3.64 ± 1.89

4.3.2 Performance Variable

A two-way repeated measures ANOVA was run to determine a significant difference in performance between week one and week two, regardless of the intervention. The results show a significant difference *($F=5$, $p<0.048$)* in performance between week one and week two with Bonferroni adjusted post hoc tests exposing a significantly lower mean performance score in week one. Figure 6. demonstrates this significance.

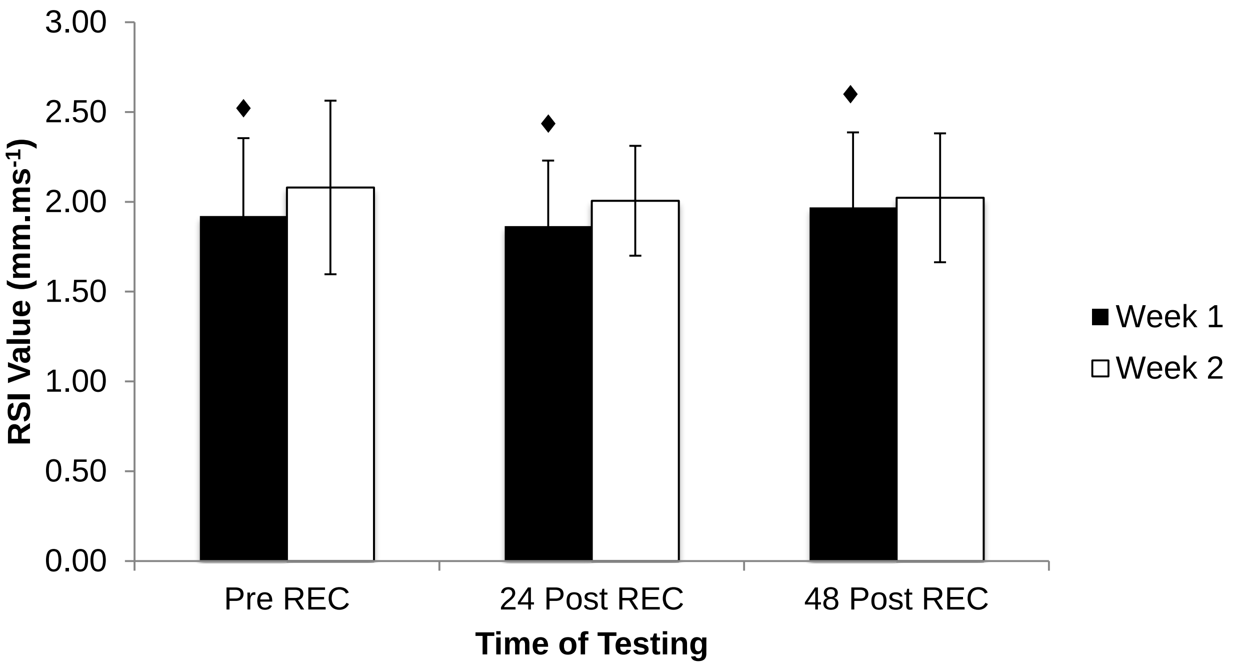

Figure 6. Mean values for RSI performance variable at each of the testing intervals for week one and week two of testing (♦significantly lower mean RSI)

4.3.3 Physiological Restoration (CK) Variable

A two-way repeated measures ANOVA was run to determine a significant difference in mean CK levels between week one and week two, regardless of the intervention. The results showed a significant difference in mean CK levels *(F=6.6, p<0.026)* between week one and week two, with Bonferroni adjusted post hoc tests revealing significantly higher mean CK levels in week one *(p<0.023).* A significant difference *(F=4.7, p<0.020)* was also recorded between the mean values 24 hours post-REC and 48 hours post-REC, with Bonferroni adjusted post hoc tests highlighting significantly lower CK levels *(p<0.015)* at 48 hours post-REC compared to 24 hours post-REC. There was a significant interaction between the week and CK levels at the various time intervals *(F=5.9, p>0.009)*, with Bonferroni adjusted post hoc tests exposing significantly higher CK levels *(p<0.006)* in week one in the pre-REC blood sample. Another Bonferroni adjusted post hoc test revealed there was a significant difference in CK levels in week one *(p<0.007)* between pre-REC and 48 hours post-REC, with the 48 hour post-REC CK score being significantly lower. A final Bonferroni adjusted post hoc test exposed another significant difference in CK values in week one *(p<0.005)* between 24 hours post-REC and 48 hours post-REC, with the 48 hour post-REC CK score being significantly lower. These differences can be observed clearly in Figure 7.

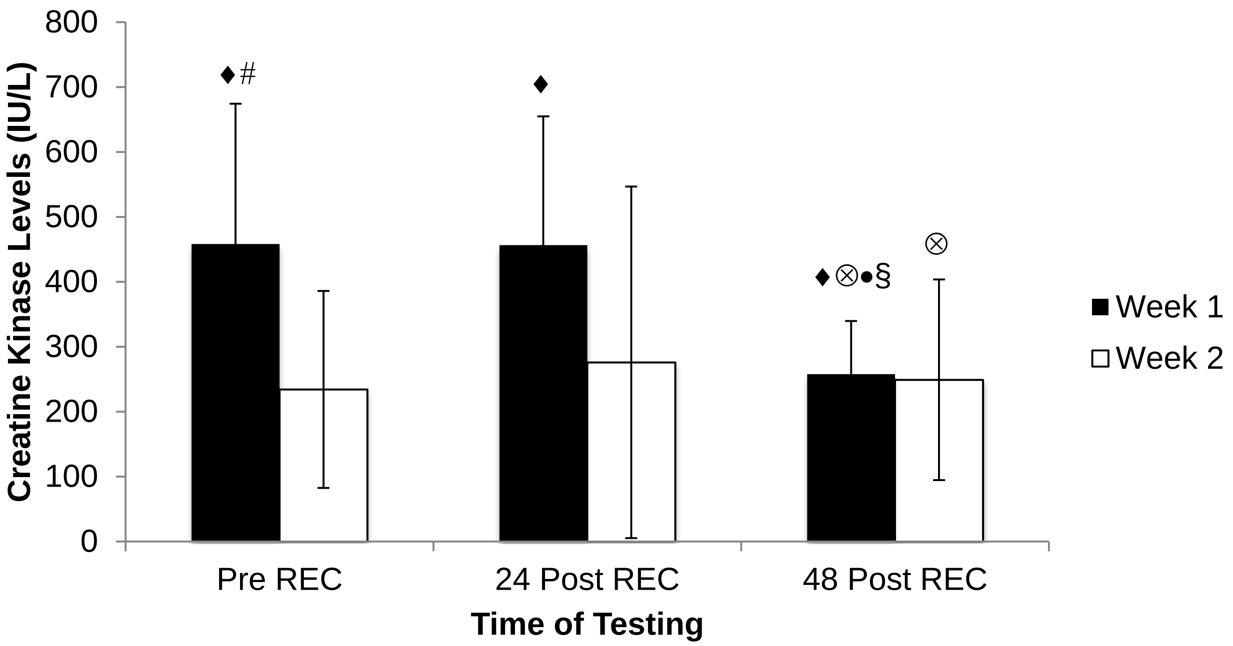

Figure 7. Mean values for CK levels at each of the testing intervals in week one and week two of testing (♦significantly higher mean CK in week one; ⊗significantly lower 24 to 48 hour post-REC; #significantly higher pre-REC in week one; •significantly lower compared to pre-REC; §significantly lower compared to 24 hour post-REC)

4.3.4 Perceived Effect Variable

A two-way repeated measures ANOVA was run to determine a significant difference in perception of recovery between week one and week two, regardless of the intervention. The results showed a significant difference *(F=6.3, p<0.007)* in perception of muscle soreness between the testing intervals, with Bonferroni adjusted post hoc tests revealing a significantly higher *(p<0.016)* VAS score between pre-REC and 24 hour post-REC. There was no significant interaction between the week and VAS scores at the time intervals *(F=2.2, p>0.136)*, however Bonferroni adjusted post hoc tests showed a significant increase in perceived muscle soreness *(p<0.000)* during week one from pre-REC to 24 hour post-REC. The Bonferroni adjusted post hoc test also revealed a significant increase in perceived muscle soreness *(p<0.013)* during week one from pre-REC to 48 hours post-REC. These results have been displayed below in Figure 8.

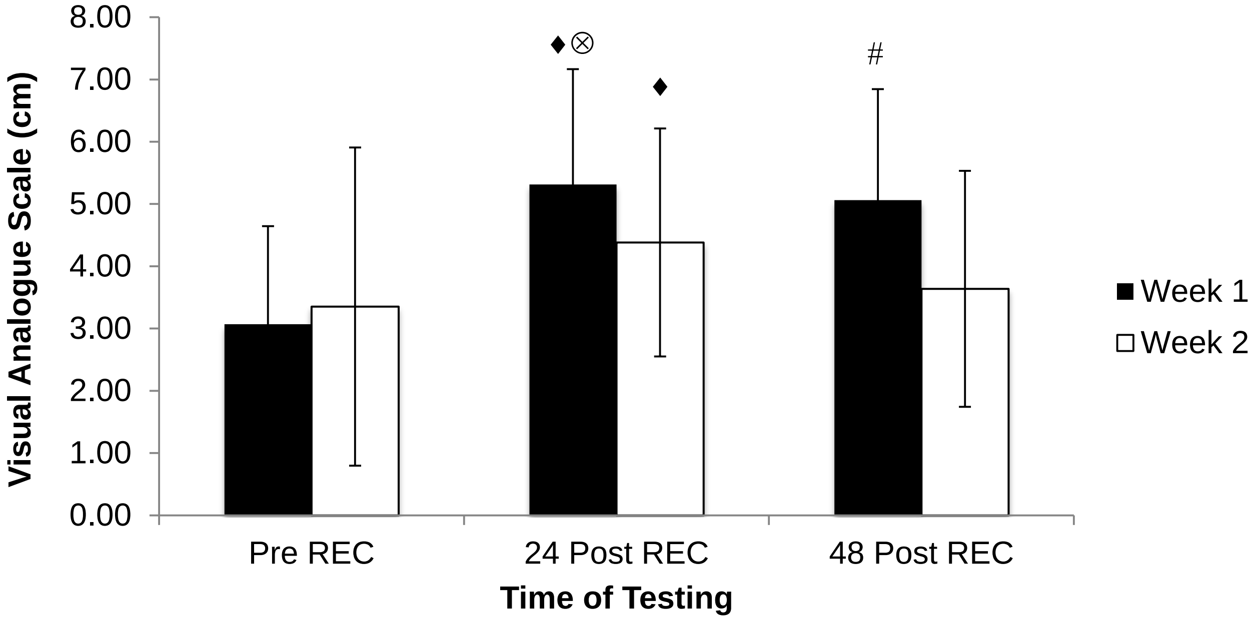

Figure 8. Mean values for VAS score of perceived muscle soreness at each of the testing intervals for week one and week two of testing (♦significantly higher 24 hours post-REC compared to pre-REC; ⊗significant increase from pre to 24 hours post-REC in week one; #significant increase from pre to 48 hour post-REC in week one)

4.4 Rate of Perceived Exertion (Borg Scale)

Participants were requested to report their rate of perceived exertion on immediate completion of the REC in both instances. The Borg scale from 6-20 was utilised in this scenario with all participants reporting scores above 17. The mean value and standard deviation score being 18.29 ± 0.81. This measure was incorporated in the study to ensure participants were subjected to sufficient physiological strain during the REC, with maximal effort ensuring the effect of DOMS was induced (Lythe & Kilding, 2011).

CHAPTER 5

DISCUSSION

5.1 Introduction

The aim of this study was to demonstrate whether ice baths affect the rate of recovery from eccentric exercise-induced DOMS in male university field hockey players. This chapter provides a discussion around the main concepts by reflecting on the key findings and referring back to the hypothesis. The results appear to show some significant differences between ice baths and passive recovery on the alleviation of DOMS in certain variables that were tested, reflecting elements of the hypothesis made in chapter two. This will be discussed in greater detail throughout this chapter.

It is important to note that statistical significance is not always significant in a practical sense. Statistical significance is regarded as mathematical where practical significance is somewhat subjective and can be based on other factors. Results should be considered practically significant if the result actually has an affect on a decision that is to be made. This is the approach that will be utilised in the discussion of the results found in this study.

5.2 Reflection on the Key Findings

5.2.1 Intervention versus Control Comparison

There was a significant decrease in mean performance found 24 hours post-REC during the ice bath week, where this was not the case during the control week, in fact performance improved from pre-REC to the post-REC test interval. This decrease during the ice bath week could be due to CK levels being significantly higher throughout this intervention, and a significant increase in CK levels from pre-REC to 24 hours post-REC, as was expected, during the ice bath week. A result which supports the ice bath recovery strategy is the significant decrease in CK levels from the 24 hour post-REC test to the 48 hour post-REC test during the ice bath week; the decrease displayed during the control was not found to be significant. The results showed a slight improvement in performance 48 hours post-REC which is consistent with the physiological restoration that occurred. It is worth noting that the ice bath week CK level was still higher than that of the control at the 48 hour post-REC test interval. CK levels in the control were at their highest value pre-REC, decreasing at each of the post-REC testing intervals, however not at a significant rate. Participants experienced significantly higher perceived muscle soreness 48 hours post-REC during the ice bath week compared to the control. This is not consistent with the improved performance, but it could answer why RSI values were lower 48 hours post-REC in the ice bath week. The ice bath week also produced a significant increase in perceived muscle soreness from pre-REC to the post-REC test interval. The graph profiles are as expected when looking at CK levels and perceived muscle soreness ratings during the ice bath week, however the control displays noticeably lower ratings than during the ice bath week and less variability in general throughout.

5.2.2 Week 1 versus Week 2 Comparison

Mean performance scores were significantly lower during week one of the testing, evident by comparison in Figure 6. This corresponds with the significantly higher mean CK levels recorded during the same week (especially pre-REC and 24 hours post-REC, where CK levels were nearly double the value of week two) and perceived muscle soreness increased significantly from pre-REC to 24 hours post-REC. The increase experienced in week two was not found to be significant in comparison. Week one pre-REC CK levels were significantly higher compared to those at the same test interval in week two; and CK levels were significantly lower at the 48 hour post-REC test interval compared to the levels collected pre-REC, supporting that CK levels were higher than expected pre-REC and a degree of muscle damage was perhaps already present (Nicholson et al., 1985). There was a significant decrease in CK levels from the 24 hour post-REC test to the 48 hour post-REC test during week one, but this is not consistent with the significantly high perceived muscle soreness rating recorded 48 hours post-REC during week one, compared to the level recorded pre-REC. The level of perceived muscle soreness did not decrease notably in week one, whereas the decrease in week two could be interpreted as notable. The decrease in CK levels during week two at the same interval was not found to be significant. Mean CK levels significantly decreased from 24 hours post-REC to 48 hours post-REC, and by a significant amount specifically in week one. It is worth noting that CK values collected pre-REC were much higher in week one, nearly double the level recorded in week two, perhaps reflecting prior exercise or muscle damage (Nicholson et al., 1985; Clarkson & Ebbeling, 1988). The graph profile of week two shows little variance in comparison to week one.

5.3 Physiological Effects

There are several mechanisms in question for contribution to the effects of DOMS and as previously stated a combination of those factors is possibly the cause of this effect (Smith, 1991). This particular study was originally set to focus on cell inflammation and muscle damage as primary contributors (Szymanski, 2001). It is possible that these mechanisms can have a negative affect on performance, a perception of muscle soreness and an increase in CK levels, resulting in an increased risk of injury if managed incorrectly, and especially if the athlete was to return to sport prematurely (Cheung et al., 2003; Coudreuse, Dupont & Nicol, 2004; Wilcock et al., 2006; Rowsell et al., 2009; Eston, Byrne et al., 2003). Muscle damage (indicated by increased CK levels) has a negative effect on muscle function and could be considered as an answer to decreased performance (Warren et al., 1999), as CK levels decreased, performance improved. Increased blood flow and an increase in the metabolism of substrates produced during exercise are associated effects of active recovery that can reduce cell inflammation and athletes perceived effect of DOMS (Wilcock et al., 2006). Observations have determined that ice baths produce similar physiological responses to active recovery; this comes with the added benefit of expending less energy (Lateef, 2010). Hydrostatic pressure is another aspect of ice baths that has shown to aid the recovery process by significantly reducing soft tissue inflammation (Vaile et al., 2008). Hydrostatic pressure acts on the immersed region by forcing the accumulated extracellular fluid (inflammation) back into vascular compartments, reducing soft tissue inflammation (Wilcock, 2006).

Results showed that there was an increase in performance from 24 hours post-REC to 48 hours post-REC and a slight decrease in perceived muscle soreness from 24 hours post-REC to 48 hours post-REC; but there was a significant decrease in CK levels from 24 hours post-REC to 48 hours post-REC. The degree of variation observed 48 hours post-REC during the control, was not to the same extent as that which was observed during the ice bath week. This is perhaps a result of these physiological responses associated with ice baths having a positive effect on recovery, especially from 24 to 48 hours post-REC, on the effects of DOMS.

Research has shown that the cold temperatures associated with ice baths cause the local blood vessels to constrict and a decrease in tissue temperature is a result (Freeman, 2005). This decrease blood flow and slows cell metabolism, which is vital to limiting inflammation and muscle damage, connected to DOMS. Freeman (1995) discovered that

20 minutes post exposure to the cold was when vessels began to dilate, increasing temperature in the tissue, this is termed “reactive vasodilation”. Contradictory to the believed positive effects of this physiological function, Knight (1999) stated that there was a significant and prolonged reduction in local blood volume of the exposed area, perhaps detrimental to recovery.

Similar studies have had mixed results. Paddon-Jones and Quigley (1997) reported findings that supported the use of ice baths by trained athletes on efforts to alleviate the effects of DOMS, suggesting that trained athletes (field hockey players in the instance of this study) are more resistant to eccentric exercise induced muscle damage and should respond positively to an ice bath recovery strategy. Contradictory to this statement, many studies believe that there is insufficient, significant evidence to support this and further research is required to confirm whether there is a difference in response between trained and untrained athletes (Gulick, Kimura, Sitler, Paolone & Kelly, 1996). A study performed by Sellwood, Brukner, Williams, Nicol and Hinman (2007) observed participants separated randomly to three, one minute immersions in either 5°C water or similar protocol in 24°C water. The study found that the ice immersion (5°C water) was ineffective at reducing markers of DOMS. Likewise in a study by Schniepp, Campbell, Powell and Pincivero (2002) on trained cyclists that were exposed to a brief ice bath and were then required to perform a subsequent bout of exercise; performance was impaired due to the cold water producing noticeable physiological effects (maximum power decline 13.7% versus 4.7%, maximum heart rate decreased by 8.1% versus 2.4% compared with the respective control groups). These mixed results suggest uncertainty surrounding ice baths as a method of recovery from DOMS.

5.4 Familiarisation

Observation of the graphs (Figures 3, 4 and 5) demonstrates quite different profiles between the two intervention strategies. The ice bath intervention graph columns display profiles that were to be expected: a decrease in performance in the 24 hour post-REC test followed by an increase 48 hours post-REC; an increase in CK levels at the 24 hour post-REC test followed by a decrease 48 hours post-REC; and an increase in muscle soreness at the 24 hour post-REC test followed by a decrease 48 hours post-REC. The control graph columns generally displayed less variability. Variation in the tested variables was observed as more subtle and this brought to question whether a possible adaptation had taken place between week one and week two of the testing (Halson and Jeukendrup, 2004), making the REC more familiar.

The participants were originally evenly randomised in week one of the testing to either receive the ice bath intervention or the passive recovery strategy. They would then crossover the following week, experiencing the other intervention. However due to participant availability and certain unforeseen circumstances, the majority of the participants received the ice bath intervention in their first week of testing. In response to this theory being developed, the results were then separated into week one and two testing intervals, regardless of the intervention and a data analysis was run. The results generated from the analysis show that in week two of the testing, mean CK levels were significantly lower, mean performance was significantly higher compared to week one and mean perceived muscle soreness was notably reduced. These results provide evidence in support of the theory of familiarisation having occurred between week one and two (Bamman et al., 2001; Hather, Tesch, Buchanan & Dudley, 1991).

The drop jump was employed as the performance measure because the variables that can be scrutinised for significance are directly relevant to field hockey and the physical qualities essential for success at competitive, university standard (Reilly & Borrie, 1992). RSI is a reliable value representative of plyometric ability and performance (Schmidtbleicher, 1992). There was a significant decrease in performance during the ice bath intervention week from pre-REC to the 24 hour post-REC score, but this was not the case during the non-intervention week. This gives further evidence towards physiological adaptation occurring, with the REC having provided an unfamiliar stress in week one and inadvertently the body responded to the stimulus through supercompersation; thus more resistance to the stressor was obvious in the week two results (Kraemer et al., 2000). Research by Halson and Jeukendrup (2004) supports this declaration as they stated that physiological adaptation can take place in the presence of a stimulus overload (athletic training/unfamiliar activity) and adequate rest, resulting in adaptation to the stress and possibly performance enhancement.

5.5 Practical Implications

Van Wyk and Lambert (2009) stated that ice baths are the most popular strategy for recovery, based on anecdotal evidence. This increases the importance of substantiated evidence to answer the inconclusive results surrounding the use of this strategy in past literature. Knowledge of how the strategy benefits recovery and how effective it is at accelerating recovery would be most beneficial to coaches and athletes, and would assist this specific population in prescribing it for use. Knowing these factors would also enable coaches to design more accurate training programs and ensure the athlete has recovered to a suitable level before the next bout of exercise or competition, thus optimising performance. This study provides evidence supporting the use of ice baths, in particular the significant physiological improvement that was observed from 24 to 48 hours post-REC, and the subsequent improvement in performance at the same test intervals.

Establishing a protocol would ensure the strategy was administered in the most effective way to enhance the desired result. It would limit confusion around which protocol to utilise by providing substantiated rationale to the advised procedures. Some previous research by White (2011) and Sramek et al. (2000) has assisted in the development of this to an extent by providing an optimal temperature range and immersion duration respectively, but due to the vast number of protocols that are still practiced anecdotally, further information is still required.

5.6 Strengths

The study set out to explore ice baths as a recovery strategy, focusing on key measures that would consider this intervention beneficial in accelerating the effect of DOMS to encourage shorter recovery periods. This is vital to university hockey players who are required to perform repeated bouts of competitive exercise at a high level, separated by minimal recovery periods, over several months. The study was built on a strong experimental design, examining the effects of eccentric, exercise induced DOMS and the effect ice baths have on recovery, across three relative variables; physiological, psychological and importantly performance. If any of these variables responded positively to the ice bath intervention it should be considered as an employable strategy.

A crossover design was used to expose the participants to each strategy (ice bath or passive recovery) as opposed to randomizing the participants to only one of the variables; this is advantageous as variability across the results is limited (Katz, 2006).

Testing took place up to 48 hours post-REC, this is realistically a common duration between strenuous bouts of competitive exercise experienced by university hockey players, and thus it was the time scale over which the investigation was carried out.

Testing was separated by a week and not carried out right away, to allow the participants time to fully recover, eliminating disadvantages to the study design. It was also highlighted in chapter two how acute pain and inflammation can take up to five days to subside while full muscle function can take even longer (Cheung et al, 2003).

The participants included in the study were all taken from a specific population of trained, male, university level hockey players. Keeping the study sport specific allows the information obtained to contribute knowledge to coaches and players, who reside in similar populations, however this information might not be transferable to untrained individuals who would not have attained comparable physiological adaptations (Maron & Pelliccia, 2006).

Participants were given detailed guidelines/restrictions for the study and were asked to comply with these in a self-reported manner. This was implemented to reduce the controllable variables, however after investigation into some of the data gathered, it is unclear as to whether these guidelines were completely adhered to by the participants throughout the study.

RPE was observed to ensure the participants gave maximal effort at all times. This also guaranteed that the participants were subjected to maximal effects of DOMS.

5.7 Limitations

As with all research, there are limitations to this study. Many factors have shown to influence recovery, and this put emphasis on reducing the controllable variables. Efforts were made to reduce these factors with participants being requested to comply on a self-reported basis. However, with the participants being university students, many factors were uncontrollable, such as the level of hydration, nutrition and further activity outside that of the study. These factors will have an influence on the data gathered. In future research, a diary of these factors should be kept to monitor the participants or the study should ideally be carried out on a professional team where nutrition, hydration and activity are controlled.

CK was the measure used to measure physiological restoration. This value is a direct reflection of muscle damage, ideal for the study. The measurements however, can be influenced by a number of factors, specifically hydration for example, but other factors can also be responsible (Clarkson & Ebbeling, 1988). In this study, factors that influence the CK reading could have been more closely monitored.

Participant availability was restricted and influenced by uncontrollable factors such as individual training, workload, team obligations and university commitments. It was difficult to find a two-day window where participants were completely free from any form of activity outside of the testing parameters. Two consecutive days is a lot to ask from a team mid-season, therefore a similar approach to a study by Rowsell et al. (2009) should be adopted in future studies, where testing was performed during preseason or incorporated into the preseason plan. Due to participant and facility availability, the original randomised intervention allocation was unable to be implemented, and the majority of the participants received the ice bath intervention in the first week of their testing. This has highlighted an element of familiarisation to the REC, which has been observed in the data collected. The intervention randomisation was an attempt at eliminating this effect, but was not entirely executed as planned. This might have been avoided if a crossover design was not adopted, but there are many advantages associated with this design.

The crossover design and with the participants giving informed consent as a requirement to take part in the study, made it obvious what was being investigated and participant bias might have influenced the data. The participant's knowledge of the study to this extent might have influenced the answers given in the perceived soreness questionnaire and the effort expended during the performance tests of the different intervention strategies. Encouragement was constantly given to the participants throughout the testing to prevent this influence. Similarly the researcher could have encouraged a certain group to a greater degree, trying to persuade results favourably toward what they believed should be the outcome, this is known as observer bias.

CHAPTER 6

CONCLUSION

6.1 Conclusion

The study aimed to determine whether ice baths have an effect on recovery enhancement in performance, physiological restoration and perceived muscle soreness variables from the symptoms associated with DOMS. The REC was sufficient in difficulty an can be recommended as an effective method of inducing eccentric exercise DOMS. This was evident through the increased CK levels from pre to post-REC, the decrease in performance from pre to post-REC and the heightened perception of muscle soreness from pre to post-REC. The study produced significant results among the performance, perception and physiological variables, supporting the use of ice baths in alleviating the effects of DOMS. However the comparison against the control set of results should not be seen as entirely reliable. This element of unreliability occurred due to an unintentional adaptation, which took place between the two testing weeks, specifically affecting the intended effects of the REC in the control week. The effects of the REC were desensitised to a degree, resulting in less severe symptoms being generated. Even though the control results are unreliable to an extent, a significance decrease in CK level was observed from 24-48 hours post-REC during the ice bath week compared to a non-significant decrease occurring in the control week. This should be regarded as a noteworthy result and should encourage further similar research.

Ice baths being a popular method of recovery, will remain pertinent but be practiced anecdotally, until scientific evidence can provide rationale to support the use of the intervention or on the other hand evidence to avoid it as a strategy altogether for alleviating the effects of DOMS.

6.2 Recommendations for Future Research

Past literature is contradictory and inconclusive surrounding cryotherapy, in relation to recovery from DOMS. There is a need for further investigate into whether ice baths actually have an effect on recovery, as it is such a popular strategy adopted by athletes and coaches from many sports. This should encourage testing to focus on certain variables, which affect recovery, known to be critical in sport. For example: performance, physiological restoration and the perceived effect are suitable variables for this type of research. Future research should seek to establish whether there is a definite effect on recovery from ice baths and look to narrow the focus of the research on more specific aspects of this. Critical in moving forward is the need of an established set of protocols. This should perhaps be considered as another primary focus with much of the prescribed protocol being practiced anecdotally.

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APPENDICES

APPENDIX A

ETHICS STATUS

Cardiff Metropolitan University
Prifysgol Fetropolitan Caerdydd
UWIC

Date: 18/03/14

To : Ross Matthews

Project reference number: 14/3/30U

Your project was recommended for approval by myself as supervisor and formally approved at the Cardiff School of Sport Research Ethics Committee meeting of 29th May 2013.

Yours sincerely

Rmeyers

Rob Meyers
Supervisor

APPENDIX B

PARTICIPANT INFORMED CONSENT FORM

Cardiff Metropolitan University

Participant Consent Form

UREC reference number:
Title of Project: Comparative effects of ice baths and passive recovery on physiological restoration, perceived recovery and repeated sports performance in university field hockey players
Name of Researcher: Ross Matthews

Participant to complete this section: Please tick each box.

1. I confirm that I have read and fully understand the information sheet dated …………..for this comparative study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I agree to give my best efforts in any tests I take part in this study ☐

3. I understand that my participation in the study is voluntary and that it is possible to opt out at any time, without giving a reason. ☐

4. I also understand that if this happens, my relationship with Cardiff Metropolitan University and my legal rights will not be affected. ☐

5. I understand that the information from this study may be used for reporting purposes and will be seen by others, but at all times my identity will remain confidential. ☐

6. I agree to take part in this study. ☐

____
PRINT NAME OF PARTICIPANT

______________________________ ______________________________
SIGNATURE OF PARTICIPANT **DATE**

______________________________ ______________________________
SIGNATURE OF RESEARCHER **DATE**

APPENDIX C

PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Project Title: Comparative effects of ice baths and passive recovery on physiological restoration, perceived recovery and repeated sports performance in university field hockey players

Background Introduction

I am a university student reading Sports conditioning, rehabilitation and massage at Cardiff Metropolitan University. I am performing a study to understand more about recovery strategies that can be adopted by university hockey players to speed up recovery and improve performance when recovery time is short. I would like to invite you to participate in the study. You will receive information on the research and if you have any questions feel free to ask me or speak to anyone you feel comfortable talking about it with.
Recovery from exercise in rapid fashion in order to perform at the same level in a short period of time is an important element in a university hockey player's season. The hockey season is long and intense making recovery important. We will be testing whether passive rest or ice baths are a more beneficial strategy when it comes to recovery and performance.

Procedures

The research procedures will follow the step by step proceed as follows:
<u>Familiarisation Session (Pre Test Protocols)</u>

- Participants weight and height will be recorded.
- Reporting on perceived muscle soreness (PMS)
- A 10 minute general RAMP (raise, activation, mobilisation and potentiation) warm up procedure.
- Performance Test (PT): drop jumps on a Smartspeed jump mat (a maximal jump performed as quickly as possible from a 30 centimetre block height).

This first part of the familiarisation session will be referred to as the: Pre Test Protocols.

Participants will then be taken through one set of the REC performed using a Keiser squat machine. This will consist of:

- 15 full squat jumps
- 20 half squat jumps
- A 10 kilogram load will be added to a 10 kilogram barbell. Total load: 20 kilograms
- A two minute rest will be implemented between sets

<u>Week A)</u>

A week following the familiarisation session, participants will execute one of two REC's to induce delayed onset muscle soreness (DOMS). The protocol will be as follows:

- Pre test protocols (previously stated), including a blood capillary sample.
- 8 sets of the REC (previously stated)
- Participants will complete a series of blood samples, RPE and PT (Post REC Protocol)
- Ice Bath Intervention (10 minutes in water ±10°C)
- 24 hours post REC, participants return for Post REC Protocols
- 48 hours post REC, participants return for Post REC Protocols

Week B)
The following week, participants will execute their second of two REC's to induce delayed onset muscle soreness (DOMS). The protocol will be as follows:

- Pre Test Protocols (previously stated), including a blood capillary sample.
- 8 sets of the REC (previously stated)
- Participants will complete a series of blood samples, RPE and PT (Post REC Protocol)
- Ice Bath Intervention (10 minutes in water ±10°C)
- 24 hours post REC, participants return for Post REC Protocols
- 48 hours post REC, participants return for Post REC Protocols

Participants will be required to undergo both Week A) and Week B). Participants will not be made aware of the sequence of the weeks to be followed prior to the day of the testing. They will be made aware of this on the day of testing.
Capillary blood samples will be collected from the tip of the participant's finger or ear lobe. This is a simple procedure, which will be carried out by a trained laboratory technician.

Participant Selection
You have been selected to participate in this study because I am inviting anyone who plays hockey at university standard.

Voluntary Participation
Your participation in this study is entirely voluntary. If you originally agree to participate, you can opt out ant any stage of the process without a reason. Your relationship with the university will be unaffected, as well as your position in the team.

What are the risks?
There are risks in most research. With the participant performing a resistance exercise challenge (REC) to induce delayed onset muscle soreness and performance testing, there is always the chance of injury however small. Safety procedures in the gym will be strictly followed to minimise any potential risk.
The risks involved with invasive testing such as the blood samples required in this study are:

- Contamination.
- Infection.
- Damage to blood cells, resulting in an inaccurate test, therefore the test will need to be repeated.
- New equipment will be used in each test.
- Excessive bleeding
- Fainting or feeling light headed.
- Scarring - occurs from multiple punctures in the same area.

Every effort will be made to ensure these risks to participants, researcher and research are minimised by following the procedure to the letter and ensuring trained personnel in the form of laboratory technicians obtain the samples.

Are there any benefits from participating?
Yes, you will be part of a study that directly influences you and your team. The study can potentially give you insight into which recovery strategy will benefit you the most and improve your repeated performance. Being a university student, you will benefit in your

studies being a part of this study, it could be relevant to you and your degree. You will learn protocols and which will benefit you when performing a study of your own.

Confidentiality

The information collected in the study will be kept confidential. Only people actively involved in the research will be able to see your information, but this will be kept to a minimum. Any information about you will have an identification number on it instead of your name. People may become aware that you are participating in the study and these people may ask you questions. You are welcome to talk freely about the study to anyone you feel comfortable with but we will not share the identity of anyone participating in the research.

Sharing the results

The knowledge acquired through carrying out this research will be shared with you through team meetings. Benefits from the results will be shared as soon as possible so that the optimal recovery treatment can be known and used. There is a possibility that these results can be published so that other interested people can learn and benefit from the research. Confidential information will not be shared at any point.

Right to refuse or withdraw

You do not have to participate in this study if you do not wish to do so. Refusing to participate will not affect your relationship with the university or the hockey team in any way. You may stop participating in the research at any time that you wish without losing any of your rights as a student or player here. Your status as a student/player will not be affected in any way.

Further Information

If you require any further information, have any questions about the research or how I intent to conduct the study, please contact me.

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APPENDIX D

PHYSICAL ACTIVITY READINESS QUESTIONAIRE (PAR-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing

APPENDIX E

BORG (1970) SCALE OF PERCEIVED EXERTION

Table 5.2A The original Borg Scale Rating Perception of Effort (RPE)

Rating	Perception of effort
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

APPENDIX F

WARM-UP PROTOCOL

Participant Warm-Up Program				
No.	**Exercise**	**Sets**	**Repetitions**	**Duration**
1	**Jog (50%)**			**2 Laps of Track**
2	**Clams**	**2**	**10**	
3	**Elastic band crab walks**	**2**	**10**	
4	**Open/close gate (hip mobility)**	**2**	**5/5**	
5	**Half squat jumps**	**1**	**5**	
6	**Full squat jumps**	**1**	**5**	